DIVERSITY AND DISTRIBUTION OF THE CETACEANS ALONG THE INDIAN SEA AND THE CONTIGUOUS SEA

Thesis submitted to Mangalore University in partial fulfillment of the requirement for the award of the degree of

Doctor of philosophy Under the Faculty of Biosciences

by

K.S.SHIAK MOHAMED YOUSUF, M. Sc

Central Marine Fisheries Research Institute
P.B. No. 1603, Ernakulam North P.O
Cochin-682018, Kerala, India

December, 2009

Declaration

*I do hereby declare that the thesis entitled "**Diversity and Distribution of the cetaceans along the Indian sea and the contiguos sea**" is an authentic record of research work carried out by me under the guidance and supervision of Dr. P. Kaladharan, Principal Scientist, FEM Division, Central Marine Fisheries Research Institute, Cochin in partial fulfillment for the award of Ph.D degree under the Faculty of Biosciences of Mangalore University and no part thereof has been previously formed the basis for the award of any diploma or degree, in any University.*

Cochin

December, 2009

(K.S. Shiak Mohamed Yousuf)

Certificate

*This is to certify that this thesis entitled "**Diversity and Distribution of the cetaceans along the Indian sea and the contiguous sea**" is an authentic record of research work carried out by **Mr. K.S. Shiak Mohamed Yousuf, M. Sc.,** under my guidance and supervision in Central Marine Fisheries Research Institute, Cochin, in partial fulfillment of the requirement for the award of Ph.D degree under the Faculty of Biosciences in Mangalore University. The thesis or part thereof has not previously been presented for the award of any degree in any University.*

Dr. P. Kaladharan
(Supervising Guide)
Principal Scientist
CMFRI
Cochin

Cochin
December, 2009

Acknowledgement

I place on record, the deepest gratitude to my supervising guide Dr. P. Kaladharan, Principal Scientist, Central Marine Fisheries Research Institute (CMFRI), for his support, determined guidance, and patience with me and for wrap up the actual writing part of this thesis and constructive criticism I received from him throughout the course of my study.

I sincerely express my heart felt gratitude and indebtedness to Dr. M. Rajagopalan, Principal Scientist & (Former HOD) Fisheries Environment Management Division (FEMD) of CMFRI for providing me with numerous opportunities and learning experience during my study period as a research scholar. His guidance, affectionate advice, constant encouragement, help, criticism and moral support during the course of my investigation is greatly acknowledged.

I am profoundly appreciative to Dr. E. Vivekanandan, Principal Scientist & Head, Demersal Fisheries Division of CMFRI for his moral support, perspective and advice for the theoretical frame work of this thesis during the course of the study.

I owe my thanks to Prof. Dr. Mohan Joseph Modayil, Former Director, CMFRI, and to the present Director of CMFRI Dr. G. Syda Rao for extending all the facilities of CMFRI for the successful completion of my research work.

I am extremely express my gratitude to Dr. H. Mohamed Kasim, Principal Scientist & Scientist in Charge, RC of CMFRI, for being great and wholehearted support along the way in many different ways.

I would like to express my sincere thanks to Dr. Raveendranathan (Former Adviser), Dr. V.N Sanjeevan, Director and Dr. T. Shanmugaraj, Scientist E, the authorities of Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, for granting Senior Research Fellowship for the project "Studies on Marine Mammals of Indian Exclusive Economic Zone and the Contiguous Seas".

I owe an immense dept and special thanks to Shri. R.P. Kumarran, for his advice for the practical frame works for this thesis and for his scientific and moral support; owes a lot to your intellectual influence. I am also indebted to Dr. R. Narayanakumar, Principal Scientist & Former SIC, RC of CMFRI, Kakinada for the generous helps in various forms, encouragements and moral support during the entire course of study.

I am deeply obliged to Dr. P.K. Krishnakumar, (Former Principal Scientist, CMFRI), Dr. P. Jayasankar, Principal Scientist, CIFE, Dr. L. Lakshminarayana, (former Principal Scientist &, Fisheries Environment Management Division, FEMD), Dr. Grace Mathew, *Principal Scientist and Head of FEMD for their enthusiastic encouragements and help in various forms extended throughout my study.*

I acknowledge deep sense of gratitude to my colleagues at CMFRI, Cochin, Dr. Anoop. A. Krishnan, Shri. B. Anoop, Shri. V.V. Afsal and Dr. P. Kannan. Their kind support, help and cheerful encouragements during the study period are incredibly acknowledged.

I owe an immense debt to Shri. Hussain Ali, Dr. T. Ganesh, Dr. Raveendra Durgaker, Dr. Gireesh for their great help in analysing data and constant encouragement in carrying out my work.

I also express my special thanks to my friends Shri. H. Kingsley, Shri. B. Jasper, Shri. Hashim Manjebrayakath Shri. K. Ratheesan, Shri T.V. Ambrose, Dr. Radhika Gopinath,Shri. M.S.V. Prabakar, Shri. MVSL. Sai, Shri. Chittbabu, Shri. Kasi, Shri. P.R. Abhilash, Shri. K. Kannan, M. Basheer Ahemed, P. Mani Kandan, S.Jalaludeen and R. Selvaraj as well as staff of RC of CMFRI, Visakhapatnam, especially, K. Ram Mohan, T. Nageshwara Rao and C.K. Sajeeve for picking me up when thesis felt like it was never going to end.

I express my sincere thanks to Dr. D. Prema, Senior Scientist, and Dr. R. Jeyabaskaran Senior Scientist, A. Nandakumar, L.R. Khambadkar and Smt. K.K. Valsala, Technical Officers, FEMD, CMFRI, Smt. A.K. Omana, Private Secretary and Smt. Latha, Private Secretary for their cheerful enthusiasm and ever-friendly nature throughout my study.

Masters, navigational officers and crews of FORV Sagar Sampada made the whole endeavor possible. Onboard staffs of Centre for Marine Living Resources and Ecology, especially, Shri. K.A.Renjan Shri. M. Rathinavel and Shri. Tapan Kumar malo were helpful with any issues. I also owe special thanks to the all onshore staffs of Centre for Marine Living Resources and Ecology especially, Shri M. Subramanian for his logistical support during the cruise period.

I am grateful to Library in Charge, RC of CMFRI, Visakhapatnam and OIC of Library, CMFRI, Cochin and other staff members in the Library for their sincere help and cooperation extended during the course of my study.

Above all, words are inadequate to express my love and indebtedness to my very beloved Grand parents, parents, Shri. T.K.M. Shahul Hameed, Smt. H. Ameena Bevi, Shri. S.P Mohamed Yousuf John, Smt. H. Jareena Bevi and my beloved brothers and sisters for their wholehearted support, love, encouragement in all my professional endeavors.

Above all, I bow my head before God almighty.

CONTENTS

List of Tables

Chapter-3

Chapter-4

List of Figures

Acronyms

AS- Andaman Sea

BAL sp & bal- *Balaenoptera* sp

BEDE- *Balaenoptera edeni*

BMUS- *Balaenoptera musculus*

Cd- Cadmium

Cu- Copper

DCAP & dcap- *Delphinus capensis*

EEZ-Exclusive Economic Zone

EICC- East Indian Coastal Current

ETP- Eastern Tropical Pacific

Fe- Iron

FORV- Fishery and Oceanographic Research Vessel

G-Grid

GGRI- *Grampus griseus*

GM-Gulf of Mexico

GMAC- *Globicephala macrorhynchus*

GPS-Global Position System

HCB- Hexachlorobenzene

HCH-Hexa chlorocyclohexane

IUCN- International Union for the Conservation of Nature and Natural Resources

IWC- International Whaling Commission

MNOV- *Megaptera novaeangliae*

Mn- Manganese

NBOB- Northern Bay of Bengal

NeAS- Northeastern Arabian Sea

Ni-Nickel

NMC- northeast monsoon current

NPHO- *Neophocaena phocaenoides*

PCB- Polychlorinated biphenyl

Pb- Lead

PCRA- *Pseudorca crassidens*

PMAC & pmac- *Physeter macrocephalus*

ppt- parts per thousand

PRIMER- Plymouth Routines In Multivariate Ecological Research

SBOB-Southern Bay of Bengal

SD- Standarad deviation

SeAS-Southeastern Arabian Sea

SF- Sighting frequency

SATT- *Stenella attenuate*

SCHI & schi- *Sousa chinensis*

SLON & slon- *Stenella longirostris*

SPSS-Statistical Package for the Social Sciences

SRL- Sri Lanka water

Ssp & stn- *Stenella* sp

SSS- sea surface salinity

SST -*Sea surface temperature*

TADU & tadu- *Tursiops aduncus*

UID -unidentified dolphins

UIW- unidentified whales

WICC- West India Coastal Current

WTIO -Western Tropical Indian Ocean

Zn- Zinc

Chapter 1

INTRODUCTION

Biodiversity is a term that describes the ecosystem complexity or taxonomic diversity at the species, genus, family and order or phylum level and distributed unevenly across different environment (Allaby, 1998; Chase and Leibold, 2002). Marine and tropical environments maintain extremely diverse species assemblages, whereas others such as dessert and alpine support a restricted range of species (Gastan, 2000). The ocean makes up 97% of the biosphere and support tremendous species diversity but understanding the most species diversity in marine environment remain extremely limited. The marine mammal is one of the major neglected communities in the pelagic ecosystem of most of the oceans.

Marine mammals are important components and occupy elevated trophic level in the oceanic environment. They are generally classified under three major orders namely Cetacea (whales, dolphins and porpoises), Sirenia (manatees and dugong), and Carnivora (sea otters, polar bears, and pinnipeds). To date, there are 130 marine mammals species of these three groups are known to occur in the world ocean (Jefferson *et al.,* 2008). Among the three groups, the order Cetacea is the most diverse, having evolved from land-dwelling ancestors around 55 to 60 million years ago and are known to occur in all marine habitats (Reeves *et al.,* 2002). Order Cetacea incorporates two suborders such as Mysticeti (baleen whales) and Odontoceti (toothed cetaceans). Mysticeti represents four families of 14 species, while Odontoceti represents 73 species under ten families (Jefferson *et al.,* 2008).

Many cetaceans have fully adapted to live in almost all marine ecosystems and have evolved to exploit a wide variety of prey species. Being apex predators, cetaceans have the potential to be important barometers of marine diversity and give them significant role as indicators of marine ecosystem conservation state. In general, cetaceans are thought to have a major influence on marine food webs as well as the structure and function of some aquatic communities because of their large body size, high metabolic rates, and large numbers (Bowen, 1997; Croll and Tershy, 1998). Therefore, an understanding the role of cetaceans in marine ecosystem is imperative because it provides a context to evaluate the potential impact of their predation on prey population, prey community structure and variation in prey population (Bowen, 1997).

Cetaceans are highly mobile animals with complex habitat requirements and are distributed unevenly across oceans ranging from temperate, tropical, subtropical, and polar water of the deep ocean. These apart, estuaries and the tributaries of some of the world's largest rivers act potential habitat for few cetaceans (river dolphin) and sirenians group (dugong). Some habitats, such as tropical, subtropical and temperate, maintain extremely diverse cetacean species assemblages, whereas Polar Regions support a restricted range of species (Gaston, 2000). Among the different marine habitats, tropical water occupies vast part of the world ocean and covers nearly 50% of the world's ocean, which supports a wide range of distribution of tropical cetacean species (Longhurst and Pauly, 1987; Ballance and Pitman, 1991).

With increasing threat of anthropogenic activity, cetacean diversity is under significant pressure with several species may become extinct likely in near future. Commercial fisheries for small cetaceans (Amir, 2002; Razafindrakoto, 2004), widespread use of agricultural and industrial chemical (Tanabe *et al.,* 1994; Reijnders *et al.,* 1999) are known to be major anthropogenic factors that pose serious threat to the cetacean community in different marine environments. In addition, direct competition between human beings and cetaceans for commercially important fishes establishes a conflict between fisheries and cetacean communities across the world. Thus, this competition makes many cetacean species vulnerable to fishing gears. As a result of rapid decline of marine mammal community, conservation of this endangered group has become growing concern in many parts of the world. IUCN has categorized 33% of the cetacean species as low risk, conserve dependent and critically endangered and the status of 44% of others are uncertain due to lack of adequate data. Hence, defining the spatial and temporal distribution of marine mammal has become necessary for effective conservation and management.

Distribution is the part of ecology that deals with different geographic ranges of species diversity in space and time. Defining distribution of cetaceans is a critical component in understanding cetacean function in marine ecosystem. The complexity of distribution pattern of cetacean depends on different environment factors that affect the species diversity as well as habitat. Cetaceans prefer habitats that meet their requirement during their feeding and breeding time and therefore distribution may change in short term as local conditions change. Regional abiotic and biotic factors play a key role and have a strong influence on distribution patterns of cetaceans over time and space. The importance of these variables appears to vary between regions and species and urges the need to study the role of oceanography in habitat preference by cetaceans on regional basis. Studying habitat characteristics of cetaceans is crucial to understand the ecology and community structure of cetacean species (Katona and Whitehead, 1988).

The need to monitor incidental bycatch has prompted extensive research on occurrence and distribution of cetacean community in many tropical waters such as eastern tropical Pacific and Gulf of Mexico. Species composition, distribution, abundance, habitat preference and inter annual variation of these tropical areas in many major oceans have been well studied. The Indian Ocean is the third largest of the world's oceanic divisions, covering about 20% of water and includes major tropical zones on the Earth's surface. In 1979, the Indian Ocean Cetacean Sanctuary was established by International Whaling Commission, encompassing the entire Indian Ocean north of 55°S with view of conserving the cetacean population (Leatherwood and Donovan, 1991).

The cetaceans of the southern and northern parts of Indian Ocean have also been well studied relative to those of the other oceans, resulting in a basic understanding of distribution and abundance (De Silva, 1987; Leatherwood and Reeves 1989; Gordon, 1990; Kasuya and Wada, 1990; Leatherwood and Donovan, 1991; Smeenk *et al.*, 1996; Peddemors *et al.*, 1997; Amir *et al.*, 2005; Stensland *et al.*, 2006; Kiska *et al.*, 2007; Cornelis *et al.*, 2008). In contrast to these parts of the Indian Ocean, studies on cetacean in the northeastern part of Indian Ocean, in particular, in the Indian peninsula are very few due to complete lacking of systematic Programme in the last century.

The Indian Sea is a highly productive area and one of the most important marine regions in the northeastern Indian Ocean. India has an Exclusive Economic Zone of 2.02 million km^2 and is endowed with a rich marine biodiversity. The Indian Sea is characterized by more diverse topography and hydrology, which supports substantial populations of fish, birds and other marine organisms. The tropics of Indian Sea also support a variety of marine mammal species, which includes baleen whales, toothed whale, dolphins and dugong. Earlier reports on occasional stranding of cetacean show that the water of Indian EEZ is a habitat for several species of cetacean, which supports the 25 species of cetacean and one species of Sirenia (Kumaran, 2002). Of the 25 species of cetaceans six species are Mysticeti (baleen whales) and the rest are Odontoceti, which includes three families of dolphins, one family of porpoise and one family of toothed whale.

Distribution of cetaceans in the Indian Sea is poorly understood. There is no uniformity among different authors as to exact number of cetacean species occurrence in Indian water. Recent advancement in fishing has extended fishing activity to oceanic waters and thereby has added new species to cetacean community in the Indian Sea. Information from incidental catch (by-catch) in fisheries and sightings indicate that Indo-Pacific bottlenose (*Tursiops aduncus*), humpback (*Sousa chinensis*) and spinner dolphins (*Stenella longirostris*) are the most common species in India (Lalmohan, 1985; Kumaran, 2002; Yousuf *et al.*, 2008). Few species such as Cuvier beaked whale (*Ziphius cavirostris*), Melon headed whale and Killer whale (*Orcinus orca*) have been recorded very rarely in the last 200 years and rises uncertainty as to distribution of these species in Indian waters (Kumaran, 2002).

During the last century, occasional report on dead animals caught in fishing nets, washed ashore and stranded event were the only source available for documenting the occurrence of cetaceans. Documenting stranding or sighting locations is one of the alternative approaches to mapping species distributions. However, this approach does not show actual species distribution of cetaceans in a particular niche (Perrin *et al.*, 1994; Jefferson and Schiro, 1997). Few opportunistic and dedicative surveys on the occurrence and distribution of cetaceans have been conducted in Indian waters (Harwood, 1980; Leatherwood *et al.*, 1984; Alling *et al.*, 1986; Jayaprakash *et al.*, 1995). The oceanic water of eastern Arabian Sea of India (Alling, 1986) and coastal waters northeast Arabian Sea (Sutaria and Jefferson, 2004) have been subjected to a few investigations on occurrence and distribution of cetaceans, whereas the information available is very poor in the rest of the Indian waters. Nevertheless, there have been no systematic studies to map their distribution in Indian Seas. Lack of information on the distribution is disturbing, as Indian coast is located within the Indian Ocean Sanctuary.

Delineating geographic ranges of marine mammals is hampered by difficulties in monitoring distributional limits of these elusive and often highly mobile animals. Various survey techniques have been developed for assessing marine mammals' distribution and abundance. This includes sighting survey on ship or boats, aerial survey, acoustic survey and interview survey (Hammond, 1986; Holt *et al.*, 1987; Jefferson and Leatherwood, 1997; Gordon and Tyack, 2002). Dedicated survey on charted vessel is expensive and surveying broader geographical region is generally difficult (Williams *et al.*, 2006; Dawson *et al.*, 2008). Designated surveys usually cover only a small fraction of the distributional ranges of most species, and often yield little information, both in time and space, of a given species occurrence and geographic range (Kasamatsu *et al.*, 2000; Hammond *et al.*, 2002).

Due to the vastness of the seas, the dedicative surveys on charted vessel is generally prohibitive in terms of carrying out regular surveys, for this reason, in the present study, visual surveys were made using platform of opportunity (passing mode) as means to assess the occurrence and distribution of cetacean group in the Indian Seas. Survey using Platform of Opportunity such as ferries, fishing vessels and oceanographic research vessels are considered as valuable source and being exploited for cetaceans research in worldwide (Evans and Hammond, 2004; Kizka *et al.*, 2007; Dawson, 2008). Platform of opportunities have been proven to contribute to the body of knowledge about cetaceans (Ritter, 2003; Robbins *et al.*, 2006). The use of ship as platform of opportunity provides affordable tool for the collection of data on cetacean distribution. Such platform can provide opportunity to survey inaccessible offshore habitat and enable long term monitoring cetacean diversity in areas of interest (Walker and Macleod, 2004). Ship based visual survey can also provide quantitative data on distribution relative and absolute abundance of marine mammals at species level (Aragones *et al.*, 1997).

Scope of the Study

As mentioned earlier, cetaceans are currently susceptible to several types of anthropogenic pressures, accumulation of contaminants and interactions with fisheries, global warming, and potential food competition (Macleod *et al.*, 2005; Evans, 2008; Perrin *et al.*, 2008). Other sources of pressures and threats include disturbance, collisions with ships, acoustic pollution and ever-increasing pressure of human population growth has led to worldwide habitat degradation that has driven many species of cetaceans to extinction and put numerous others in vulnerable state (Cole *et al.*, 1994; Amir *et al.*, 2002; Berggren *et al.*, 2007).

There are number of potential threats to cetaceans and their habitat, which could have possible impact on cetacean diversity in India too (Kumaran, 2002). Cetacean entanglement in fishing gear represents one of the most immediate threats to their diversity in India (Lal Mohan, 1985; Jayaprakash *et al.*, 1995; Kumaran, 2002; Yousuf, *et al.*, 2008). Bycatch of several species of marine mammals are reported regularly in the Indian fisheries during all the season. Cetaceans entanglement has been observed in a wide range of fishing gear including pelagic driftnets (James, 1990), bottom-set gillnets (Silas *et al.,* 1984; Lalmohan, 1995), trawl nets (Seshagiri Rao and Narayana Rao, 1993) and purse seines (Yousuf *et al.,* 2008). Such entanglement causes physical damages to fishing gear and also causes injuries to cetaceans or death through drowning. Conflicts between cetaceans and fishing gear are continuing and have extended to oceanic waters. Many cetacean populations are decimated significantly, and therefore they are entering either threatened, endangered or at risk of entering these two categories.

Among many gears used in Indian fisheries, gillnet is main cause for massive cetacean entanglement. The Indian gillnet fishery is one of the largest driftnet fisheries in the world with around 14,800 operational fleet across the Indian Seas (CMFRI, 2006). About 90% of the fleet is using nets of 0.5-1.5 km in length, and around 6-12m in depth, with a few vessels using 6km or more of netting. Cetacean populations are increasingly threatened by continuous by-catch in gillnet fisheries (Kumaran, 2002). The recent investigation shows the increased magnitudes of cetacean bycatch in gillnet considerably with the catch rate of one animal in every two days (Yousuf *et al.,* 2008). The increasing bycatch of cetaceans in gillnet has led few cetacean to vulnerable and put other species at risk. Of the 25 cetacean species in India, according to the IUCN, the status of one species is endangered, four species is vulnerable and the status of 20 species is insufficiently known (Klinowska, 1991). In India, All cetacean species are protected under the Wildlife (Protection) Act (1972). Few cetacean species are listed in schedule I, which identifies species in need of strict protection.

Conservation concern is one of the major reasons to determine the distribution and numbers of marine mammals using inshore and estuarine systems. Determining regions with high concentrations of cetaceans may aid in prevention of incidental bycatch of cetaceans through fishery interaction. Limited information about species diversity and areas which may be critically important is an obstacle in developing efficient conservation management strategies. Differences in species distribution and relative abundance across geographical area and between different marine habitats must be considered when drawing up conservation plans for cetacean and its habitat. Increased knowledge on the distribution would help identify important cetacean habitats and predict temporal distributions of marine mammals at sea. Thus, it would help address these conservation issues by providing data that could be linked to monitoring other components of the ecosystem.

Due to the lack of knowledge and data, it is not currently possible to assess the conservation status of the species in Indian region. Investigations are therefore required to understand temporal and spatial distributional trends of cetaceans in these regions to support conservation efforts. The collection of baseline data on distribution and population would assist in identifying areas that provide habitat to especially vulnerable populations of cetaceans. It would also become possible to compare Indian cetacean communities with other cetacean communities to understand variations in the ecosystem. The purpose of this study was to examine the distribution of cetacean species, using the visual sighting survey in the Indian EEZ and the contiguous sea. This thesis provides information on species diversity and distribution of cetacean in the Indian sea and the contiguous seas. The relation between cetacean distribution and environmental features is also discussed. The outcome of this thesis would be basic knowledge of the composition of cetacean community and describe the distribution along the Indian coast and the contiguous seas.

Objectives of the study

In view of lack of adequate knowledge on species diversity and distribution range, the aim of this thesis is to gain an insight into the distribution and ecology of cetaceans in the Indian sea and the contiguous sea. Hence, this study is aimed to achieve the following objectives:

1. To examine regional information on species diversity and distribution of marine mammals along the Indian sea and the contiguous sea using opportunistic visual survey method (passing mode);

2. To estimate the relative abundance of cetaceans in the Indian seas, including Lakshadweep sea, Andaman sea and the contiguous seas;

3. To investigate the relationship between the observed distribution of cetaceans and different climatic and oceanography parameters such as Sea Surface temperature, salinity, bathymetry and distance from the shore.

Chapter 2

REVIEW OF LITERATURE

Knowledge on distribution and abundance of cetacean species is an important element in defining their function and role in tropical ecosystem (Hain *et al.*, 1985; Bowen, 1997). Studying cetacean distribution and the related environment parameters, which influence the marine mammal occurrence, are crucial to understand the ecology of species and the structure of cetacean communities in the different habitats (Katona and Whitehead, 1988). It has important implications for conservation and management, which depend on accurate information about the distribution and abundance of animals and the way these patterns change over time and space (Dawson *et al.*, 2008).

Assessing the distribution and abundance of cetaceans using sighting survey has been a standard and conventional practice throughout the world (Leatherwood, 1991). It provides important insight into distribution pattern, species composition and behavioral pattern of cetaceans. Though various method are followed to survey the distribution of marine mammal, sighting survey has proved viable method to assess the distribution and relative abundance of marine mammals (Aragones *et al.*, 1997) and opportunistic platform survey has become a standard and widely followed practice (Ritter, 2003; Robbins *et al.*, 2006). Using the opportunistic platform, there has been great deal of comprehensive and profound works on occurrence, distribution and abundance of marine mammals in different maritime zone of the world oceans (Evans, 1980; Williams *et al.*, 2002; Kiszka *et al.*, 2004).

2.1 Distribution and abundance of marine mammal in different ocean

2.1.1 Distribution and abundance in Indian Ocean

The Indian Ocean is an important region for cetaceans, and has been declared as sanctuary by International whaling commission (Leatherwood and Donovan, 1991). The rich diversity of cetacean in this sanctuary stimulated a great deal of research on distribution and abundance of cetacean in Indian Ocean. Effort to inventory the cetacean fauna of Indian Ocean have focused on describing the distribution and abundance of the many cetacean species found in this region (Keller *et al.*, 1982; Leatherwood, 1985). Considerable attention has been paid to assess the cetacean distribution in southwestern part of Indian Ocean (Peddemors, 1993; Best *et al.*, 1996; Ljungblad *et al.*, 1997; Stensland *et al.*, 1998), northeast (Rice, 1998; Rudolph and Smeenk, 2002), southern (Tynan, 1996; Thiele *et al.*, 2000).

Cetacean diversity in the pelagic Western Tropical Indian Ocean (WTIO) was similar to that of the Eastern Tropical Pacific (ETP) and the Gulf of Mexico (GM) (Ballance and Pitman, 1998). Some studies have been undertaken in western reaches of the Indian Ocean Sanctuary (Amir *et al.*, 2002, 2005; Rosenbaum *et al.*, 2003; Stensland *et al.*, 2006; Berggren *et al.* 2007; Kiszka *et al.*, 2006, 2007). Robineau (1991) gave brief account on distribution and seasonality of few *Balaenoptera* species in the Western Tropical Indian Ocean. A survey conducted around the Republic of the Maldives in WTIO, exhibited that the cetacean community of Maldives consisted of 16 species of cetacean, including three new species, *Ziphius cavirostris, Mesoplodon densirostris* and *Kogia simus* (Ballance *et al.*, 2001). Cetacean observations along Somalia water in southwestern Indian Ocean indicated occurrence of 14 cetacean species, which included four larger cetaceans with predominant occurrence of sperm whale (Small and Small, 1991). Prematunga *et al.* (1991) reviewed and summerised distribution, abundance and habitat preference of Blackfish (killer and false killer, pilot, pygmy pilot and melon-headed whales) in the Indian Ocean Sanctuary, based on sighting and stranding data. Similarly, distribution of risso's dolphins in Indian Ocean was reviewed and summerised by Kruse *et al.* (1991) indicated wide range of distribution in Indian ocean, particularly in deeper coastal waters.

Marine mammal distribution and abundance in the northeastern part of Indian oceans, in particular, Southeast Asia is insufficiently known. Although, few attempts were made to delineate the distribution and abundance level of marine mammals in the entire northern Indian Ocean (Leatherwood *et al.*, 1984). Alling (1986) conducted extensive survey in the northwest of Indian Ocean and off Sri Lankan coast with the principal purpose of documenting sperm whale distribution. This survey showed high sighting frequency and abundance of *Stenella longirostris* and *Tursiops* sp throughout the survey area. Chantrapornsyl *et al.* (1991) reviewed distribution of two *Kogia* species in the northern Indian Ocean. Surveys along Bay of Bengal (Bangladesh water) and the northern coast of Myanmar recorded sightings of *Tursiops aduncus, Orcaella brevirostris, Stenella longiriostris*; the small-form of the Bryde's whale (*Balaenoptera edeni/brydei*) (Smith *et al.*, 1997; 2008a and 2008b). Baldwin *et al.* (1998) reviewed earlier records available on small cetacean to define the occurrence of 16 small cetaceans and their distribution in the Arabian Peninsula.

Minton *et al.* (2002) reported the distribution and relative abundance of humpback whales off Oman coast. Population size estimated for spinner dolphins was around 4,000 individuals (Dolar *et al.*, 1997). In the Inland Sea of Japan the number of porpoises observed during the breeding season (April) was 4,900. Off western Kyushu, about 3,100 porpoises were estimated in the Ariake/Tachibana Bay and 200 in the Omura Bay (Kasuya, 1999). Recent sightings and questionnaire surveys in the Seto Inland Sea, which is a major habitat for finless porpoise in Japan, indicated a decrease in abundance of this species (Amano, 2002). Gowans and Whitehead (1995) reported on seasonality of common dolphin abundance in the Gully, off Nova Scotia. Barco *et al.* (1999) investigated the patterns of abundance and distribution of *T. truncatus* and revealed significant differences in local abundance throughout the year. Smith *et al.* (2006) used a mark-recapture analysis of concurrent counts that indicated relatively large populations of Ganges River dolphins in Sundarban Area.

Eastern Indian Ocean has also been well surveyed to address the distribution of cetaceans in this region (Kato *et al.*, 1996; Gill, 1997; Burton *et al.*, 2001). Cokeron *et al.* (1997) surveyed off southeast Queensland to examine the distribution of humpback dolphins and found that density of humpback dolphin was approximately 0.1 dolphin/km^2. Bannister and Hedley (2001) conducted continuous aerial survey to delineate the winter distribution of humpback whale and estimated stock in western Australian coast. Aerial survey within Shark Bay to examine the spatial distribution of humpback whale indicated that distribution of humpback whale is seasonal and influenced by unique oceanographic condition. (Burton, 2001). McCauley *et al.* (2001) defined seasonal distribution of pygmy blue whales, *Balaenoptera musculus brevicauda* using aerial, boat and acoustic monitoring surveys in eastern Indian Ocean Sanctuary. A study on summer distribution of nine large cetaceans in the Indian Ocean, using the sighting data collected from Japanese scouting vessel showed the occurrence of blue whale, humpback and minke whales in the higher latitudes whereas other baleen whales (Fin, Sei, pygmy blue and Bryde's whales) prefer lower latitudes (Kasuya and Wada, 1991). Stafford *et al.* (2004) investigated winter distribution of Antarctic blue whales by examining acoustic data from the eastern tropical Pacific Ocean and the Indian Ocean during the austral autumn and winter and opined that the Antarctic blue whales appear to use both the Indian and Eastern Pacific Oceans concurrently.

The cetacean diversity and their distribution of the central Indian Ocean have not been systematically estimated. However, a series of preliminary attempt has been made to assess abundance (Grace, 1994; Eyre, 1995 and 2000; de Boer *et al.*, 2000 and 2001). Spinner dolphins and sperm whales appear to be major components of the cetacean fauna in the Central Indian Ocean (Eyre, 1997). *Stenella* sp, *Delphinus* sp, *Physeter macrocephalus, Globicephala* sp, *Balaenoptera musculus, B .edeni* have been observed in the oceanic water of central Indian Ocean (Leatherwood, 1980; Eyre, 2000). Robineau (1991) reported seasonal occurrence of Balaenopterids in central Indian Ocean. Kasuya and Wada (1991) defined geographical range of sperm and killer whales and concluded that they share similar geographical area in central Indian Ocean Sanctuary. Kato *et al.* (1995) reports the distribution of blue whale sub species *Balaenoptera musculus brevicauda* in mid latitudes of central Indian Ocean.

2.1.2 Southern Ocean distribution

The Southern Ocean is one of the most dynamic oceans in the world and richness of marine mammals is high especially, the rarqual whales (Clarke and Lamberson, 1982; Kasamats and Joyce, 1995 and 1998; Kasamatsu, 2000; Jayasankar *et al.*, 2007). The distribution of rarqual whales such as blue whale (Branch *et al.*, 2007), minke whale (Best, 1985; Arnold *et al.*, 1987), fin whale (Gedamke, 2007) and Sei whale (Kawamura, 1994) were well documented. Similarly, the distribution of other small cetacean in southern ocean was also well described by Sigurjonsson (1991); Weir *et al.* (2001); Compton *et al.* (2007). Bellison (1966) listed the occurrence of false killer whales in Antarctic water and concluded that distribution of false killer whale is rare in higher latitude. Long-finned pilot whales have been recorded in Antarctic and in higher latitudes (Borsa, 1997). Three forms of killer whale are known to occur in Antarctica water (Pitman and Ensor, 2003) Kasmatsu *et al.* (1990) reported that hourglass dolphin inhabit the Southern Ocean sanctuary mainly between 43°S-67°S with most sightings between 54°S-62°S near the convergence area. Dusky dolphin and spectacled porpoise are the other small cetaceans occurred in Southern Ocean (Jefferson *et al.*, 1994).

2.1.3 Pacific Ocean distribution

In contrast to the Indian Ocean, cetacean communities in Pacific Ocean, in particular, in Eastern Tropical Pacific (ETP) is relatively well studied area for cetacean distribution and abundance. Studies on tuna purse-seine fishery to monitor the impact of incidental mortality of dolphins resulted a basic knowledge on composition of the cetacean community, distribution and abundance patterns, species-specific habitat preferences of cetacean in eastern tropical Pacific (Au and Perryman 1985; Smith 1986; Au and Pitman 1986; Holt and Sexton 1990; Reilly, 1990; Gerrodette and Wade, 1991; Wade and Gerrodette, 1993; Fiedler and Reilly, 1994; Reilly and Fiedler, 1994; Gerodette, 2002). Recent attempt to identify delphinids using acoustic method documented the vocalization of nine delphinid species (Oswald *et al.*, 2003). Ferguson *et al.* 2006 studied geographical distribution pattern of Cuvier beaked whale and *Mesoplodan* beaked whale population in eastern tropical Pacific. Abundance estimation of blue and humpback whales using capture and recapture method was attempted by Calambokidis and Barlow (2004) in eastern tropic of Pacific.

Perrin *et al.* (1979) described three forms of *Stenella longirostris* that have served as stock units for management of populations of dolphins in Eastern Pacific. Estimates for the southern whitebelly stock showed little evidence of population changes, although the pattern for this may be approximately the same as that for the northern whitebelly spinner dolphin (Reyes, 1991). The most recent estimates of absolute population size are 583,500 for the eastern spinner and 992,400 for the whitebelly spinner (Wade and Gerrodette, 1992). For the eastern Tropical Pacific Ocean, Gerodette (1999) reported a population size of 339,000 eastern spinner dolphins. Barlow (1995) estimated abundance of *D. capensis,* to be 9,470 animals, and 226,000 for *D. delphis* in Californian waters. Aerial line-transect surveys were used to estimate the abundance of 11 cetacean species in Hawaiian water (Mobley *et al.*, 2000, 2001)

2.1.4 Cetacean distribution and abundance in Gulf of Mexico

The cetaceans of the Gulf of Mexico have also been well studied, which results in basic understanding of distribution (Mullin *et al.*, 1994; Blaylock *et al.*, 1995; Davis and Fargion 1996; Jefferson 1996; Jefferson and Schiro, 1997). Cetacean distribution on continental shelf water has been investigated and reported the occurrence of three cetacean species, while 20 species have been reported in oceanic water of Gulf of Mexico (Scott, 1990; Mullin and Hansen, 1999). Hooker *et al.* (1999) assessed the distribution and abundance of cetacean relative to spatial and temporal parameters in Gully submarine canyon. Jaquet (1996) highlighted the influence of spatial and temporal scales in understanding sperm whale and other cetacean distributions.

The distribution and abundance estimation for marine mammal along the united state of Gulf of Mexico are well documented but similar studies for the Mexican coast of Gulf of Mexico are lacking (Galindo *et al.*, 2009). Heckal (1992) examined the distribution and abundance in various Mexican coast. In US waters, 34 species of marine mammal are reported to occur (Wursig, 2000). Cetacean abundance for northern continental-shelf and northwestern continental slope of Gulf of Mexico have been reported by Jefferson *et al.* (1996) and Fulling *et al.* (2003). Abundance estimation for oceanic water of Gulf of Mexico has been reported by Hansen *et al.* (1995); Mullin and Hoggard (2000); Waring *et al.* (2000). Mullin and Fulling (2004) surveyed northern Gulf of Mexico for estimating abundance of cetaceans, which revealed that *Stenella attenuate* was most abundant species among the 19 species recorded in this survey. Mullin *et al.* (2004) provided some evidence of seasonal changes in species diversity and abundance in slope waters of northeastern Gulf.

2.2 Distribution in relation to oceanographic and physiographic features

The distribution of cetaceans is driven by many oceanographic and physiographic factors. Common predictors of cetacean distribution include sea surface temperature, salinity distance to shore, and underwater topography (Hoelzel *et al.*, 1989; Woodley and Gaskin, 1996; Tynan *et al.*, 2005), but the mechanisms linking these variables to patterns of habitat selection have only been investigated recently (Croll *et al.*, 2005). Several studies have linked distribution patterns of both deep water and coastal cetaceans to oceanographic features and environmental conditions. Studying cetacean habitat selection can be extremely challenging as they spend most of their lives under water (Hastie *et al.*, 2003). Fine-scale surveys have led to discovery of habitat partitioning between cetacean species and several oceanographic parameters, which have been recognized as necessary vehicles to better understand the ecology and habitat preferences of deep water species (Waring *et al.*, 2001).

Bathymetric characteristics are the variable often cited in studies of cetacean distribution (Canadas *et al.*, 2002; Yen *et al.*, 2004). Coastal studies have also shown a relationship of cetaceans to bottom topography (Liret and Ridoux, 1998; Hastie *et al.*, 2004). Moore and DeMaster (1998) and Moore (2000) found that cetacean distribution in the Alaskan Arctic could be quantified by depth and the bathymetry features. The genus *Delphinus* has been observed associated with water characterized by offshore bathymetry feature in Canada and ETP (Polacheck, 1987; Gaskin, 1992). Distributions of Humpback whales and fin whale were associated with bathymetric features in the Eastern Bering Sea. Occurrence of fin whales and humpback whale occurred were seen on the middle shelf and on the outer shelf (Moore *et al.*, 2002). The habitat of several cetacean species could be defined on the basis of physiographic variables such as depth and slope (Hui, 1979; Forcada *et al.*, 1990; Forney, 2000).

In the Eastern North Atlantic, depth plays major role in determining distribution of *Stenella longirostris.* It is found in deep water (greater than 1,000m) past the continental slope (Perrin *et al.*, 1994). In western north Atlantic, striped dolphins is confined to the Gulf Stream or the waters off the continental slope (Davis *et al.*, 1998). In the Strait of Gibraltar, it is found in waters of 600m or more depth (Hashmi, 1990). Atlantic spotted dolphins were consistently found in the shallowest water on the continental shelf and along the shelf break within the 250-m isobath (Davis *et al.*, 1996). Griffin and Griffin (2003) examined habitat partitioning between *Stenella frontalis* and *Tursiops truncatus. T. truncatus* were the dominant cetacean species in shelf waters shallower than 20 m, whereas *S. frontalis* were the most common shelf species at depths of 20–180 m. *Sousa chinensis* have been reported to prefer shallow depth area including sandy beaches, enclosed bays and coastal lagoons, mangrove mangrove channels, over sea grass meadows, around rocky and coral reefs, and in turbid estuarine waters (Beadon, 1991; Durham, 1994; Guissamulo, 2000; Karczmarski, 1996 and 2000).

Baumgartner (1997) characterized the distribution of risso's dolphin with respect to bathymetric features of northern Gulf of Mexico. The habitat characteristics of 13 cetaceans in the Bay of Biscay proved that bathymetry clearly plays a significant role in the distribution and habitat partitioning of toothed cetaceans in the region (Kiszka *et al.*, 2007). Davis *et al.* (1998) characterised the physical habitat of cetaceans found along the continental slope in the north-central and western Gulf of

Mexico and opined that *Stenella longirostris* was found over intermediate bottom depths, its distribution overlapping with that of purely pelagic and purely coastal species.

Studies of cetacean habitat preferences in terms of topographical and environmental variables have also been investigated in the different part of the world (Jaquet and Whitehead, 1996; Macleod *et al.*, 2005). Northern bottlenose whales (*Hyperoodon ampullatus*), sperm whales (*Physeter macrocephalus*) and beaked whales (family Ziphiidae) are often found in association with submarine canyons off the Nova Scotia shelf (Whitehead *et al.*, 1992; Gowans *et al.*, 2000). Baumgartner *et al.* (2000) studied the distribution of *Tursiops truncatus, Grampus griseus, Kogia breviceps, K. sima, Stenella attenuata* and *Physeter macrocephalus* with respect to depth, depth gradient, surface temperature, chlorophyll concentration and epipelagic zooplankton in northern Gulf of Mexico. The distribution of *Tursiops truncatus, Grampus griseus, Stenella attenuata, Kogia* spp and *Physeter macrocephalus* in the northern Gulf of Mexico was easily partitioned by depth, with each of the five species studied distinguishable from at least three of their counterparts by depth alone (Baumgartner *et al.*, 2001).

Marine mammal distribution patterns have also been linked to dynamic environmental variables. The most important variables seem to be sea surface temperature (Brown and Winn, 1989; Fiedler *et al.*, 1998; Hamazaki, 2002) and salinity (Selzer & Payne, 1988). Cetacean distribution in Bangladesh water was closely tied to environmental gradients, with Irrawaddy dolphins and finless porpoises occurring most often in nearshore, turbid, low-salinity waters (Smith *et al.*, 2009). Sykes *et al.* (2003) investigated the variables that best predict the seasonal distribution of sightings of bottlenose dolphins along the England coast. The factors investigated included salinity, sea surface temperature, chlorophyll a (an indicator of primary productivity) and fish distribution. They found that chlorophyll a and fish distribution were the main factors influencing bottlenose dolphin distribution. A group of bottlenose dolphins in the coastal waters of Cornwall, UK, demonstrated a seasonal residency pattern, spending the winter in southern Cornwall and moving further north-eastward during spring and summer (Wood, 1998). Hastie *et al.* (2005), in acoustic survey, used the environmental model to predict oceanic dolphin habitat in the northeast Atlantic. Their result suggested water depth and surface temperature were factors for detecting dolphins acoustically.

Study on seasonal movement of striped dolphin in Mediterranean Sea suggested the dolphins move towards northern part of the basin as SST increases in southern part (Perrin *et al.,* 1994). The near-shore distribution and abundance of *Delphinus delphis* during summer summer in the west coast of New Zealand's south Island, suggested a seasonal preference of D. *delphis* for this coast (Braeger and Schneider, 1998). Seasonal offshore and inshore shift of short-beaked common dolphins was correlated with SST variation in New Zealand water (Neumann, 2001). Norris *et al.* (1994) summarized that spinner dolphin distribution and abundance in relation to certain local oceanographic phenomenon. He found that divergence zones at current margins and current ridges concentrate food organisms and are heavily frequented by dolphins of various species. Aggregations of deep-water cetaceans were also found to be linked with more dynamic oceanographic features such as warm/cold frontal boundaries formed in the Gulf of Mexico and off Georges Bank (Griffin, 1999; Biggs *et al.,* 2000; Ortega-Ortiz, 2002). Three variables (distance from the shore, SST and primary productivity) was used as dynamic variables to determine the habitat preference of seven cetacean species in west of Scotland (Macleod *et al.,* 2007).

2.3 Distribution in relation to feeding habit

The relationship between cetacean and their prey is a critical ecological factor that affecting their distribution and relative abundance. Only a few attempts have been made to study the relationship between cetaceans and their prey (Wishner *et al.,* 1995; Lindstrom *et al.,* 2002). The distribution of three species; horbour porpoise, white beaked whale and minke whale in British Isles was attributed to food and feeding habit to large extends and to breeding habitat to some extend (Northridge *et al.,* 1995). The distribution of Hawaiian long-snout spinner dolphin (*Stenella longirostris*) is associated with its feeding habit that it feeds on organisms associated with the deep scattering layer (DSL) that follow vertical diel movements (Norris *et al.,* 1994). Habitat partitioning of three species; *Tursiops truncatus, Delphinus delphis* and *Delphinus capensis* in Santa Monica Bay California revealed that habitat partitioning in the bay probably relates to resource partitioning among three dolphins species with roughly similar ecological needs (Bearzi, 2005).

Distribution of pan-tropical spotted dolphins is attributed to its feeding habits on epipelagic species and mesopelagic species that rise towards surface at night in the eastern tropical pacific (Robertson and Chivers, 1997; Scott and Cattanach, 1998). Similarly, study on subsurface and night time behaviour of pantropical spotted dolphins in Hawaii suggested that activity levels and feeding behavior were more at night (Baird *et al.*, 2001). Same behavior pattern of pan-tropical spotted dolphin was reported elsewhere in the world (Scott *et al.*, 1993; Richard and Barbeau, 1994). The abundance of *Balaenoptera physalus* in the Mediterranean Sea were more in relatively cooler waters during the summer feeding season (Forcada *et al.*, 1996). Deep water and steep bottom gradients-habitat characteristic of pilot whale and risso's dolphin was linked to its squid feeding habit (Evans, 1987; Wurtz *et al.*, 1992; Gonzalez *et al.*, 1994). Pygmy and dwarf sperm whale's bottom feeding habits *i.e* feeding on squid benthic and mesopelagic fish and crustaceans suggested that its distribution was rather common along the continental slope (Caldwell and Caldwell, 1989).

Larger cetacean distribution is directly associated with prey distribution patterns when these data are available (Jaquet and Gendron, 2002; Baumgartner *et al.*, 2003). The distribution of rorqual whales on their feeding grounds is mostly related to the abundance and patchiness of krill (Murase *et al.*, 2002) and fishes (Whitehead and Carscadden, 1985). Positive correlations have been found between the distribution of rorquals and their prey in coastal environments (Piatt *et al.*, 1989). Fluctuations in abundance of rorqual whales in the Gulf of Maine were related to changes in abundance of their prey (Payne *et al.*, 1990). As the most fundamental indicator of productivity, areas with persistently high chlorophyll -a concentrations should be of importance to cetaceans. In cetaceans, links between primary production and Mysticeti may be easier to establish because they are feeding at a lower trophic level than Odontoceti. Several cetacean species concentrate near meso-scale features and coastal upwelling areas (Benson *et al.*, 2002) but specific information on rorqual whales is very scarce. Broad-scale distributions of whales are thus direct consequences of the spatio-temporal patterns of marine primary productivity (Gulland, 1974).

An acoustic survey conducted off the northeast coast of Sri Lanka in Bay of Bengal to describe the spring distribution and feeding habits of *Balaenoptera sp*, suggested that the occurrence of blue whale in Northeast coast of Sri Lanka was seasonal and this area appeared to be important feeding ground for blue whales (Alling *et al.*, 1991). In the California Channel Islands, blue whales were found in cold, well-mixed, productive waters resulting from upwelling, where they fed on dense aggregations of euphausiids both on the shelf and off the shelf edge (Fiedler *et al.*, 1998). A shift in the distribution of humpback whales occurred in response to a shift of their prey in the same area (Weinrich *et al.*, 1997) and their spatial distribution on George's Bank was strongly correlated with the presence of sand eels (*Ammodytes americanus*) (Payne *et al.*, 1986). The occurrence of finback and humpback whales off Newfoundland was correlated with peak abundance of capelin, *Mallotus villosus* (Whitehead and Carscadden, 1985). In the North Pacific, blue whales seem to aggregate in locations and at times that correspond with peak euphausiid biomass (Burtenshaw *et al.*, 2004).

Zooplankton community structure was found useful in understanding oceanographic characteristics of the habitat of odontocete. The movements of Zooplankton helped to describe the distribution shift of striped dolphin off the French Riviera in the Ligurian Sea Gannier (1999). Griffin (1997) reported that sighting rates of *Stenella coeruleoalba* increased with increasing copepod diversity. The abundant of blue whales (*Balaenoptera musculus*) off the Californian coast is highly correlated with high densities of euphausiids (Croll *et al.*, 1998). The distribution of 19 species of cetacean in the Gulf of Mexico depends on concentration of zooplankton and micro nekton. Furthermore, a significant relationship between zooplankton biomass and cephalopod para larvae numbers, suggested that elevated phytoplankton and zooplankton concentrations result in the presence of prey species of cetaceans (Davis *et al.*, 2002).

2.4 Indian scenario

The present knowledge on cetacean diversity and the distribution in Indian water is limited to a few observations. Pillay (1926); Moses (1940, 1947) and James and Soundararajan (1979) listed whale species in India based on stranding records. Pilleri and Gihr (1974) and Parson (1998) gave brief report on cetacean in coastal region of northern Arabian Sea, in the Indus delta and off the coast of Goa. James and Lal Mohan (1987) documented the list of 21 Indian marine mammal species with description of their salient features based on earlier stranding and sighting report.

Kumaran (2002) reviewed Indian marine mammal diversity based on 200years stranding, landing and occasional sighting data after correcting errata found in species identification reported by various authors.

Opportunistic sighting of dolphin school belong to *Tursiops aduncus* was reported by Krisnapillai and Kasinathan (1987) during the trawl survey in Mandapam area. Observation of dugong was reported by Das and Dey (1999). Sutaria and Jefferson (2004) have studied the abundance and distribution pattern of *Sousa chinensis* along the northwest coast of India and Sri Lankan coast based on sighting and literature survey. According to them the morphological difference between west and east coast *Sousa chinensis* revealed the presence of two different forms of *Sousa*. West coast forms have a large hump and dark in colour, while hump is absent in east coast form.

Records of occasional stranding are available for rorqual whales and toothed whale such as *Balaenoptera musculus* (James and Soundararajan, 1979) *B.edeni* (Lal Mohan, 1992) *B.borealis* (Krishnapillai *et al.*, 1995) *Physeter macrocephalus* (James, 1990; Nammalwar, *et al.*, 1992). Alagarswami *et al.* (1973) reported the mass stranding of short fin pilot whale in the Gulf of Mannar and carried out elaborate investigation on general morphology and skeletal features of the stranded whales. Consumption of dolphin meat has been reported from Lakshadweep (Laccadive Islands) where the inhabitants of some islands catch dolphins, either by harpooning or by driving them into shallow lagoons (Burton, 1940; Manikfen, 1983).

Karbari *et al.* (1985) reported the food habits of the spinner dolphin from samples collected near Mumbai. Silas *et al.* (1985) has reported that the stomach content of the sperm whale stranded at Tranquebar on the east coast of India contained 156 squid beak belong to genus *Chiroteuthis* and has reviewed work on food and feeding habits of the sperm whale from other parts of the world. A brief account of diet of incidentally caught 4 dolphin species such as spinner dolphin, finless porpoise from Mangalore and Chennai coasts was studied by Anoop *et al.* (2008). This study revealed that all four studied cetaceans species feed mostly on teleosts with wide range of trophic levels.

Rajaguru and Natarajan (1985) carried out morphometric investigation on a *Stenella longirostris* and *Tursiops aduncus*, which landed at Protonova on east coast of India. Lal Mohan (1985) described the skull morphometry of four Delphinidae species such as *Delphinus delphis, Stenella longirostris, Tursiops aduncus* and *Sousa chinensis* and compared it with the information of those available from the other part of the world. Similarly, skull measurement of *Physeter macrocephalus*, which stranded along the Gulf of Mannar coast, was described by Sivadas *et al.* (1987). Krishnapillai and Kasinathan (1987) reported the morphometry measurement of three *T. aduncus* and two *D. delphis* caught incidentally in gillnet fishing in Mandapam. Similarly, morphometry of foetus of finless porpoise landed at Goa coast was studied by Hafeezullah (1984).

Incidental catch of cetacean in different fishing gear has been reported over 50years along the Indian coast. Though the dolphins are caught along the Indian coast as bycatch in the gillnets set for commercial fin fishes, Information on the magnitude of the bycatch of dolphin along the Indian coast is very scarce and confined to occasional report with limited information of its entanglement. Frequent entanglement of various cetacean species in different fishing gears was reported in India (Kasim *et al.*, 1993; Nageshwara Rao and Venkataramana, 1994; Nammalwar *et al.*, 1994; Venkataramana and Achaya, 1998). Finless porpoise and the common dolphin were reported to take accidentally in the shore seine fishery off Goa, India (Thomas, 1983). Devaraj and Bennett (1974) reported occurrence of *Xenobalanus globicipitis* (Steenstrup) on the finless Porpoise, *Neomeris phocoenoides* in Indian Sea.

As a result of practicing gillnets in larger level resulted unknown numbers of incidental catch of small cetaceans (Sivaprakasm, 1980; James, 1984; Silas, 1984; James 1990; Kumaran and Subramanian, 1993; Arumugam *et al.*, 1995; Mohan Raj, 1995; Lal Mohan, 1996; Jadhav and Rao, 1998). Other than gillnet occasional incidental catch of cetacean by trawl and purseseine has also been reported (Chandrasekar *et al.*, 1993). Observations on species composition, seasonal variation and sex ratio of the dolphin bycatch in gillnets off Calicut coast showed that the five main species involved in bycatch were the Indo-Pacific humpbacked dolphin (*Sousa chinensis*), bottlenose dolphin (*Tursiops aduncus)*, spinner dolphin, common dolphin and Finless Porpoise (*Neophocaena phocaenoides*). *Stenella longirostris* and *Delphinus tropicalis* was landed more in October, whereas *Tursiops aduncus* and *Sousa chinensis* in December (Lal Mohan, 1985). Jayprakash *et al.* (1995) gave brief account of incidentally caught dolphins that landed as bycatch at Cochin fisheries harbour and bycatch of dolphin showed landing of 11,415 kg of *Stenella longirostris*.

Dugong is widely distributed in the in Indian coastal waters with predominant occurrence in inshore waters of Gulf of Mannar and Palk Bay (Silas and Bastian Fernando, 1985). They discussed the facts of illegal hunting and trading of dugongs in both Gulf of Mannar and Palk Bay and also discussed the measures to be adopted for dugong conservation. Thomas (1966) discussed briefly the habitat and feeding habit of dugong inhabiting in Rameswaram water and reported the transportation of dugong, caught alive incidentally in drift gillnet at Rameswaram. Nair *et al.* (1975) gave general account of dugong along the Gulf of Mannar and Palk Bay. Their studies on stomach content of dugong captured in Gulf of Mannar and Palk Bay showed that the *Cymodacea serrulata* was the main food item, while *Halophila ovalis* formed a minor food item. Badrudeen *et al.* (2004) gave a general account of some aspects of dugong, which include distribution, food and feeding, reproduction and incidental catch along the Gulf of Mannar and Palk Bay.

Very few studies have been conducted on pollutant accumulation in Indian marine mammals. Velayutham *et al.* (1999) reported the lower level distribution of mercury content in different organs of three spinner dolphins and emphasized the possibility of mercury level being increased with the age. Kannan *et al.* (1993) reported accumulation of heavy metal such as Fe, Mn, Zn, Cu, Pb, Ni, Cd and Organochlorines such as PCB, DDT, HCH, HCB in various organs of Ganges river dolphins from India. Similarly, Karuppiah *et al.* 2005 reported organochlorine residues accumulation in some of dolphin species from southeast coast of India.

Chapter 3

MATERIALS AND METHODS

3.1 Study area

The surveyed area extended between 5°N-23°N latitude and 66°E-95°E longitude with depth range varied between 20m and 4000m (Fig. 3.1). The Indian Sea is divided into two distinct western (Arabian Sea) and eastern parts (Bay of Bengal) by a land mark. The study area included the coastal, continental shelf and oceanic waters of the Indian EEZ, which includes Lakshadweep Sea in eastern Arabian Sea and Andaman Sea in Bay of Bengal and the Sri Lankan Sea, which is the contiguous sea of India.

3.1.1 Eastern Arabian Sea

The west coast of India (eastern Arabian Sea) is located in the northwestern Indian Ocean (8°N - 24°N and 65°E - 78°E), encompass three sub regions in Indian Ocean. It is bordered by India (to the east), Iran (to the north) and the Arabian Peninsula (western border). The topography of eastern Arabian Sea shows broad little coastal plain Arabian basin, which opens to the central part of Indian Ocean through Carlsberg and Chagos-Laccadive ridges. The continental shelf of Arabian Sea is wider compare to the east coast of India (Bay of Bengal).

The water circulation of west coast is unique and influenced by seasonal monsoon and northeast monsoon (Shetye *et al.*, 1996a). During the southwest monsoon, the current in the eastern Arabian Sea is clockwise currents and is reversed during northeast monsoon. The strong West India Coastal Current (WICC) causes intense upwelling in the southern Arabian Sea during southwest monsoon, while cold dry continental wind flow generates winter surface cooling by vertical mixing enhance biological productivity during northeast monsoon in the northeastern part of Arabian Sea (Goes *et al.*, 2005).

3.1.2 Bay of Bengal

The Bay of Bengal is one of the two northeastern embayment of the Indian Ocean (approximately 06°N - 22°N and 80°E - 90°E), flanked by the Indian peninsular and Sri Lanka in the west, Bangladesh in the north and the Andaman and Nicobar Islands and Myanmar in the east. The sea is bordered on the north by the deltaic regions of Ganges and Brahmaputra rivers. On the east are the Burmese peninsula and its extension to the south, the Andaman & Nicobar ridges. The southern boundary extends from Dondra head at the south end of Sri

Lanka to the north tip of Sumatra and opens to the Central Indian Ocean. The sea floor topography shows the broad U shaped basin. The continental slopes descent almost uniformly from 2000-4000m. Continental shelf in northern side is broad but narrow towards south. An important feature of the Bay of Bengal is the influence of southwest and northeast winds that bring a complete reversal of the surface current pattern or counter clockwise of East Indian Coastal Current (EICC) according to the direction of wind (Shetye *et al.*, 1991and 1996b).

3.1.3 Andaman Sea

The Andaman Sea is a body of water to the southeast of the Bay of Bengal and lies between 6°-14°'N and 91°-94°'E; it is part of the Indian Ocean. It is roughly 1,200 kilometres (north-south) and 650 kilometres wide (east-west). Average depth of Andmana Sea is 870 m (2,854 ft), and the maximum depth is 3,777 metres (12,392 ft). The continental shelf is narrow in the north for about 90 km bordering Myanmar while it is about 240 km wide in the south bordering Malaysia. Krey and Babenerd (1976) described the Andaman Sea with two prevailing monsoon seasons; the northeast (November-February) and the southwest (May- August). In addition, the Andaman Sea has been well documented as a productive sea because of upwelling phenomenon prevails the sea during northeast monsoon (Wyrtki, 1973).

3.1.4 Sri Lanka

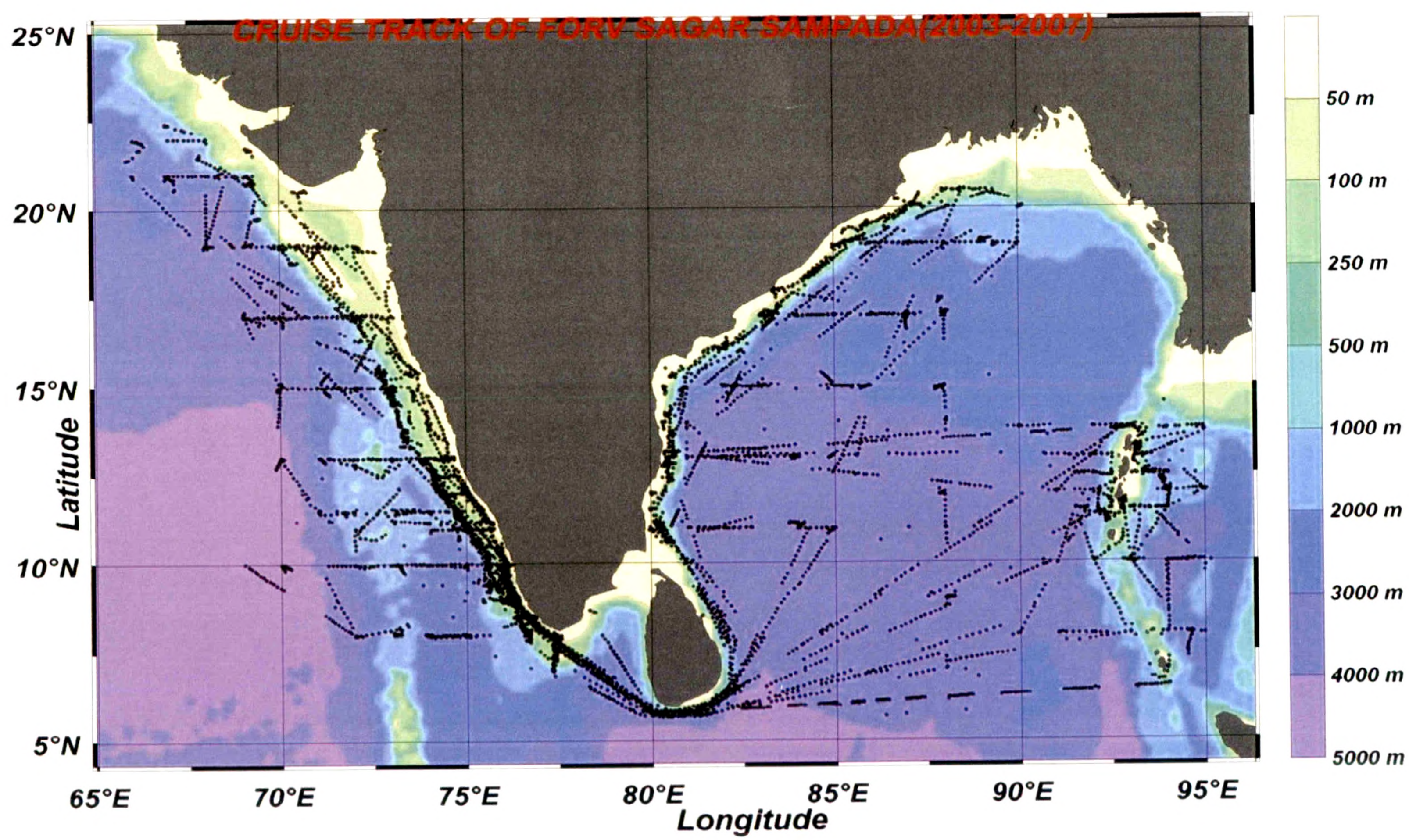
The Sri Lanka coast lies between 5°N - 9°N Latitude and 79°E - 81°E longitude, off the southern tip of peninsular India in Indian Ocean and separated from India by a channel, generally less than 20m deep and 35km away from India. The Arabian Sea lies to the west and the Bay of Bengal lies to the north with no land mass right down to the South Pole.

The Sri Lanka coast has the vast continental shelf and is narrow (2.5-25 km) and is shallower (30-90 m) than the average depth of the shelves around the world (75-125 m). The continental shelf is narrow around the southern part of the island but towards north it widens out and merges with that of India. The floor shelf is bounded by the Bay of Bengal and the Ninety East Ridge and on the west by the Laccadive –Chagos Ridge, Carlsberg ridge and the Arabian Abyssal plain.

Southern part is bounded by the Ceylon abyssal plain and Central Indian Ocean basin.

The water circulation in Sri Lanka Sea is unique and influenced by two currents such as southwest monsoon currents (SMC) and northeast monsoon current (NMC). During southwest monsoon, current flows easterly as southwest monsoon current and flow westerly as northeast monsoon current (Schott *et al.*, 1994).

Fig.3.1 Study area and Cruise track covered by survey vessel during the study period



3.2. Survey vessel

The survey was conducted from the FORV *Sagar Sampada*, which is a fisheries and oceanographic research vessel with endurance of staying at sea for continues 15 days (Fig. 3.2). The vessel's overall length is 71.5m with draft of 5.6m, which allows it to operate in waters >20m depth, and well equipped for oceanographic and fisheries research purposes. Vessel can cruise at maximum speed of 10knots with the average speed of 7knots in favorable sea condition. A sighting platform was situated at 16m above the sea surface, which enabled observer to cover vast area and increased visibility range.

Fig. 3.2 Oceanographic survey vessel

3.3 Survey design and survey period

The survey was designed to cover three regions of Indian EEZ such as west coast of India (eastern Arabian Sea), which includes Lakshadweep sea, east coast of India (Bay of Bengal) and Andaman water. Apart from these three regions, the Sri Lankan water, the contiguous sea of India was also covered. During the survey period, when survey vessel en-routed through Sri Lankan water in order to survey Bay of Bengal and Andaman regions enabled me to survey the southern and eastern part of Sri Lankan water as well. However western part was not covered in the present study.

Surveys were conducted from October 2003 to February 2007 for the continuous period of three years and four months in different Zones. The detail of regional coverage during the surveys in different season is given in Table 1. The cruises were not dedicated to marine mammal sightings alone and the cruise tracks were determined by the needs of other oceanographic studies. Hence, the marine mammal surveys are termed as opportunistic.

3.4 Opportunistic visual survey method (passing mode)

Serious of shipboard opportunistic visual surveys (passing mode) were conducted to assess distribution and relative abundance. Line transect method was not adopted because of the fact that the vessel operation was limited to other oceanographic studies. Hence, course deviation from actual track for the purpose of estimating cetacean group size was impossible and therefore absolute abundance estimation using line transect method was not attempted. I (main observer) who was responsible for both data recording and scanning 180° arc ahead of the ship was stationed on the flying bridge of 16m height above the sea level. This enabled me to look down into the wave troughs and spot out cetaceans that would typically remain hidden at lower elevations. Some species, particularly those of dolphins and porpoises are easily overlooked at higher sea states (Clarke, 1982). During the survey, I was occasionally aided to locate the animals by duty navigational officer and helm of survey vessel. They acted as secondary observer and scanned continuously for sightings while I was taking break for lunch or rest. Whenever I was engaged in collecting data and photographing the animal's cues the secondary observer continuously scanned for other sightings in the same area. In case of any sightings, while secondary observer was on searching effort, sighting was informed to the main observer to collect data on species identification and other related parameters.

The surveys were restricted to daylight hours, where weather and viewing condition allowed effective survey effort. The time of observation was from 0600 hrs to 1800 hrs and the average search effort/day was 8hrs. Search effort was curtailed during poor light and visibility range associate with early sunset, low level fog and heavy rain, which would result wrong identification. The speed of the ship varied with sea conditions and also with the kind of fisheries and oceanographic work carried out in each cruise. Survey was conducted in sea conditions corresponding to Beaufort scale 0 to 5 and was suspended when the Beaufort scale was higher than 5. The average sea- state during the survey period was between 3 and 4 in Beaufort. The visual surveys were carried out by scanning with naked eye and interspersed with a Nikon 10 x 50 mm CFWP handheld binocular with visual range of 4km for close observation of the located animal. A Nikon F80 camera fitted with Nikor 70-300mm lens and a Sony DCR-HC46E handy cam with 800x digital zoom were employed to capture appearances of cetaceans in the form of spouts, dorsal fin, flipper, upper body, fluke etc.

3.5 Data acquisition

Data on distribution of cetaceans were collected along with related oceanography and physiographic variables. A standard methodology, as suggested by SESC (Kinzey *et al.*, 2000), was adopted to record the appropriate sighting data. On sighting a cetacean, data such as date and local time and GMT of cetacean's sighting, geographical position, nearest landmark, distance between sighting and nearest shore was recorded. Simrad GN33 GPS navigator was used to record geographical position of animal sighted area. Appropriate navigational charts were used to calculate distance between the sighting and nearest shore. In addition to that Garmin map source software version 3 was also used for similar purpose. These data apart, other ancillary data on external body features and characters such as behaviour, group size of dolphins and pod size of whales were also noted.

3.5.1 Oceanographic and physiographic data

Oceanographic data were collected from area, where animal was sighted to examine the relationship between cetacean distribution and environmental parameters. For this purpose, the data such as Sea Surface Temperature (SST), maximum depth of animal occurrence, sea surface salinity (SSS), wind speed, humidity and pressure were collected from the location of sightings. EMCON SBE 9plus underwater shipboard sensors unit provided SST and salinity data. For recording the depth of the area of sighting Simrad EK 60 Echo-sounder of frequency 38kHz was employed and navigational chart was also referred wherever needed.

3.5.2 Species identification

The observed cetaceans were identified to the lowest taxonomic level possible, using standard field guides and photos that were taken at the time sightings. Published pictures of cetacean species along with their description on morphological characters and behaviours were compared with the observed characters of the present study for identification of the sighted individuals. 'Marine Mammals of the World' (Jefferson *et al.,* 1993) and 'Sea Guide to Whales of the World' (Watson, 1981) aided for the identification. In addition, species identification was further substantiated with the photos taken at the time of sighting. Sightings were identified to species level, wherever possible, with species identifications being graded as "definite", "probable" or possible. Wherever species identification could not be confirmed, sightings were downgraded to 'unidentified dolphin' or 'unidentified whale'.

3.6 Data Analysis

For the geographical distribution, relative abundance and diversity analysis, the surveyed area was segregated into six geographical zones, namely northeastern Arabian Sea (15°N-23°N and 66°E-74°E), southeastern Arabian Sea (07°N-15°N and 68°E-78°E), northern Bay of Bengal (15°N-21°N and 80°E-90°E), southern Bay of Bengal (07°N-15°N and 78°E-90°E), Andaman Sea (05°N-15°N and 90°E-96°E) and southern Sri Lanka (05°N-07°N and 76°E-90°E). Each region was further divided into 2° latitude and 2° longitude grids. Survey effort was calculated for every 2° grid and summed for total survey effort for each region. Relative abundance was calculated for each 2° using the following index

Sighting frequency = n / e x 1hour

Where n is number of sighting/individuals and e is total surveyed effort

3.6.1 Seasonal distribution

Seasonal variation in species diversity and distribution of cetacean was assessed for all surveyed regions. Considering the prevailing monsoonal condition and oceanographic changes, months were grouped into four seasons. The four seasons are fall monsoon (March to May), summer monsoon and also known as southwest monsoon (June to August), Inter monsoon (September-October) and winter monsoon and also known as northeast monsoon (November to February). Monthly sighting and relative abundance data were pooled according to the season for each surveyed regions and analyzed to observe the seasonal variation in species diversity and distribution among the surveyed regions.

3.6.2 Calculation of Biodiversity Index

Biodiversity indices based on the approximate numerical count data of cetacean that collected during the survey were calculated using PRIMER Version 5 software (Plymouth Routines in Multivariate Ecological Research) software package (Clarke and Warwick, 1994). Diversity was calculated using the following Shannon-Weiner (*H'*) index (Shannon-Weiner, 1963):

$$H' = -\Sigma i \, pi \, (\log \, pi),$$

where p*i* is the proportion of the total count arising from the *ith* species.

This indices are not dependent on sampling methods, sample size and habitat types and are widely used for broad scale geographical comparisons of biodiversity, environmental impact assessment and evaluation of surrogates for biodiversity estimation (Clarke and Warwick, 2001). This index was determined using the DIVERSE routine within the PRIMER software package.

3.6.3 Taxonomic distinctness

Warwick and Clarke (1995) introduced the concept of taxonomic distinctness diversity (Δ^+) as a univariate (bio) diversity index which in its simplest form, calculates the average 'distance' between all pairs of species in a community sample, where this distance is defined as the path length through a standard Linnean or 'phylogenetic tree' connecting these species (Clarke and Warwick, 1999). Its appealing properties are: i) it attempts to capture phylogenetic diversity rather than simple richness of species and is more closely linked to functional diversity, ii) it is robust to variation in sampling effort and there exists a statistical framework for assessing its departure from 'expectation', iii) it appears to decline monotonically in response to environmental degradation whilst being relatively insensitive to major habitat differences and iv) in its simplest form, it utilises only simple species lists (presence/absence data) (Clarke and Warwick, 1999).

Clarke and Warwick (2001) introduced a further biodiversity index, variation in taxonomic distinctness (Λ^+), which is defined as mean path length through the taxonomic tree connecting every pair of species in the list. They suggested that a combination of Δ^+ (average taxonomic distinctness) and Λ^+ (variation in taxonomic) could provide a statistically robust summary of taxonomic (or phylogenetic) relatedness patterns within an assemblage, which has the potential to be applied to a wide range of historical data in the form of simple species lists. During this study, an attempt was made to use both Δ^+ and Λ^+ values to find out the taxonomic related patterns among cetaceans according to PRIMER routines

3.6.4 Distribution in relation environmental parameter

Among several environmental parameters collected in the present study, four variables consisted of two physiographic variables (Depth and Distance from the shore) and two oceanographic variables (Sea surface temperature and sea surface salinity) were considered to study habitat characteristics of cetaceans sighted in these surveys. All the four variables were collected along with sightings during the survey period for each species. However, habitat characteristics were studied for only few species for which adequate sightings along with data of these four variables are available. Descriptive statistics such as mean, standard deviation, as well as inter-quartile deviation were performed and was plotted in box whisker graph, using. Differentiation among the species with regards to oceanographic and physiographic variables was tested, using the Kruskall- Wallis test for the species or species group that had more than 15 or more sightings. Statistical analyses were conducted with the statistical software SPSS, version 13 (SPSS, 2007).

Table 3.1 Details of marine mammal survey onboard *FORV Sagar Sampada*

Sl. No.	Cruise No.	Cruise duration (days)	Regional coverage	Survey effort	
				days	hours
1	218	15	Southeastern Arabian Sea	13	104
2	219	19	South and northeastern Arabian Sea	17	136
3	220	39	Southeastern Arabian Sea, Sri Lanka water and Andaman Sea	35	280
4	221	11	Southeastern Arabian Sea	9	72
5	222	19	South and north eastern Arabian Sea	17	136
6	223	11	Southeastern Arabian Sea	9	72
7	224	20	Northeastern Arabian Sea	18	144
8	225	24	Southeastern Arabian Sea, Sri Lanka Sea and South and northern Bay of Bengal	22	176
9	226	34	Andaman Sea, Sri Lanka and Southeastern Arabian Sea	32	256
10	227	15	Southeastern Arabian Sea	13	104
11	228	20	South and north eastern Arabian Sea	18	144
12	229	19	Southeastern Arabian Sea	17	136
13	230	14	Southeastern Arabian Sea, Sri Lanka Sea and southern Bay of Bengal	12	96
14	231	25	Southern Bay of Bengal and Andaman Sea	23	184
15	232	25	South and northern Bay of Bengal Sri Lanka Sea and Southeastern Arabian Sea	23	184
16	233	10	Southeastern Arabian Sea	8	64
17	234	15	Southeastern Arabian Sea	13	104
18	235	29	South and northeastern Arabian Sea	26	208
19	236	28	Southeastern Arabian Sea, Sri Lanka Sea and southern and northern Bay of Bengal	24	192
20	237	33	South and northeastern Arabian Sea	29	232
21	238	18	Southeastern Arabian Sea	16	128
22	239	26	Southeastern Arabian Sea, Sri Lanka water and Andaman Sea	22	176
23	240	45	Southeastern Arabian Sea, Sri Lanka Sea and southern and northern Bay of Bengal	41	328
24	241	19	South and northeastern Arabian Sea	17	136
25	242*	18	Southeastern Arabian Sea	1	6
26	243	20	Southeastern Arabian Sea, Sri Lanka water and Andaman Sea	17	136
27	244	20	South and northeastern Arabian Sea	17	136
28	245	22	Southeastern Arabian Sea, Sri Lanka Sea and southern and northern Bay of Bengal	20	160
29	246	13	Southeastern Arabian Sea	11	88
30	247	28	Southeastern Arabian Sea, Sri Lanka Sea and southern and northern Bay of Bengal	19	152
31	248	21	Sri Lanka Sea, Andaman Sea and Southeastern Arabian Sea	19	152
32	249	37	Southeastern Arabian Sea, Sri Lanka Sea and southern and northern Bay of Bengal	29	232
33	250	12	South and northeastern Arabian Sea	10	80
34	251	22	Northeastern Arabian Sea	20	160
35	252	28	Southeastern Arabian Sea, Sri Lanka water and Andaman Sea	20	160

* Cruise cancelled due to winch failure

Chapter 4
RESULTS

Between 2003 and 2007, a total of 35 cruises were conducted in the six geographical regions. The number of observation days was 657 and cetaceans were sighted on 299 days (Fig. 4.1). The duration of observation was 5254 hours. The survey covered majority of the area in the Indian EEZ and Sri Lanka Sea. However, the quantum of survey effort varied between survey regions. A total of 764.7 hours (14.6% of total observation) was spent for observation in the northeastern Arabian Sea (NeAS), 2017.8 hours (38.4%) in the southeastern Arabian Sea (SeAS), 636.0 hours (12.1%) in the northern Bay of Bengal (NBOB), 843.0 hours (16.0%) in the southern Bay of Bengal (SBOB), 595.5 hours (11.3%) in Andaman Sea (AS) and 397.0 hours (7.6 %) in the Sri Lanka Sea (SRL). Observation conditions during the survey were good with ranging from 0 to 5 at Beaufort scale. Of the total sightings, 33.4% was at Beaufort 0-2, 57.1% at Beaufort 3-4, and 9.5% at Beaufort 5.

In all, a total of 473 cetacean encounters were made (Fig 4.2). A total of 5865 individuals, represent 13 species of confirmed identities belonging to three families from two suborders and unidentified cetaceans were recorded. On an average there was one sighting every 11 hours of sighting effort. Of the 473 sightings, during 223 instances (47.1% of the sightings), identification was made up to generic or species level, either as confirmed or as 'possible'. The remaining 250 sightings (52.9%) were recorded as unidentified dolphins (UID) / unidentified whales (UIW).

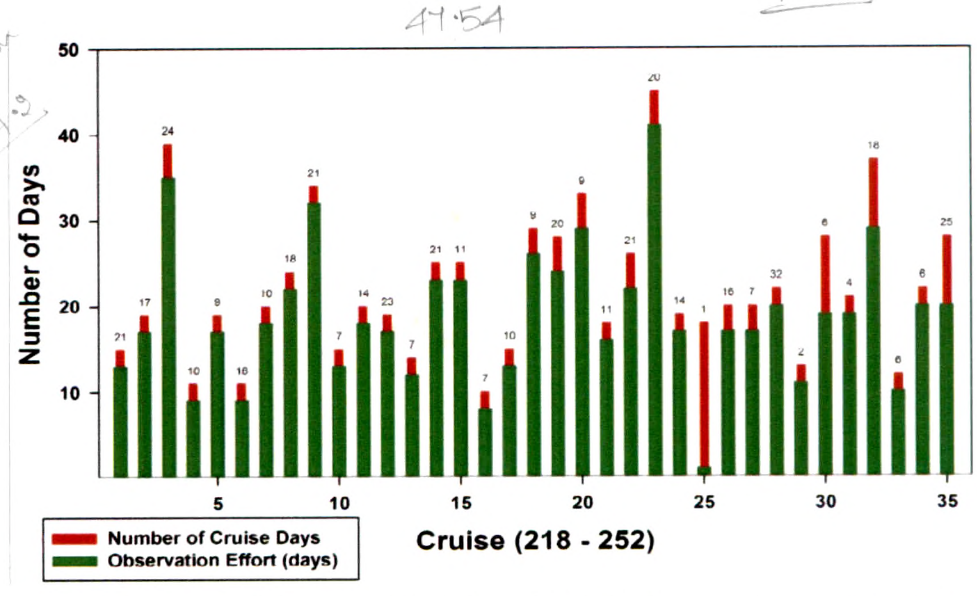


Fig. 4.1 Cruise days & survey effort onboard FORV *Sagar Sampada* and numbers on bar represent number of sightings obtained in each cruise

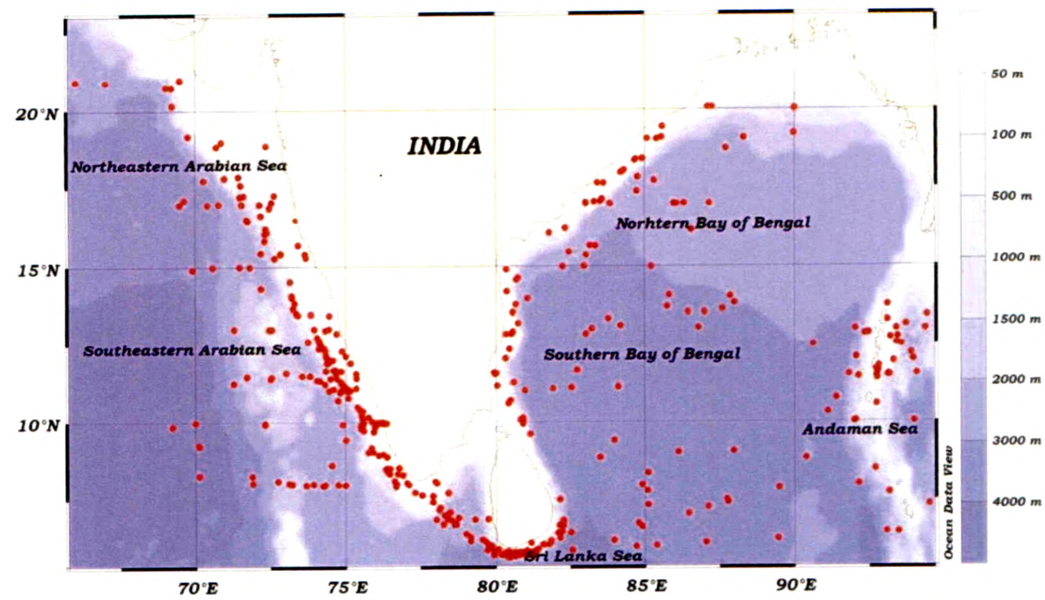


Fig. 4.2 Sighting of cetacean recorded during the survey period in different survey region

4.1 Species diversity

Of 13 identified species, three were from Mysticeti group and 10 were from Odontoceti, which includes two families. The four whale species which include three species of baleen whales from Balaenopteridae family (Mysticeti) and one species of toothed whale from Physeteridae family (Odontoceti) were recorded. All the other 9 species belonged to 7 genera from the family Delphinidae (dolphins), which consisted of 6 smaller delphinids and 3 larger delphinids. The species observed in the present study is given in Table 4.1.

Delphinids were sighted more frequently than *Balaenoptera* sp. The bottlenose dolphin, *Tursiops aduncus* was the most abundant species in terms of number of sightings whereas the spinner dolphin, *Stenella longirostris* (spinner dolphin) was the most abundant in terms of number of individuals (Table 4.2). *Delphinus capensis* (common dolphin) and *Sousa chinensis* (Indopacific humpbacked dolphin) were also found abundant. *Physeter macrocephalus* (sperm whale) was the most frequently sighted species among large whales. *Grampus griseus* (Risso's dolphin), *Pseudorca crassidens* (false killer whale), *Globicephala macrorhynchus* (short-finned pilot whle) *Stenella coeruleoalba* (striped dolphin) and *Stenella attenuate* (pan- tropical spotted dolphin) were other species sighted less often.

Table 4.1 Species diversity of cetaceans sighted during the survey

Family	Species	Common name
Balaenopteridae	***Balaenoptera musculus***	Blue whale
Balaenopteridae	***Balaenoptera edeni***	Bryde's whale
Balaenopteridae	***Megaptera novaeangliae***	Humpback whale
Physeteridae	***Physeter macrocephalus***	Sperm whale
Delphinidae	***Pseudorca crassidens***	False killer whale
Delphinidae	***Globicephala macrorhynchus***	Short finned pilot whale
Delphinidae	***Grampus griseus***	Risso's dolphin
Delphinidae	***Stenella coeruleoalba***	Striped dolphin
Delphinidae	***Stenella longirostris***	Spinner dolphin
Delphinidae	***Tursiops aduncus***	Bottlenose dolphin
Delphinidae	***Delphinus capensis***	Common dolphin
Delphinidae	***Sousa chinensis***	Indopacific humpbacked dolphin
Delphinidae	***Stenella attenuata***	Pantropical spotted dolphin

Table 4.2 Sightings and abundance of cetacean species recorded in the present study

Species	No. of sightings	% sighting	No. of individuals	% individuals
Balaenoptera edeni	1	0.21	1	0.02
Balaenoptera musculus	4	0.85	12	0.2
Megaptera novaeangliae	1	0.21	1	0.02
Balaenoptera sp.	23	4.86	59	1.01
Balaenoptera sp. (P)	9	1.9	41	0.7
Physeter macrocephalus	9	1.9	41	0.7
Physeter macrocephalus (P)	7	1.48	12	0.2
Pseudorca crassidens	4	0.85	22	0.38
Globicephala macrorhynchus	3	0.63	19	0.32
Globicephala macrorhynchus (P)	1	0.21	1	0.02
Grampus griseus	4	0.85	72	1.23
Grampus griseus (P)	2	0.42	22	0.38
Stenella coeruleoalba	1	0.21	5	0.09
Stenella coeruleoalba (P)	1	0.21	6	0.1
Stenella longirostris	19	4.02	602	10.26
Stenella longirostris (P)	19	4.02	579	9.87
Stenella attenuata	1	0.21	5	0.09
Stenella sp.	11	2.33	339	5.78
Stenella sp. (P)	8	1.69	94	1.6
Tursiops aduncus	28	5.92	329	5.61
Tursiops aduncus (P)	26	5.5	228	3.89
Delphinus capensis	8	1.69	132	2.25
Delphinus capensis (P)	15	3.17	323	5.51
Sousa chinensis	18	3.81	65	1.11
Unidentified dolphins	207	43.76	2788	47.54
Unidentified whales	43	9.09	67	1.14

4.1.1 Mysticeti (Baleen whale)

Balaenoptera sp

Of the 473 sightings, 32 records (6.8%) were baleen whales of *Balaenoptera* sp. Most of the sightings were off south and southwest Sri Lanka between 5°N-7°N latitude and 78°E-82°E longitude (Fig. 4.4). The pod size varied from a single solitary animal to ten individuals. The mean pod size of confirmed sightings was 2.5 (SD = 2.3) (Table 4.3). The animals were identified up to generic level as *Balaenoptera* sp on 23 occasion comprising 59 individuals. The sightings of *Balaenoptera* sp were less frequent in Indian seas compared to the sightings off southern Sri Lanka.. The sea condition at the time of sightings ranged between 1 and 5 at Beaufort and most of the sightings were at Beaufort 3-4.

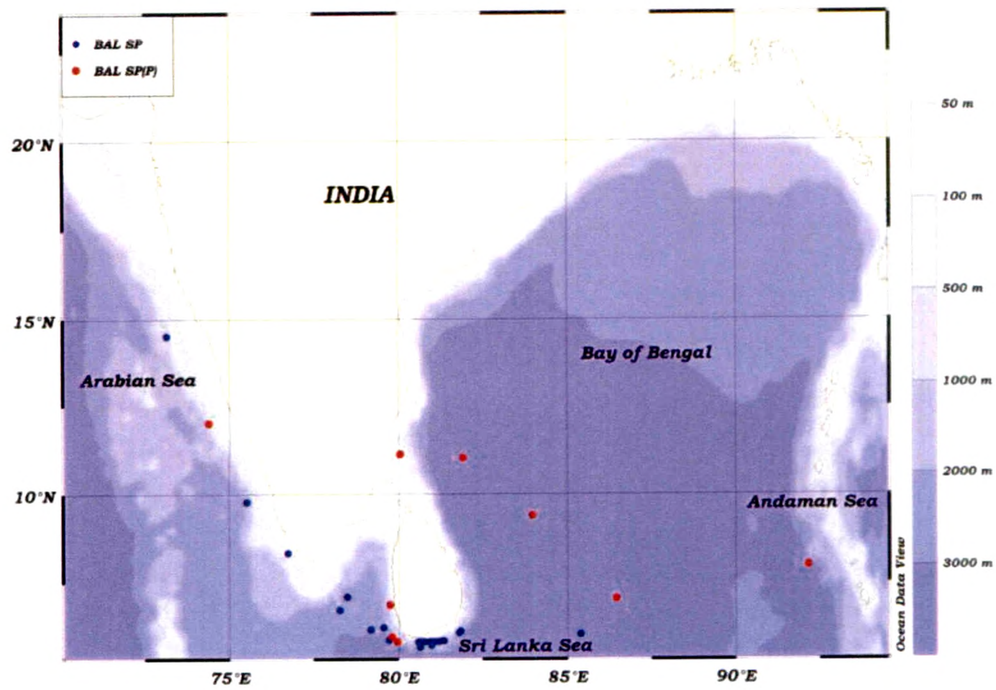


Fig 4.3 sighting of *Balaenoptera* sp (BAL sp) recorded during the study period BAL sp (P) represents possible sightings of *Balaenoptera* sp

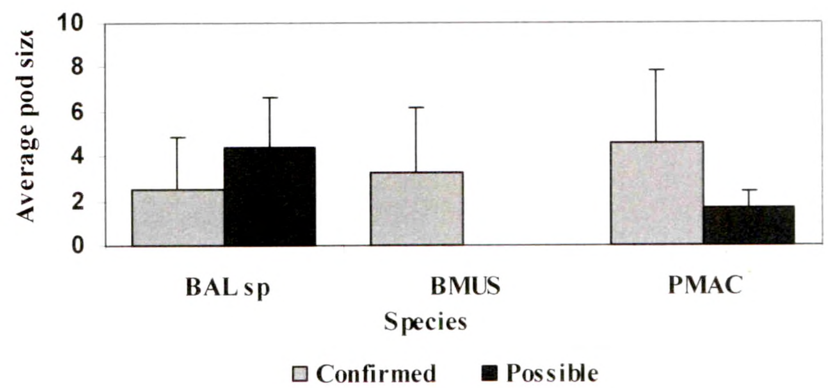


Fig. 4.4 Pod size of Baleen and Sperm whales; **Bal sp** –*Balaenoptera* sp, **BMUS**- *Balaenoptera musculus* and **PMAC**- *Physeter macrocephalus*; lines on bars represent standard deviation

Table 4.3 Pod size of whales recorded during the survey

Species	No. of sightings	No. of individuals	Individuals in a pod	
			range	mean
Balaenoptera edeni	1	1	1	1.0
Balaenoptera musculus	7	29	1-10	3.3
Megaptera novaeangliae	1	1	1	1.0
Balaenoptera sp.	29	72	1-10	2.5
Physeter macrocephalus	16	53	1-9	4.6

Balaenoptera musculus- Blue whale (Linnaeus, 1758)

A total of four *Balaenoptera musculus* sightings (0.85% in total sightings) consisting of 13 individuals were encountered during the survey. In both the confirmed sightings, it was solitary animal. The pod size of the blue whale ranged from 1 to 7 with the mean of 3.3 (SD =2.9) (Table 4.3). All the sightings were off south and southwest Sri Lanka between 5-9°N latitude and 78-82°E longitude with 71.4% of the sightings in 5°N-7°N and 80°E-82°E (Fig. 4.5). The sea state was 2-4 at beaufort scale.

Balaenoptera edeni - Bryde's whale (Anderson, 1879)

A single record of a solitary bryde's whale was made in oceanic water of southern Bay of Bengal (14°59'N and 82°16'E) (Fig. 4.5). The depth of the area was 3080m, which was 214 km away from shore. The sea state was 3 at Beaufort scale. The SST and surface salinity of animal sighted area were 26°C and 33ppt respectively.

Megaptera novaeangliae -Humpback whale (Borowski, 1781)

Humpback whale was one of the rarely sighted species in the study area. A single record of a humpback whale was observed at 7°47'N latitude - 85°06'E longitude, 222km away from the nearest shore in southern Bay of Bengal (Fig.4.5). The depth of sighting area was 3853m. The sea surface temperature was 27.9°C and the salinity was 33.7ppt in the sighted area. The sea state was 3 at beaufort scale.

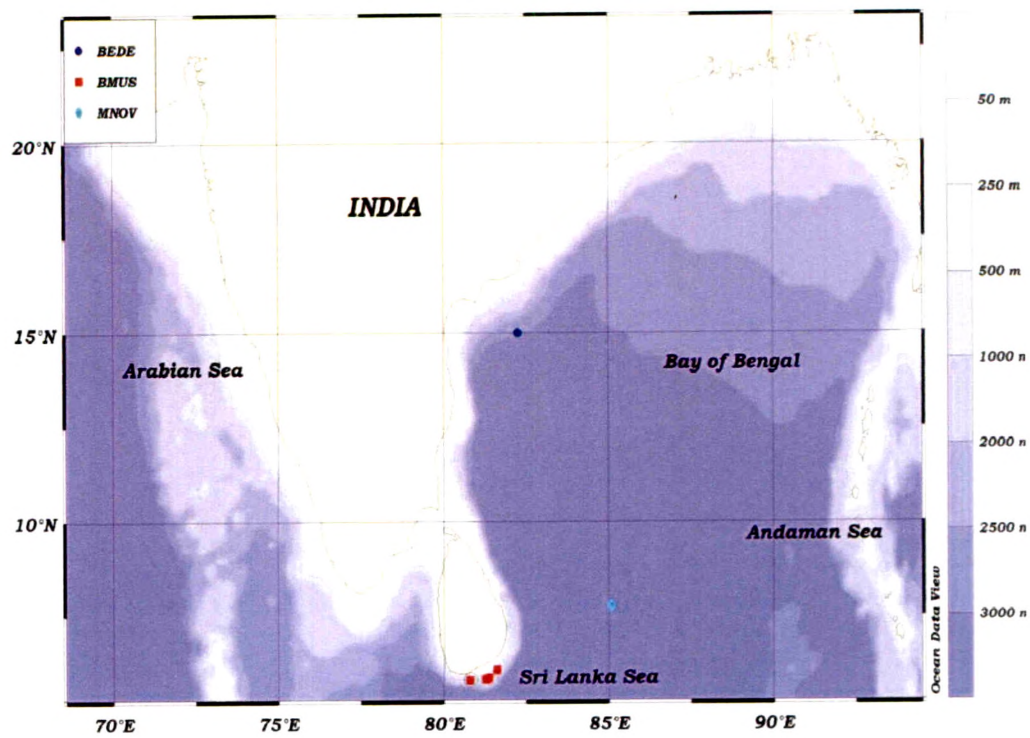


Fig. 4.5 Sighting of *Balaenoptera musculus* (BMUS), *B.edeni* (BEDE) and *Megaptera novaeanglia* (MNOV)

4.1.2 Odontoceti (Toothed cetacean)

4.1.2.1 Physeteridae

Physeter macrocephalus - Sperm whale (Linnaeus, 1758)

Sperm whale was the most common large toothed whale observed in the study area. Sperm whales were sighted on 16 (3.4%) occasions consisting of 53 (1.9%) individuals, of which 9 sightings (56.3%) with 41 individuals were confirmed and 7 (43.7%) with 12 individuals were recorded as "possible". Sperm whale widely occurred in the Indian EEZ and the Sri Lanka seas. Sperm whales were sighted between 5°N -15°N latitude and 72°E - 86°E longitude in the Indian Sea and the Sri Lankan waters and also between 92°E-94°E longitude in the Andaman Sea (Fig. 4.6). The pod size ranged from 1 to 9 individuals with the mean pod size of 4.6 (SD = 3.3) (Fig. 4.4). All sightings were made at sea conditions ranging from 2 to 4 at beaufort scale.

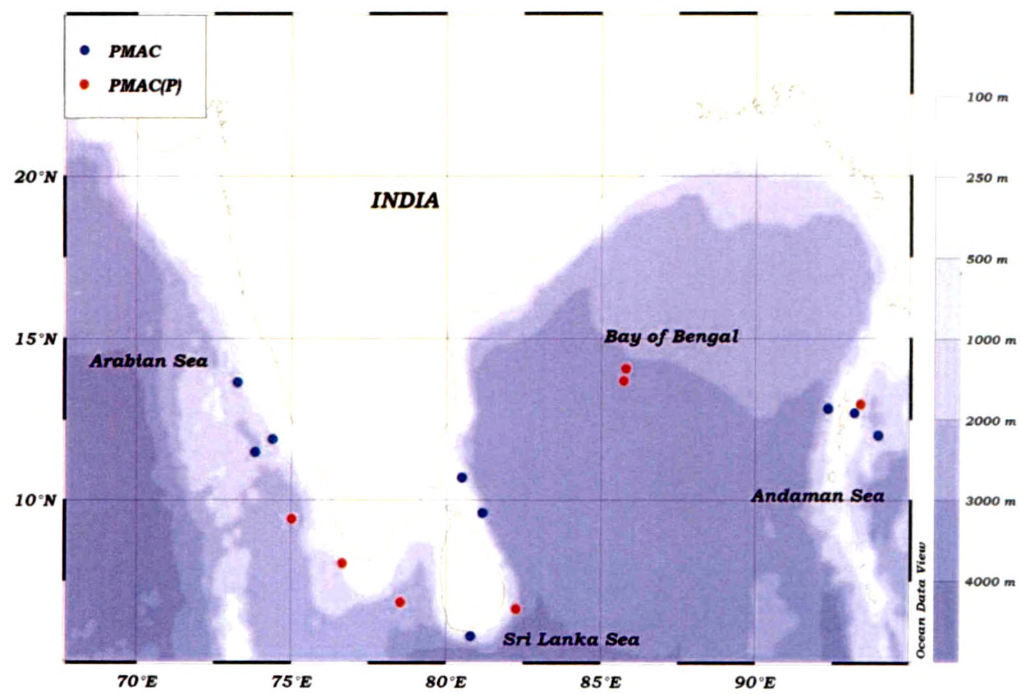


Fig. 4.6 Sighting of *Physeter macrocephalus* (PMAC) PMAC (P) represents possible sightings of *Physeter macrocephalus*

4.1.2.2 Delphinids

Globicephala macrorhynchus -Short finned pilot whale (Gray, 1846)

There were four sightings (0.85%) of short finned pilot whales, which consisted of 20 individuals. On three occasions the animal was identified up to species level. The other one was recorded as possible identity. One sighting was in the shelf break of southeastern Arabian Sea at 10°10'N and 75°58'E and the other 3 were on slope of oceanic water in southern Bay of Bengal (Fig. 4.7). The group size ranged from 1 to 10 and the mean group size was 6.6 (Table 4.4). The sea state of the sighted area was 2-4 at Beaufort scale.

Pseudorca crassidens -False killer whale (Owen, 1846)

Four sightings of false killer whale with 22 individuals were observed during the survey, which contributed 0.85% to the total sightings. All the sightings were of confirmed identity. Three sightings were in the southeastern Arabian Sea between 12°N-15°N latitude and 71°E-73°E longitude. The other one was in the northern Bay of Bengal at 15.65°N and 83.18°E (Fig. 4.7). All the three sightings were observed in the continental shelf of oceanic water. Solitary animal was also recorded on single occasion. A maximum of 11 individuals were recorded in a school sighted off Mangalore (Table 4.4). Mean group size was 5.5 (SD= 4.2) (Fig. 4.8). The sea state in animal observed area was 0 to 2 at beaufort scale.

Grampus griseus - Risso's dolphin (G. Cuvier, 1812)

Six sighting records (1.3%) of Risso's dolphin were made; four were confirmed up to species level and other two sightings were unconfirmed. A total of 94 individuals were observed. On three occasions they were sighted on continental slope between 11°-14°N latitude and 73°-75°E longitude (Fig.4.7). Apart from one sighting, which consisted of two individuals, the other sighted schools consisted of group size of 12 to 25 individuals with the mean group size of 18.0 (S.D = 5.7) (Table 4.4).

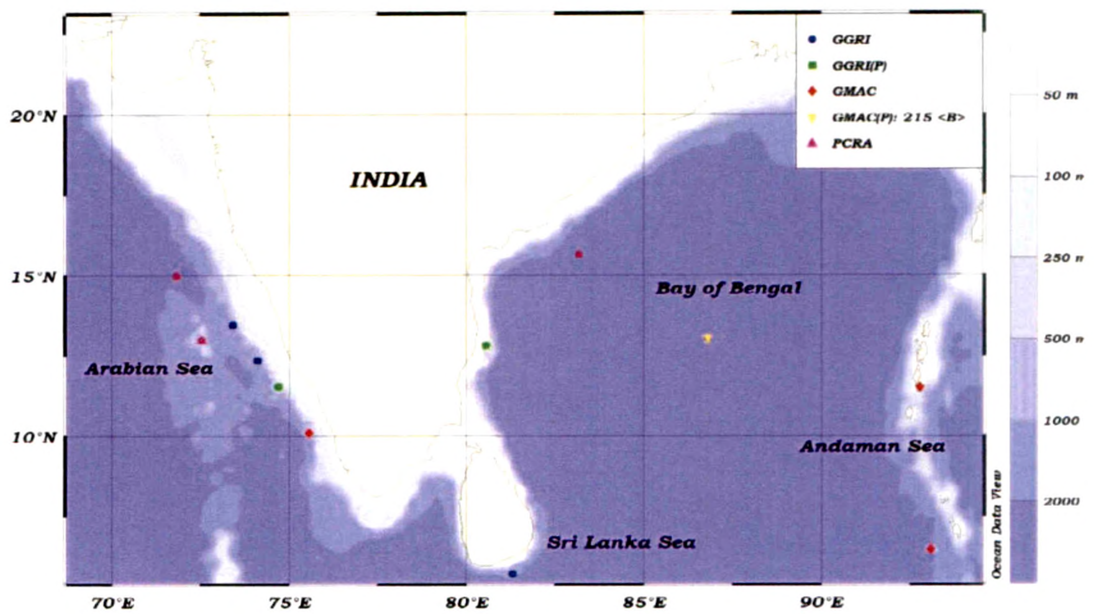


Fig 4.7 Sighting of Larger delphinids *Grampus griseus* (GGRI), *Globicephala macrorhynchus* (GMAC) and *Pseudorca crassidens* (PCRA)

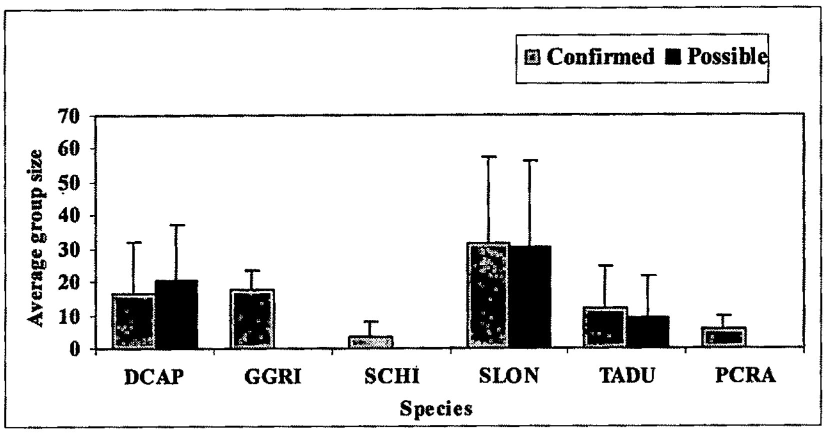


Fig. 4.8 Group size of Delphinids sighted during the survey: DCAP- *Delphinus capensis*, GGRI-*Grampus griseus*, SCHI- *Sousa chinensis*, SLON *Stenella longirostris*, TADU-*Tursiops aduncus*, PCRA *Pseudorca crassidens*; lines on bars represent standard deviation

Table 4.4 Species wise group size of delphinids

Species	No. of sightings	No. of individuals	range	Mean
Pseudorca crassidens	4	22	1-11	5.5
Globicephala macrorhynchus	3	20	1-10	6.6
Grampus griseus	6	99	2-25	16.5
Stenella coeruleoalba	2	11	5-6	5.5
Stenella longirostris	38	1181	4-110	31.1
Stenella attenuata	1	8	--	--
Stenella sp	19	433	3-200	22.8
Tursiops aduncus	54	557	1-75	10.0
Delphinus capensis	24	460	2-50	19.2
Sousa chinensis	18	65	1-8	3.6

Stenella longirostris -Spinner dolphin (Gray, 1828)

Spinner dolphin was second commonest species recorded often in all surveyed area. A total of 38 sightings were recorded either as confirmed or possible, accounting for 8% of the total sightings (Table 4.2). They showed wide distribution in the Indian EEZ and the contiguous seas (Fig. 4.9). A total of 19 sightings of spinner dolphin were documented as "confirmed", whereas the rest of the sightings were recorded as "possible". Considering the number of individuals observed, the spinner dolphin recorded the maximum during the survey with 602 individuals (34.1% of the total number of individuals in confirmed sightings). The group size varied from 5 to 110 individuals with the mean group size of 31.0 (S.D= 25.6) (Fig. 4.8). The sea state at the time of sightings was 1 to 5 at beaufort scale.

Stenella coeruleoalba - Striped dolphin (Meyen, 1833)

Two records of striped dolphin with 11 individuals were made (Fig. 4.10). One of the sighting consisted of 5 individuals was observed at 8°N and 73°E off Minicoy. The distance from the atoll was 62km and the depth was 2500m. The SST was 28.6° C and the sea state was 1 at beaufort scale. The other possible sighting, consisted of 6 individuals was sighted at 6.53°N and 78.24°E. The distance from the shore was 186km and the depth of animal occurred area was 2500m. The SST was 27.5°C and salinity was 34.3ppt. The sea state was 4 at beaufort scale.

Stenella attenauate - Pan-tropical spotted dolphin (G. Cuvier, 1829)

Spotted dolphin was rarely seen in the study area with one confirmed sighting of 8 individuals. This species was sighted in the deep oceanic water of southeastern Arabian Sea (Fig. 4.10). The depth of the area from where animals were sighted was 2100m. SST and salinity recorded in the sighted area was 27.6°c and 33.6ppt respectively.

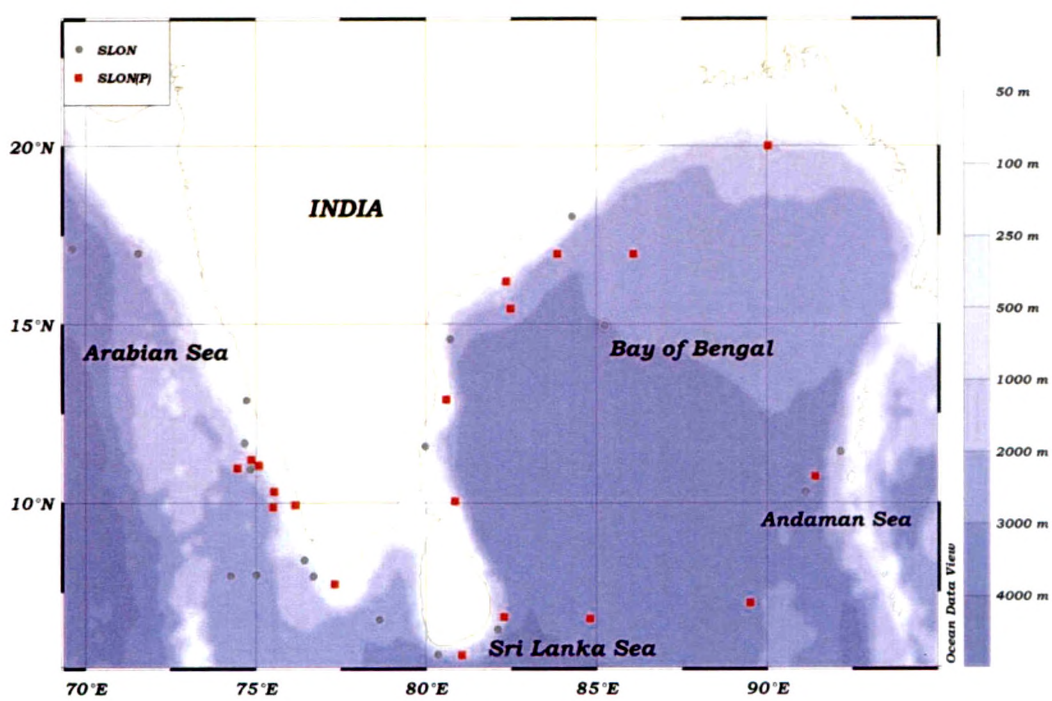


Fig. 4.9 Sighting of *Stenella longirostris* (SLON) SLON (P) represents possible sightings

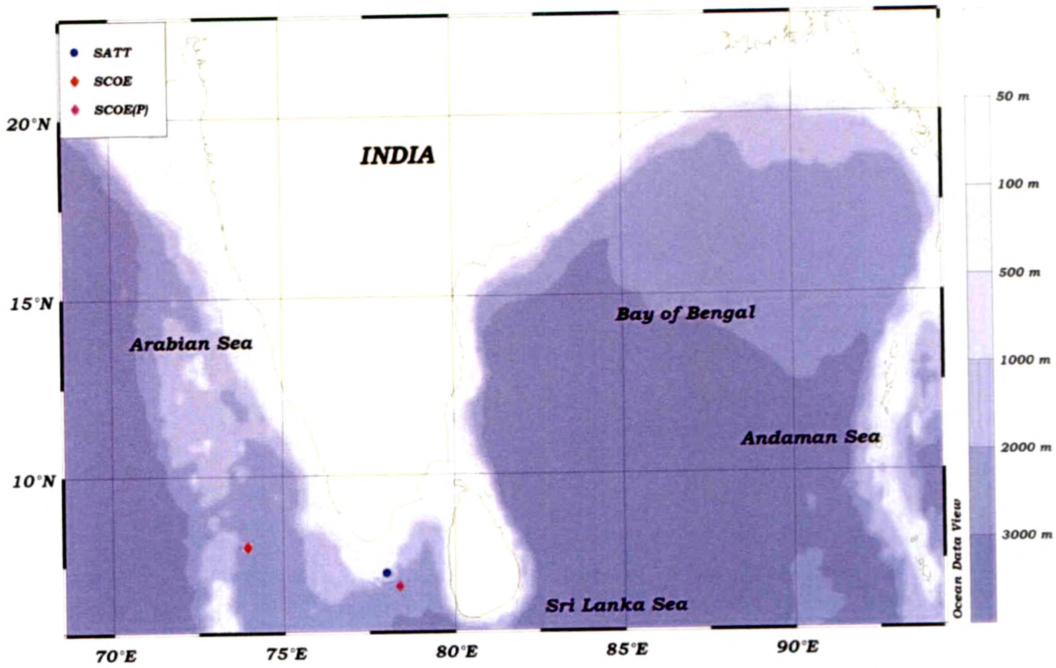


Fig. 4.10 Sighting of *Stenella attenuata* (SATT) and *S. coeruleoalba* (SCOE), SCOE (P) represent possible sightings of *S. coeruleoalba*

Stenella sp.

The distribution was wide of *Stenella* sp in the Indian seas (Fig. 4.11). There were 19 sightings (4.0%) with 433 individuals recorded as *Stenella* sp. Eleven sightings with 339 individuals were confirmed to generic level, while on eight occasions it was identified as "possible". One record was made in the Sri Lankan waters. Group sizes were moderately large, ranged from three to 200. Group size of confirmed sightings ranged from a minimum of 3 individuals to a maximum of 200 individuals with an average of 37 individuals (SD= 56.6) (Table 4.4). The sea condition of the sighted area varied from 1 to 5 at beaufort scale.

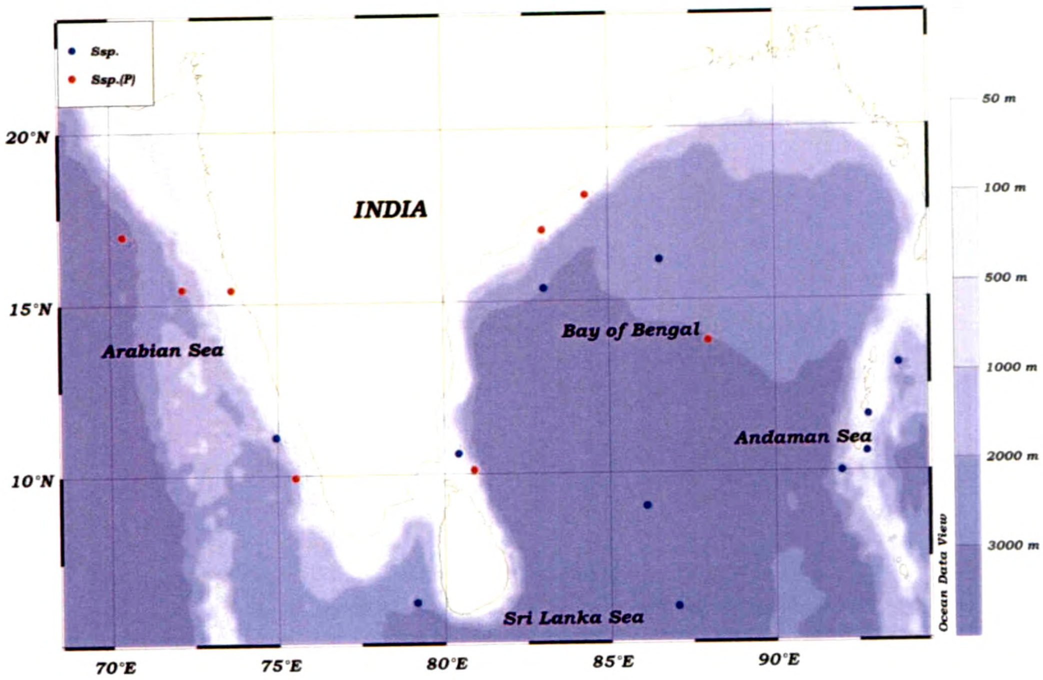


Fig 4.11 Sighting of *Stenella* sp (Ssp) Ssp (P) represents possible sighting of *Stenella* sp

Tursiops aduncus –Indo-pacific bottlenose dolphin (Ehrenberg, 1833)

The Indo-pacific bottlenose dolphin was the commonest species encountered than any other cetaceans during the survey. The species was encountered on 54 occasions, accounting for 11.4% of the total sightings. Of this, 28 sightings (48.2 %) were confirmed and 26 were identified as possible. A total of 557 individuals, which included 325 individuals of confirmed sightings were observed (Fig.4.12). The group size of confirmed sightings ranged from minimum of 1 to maximum of 75, with an average of 10 (S.D= =12.6) (Fig.4.8) (Table 4.4). The sea state varied between 0 and 5 at beaufort scale.

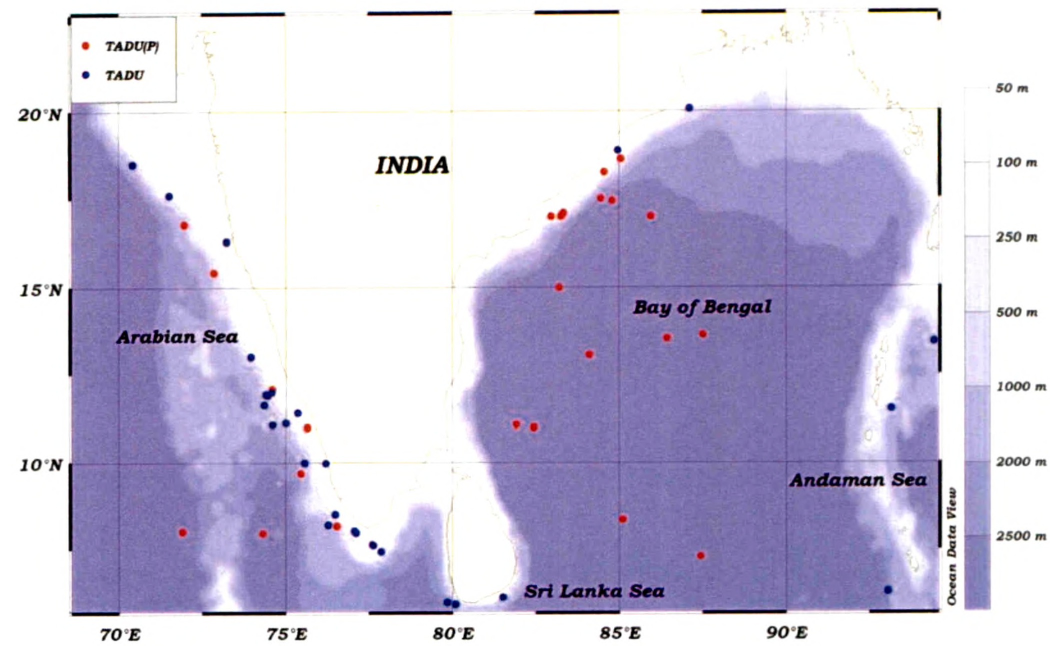


Fig 4.12 Sighting of *Tursiops aduncus* (TADU) TADU(P) represents possible sighting of *Tursiops aduncus*

Delphinus capensis – Long beaked common dolphin (Gray, 1828)

Sighting of *Delphinus capensis* was recorded on 24 occasions, which was 5.1% of the total sightings. Eight records 132 individuals were confirmed up to species level while it was identified as possible on 15 occasions. Thirteen sightings were made between 9°N-13°N and 74°E-76°E and 11 on continental shelf and shelf break, where the depth was less than 200m (Fig. 4. 13). The number of individuals in the group of confirmed sightings varied between two and 50. The mean group size was 19.2 (SD = 20.5) individuals. Six sightings were from southeastern Arabian Sea and the rest from Sri-Lankan Sea and the Andaman Sea. The sea state varied from 0 to 5 at Beaufort scale.

Sousa chinensis –Indo-pacific humpback dolphin (Osbeck, 1765)

Indo-pacific humpback dolphins were sighted on 18 occasions, which was 3.8% of the total sightings with a total of 65 individuals. Most of the sightings (88.9%) were from Cochin backwaters and Cochin bar-mouth area between 9°40'N-9 °59'N latitude and 75°35E-76°18'E longitude in southeastern Arabian Sea (Fig. 4.14). Group size was generally small ranging from 1 to 8 with the average of 3.6 (SD = 4.5) (Table 4.4). The sea condition at the time of sightings was between 2 and 4 at beaufort scale.

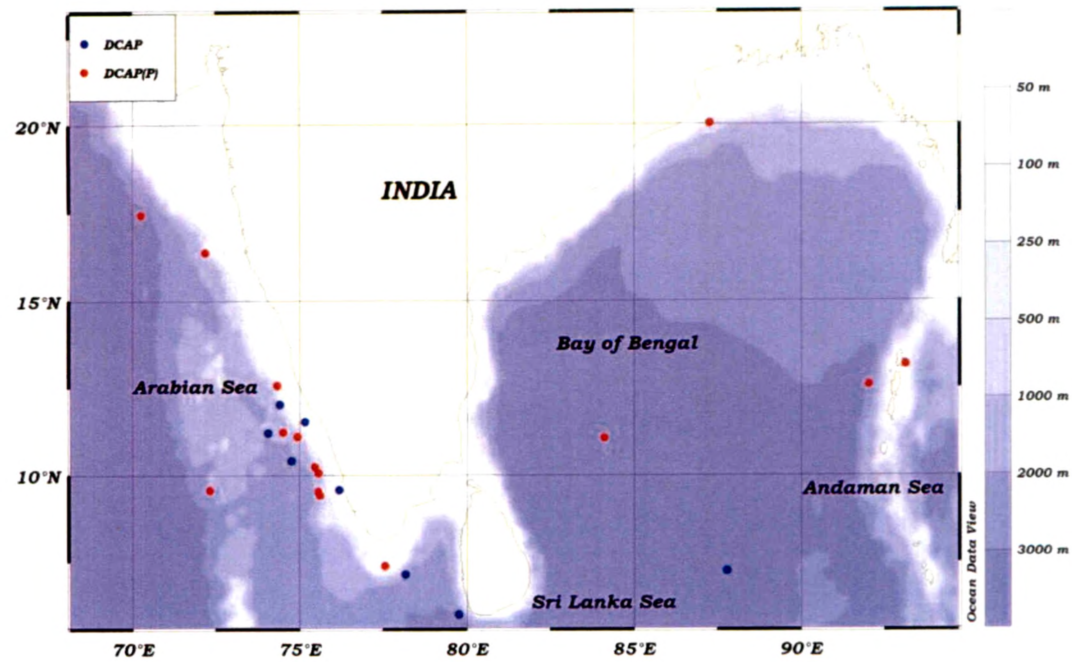


Fig 4.13 Sighting of *Delphinus capensis* (DCAP); DCAP(P) represents possible sighting of *Delphinus capensis*

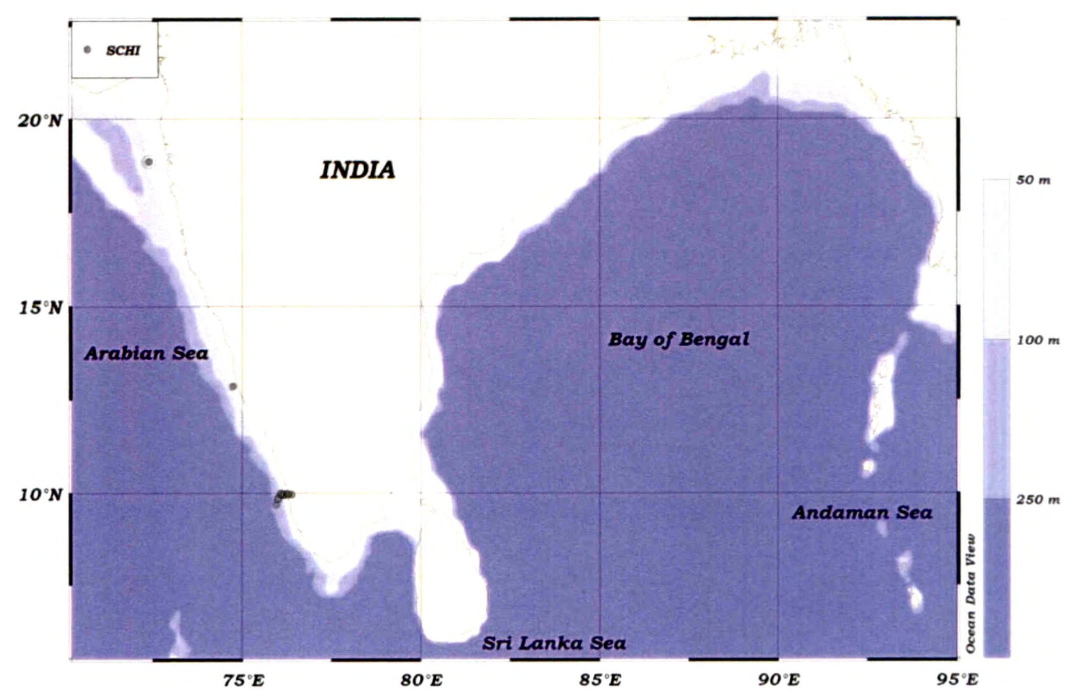


Fig 4.14 Sighting of *Sousa chinensis* (SCHI); SCHI(P) represents possible sighting of *Sousa chinensis*

Unidentified cetaceans

Among the 473 sightings, species or generic level identification of 250 sightings (52.8% of the total number of sightings) was not possible due to far range of occurrence from sighting platform and were recorded as "unidentified". Of this, 43.8% of the sightings were delphinids with a total of 2788 individuals and the remaining 9.1% sightings were whales with 67 individuals.

4.2 Geographical distribution

The sighting surveys showed wide range of distribution of cetaceans ranging from coastal shelf water to oceanic slope water in the Indian EEZ and the contiguous seas. A total of 124 sightings (26.2%) were within the continental shelf (<200m depth) and the remaining (73.8%) were from oceanic waters (>200m depth). The species diversity observed in each surveyed region is given in Table 4.5. The observational effort and relative sighting frequency in surveyed area are shown in Fig. 4.15.

Table 4.5 Species composition recorded in different surveyed region

Species	Ne. Arabian Sea	Se. Arabian Sea	S. BOB	N. BOB	Sri Lanka Sea	Andaman Sea
Balaenoptera edeni			•			
Balaenoptera musculus					•	
Megaptera novaeangliae			•			
Balaenoptera sp.		•	•		•	
Physeter macrocephalus		•	•	•	•	•
Pseudorca crassidens	•	•	•	•	•	
Globicephala macrorhynchus		•	◆	•	•	•
Grampus griseus	•	•	◆	•	•	•
Stenella coeruleoalba		•	•	•	◆	•
Stenella longirostris	•	•	•	•	•	•
Stenella attenuata					•	
Stenella sp	◆	•	•	•	•	•
Delphinus capensis	◆	•	•	•	•	•
Tursiops aduncus	•	•	•	•	•	•
Sousa chinensis	•	•				

• Confirmed ◆ Possible

4.2.1 Southeastern Arabian Sea

A greater diversity of cetacean species was encountered in southeastern Arabian Sea. A total of 194 sightings (41% in total sightings) of 2506 individuals (42% in total individuals) were recorded with sighting frequency of 0.10/hr in this region. Of the 13 species recorded in this survey, a total of 10 species were recorded in southern Arabian Sea region (Table 4.6). Majority of the sightings (67.9%) were distributed on continental shelf and 32.1% of sightings occurred on continental slope area. The ten species include baleen whale from Balaenoptera family, one toothed whale from Physeteridae family and eight species from delphinids family. *Delphinus capensis, Stenella longirostris, Sousa chinensis* and *Tursiops aduncus* were most frequently sighted species in this region.

4.2.2. Southern Bay of Bengal

The diversity of cetacean in southern Bay of Bengal region was also diverse. A total of 66 sightings (14%) of 995 (17%,) individuals, representing two species of baleen whales, one species of sperm whale and five species of delphinids were encountered on continental slope and shelf water. The sighting frequency was 0.08/hr (Fig 4.15). The southern Bay of Bengal was dominated by *Stenella longirostris, Tursiops aduncus* and *Balaenoptera* sp and distribution of rest of the species were sparse. Two species were identified possibly as *Grampus griseus* and *Globicephala macrorhychus. Balaenoptera edeni* and *Megaptera novaeanglia* from Balaenopteridae family and *Physeter macrocephalus* from Physeteridae family were the larger whale observed in this region.

4.2.3 Northeastern Arabian Sea and Northern Bay of Bengal

The northeastern Arabian Sea and northern Bay of Bengal were the less surveyed areas. Hence, cetacean diversity and number of sightings observed in these areas were very sparse. There were 45 (9.5%) sightings of four species comprised of 411 (7%) individuals observed during the effort in the northeastern Arabian Sea with sighting frequency of 0.05/hr (Fig. 4.15). Species composition in this region was made up of *Grampus griseus, S. longirostris, T. aduncus* and *S. chinensis.* Most of the sightings were from continental slope (70%) and rest of the sightings was from continental shelf (30%). Similarly, very few sightings were made from northern Bay of Bengal. A total sighting encountered in this region was 39 sightings (8.2%) of 4 species comprising of 751 individuals (12.8%) and the sighting frequency was 0.06/hr.

4.2.4 Andaman Sea

The Andaman Sea was one of the less surveyed areas and contributed five species of 46 sightings (9.7%) and 514 (9%) individuals with sighting frequency of 0.08/hr (Fig. 4.15). Observed species composition in this area was dominated sighting by *Stenella* sp from delphinids and *Physeter macrocephalus* from physetridae. *Globicephala machrorhyncus*, *D. capensis* and *T. aduncus* were the other delphinids sighted less frequently.

4.2.5 Sri Lanka

The Sri Lanka Sea was the most diverse area of all surveyed regions, which accounted for 83 sightings (17.5%) of seven species comprising of 688 individuals (11.7%). The sighting frequency was 0.21/hr (Fig. 4.15). Most of the baleen whale sightings were encountered in the Sri Lanka water. Among the baleen whale, *B. musculus* was the only species identified upto species level and rest of the sightings were identified upto generic level only. *P. macrocephalus* and four species of delphinids were recorded in less significant numbers. *T. aduncus* and *Stenella* sp were by far the most frequently sighted species of all the delphinids.

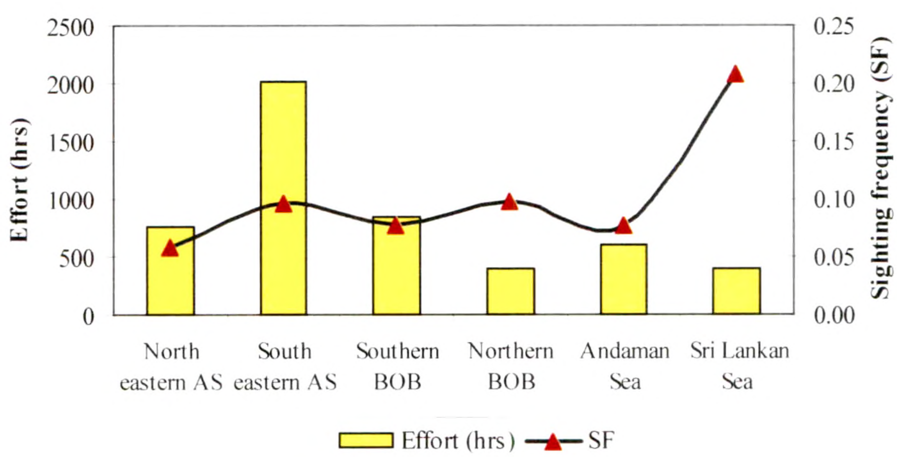


Fig. 4.15 Observational effort and sighting frequency (SF) in six surveyed area

4.3 Grid distribution

The sightings of cetacean were distributed in 86 grids (2°x2°) to examine richness within the surveyed regions (Fig. 4.16). To remove the bias due to unequal distribution of effort between the grids, the sightings and abundance were estimated for one hour of observation. Of the 86 observed grids, the cetaceans were sighted in 70 grids. Maximum effort of observation was in the southeastern Arabian Sea, specifically in grid 24 (G24), between 9°N -11°N latitude and 74°E -76°E longitude, where 401 hours of observation was made (Table 4.6). This was followed by 7°N-9°N and 76°E-78°E (G29) and 11°N -13°N and 74°E-76°E (G20) where the effort was 383.4 hrs and 320.7 hrs, respectively..

In southeastern Arabian Sea, sighting frequency was more in G14 (0.18/hr). Sightings observed in this area were 7 of 23 individuals. Maximum number of sightings was found in G20, where 54 sightings and 779 individuals were recorded and the sighting frequency was 0.5/hr. G20 was third area, which received highest survey effort in southeastern Arabian Sea as well as in entire survey regions. This was followed by G24 where 34 sightings with 574 individuals and sighting frequency was 0.08/hr. The grids 25 and 29 were also rich in cetacean abundance and the sighting frequency of 0.08/hr and 0.06/hr respectively. Sighting frequency was high in G3 and G11 in northeastern Arabian Sea. Maximum sightings were observed in G8 ad G12 with the sighting frequency of 0.07/hr and 0.08/hr respectively. There was no sighting in G1 and G2 where effort spent was 55hrs and 30hrs respectively in northeastern Arabian Sea.

G63 in southern Bay of Bengal showed highest sighting frequency (1.0/hr) of all grids followed by G58 (0.66/hr). There were no sightings observed in G57, G58 and G61, which received maximum survey effort in southern Bay of Bengal. In northern Bay of Bengal, sighting frequency was high in G33 (0.66/hr), which received very lowest effort and G35 (0.10/hr), which received highest survey effort of 106hrs. No sightings were made in G37, where effort was 23hrs. G70 and G79 in Andaman Sea showed maximum sighting frequency whereas those was observed low in G67, G71 and G73, inspite of maximum survey effort than that of other grids in Andaman region. In the southern Sri Lankan Sea, a number of sightings and individuals per hour of observation were the highest in G81 (0.21/hr) and G82 (0.4/hr).

Table 4.6 Effort distribution, sighting and Individuals recorded in each 2°x2° Grid of all surveyed regions

Area	Grid No:	Position	Effort (hrs)	Sightings	Sightings / hr	Individuals	Individuals/hr
Northeastern Arabian Sea	1	21-23°N/66-68°E	55	0	0.000	0	0.00
	2	21-23°N/68-70°E	30	0	0.000	0	0.00
	3	19-21°N/66-68°E	27	3	0.111	49	1.81
	4	19-21°N/68-70°E	130	5	0.038	71	0.55
	5	19-21°N/70-72°E	31	0	0.000	0	0.00
	6	19-21°N/72-74°E	2	0	0.000	0	0.00
	7	17-19°N/68-70°E	48.7	1	0.021	50	1.03
	8	17-19°N/70-72°E	128	10	0.078	51	0.40
	9	17-19°N/72-74°E	39	2	0.051	10	0.26
	10	15-17°N/68-70°E	28	1	0.036	20	0.71
	11	15-17°N/70-72°E	48	6	0.125	50	1.04
	12	15-17°N/72-74°E	198	17	0.086	110	0.56
Total	**12**		**764.7**	**45**	**0.059**	**411**	**0.54**
Southeastern Arabian Sea	13	13-15°N/68-70°E	21	1	0.048	100	4.76
	14	13-15°N/70-72°E	39	7	0.179	23	0.59
	15	13-15°N/72-74°E	183	13	0.071	91	0.50
	16	13-15°N/74-76°E	39	3	0.077	10	0.26
	17	11-13°N/68-70°E	11	0	0.000	0	0.00
	18	11-13°N/70-72°E	90	3	0.033	34	0.38
	19	11-13°N/72-74°E	127	8	0.063	92	0.72
	20	11-13°N/74-76°E	320.7	54	0.168	779	2.43
	21	9-11°N/68-70°E	11	1	0.091	20	1.82
	22	9-11°N/70-72°E	36	3	0.083	22	0.61
	23	9-11°N/72-74°E	55	2	0.036	19	0.35
	24	9-11°N/74-76°E	401.6	34	0.085	574	1.43
	25	9-11°N/76-78°E	155.1	23	0.148	53	0.34
	26	7-9°N/ 70-72°E	19	3	0.158	28	1.47
	27	7-9°N/ 72-74°E	52	8	0.154	129	2.48
	28	7-9°N/ 74-76°E	74	6	0.081	101	1.36
	29	7-9°N/76-78°E	383.4	25	0.065	431	1.12
Total	**17**		**2017.8**	**194**	**0.096**	**2506**	**1.24**
Northern Bay of Bengal	30	19-21°N/84-86°E	53	2	0.038	4	0.08
	31	19-21°N/86-88°E	74	2	0.027	21	0.28
	32	19-21°N/88-90°E	32	1	0.031	2	0.06
	33	19-21°N/90-92°E	3	2	0.667	104	34.67
	34	17-19°N/82-84°E	73	6	0.082	22	0.30
	35	17-19°N/84-86°E	106	11	0.104	114	1.08
	36	17-19°N/86-88°E	44	3	0.068	72	1.64
	37	17-19°N/88-90°E	23	0	0.000	0	0.00
	38	15-17°N/80-82°E	65	1	0.015	20	0.31
	39	15-17°N/82-84°E	92	8	0.087	318	3.46
	40	15-17°N/84-86°E	27	1	0.037	4	0.15
	41	15-17°N/86-88°E	42	2	0.048	70	1.67
	42	15-17°N/88-90°E	2	0	0.000	0	0.00
Total	**13**		**636.0**	**39**	**0.061**	**751**	**1.18**

Southern Bay of Bengal	43	13-15°N/80-82°E	168	8	0.048	148	0.88
	44	13-15°N/82-84°E	54	4	0.074	64	1.19
	45	13-15°N/84-86°E	32	4	0.125	34	1.06
	46	13-15°N/86-88°E	36	5	0.139	51	1.42
	47	13-15°N/88-90°E	16	1	0.063	6	0.38
	48	11-13°N/78-80°E	6	1	0.167	100	16.67
	49	11-13°N/80-82°E	145	14	0.097	337	2.32
	50	11-13°N/82-84°E	36	1	0.028	3	0.08
	51	11-13°N/84-86°E	17	1	0.059	4	0.24
	52	11-13°N/86-88°E	24	0	0.000	0	0.00
	53	11-13°N/88-90°E	9	0	0.000	0	0.00
	54	9-11°N/ 78-80°E	5	0	0.000	0	0.00
	55	9-11°N/80-82°E	94.7	7	0.074	82	0.87
	56	9-11°N/82-84°E	7	2	0.286	10	1.43
	57	9-11°N/84-86°E	20	0	0.000	0	0.00
	58	9-11°N/86-88°E	3	2	0.667	13	4.33
	59	9-11°N/88-90°E	27.3	0	0.000	0	0.00
	60	7-9°N/ 78-80°E	21	5	0.238	73	3.48
	61	7-9°N/80-82°E	27	0	0.000	0	0.00
	62	7-9°N/ 82-84°E	34	2	0.059	9	0.26
	63	7-9°N/ 84-86°E	4	4	1.000	19	4.75
	64	7-9°N/ 86-88°E	30	4	0.133	22	0.73
	65	7-9°N/ 88-90°E	27	1	0.037	20	0.74
Total	**23**		**843.0**	**66**	**0.078**	**995**	**1.18**
Andaman Sea	66	13-15°N/90-92°E	13	0	0.000	0	0.00
	67	13-15°N/92-94°E	89.5	3	0.034	55	0.61
	68	13-15°N/94-96°E	26	2	0.077	35	1.35
	69	11-13°N/90-92°E	40	2	0.050	5	0.13
	70	11-13°N/92-94°E	146	23	0.158	232	1.59
	71	11-13°N/94-96°E	43	2	0.047	35	0.81
	72	9-11°N/90-92°E	30	2	0.067	55	1.83
	73	9-11°N/92-94°E	67	3	0.045	30	0.45
	74	9-11°N/94-96°E	37	1	0.027	20	0.54
	75	7-9°N/ 90-92°E	15	1	0.067	8	0.53
	76	7-9°N/ 92-94°E	28	3	0.107	17	0.61
	77	7-9°N/ 94-96°E	28	1	0.036	5	0.18
	78	5-7°N/90-92°E	12	0	0.000	0	0.00
	79	5-7°N/92-94°E	21	3	0.143	17	0.81
Total	**14**		**595.5**	**46**	**0.076**	**514**	**0.88**
Southern Sri-Lanka Sea	80	5-7°N/76-78°E	8	0	0.000	0	0.00
	81	5-7°N/78-80°E	90	24	0.267	215	2.39
	82	5-7°N/80-82°E	110	40	0.364	343	3.12
	83	5-7°N/82-84°E	73	12	0.164	41	0.56
	84	5-7°N/84-86°E	55	5	0.091	68	1.24
	85	5-7°N/86-88°E	36	1	0.028	20	0.56
	86	5-7°N/88-90°E	25	1	0.040	1	0.04
Total	**7**		**397.0**	**83**	**0.21**	**688**	**1.73**
Grand Total			**5254.0**	**473**	**0.09**	**5865**	**1.12**

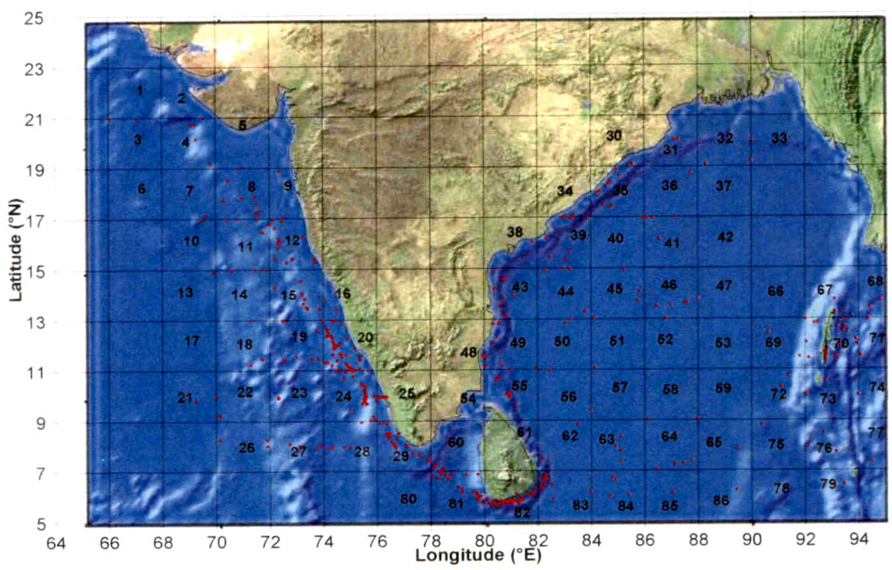


Fig. 4.16 Cetacean distribution in 2°x2° grid in different survey regions; numbers inside the each grids represents grid number

4.4 Taxonomic distinctness-Average and Variation

An attempt was made to use both Δ^+ and Λ^+ values to find out the geographical distribution patterns of the cetacean species following PRIMER routines. Average Taxonomic Distinctness (Delta Δ^+) and Variation Taxonomic Distinctness (Lambda Λ^+) and 95% confidence funnel are shown in (Fig 4.17 and 4.16). The results showed that the Average Taxonomic Distinctness (Delta Δ^+) of southeastern Arabian Sea (SeAS), Sri Lanka water (SRL), southern Bay of Bengal (SBOB) and Andaman water were falling within the 95% of simulated values for all the areas except northeastern Arabian Sea (NeAS) and northern Bay of Bengal (NBOB), where the number of species are relatively low and taxonomic composition different from the other regions (Fig.4.16). Except these two northern regions, no other regions showed significant departures at $P \leq 5\%$ level under null hypothesis implying homogeneity in taxonomic distinctness.

On the other hand, the results of variation in taxonomic distinctness (Λ^+) showed that regions viz., NBOB, NeAS and SeAS departed (Fig. 4.18) from the overall taxonomic composition implying that the species of these regions are different from other regions (SBOB, AS, SRL). Fig. 4.19 displays the outcome of constructing the 95% probability envelops on Δ^+ andΛ^+plotted for each region facilitating a simple assessment of the status of these samples.

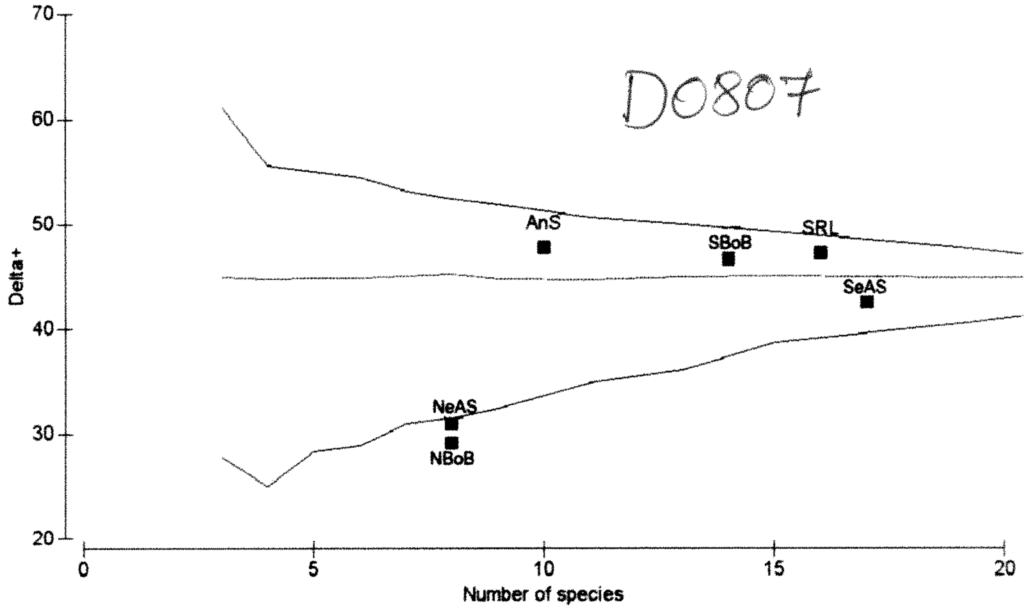


Fig. 4.17 The departure form theoretical mean of Average Taxonomic Distinctness (DeltaΔ⁺) and 95 % confidence funnel of all Cetaceans calculated using presence/absence data from the Indian EEZ.

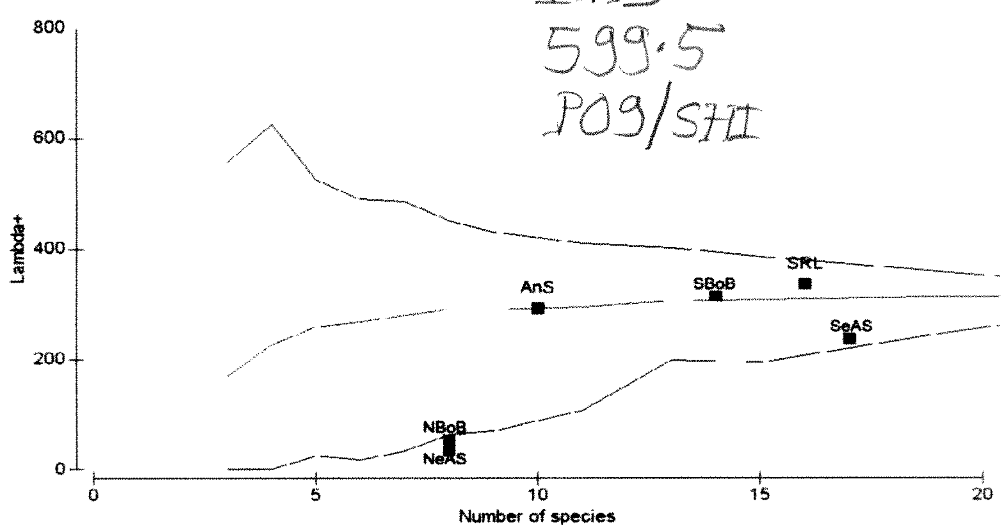


Fig 4.18 The departure form theoretical mean of Variation Taxonomic Distinctness (LambdaΛ⁺) and 95% confidence funnel of all Cetaceans calculated using presence/absence data from the Indian EEZ.

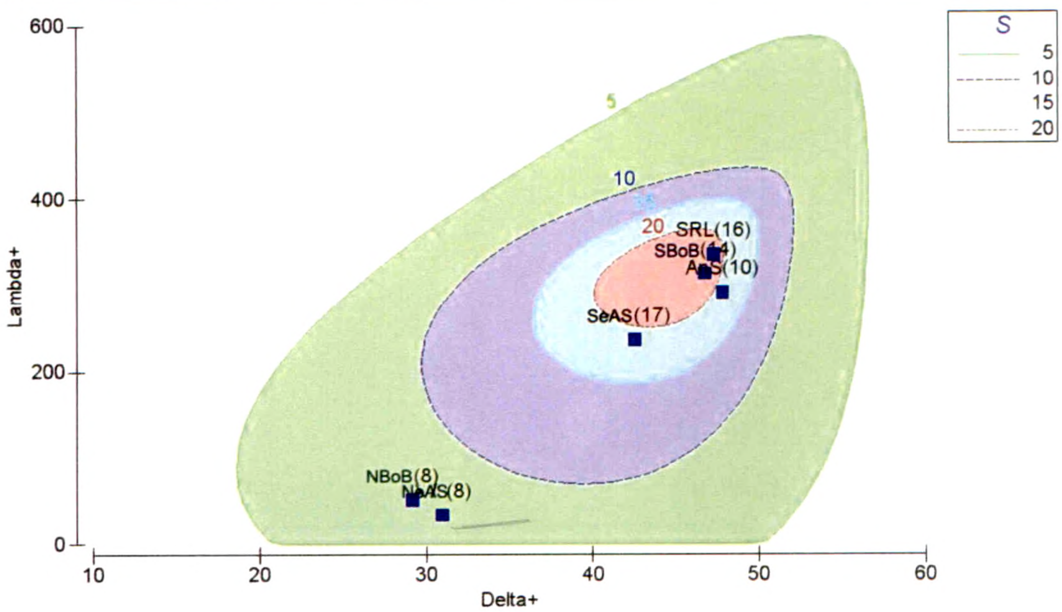


Fig. 4.19 95% probability contours of average taxonomic distinctness (deltaΔ^{+}) and variation in taxonomic distinctness (Lambda Λ^{+}) showing deviation in cetacean diversity between surveyed regions.

4.4.1 Shannon diversity

Shannon diversity index calculated for each 2°x2° grid is given in Table 4.6. The southern Sri Lankan Sea, southeastern Arabian Sea and Andaman Sea showed the highest species diversity when compared to other areas. Highest Shannon diversity value was obtained for G70 (1.72) in the Andaman Sea. In the southeastern Arabian Sea, maximum richness was calculated for G24 (1.44) and G20 (1.40). In G70 (Andaman Sea) six species and 77 individuals and in G24 (Southeastern Arabian Sea) seven species and 323 individuals were recorded. In Sri Lanka sea grids, G 81 and G82 showed highest value of 1.43 and 1.37 respectively. In southern Bay of Bengal, G55 and G49 showed maximum value of 0.93 and 0.83 respectively. Among all the regions, lowest richness Shannon value was obtained for G46 (0.14) and G44 (0.30) in southern Bay of Bengal and for G84 (0.23) in Sri Lanka Sea. In northern part of India coast, highest richness value was obtained for G12 and G11in northeastern Arabian Sea, whereas highest richness value was obtained for G35 in northern Bay of Bengal.

Table 4.6 Species richness and diversity along the 2°grids; S-total species, N-Total individuals, H'log2- Shannon index

Grid No.	Position	S	N	H'log2		Grid No.	Position	S	N	H'log2
3	19-21°N/66-68°E	2	45	0.64		**43**	13-15°N/82-84°E	1	30	0.00
4	19-21°N/68-70°E	0	0	0.00		**44**	13-15°N/84-86°E	2	11	0.30
7	17-19°N/68-70°E	1	50	0.00		**45**	13-15°N/80-82°E	3	34	0.76
8	17-19°N/70-72°E	2	17	0.61		**46**	13-15°N/86-88°E	2	31	0.14
9	17-19°N/72-74°E	1	6	0.00		**47**	13-15°N/88-90°E	1	6	0.00
10	15-17°N/68-70°E	0	0	0.00		**48**	11-13°N/78-80°E	1	100	0.00
11	15-17°N/70-72°E	3	43	0.80		**49**	11-13°N/80-82°E	3	43	0.83
12	15-17°N/72-74°E	3	32	0.92		**50**	11-13°N/82-84°E	0	0	0.00
13	13-15°N/68-70°E	0	0	0.00		**51**	11-13°N/84-86°E	1	4	0.00
14	13-15°N/70-72°E	1	7	0.00		**55**	9-11°N/80-82°E	3	77	0.93
15	13-15°N/72-74°E	3	26	0.64		**56**	9-11°N/82-84°E	1	5	0.00
16	13-15°N/74-76°E	0	0	0.00		**58**	9-11°N/86-88°E	1	3	0.00
18	11-13°N/70-72°E	0	0	0.00		**60**	7-9°N/ 78-80°E	2	13	0.67
19	11-13°N/72-74°E	3	30	1.10		**62**	7-9°N/ 82-84°E	0	0	0.00
20	11-13°N/74-76°E	7	317	1.40		**63**	7-9°N/ 84-86°E	2	11	0.30
21	9-11°N/68-70°E	0	0	0.00		**64**	7-9°N/ 86-88°E	2	19	0.51
22	9-11°N/70-72°E	1	15	0.00		**65**	7-9°N/ 88-90°E	1	20	0.00
23	9-11°N/72-74°E	1	9	0.00		**67**	13-15°N/92-94°E	2	35	0.41
24	9-11°N/74-76°E	7	323	1.44		**68**	13-15°N/94-96°E	1	15	0.00
25	9-11°N/76-78°E	3	44	0.49		**69**	11-13°N/90-92°E	0	0	0.00
26	7-9°N/ 70-72°E	1	10	0.00		**70**	11-13°N/92-94°E	6	77	1.72
27	7-9°N/ 72-74°E	1	5	0.00		**71**	11-13°N/94-96°E	0	0	0.00

Alter the table like continuous numbers & given the location name of location

NEAS

SEAS

S BOB

28	7-9°N/ 74-76°E	2	72	0.45		**72**	9-11°N/90-92°E	1	55	0.00
29	7-9°N/76-78°E	5	316	0.97		**73**	9-11°N/92-94°E	1	25	0.00
30	19-21°N/84-86°E	0	0	0.00		**74**	9-11°N/94-96°E	0	0	0.00
31	19-21°N/86-88°E	2	21	0.60		**75**	7-9°N/ 90-92°E	0	0	0.00
32	19-21°N/88-90°E	0	0	0.00		**76**	7-9°N/ 92-94°E	0	0	0.00
33	19-21°N/90-92°E	1	100	0.00		**77**	7-9°N/ 94-96°E	1	5	0.00
34	17-19°N/82-84°E	2	16	0.56		**79**	5-7°N/92-94°E	1	10	0.00
35	17-19°N/84-86°E	3	71	1.08		**81**	5-7°N/78-80°E	8	120	1.43
36	17-19°N/86-88°E	0	0	0.00		**82**	5-7°N/80-82°E	7	143	1.37
38	15-17°N/80-82°E	0	0	0.00		**83**	5-7°N/82-84°E	3	24	0.54
39	15-17°N/82-84°E	4	317	0.95		**84**	5-7°N/84-86°E	2	32	0.23
40	15-17°N/84-86°E	1	4	0.00		**85**	5-7°N/86-88°E	1	20	0.00
41	15-17°N/86-88°E	2	70	0.60		**86**	5-7°N/88-90°E	0	0	0.00

4.5 Seasonal distribution

Seasonal variability in diversity and distribution was assessed for four seasons such as fall monsoon, summer monsoon, inter -monsoon and winter monsoon. The details of seasonal survey effort and sighting frequency are given in Table 4.8. The number of observation days was not equally distributed between the seasons. Hence, there was variability in survey effort between seasons and years as well as between season and five surveyed regions. However, sighting records are available for all the four seasons. Consecutive surveys were possible in October (inter-monsoon) and January and February (winter monsoon) for all the four years of the study period. In all, maximum number of sightings was in February in late winter monsoon with sighting frequency of 1.02/hr and the lowest was in August in late summer monsoon with sighting frequency of 0.18/hr. The number of sightings per day or per hour was maximum in November (winter monsoon) and minimum in August (summer monsoon) (Table 4.8).

Table 4.8 Number of sightings in each month (pooled for all regions)

Season	Month	Observation effort Days	Hours	No. of days of sighting	No. of sightings	Sightings/day	Sightings/hr
Winter monsoon	JANUARY	62	496	27	40	0.65	0.08
	FEBRUARY	61	488	33	62	1.02	0.13
Fall monsoon	MARCH	32	254	18	24	0.75	0.09
	APRIL	58	464	27	36	0.62	0.08
	MAY	42	336	27	37	0.88	0.11
Summer monsoon	JUNE	70	560	31	50	0.71	0.09
	JULY	65	520	27	38	0.58	0.07
	AUGUST	44	352	6	8	0.18	0.02
Inter monsoon	SEPTEMBER	53	424	31	46	0.87	0.11
	OCTOBER	51	408	24	42	0.82	0.1
Winter monsoon	NOVEMBER	47	376	24	53	1.13	0.14
	DECEMBER	72	576	24	37	0.51	0.06

4.5.1 Seasonal variability in cetacean diversity in different regions

Between the different surveyed regions, there was not much seasonal variability in species composition and distribution. Seasonal species diversity in different region is given in Table 4.9. Seasonal sighting records and observed individuals in each surveyed region are shown in Fig 4.20 and 4.21. In southeastern Arabian Sea, species composition was diverse in winter and inter monsoon seasons, accounting for 8 species in each season and comprising of 82 (42.3%) and 53 (27.3%) sightings respectively (Fig. 4.22). There were 1000 (39.9%) individuals in winter monsoon and 721(27.8%) individuals in inter monsoon. A total of 7 (24.7%) species of 678 (27.1%) individuals were found in fall monsoon season. *T.aduncus,* and *S. longirostris* were the dominant species from delphinid family and occurred in all the seasons. Among these two species, occurrence of *T. aduncus* was more dominant in winter season whereas inter monsoon was dominated by *S. longirostris*. *D. capensis* was the third common species.

There was larger whale occurrence in all the seasons, in particular, during winter monsoon. But 90% of the sightings were unidentified. Among the larger whale, *Physeter macrocephalus* was dominant species and observed in inter as well as winter monsoon. Baleen whale sightings were observed in fall and inter monsoon. Species composition was very less in summer monsoon. There were only 5.7%

sightings of three species, comprising of 132 individuals (5.3%), but two of the four species were identified as possible. *Tursiops aduncus* and *Sousa chinensis* were the two confirmed species. Other species was identified possibly as *Delphinus capensis, Grampus griseus* and *Globicephala macrorhynchus* were the other two species observed in winter monsoon. *Pseudorca crassidens* was observed in fall monsoon and inter monsoon.

Cetacean diversity was very scanty in all the seasons in northeastern Arabian Sea. Sightings were high in winter (37.8%) and fall monsoons (28.9%). Three confirmed species such as *G. griseus, S. chinensis* and *S. longirostris* of 136 individuals were recorded. *T. aduncus* was sighted in inter and summer monsoons. One species, *S. longirostris* was observed in winter season. There was no sighting of larger whales except solitary sighting of unidentified whales in winter season.

In southern Bay of Bengal, maximum diversity was found in summer and winter monsoons. A total of six species of 22 encounters (33.3%) and 471 individuals (47.3%) were recorded in winter monsoon whereas seven species of 18 sightings (27.8%) of 247 individuals (24.8%) were in summer monsoon. *Balaenoptera* sp, *S. longirostris, T. aduncus* and *D. capensis* was the major delphinid species that was found in all the seasons. *P. macrocephalus* were sighted in summer and inter-monsoon seasons. Inter-monsoon showed poor diversity and only 4 species were recorded but all the identification was possible. In winter monsoon two species from balaenoptera family namely, *B. edeni* and *Megaptera noveanglia* were encountered.

Among the six surveyed regions, northern Bay of Bengal and Andaman Sea showed poor diversity during the entire seasons. Maximum record of five species but two of the five species was possible identification in northern Bay of Bengal and Andaman Sea. In northern Bay of Bengal diversity was high in both summer and winter monsoon which accounted for five species consisted of 346 (46.5%) individuals. *T. aduncus* and *S. longirostris* were sighted in three seasons as well as one unidentified whales in winter monsoon. In Andaman Sea, maximum of 4 species of 27sightings (58.7%), accounting for 285 individuals (55.4%) were recorded in winter monsoon. This was followed by summer monsoon with three species of 12 sightings (26.1%) consisted of 121 (23.5%) individuals. *P. macrocephalus* was found commonly in winter season. Pilot whale, spinner dolphin and bottlenose dolphin were the smaller cetaceans found in winter monsoon. Diversity observed in fall and inter monsoon was poor in both northern Bay of Bengal and the Andaman Sea.

A total of seven species (48.2%) of 40 sightings consisted of 329 individuals (49.3%) in winter season followed by summer monsoon with six species of 205 individuals was encountered in the southern Sri Lanka Sea. Occurrence of baleen whales was noticed in all five seasons and was the most commonly occurred whale species followed by *T. aduncus* from delphinids. Diversity in fall and inter monsoon was less with maximum record of three species, accounted for 56 individuals in fall monsoon and 45 individuals in inter monsoon. *B. musculus* was often seen in winter and summer monsoon season. Other species such as *G. griseus, S. longirostris, D. capensis* and *P. macrocephalus* were seen each on one occasion in winter monsoon season in the Sri Lanka Sea.

4 or 5 season ?

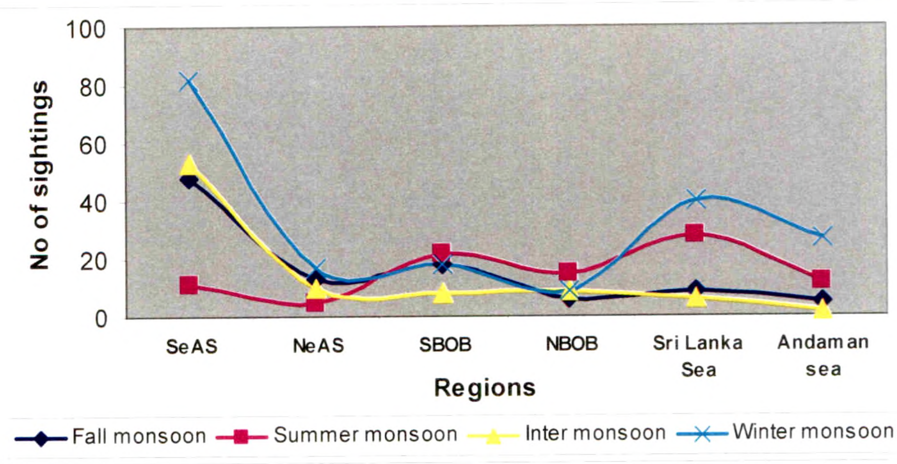


Fig. 4.20 Seasonal sighting records observed in different regions

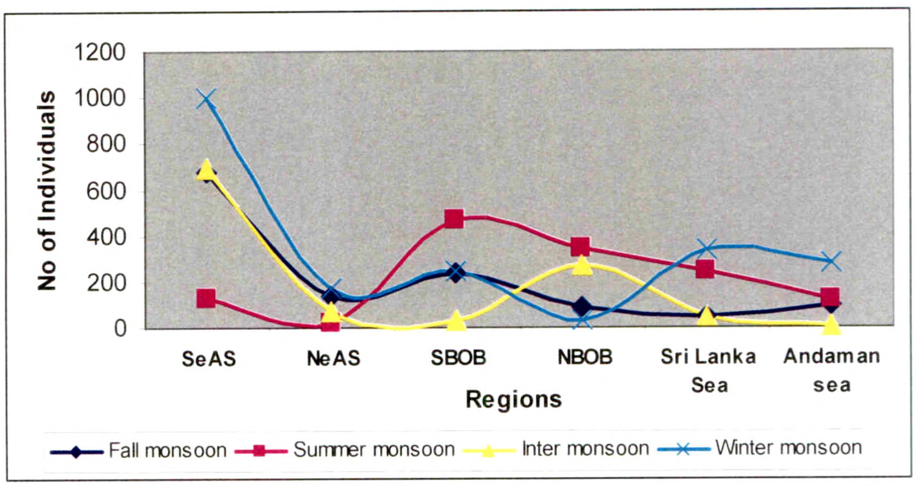


Fig. 4.21 Individuals of cetaceans recorded in different seasons in surveyed area

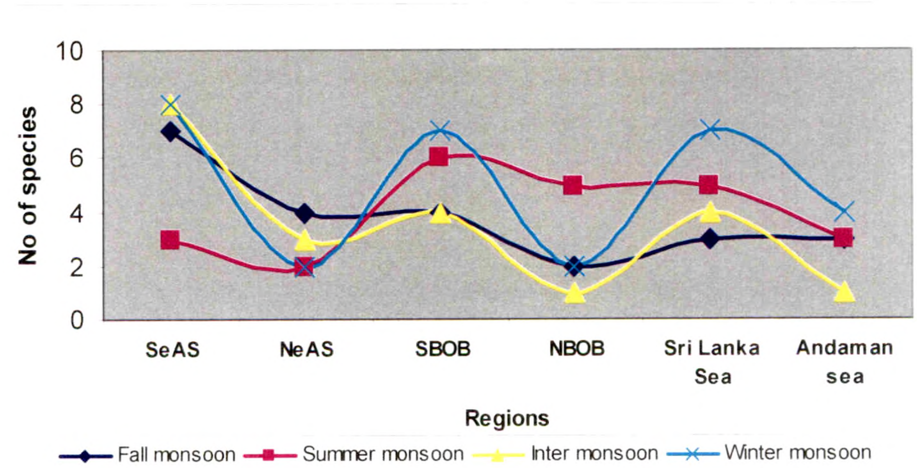


Fig. 4.22 Number of species observed in different seasons in survey area

Table 4.9 Seasonal cetacean diversity in different regions

Species	Ne. Arabian Sea	Se. Arabian Sea	S. BOB	N. BOB	Sri Lanka Sea	Andaman Sea
Balaenoptera edeni			✱			
Balaenoptera musculus					♦,✱	
Megaptera novaeangliae			✱			
Balaenoptera sp.		•,★	•,♦		•,★,♦,✱	
Balaenoptera sp. (P)			★,•		★,✱	•
Physeter macrocephalus		★,✱	♦	•	✱	★,✱
Physeter macrocephalus (P)		★	♦,★		•	•
Pseudorca crassidens	•	•,★	♦	♦	•	
Globicephala macrorhynchus		✱			♦	♦,✱
Globicephala macrorhynchus (P)			✱	•		•
Grampus griseus	•	✱			✱	
Grampus griseus (P)		•	•,♦	•		•
Stenella coeruleoalba		★	•	•		•
Stenella coeruleoalba (P)			•	•	•	•
Stenella longirostris	✱	•,★,✱	✱,♦	♦	♦,✱	✱
Stenella longirostris (P)	•	★,✱	•	★,♦	★,♦	•
Stenella attenuata						
Stenella sp		✱	✱,♦,•	♦	♦	♦
Stenella sp (P)	★,♦		♦	♦,✱		
Tursiops aduncus		•,★,♦,✱	✱,♦	♦,✱	✱	✱
Tursiops aduncus (P)	★,♦	★,✱	✱,★,•	•,♦		
Delphinus capensis		•,★,✱	✱		✱	
Delphinus capensis (P)	★,✱	★,♦,✱	★	•	★	•
Sousa chinensis	•	•,★,♦,✱				

• fall monsoon, ♦ summer monsoon, ★ inter monsoon, ✱ winter monsoon

4.5.2 Seasonal distribution of different species

The occurrence of spinner and bottlenose dolphins was common in all the seasons. The spinner dolphin was more predominant in winter monsoon season, followed by inter monsoon season with the mean group size of 55 (SD= 41) in inter monsoon and 19 (SD =14.2) in winter monsoon (Table 4.11). The sighting frequency was 0.005/hr during winter monsoon and 0.05/hr in inter monsoon (Table 4.10). The bottlenose dolphin was most commonly found in winter monsoon season with sighting frequency of 0.009/hr and the mean group size was 11 (SD= 6.0). The humpbacked dolphins were encountered high in winter monsoon and inter monsoon. The mean group size was 4.8 (SD=6.5) in winter monsoon and 2.6 (SD= 1.5) in inter monsoon. Similar trend was observed in the occurrence of common dolphin. The most of the sightings were occurred in winter monsoon. The sighting frequency was 0.006/hr and group size was 23 individuals.

The larger whale encounters were also considerably high in winter and inter monsoons. The sperm whale was found more in winter monsoon with sighting frequency of 0.003/hr. The mean pod size was 4.1(SD=2.6) (Table 4.11). In inter monsoon, there were considerable sightings with sighting frequency of 0.007/hr. There were no sighting records of sperm whale in fall monsoon. The summer and winter monsoon were the season in which baleen whale sightings were predominant with sighting frequency of 0.006/hr and 0.010/hr respectively. The mean pod size in summer monsoon was 1.83 (SD = 2.6) and 3 (SD=2.6) in the winter monsoon season.

Table 4.10 Cetacean sighting frequency /hr in different seasons

Species	Fall monsoon	Summer monsoon	Inter monsoon	Winter monsoon
Balaenoptera sp	0.001	0.004	0.005	0.006
Physeter macrocephalus	--	0.001	0.001	0.003
Stenella longirostris	0.001	0.003	0.005	0.005
Stenella sp		0.006		
Tursiops aduncus	0.004	0.004	0.001	0.009
Delphinus capensis	0.002	--	0.002	0.002
Sousa chinensis	0.003	0.001	0.006	0.004

Table 4.11 Seasonal pod size and group size of cetacean sightings

Species	Fall Monsoon		Summer monsoon		Inter monsoon		Winter monsoon	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Balaenoptera sp	5.1	2.8	1.8	2.6	2	0.8	3.0	2.6
Physeter macrocephalus			2.6	1.6			4.1	2.6
Stenella longirostris	28*	12*	38	35	55	39	19	14.2
Tursiops aduncus	6.0	17	18	28	11*	6.7*	11	11.2
Delphinus capensis	31*	14*			13*	14*	23	18
Sousa chinensis	3.3	2			2.6	1.5	4.8	6.5

*group size of possible sightings

4.6 Distribution in relation with environmental parameters

To compare the relationship between the oceanographic parameters and distribution of cetaceans, two physiographic variables (maximum depth at the location of sighting and distance from the shore) and two oceanographic variables (Sea Surface Temperature and Sea Surface Salinity) were examined to characterise the habitat of cetaceans. Of the thirteen confirmed species sighted during the study period, adequate number of sightings were available for 5 species, namely *Physeter macrocephalus* (sperm whale), *Tursiops aduncus* (Indo-Pacific bottlenose dolphin), *Stenella longirostris* (spinner dolphin), *Delphinus capensis* (long- beaked common dolphin) and *Sousa chinensis* (Indo- Pacific humpback dolphin) were considered for Kruscal-Wallis test and Inter-quartile analysis. Inter quartile deviation was calculated for *Balaenoptera* sp and *Stenella* sp that had more than 19 sightings records.

4.6.1. Physiographic variables

4.6.1.1 Distance from the shore

The cetaceans were widely distributed from 0.05 km to 964 km from the nearest shore in the study area. A total of 228 sightings (48.2%) were distributed within 100km from the shore. In eastern Arabian Sea, distribution of cetaceans from the nearest shore ranged from 0.5 to 783.5km range, whereas it ranged from 2km to 964km in Bay of Bengal. There was significant difference among the species with regard to distance (KW=42.561, df=6, P=<0.001). *Balaenoptera* sp sightings occurred between 23km and 490km with the mean distance of 113km (SD=113.4) (Table 4.12). Most of the *Balaenoptera* sp sightings were in water <100km with few sightings were found in nearshore water <50km. Sperm whale was the other species occurred commonly in deep oceanic water between 100km to 200km and their occurrence ranged up to 579 km (Fig. 4.23A).

All the larger delphinids, false killer whale, short-finned pilot whale and Risso's dolphin were commonly found in oceanic water. Short-finned whale occurrence was in oceanic water >110km, whereas Risso's dolphin and false killer pilot whale occurrence was still deeper than that for short-finned pilot whale. Risso's dolphin and short-finned pilot whale were recorded in coastal shelf water on few occasions. Among the smaller delphinids, spinner dolphin and *Stenella* sp were constantly sighted in oceanic water and range of occurrence was greater than that of other small delphinids (Fig. 4.23A). Sighting of spinner dolphin ranged from 27km to 716km with predominant observation in deep oceanic water between 100km and 300km, whereas it ranged from 9km to 683.5km with the mean distance of 157km (SD=154) for *Stenella* sp. Bottlenose dolphin showed coastal preference and most of the sightings occurred within 100km. Common dolphin was found in coastal water with a few occurrences in deep oceanic water and most of the sightings were between 100km and 200km distance. Humpback dolphins were commonly found in nearshore water generally <0.5km. On single occasion it was found in offshore water at 50km distance from the nearest shore.

Table 4.12 Distribution frequency of cetaceans in relation to distance from the shore (km); n=number of sightings

Species	n	Mean	SD	Range
Balaenoptera sp	28	113	113.4	23 - 490
Balaenoptera musculus	4	48	23.5	19 - 144
Physeter macrocephalus	16	146	175	4 - 579
Stenella longirostris	30	77	157	27 - 716
Tursiops aduncus	39	87	53	22 - 276
Delphinus capensis	18	153	137	3 - 624
Sousa chinensis	18	23	20	0.05 - 50
Stenella sp	19	157	154	9 - 683.5
Grampus griseus	4	141	109	26 - 350
Pseudorca crassidens	4	262	22.8	228 - 274
Globicephalamacrorhynchus	3	72	58	5 - 110

4.6.1.2 Depth

There was significant difference among the species with regard to depth (KW=87.7, df= 6, P= <0.001). Preference for slope habitat by most of the cetaceans was greater (Fig 4.23B). *Balaenoptera* sp, blue whale and sperm whale sightings were found over continental slope and outer slope waters. Blue whale occurrence ranged between 1200m and 2919m with the mean depth of 1538m (SD=781), whereas sperm whale occurrence varied from 340m to 3693m. The mean depth of occurrence was 1606m (SD =1090). Spinner dolphin and *Stenella* sp occurred both on shelf and slope but generally occurred on slope water >300m (Fig. 4.23B). Bottlenose dolphin showed preference for shelf and slope water <500m (Fig. 4.23B). Occurrences of common dolphin ranged from shelf to outer slope with predominant sightings were on shelf break and slope water between 500m to 1500m. Occurrence of humpback dolphin was confined to shallow waters, generally at depth <20m. False killer whale, short-finned pilot whale and Risso's dolphin was observed over slope water >200m. Risso's dolphin and short-finned pilot whale were observed on shelf water and shelf break. Depth of Risso's dolphin occurred area ranged from 292m to 3072m with the mean depth of 1157m (SD=1254) and that of for short-finned pilot whale ranged from 50m to 2600m with the mean of 475m (SD=306). All four sightings of false killer whale were encountered in depth range of 1700m-2000m (SD= 155).

Table 4.13 Distribution frequency of cetaceans in relation to depth(m); n=number of sightings

Species	n	Mean	SD	Range
Balaenoptera sp	28	1763	1167	83-3862
Balaenoptera musculus	4	1538	781	1200 - 2919
Physeter macrocephalus	16	1606	1090	340 - 3696
Stenella longirostris	30	1834	1433	18 - 4270
Tursiops aduncus	39	322	320	34 - 1420
Delphinus capensis	18	907	1194	28 - 3701
Sousa chinensis	18	25	13	15 - 40
Stenella sp	19	1747	1254	26 - 3860
Grampus griseus	4	1157	1245	50 - 2600
Pseudorca crassidens	4	1868	155	1700 - 2000
Globicephala macrorhynchus	3	475	306	292 - 829

4.6.2 Oceanographic variables

4.6.2.1 Sea surface temperature (SST)

During the survey period, the SST of surveyed area ranged from 24.2°C to 33.0°C with the mean of 28.8°C (SD= 1.2). All the species occurred in mean surface temperature of 28°C (Table 4.14). Deeper water species occurred in water <30°C, which was lower than that for coastal species (Fig. 4.23C). There was no significant difference among the species with regard to SST (KW=2.9, df= 6, P=<0.818). All the *Balaenoptera* sp and blue whale sightings were found in narrow SST range between 28°C and 29°C. Sightings of sperm whale, Risso's dolphin, false killer and short finned pilot whale were also found in similar narrow SST range. Most of the delphinid species also found in water with narrow range of SST. *Stenella* sp and spinner dolphin sightings were restricted to SST between 26.0°C and 29.5°C with the mean of 28.5°C (SD= 1.3) and 28.1°C (SD=0.8) respectively (Table 4.14). Long beaked common dolphin and bottlenose dolphin occurred in water with wide range of variation in SST. These species were found in SST ranging widely from 26.0°C to 32°C, but most of the sightings were at mean SST of 28°C. The surface temperature in humpback dolphin occurred area varied from 26 to 30 with most of the sightings were in water with narrow SST range.

Table 4.14. Distribution frequency of cetaceans in relation to sea surface temperature(°C); n=number of sightings

Species	n	Mean	SD	Range
Balaenoptera sp	28	28.2	0.9	26.0- 30.0
Balaenoptera musculus	4	27	1.2	26.0 – 29.0
Physeter macrocephalus	16	28.4	0.9	27.0 – 30.0
Stenella longirostris	30	28.1	0.8	26.0 -29.5
Tursiops aduncus	39	28	1.5	26.0 – 33.5
Delphinus capensis	18	28.5	1.2	27.0 – 32.0
Sousa chinensis	18	28	1.0	26.0- 30.0
Stenella sp	19	28.5	1.3	26.0 - 32.0
Grampus griseus	4	27	1.2	26.0 - 31.0
Pseudorca crassidens	4	28	0.9	28.0 - 29.7
Globicephala macrorhynchus	3	28	1.2	27.5 - 29

4.6.2.2 Salinity

The surface salinity in survey area varied from 27 ppt to 36ppt with the mean of 33.3 ppt (SD= 1.5). There was significant difference among the species with regard to salinity (KW=37.41, df=6, P=<0.001). However, the average surface salinity of most of the species ranged from 33ppt to 34ppt except for humpback dolphin (Fig 4.23D). *Balaenoptera* sp and blue whale were sighted in narrow range of salinity, whereas sperm whale was found in wide rage of water with salinity varied from 29.3ppt to 36ppt. Among three larger delphinids, surface salinity in water, where Risso's dolphin and false killer whale were observed, was comparatively higher than that for short finned whale. Both the species were found in mean salinity of 34ppt, whereas short finned pilot whale was seen in mean salinity of 32.5ppt(SD= 1.6). All the smaller delphinids were also found in similar surface salinity ranging between 29ppt and 36ppt. The three dominant species such as spinner, bottlenose and common dolphins could be sighted at salinity ranging widely from 29ppt to 36ppt (Table 4.15). However, most of the sightings of these three species were between 33ppt and 34ppt. *Stenella* sp was restricted to water with narrow range of salinity. The humpback dolphin was the only species occurred predominantly in low salinity water between 30ppt and 31ppt (Fig. 4.23.D).

Table 4.15 Distribution frequency of cetaceans in relation to salinity (ppt); n=number of sightings

Species	**n**	**Mean**	**SD**	**Range**
Balaenoptera sp	28	33.0	2.0	29.5 - 36
Balaenoptera musculus	4	33.2	0.3	33.0 – 33.4
Physeter macrocephalus	16	33.2	1.7	29.3 – 36.0
Stenella longirostris	30	33.6	1.4	29.0 – 36.0
Tursiops aduncus	39	33	1.5	29.5 – 36.0
Delphinus capensis	18	33.2	1.3	30.0 – 36.0
Sousa chinensis	18	30	1.4	27.0-32.0
Stenella sp	19	33	0.5	32.0 – 34.0
Grampus griseus	4	34	0.9	33.9 - 35.7
Pseudorca crassidens	4	34.3	1.0	33.0 - 35.2
Globicephala macrorhynchus	3	32.5	1.6	32.5 – 33.0

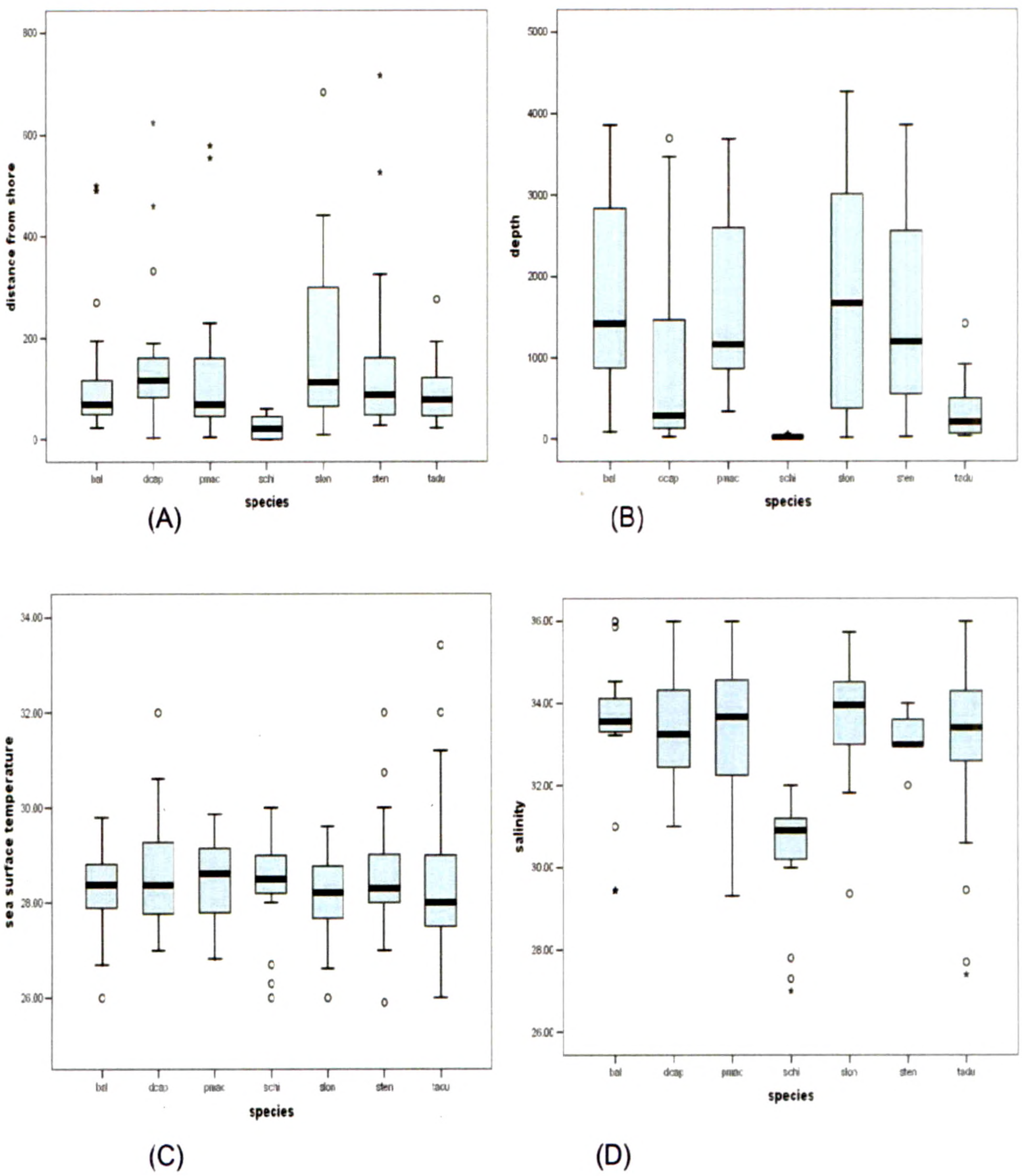
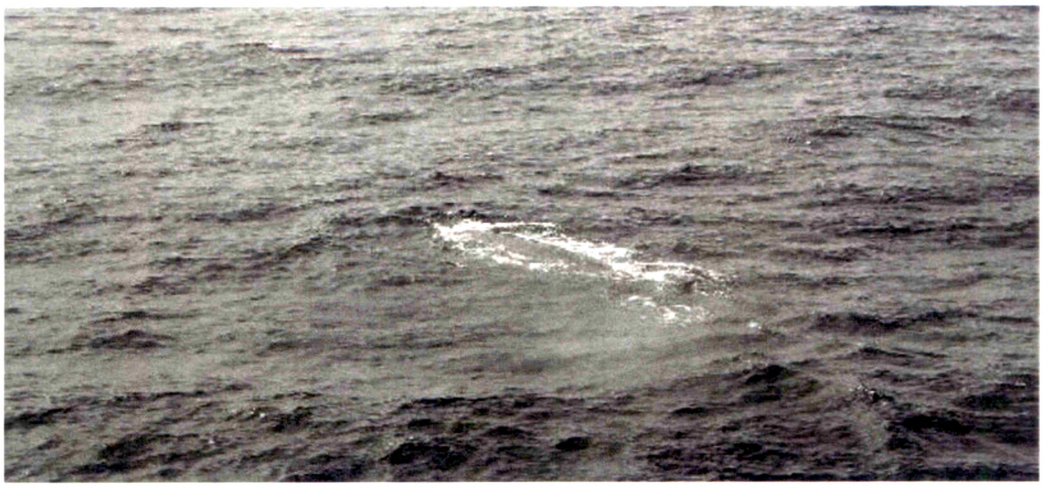


Fig. 4.23 Cetacean distribution with respect to environmental variables observed during the cruise represented by Box and Whisker plot showing median, quartiles and extreme values (The box represents the interquartile range, the whiskers are lines that extent from the box to the highest and lowest values and the line across the box indicates the median, stars and rounds are outliers); bal- *Balaenoptera* sp, dcap- *Delphinus capensis*, pmac- *Physeter macrocephalus*, schi- *Sousa chinensis*, slon- *Stenella longirostris* stn-*Stenella* sp, tadu- *Tursiops aduncus*

Balaenoptera musculus

Balaenoptera edeni



Globicephala macrorhynchus

Physeter macrocephalus

Tursiops aduncus

Stenella longirostris

Sousa chinensis

Stenella attenuata

Grampus griseus

Chapter 5

DISCUSSION

The present study represents first attempt and preliminary assessment of cetacean diversity and distribution in the Indian waters. Ship-based visual survey using platform opportunity is a conventional and widely practiced method to collect data on the relative and absolute abundance and distribution of marine mammals at the species level (Aragones *et al.*, 1997). For this study also, platform of opportunity is a valuable means to monitor the cetacean diversity, distributional range and their habitat characteristics in coastal and oceanic waters. The geographical feature of surveyed areas is highly varied, which covered several cetacean habitats ranging from shelf and slope of the oceanic water. Though, survey in nearshore coast was totally lacking and this eliminated the chance of recording the highly inshore coastal species.

This survey recorded 473 sightings of 13 species of cetaceans and accounting for 5,865 individuals in 5,254 hours of sighting effort at the rate of 1.12 individuals per hour (0.7 sightings per day) (Table 4.6). Sighting frequency in the present study is comparatively low. In the northwest Indian Ocean and Sri Lankan waters, Alling (1986) reported 0.9 sightings per day. Sighting records as high as 6.4 per day are also available in western tropical Indian Ocean (Ballance and Pitman, 1998). The low sighting records in the present study may be due to the following limitations. (i) All the cruises were opportunistic without a structured cruise programme and the uneven survey effort at temporal and spatial scale has resulted less number of records compared to records from the survey in other part of the Indian Ocean. (ii)The size of the survey vessel FORV *Sagar Sampada* is larger and not easily maneuverable for tracking an animal upon sighting. (iii) On each cruise, a single observer was employed to carry out the watch with occasional aid of non-trained observer. Two observers in each cruise would have improved the quality of observation. Employing three observers in the opportunistic survey conducted by Ballance and Pitman (1998) resulted in substantially high number of sighting records.

Inspite of few limitations, the 40 months survey has contributed considerable baseline information of cetacean community in the Indian water and the contiguous sea. Cetaceans are found to have a very wide geographical distribution in the Indian EEZ and the contiguous seas. Abundance and species richness are greater in the southeastern Arabian Sea and southern Sri-Lankan waters, whereas and relatively sparse in other surveyed area, in particular, in the northern parts of Indian coast.

5.1 Geographical and Seasonal distribution

Sri Lanka Sea was the richest diverse area with contribution of 87 sightings of seven species, accounting for 687 individuals. These areas were reported to have rich cetacean fauna in earlier studies (Alling, 1986; De Silva, 1987; Ilangakoon, 1997). There are 27 species known to inhabit in Sri Lanka water (Ilangakoon, 2002). The present survey was restricted to slope area of the Sri Lanka water and the coastal area and western part of Sri Lanka were not covered, which reflected low species records than actual species known to occur in Sri Lankan water. Most of the sightings in southern part were of *Balaenoptera* sp in the present study.

The southeastern Arabian Sea was the second most diverse area. Ten species were recorded with dominant occurrence of *Stenella longirostris, Tursiops aduncus, Delphinus capensis* and *Sousa chinensis* in southeastern Arabian Sea. Within this region, Kerala and Karnataka, between 9°-15° latitude were the two areas where diversity and concentration were diverse and dense. The greater diversity of cetacean in this regions may be attributed to the fact that the southern Arabian Sea water are one of the most biologically productive ocean regions and dense prey availability through out all the seasons. During summer monsoon, southwest monsoon current originate intense upwelling along Somalia and southern Arabian Seas. Upwelling process enhances phyto plankton and meso zooplankton population, which are basic food components in diet of most small fish population (Madhupratahp, 2001; Goes *et al.*, 2005). Abundance of zooplankton community remains unchanged over season in spite of variation in phytoplankton abundance as monsoon subsides (Bhattathiri *et al.*, 1996; Sawant and Madhupratap, 1996). Similarly, winter cooling convective mixing is causing an increase primary production in winter monsoon (Prakash and Ramesh, 2007).

Thus, enhanced biological productivity by upwelling in these regions sustains prey population throughout all the seasons and probably provides ideal habitat for cetaceans. Hence, the heterogeneity of cetacean distribution and sighting frequency in this region was greater in all the seasons except summer monsoon. In summer monsoon, most of the surveys were carried out in peak monsoon period.

Inclement weather and poor sea state that exceeded more than five at beafourt scale affected survey and thus has resulted low sightings in summer monsoon.

The southern Bay of Bengal is the third most diverse area followed by Andaman Sea. Records of past stranding events document the presence of as many as 20 species in Bay of Bengal and most of them are from southern Bay of Bengal (Kumaran, 2008). Both southern Bay of Bengal and Andaman Sea was dominated by oceanic delphinids and baleen whales. The Bay of Bengal is a distinct tropical ecosystem and has different bathymetry and oceanographic features compared to its western counterpart, the Arabian Sea (Dwivedi, 1995). The topographic feature of southern Bay of Bengal and Andaman Sea is unique and lesser shelf area with presence of seamounts and submarine canyon, occupying nearly 35% of the continental slope. As a result, the present survey exhibited occurrence of more oceanic delphinids and baleen whales and is in accordance with stranding and catch record available for this region (Kumaran, 2008). Area with rough topography, canyon structures and seamount are characterized by enhanced biological productivity. Diversity of benthic and pelagic fauna is greater than those in other habitats along the continental slope (Cartes, 1998; Gili *et al.*, 2000).

The northeastern Arabian Sea has very reduced cetacean fauna than that of its southeastern counterparts. Only four species such as *Grampus gresieus*, *S. longirostris*, *T. aduncus* and *S. chinensis* were observed in this region. This may be due to less amount of survey effort, received by this region during the study period. Review of past stranding records showed occurrence of 12 species in further northern part of this region (Kumaran, 2008). Complete lack of survey in broader shelf area between 20°N-23°N latitude, further northeast of Arabian Sea, may probably be one of the causes for sparse cetacean diversity and distribution observed in this region. Hence, the present study represents probably underestimated species composition and abundance for this region. The northeastern Arabian Sea sustains high productivity during the winter monsoon due to winter cooling (Prakash and Ramesh, 2007). Relatively higher sighting in winter and fall monsoon period indicates that aggregation of cetacean is probably more in winter monsoon. However, data in the present study is too low to substantiate this conclusion.

The diversity of northern Bay of Bengal was also poor. Three confirmed species such as false killer whale, spinner dolphin and bottlenose dolphin were recorded. The long-beaked common dolphin was sighted but identification was not confirmed. Most of the sightings were between 5°N-20°N latitude. Sighting in northern part of this region (between 20°N and 21°N) showed poor diversity with confirmed record of one species, *Tursiops aduncus* and two sightings of unidentified whale. Review of the past stranding data also demonstrates the sparse diversity in north of 20°N. Occurrences of three species only have been noted from this region and two of them, Ganges dolphin and Irrawady dolphin occur in Ganges river and Chilika Lake respectively (Dhandapani, 1992).

The northern Bay of Bengal is a region with lesser biological productivity. Biological productivity of this region is largely limited by low nutrient availability due to lack of intense upwelling (Gopalakrishana and Sastry, 1985). Freshwater influx from rivers Mahanadi and Ganga transport nutrient into the open ocean. However, this nutrient is biologically consumed within estuary and coastal region. In addition, this river runoff declines surface salinity as low as 20 ppt along the coastal region (Kumar *et al.*, 2002). As a result, river run off increases productivity along nearshore coastal area and probably supports the distribution of inshore species such as Irrawady, Ganges and humpbacked dolphins, known to inhabit in low salinity water.

Inspite of the fact that river runoff increase productivity in near coastal area north of 17°N, low nutrients in highly stratified water affects the offshore productivity due to low salinity and low density (Kumar *et al.*, 2002). Hence, low sea surface salinity and less productivity might contribute to sparse diversity in north of 20°N- 87°E. However, taxonomically diverse cetacean group has been observed over "Swatch of no ground" submarine canyon between 21°N - 90°E longitude in northern Bay of Bengal (Smith *et al.*, 2008). The presence of submarine canyon is an ideal feature for mixing of nutrients, which provides rich prey niche for cetaceans (Bearzi, 2005).

The Bay of Bengal is traditionally considered as a more productive area, in summer monsoon (Kumar *et al.*, 2002). In southern Bay of Bengal and Andaman Sea, more sightings occurred in summer monsoon, followed by winter monsoon. Inter monsoon and fall monsoon sightings exhibited very poor diversity with four species. Whale occurrence was observed in all the seasons with predominant encounters in summer and inter monsoon in southern Bay of Bengal. During winter monsoon, larger pod of sperm whales were seen frequently between 92°E-94°E in Andaman Sea. The northern Bay of Bengal showed poor diversity in three seasons except in summer monsoon.

5.2 Species diversity

Species diversity of Indian cetacean community appears similar to other cetacean communities in northern Indian Ocean. Of the 13 species of cetaceans recorded in the present study, eleven species were found in Indian waters, which is only 50% of the species reported earlier for the Indian waters (Kumaran, 2002). The 'delphinids' were the most diverse group with seven species, two of which were the most abundant and widespread species in the present survey. Among delphinids, the spinner dolphin was dominant in terms of abundance, whereas Indo-pacific bottlenose dolphin was the most dominant species in terms of number of records. They were followed by long beaked common dolphin and Indo-Pacific humpback dolphin.

Based on information published by several authors mostly on beach-cast samples concluded (Kumaran, 2002) that the spinner dolphin was the most frequently recorded species during the last century in India. In the present study, this species was sighted widely in all surveyed area and in all the season with predominant occurrence in winter season. The geographical spread of sightings and stranding suggests wide distribution of this species in Indian coast. It has also been recorded as frequently sighted and most abundant species in surveys in adjacent seas such as western tropical Indian Ocean and Maldives (Ballance and Pitman, 1998; Ballance *et al.*, 2001). Two types of spinner dolphin *S. l. longirostris* and *S. l. roseiventris* are recognised in northern Indian Ocean (Perrin, 1990 and 1999). Spinner dolphin in the entire surveyed regions except Andaman region was similar to large pan-tropical form *S. l. longirostris*. *S. l. roseiventris* is reported to occur in shallow waters in Southeast Asia (Perrin, 1999 and 2007). Hence, spinner dolphin sighted in the Andaman Sea, which lie in similar geographical region, could be possible dwarf spinner dolphin. The average group size is similar to those reported for Maldives water but lower than that of Western tropical Indian Ocean.

Bottlenose dolphin was the second commonly accounted species in the entire surveyed area with dominant occurrence in southeastern Arabian Sea. Two distinct 'types' of bottlenose dolphin, *Tursiops aduncus* and *Tursiops truncatus* are generally recognised (Hale *et al.*, 2000). Of these two, *Tursiops aduncus* were only sighted in the all surveyed region. *Tursiops aduncus* are found in bays, estuaries, shelf area, whereas *T. truncatus* ranges widely in pelagic waters beyond the continental shelf and found in coastal habitat (Rice, 1998; Gannier, 2005). There were considerable sightings of bottlenose dolphin on slope in the present study, but identification was not definite and hence not considered for the present study. Identification of this offshore sightings to be *T. truncatus* was not possible, as distinguishing these two forms is generally difficult at sea and lack of substantial photo evidence. However, there is no evidence of landing *T. truncatus* in Indian fishery, which has operational range up to 70 km (Yousuf *et al.*, 2008) The recent genetic investigation on bottlenose dolphin has suggested that bottlenose dolphin from the Indian sea can be considered as *Tursiops aduncus* (Jayasankar *et al.*, 2008). Bottlenose dolphin's mean group size of the present study is 12.0 which is comparable to those reported from Australia (13.0) (Hawkins and Gartside, 2008).

Long-beaked common dolphin *Delphinus capensis* was the third most commonly encountered species but confirmed only on eight occasions in southeastern Arabian Sea, Southern Bay of Bengal and Sri Lanka Sea. There were very few possible sightings in Andaman Sea and northern part of Arabian Sea and Bay of Bengal. During the FORV *Sagar Sampada* fishing cruise in 1987 and 1989 sighting of this species has been observed on two occasions in northern Bay of Bengal (Jayaprakash *et al.*, 1995). Similarly, their occurrence in Gulf of Mannar was also reported during the "Tulip" survey (Alling, 1986). Landing of this species have also often been reported in northern Bay of Bengal and other part of the survey areas (Lalmohan, 1985; Mahadevan Pillai and Chandrangatha, 1990; Chandrakumar, 1998; Yousuf *et al.*, 2008). This species is the third abundant species, often reported in incidental catch of Indian fishery (Lalmohan, 1985)

The genus *Delphinus* is represented currently by two species, the short-beaked common dolphin *D. delphis* and the long-beaked common dolphin *D. capensis* (Van Bree, 1971; Jefferson & Van Waerebeek, 2002). In India, earlier workers have mentioned this species as *D. delphis* (Silas *et al.*, 1984; De Silva, 1987; Krishnapillai and Kasinathan, 1987). However, geographical range of *D. delphis* has been recently excluded from northeastern Indian Ocean (Jefferson *et al.*, 2008). Morphological study and examination of photos of two specimen caught in gillnet fishing along the Indian coast has proved it to be *D. capensis* (CMFRI, 2007). This was further substantiated with molecular evidence (Jayasankar *et al.*, 2008). Group size varied between 2 and 50 individuals and larger than those reported earlier for the Indian coast (Jayaprakash *et al.*, 1995). Common dolphins are mostly found in groups of 50–70 animals with aggregations of 100–600 animals recorded occasionally (Notarbartolo di Sciara *et al.*, 1993; Forcada and Hammond, 1998; Canadas *et al.*, 2002). Although, relatively smaller group sizes can be expected in coastal habitats with low predation pressure (Acevedo-Gutierrez, 2002),

Humpback dolphins *Sousa chinensis* were the only inshore species observed in this survey. All the sightings were in Arabian Sea with predominant sightings from southeastern Arabian Sea while only a single sighting in northeastern Arabian Sea. In southeastern Arabian Sea, *S. chinensis* were frequently sighted at 9°58'N and 76°16'E throughout the survey periods in all the seasons, which suggests that this group is probably a resident and discrete population of this region. Little information on occurrence and distribution of this species is available from northern Arabian Sea (Weitkowitz, 1992; Parson, 1998; Sutaria and Jefferson, 2004).There were no sightings in Bay of Bengal, Sri Lanka Sea and Andaman Sea because of low survey effort in coastal areas of these regions. However, by-catch and sighting records of this species are available for Bay of Bengal and the Andaman Sea (Leatherwood and Clarke, 1983).

Two geographical forms of *S.chienesis* are recognised in Indian water. Individuals in Arabian Sea is characterized by large hump and appear dark grey dark in colour while hump is absent on Bay of Bengal form. The Arabian Sea form resembles the "*plumea*" type while later resembles "*chinensis*" type (Sutaria and Jefferson, 2004). The author recorded landing from incidental catch of two specimens without hump in Chennai (southern Bay of Bengal). Taxonomic status of these two geographically different forms is yet to be resolved. Average group size was 3.6, which is similar to group size of Gulf of Kachchh population (3.9) but lower than Goa population in northern Arabian Sea.

Among large whales, sperm whale is the most frequently sighted species with wide distribution in the present study. This species has been observed frequently in northern and western Indian Ocean cetacean survey during 1995 (Ballance *et al.*, 1996). Review of past stranding and sighting history demonstrates the greater distribution of this species in Indian coast, in particular, in southern Indian coast and Sri Lankan water (Bande *et al.*, 1980; Leatherwood, 1984; De Silva, 1987; Nammalwar *et al.*, 1989; James, 1990; James and Panickkar, 1994). The southern Bay of Bengal and the Andaman Sea regions presented the highest sperm whale sightings and pod size was larger. Most of the sightings in the southern Bay of Bengal were seen between 9°N-81°E and 14°N-86°E and in the Andaman Sea between 12°N-92°E and 12°N-94°E in Andaman Sea. Leatherwood *et al.* (1991) have suggested the presence of isolated population in the Arabian Sea and Bay of Bengal.

There was no sperm whale sighting from northern Bay of Bengal and it is likely that this species is absent or rarely frequent sea in this region. Absence of stranding records in Bangladesh coasts in northern Bay of Bengal is further evidence for absence of this species in this region (Smith *et al.*, 2008). Possible reason for absence of this species is not clear. The distribution of sperm whale is linked to availability of cephalopod resources, main prey of the sperm whale diet (Smith and Whitehead, 2000). Cephalopod resource, reported for northern Bay of Bengal is comparatively lower than that of other surveyed regions (Meiyappan and Mohamed, 2003). Therefore, the absence of this species may be related to devoid of adequate prey availability to support their distribution in this region. The distribution of sperm whale in northeastern Arabian Sea (15°N-17°N) is also uncertain as it was not recorded in this survey and no stranding records exist for this region.

Baleen whale sightings were very sparse in the Indian Seas, but dense in southern Sri Lanka water. Records on stranding indicate the occurrence of all six *Balaenoptera* species in Indian waters (Kumaran, 2002). Of the six species, one species was identified as *B. edeni,* while few sightings were identified up to generic level only. Kasuya and Wada (1991) have indicated the isolated group of *B. edeni* species in the Arabian Sea and in Bay of Bengal. This view is supported by several sightings in the recent survey on submarine canyon region (Swatch of no ground) in northern Bay of Bengal (Smith *et al.,* 2008). In the present survey, the sightings recorded as possible sei whale may be the bryde's whale (*Balaenoptera edeni*), as these two species are difficult to differentiate at sea and also the sei whale distribution in the area is still doubtful (Jefferson *et al.*, 2008).

There were four pygmy blue whale (*Balaenoptera musculus brevicauda*) sightings in the Sri Lanka Sea (Fig. 4.5). Jefferson *et al.* (2007) reported that the blue whale sighted in this area could be sub species of the pygmy blue whale (*B. musulus brevicauda*). Pygmy blue whales have been recorded in the northern Indian Ocean (Oman, Maldives and Sri Lanka), where they may form a distinct resident population (Branch *et al.*, 2007). The Sri Lankan waters are reported to be important to blue whale as a feeding area, even though the occurrence may be seasonal (Alling *et al.*, 1991).

False killer whale, long-finned pilot whale, Risso's dolphin and striped dolphin were less frequently observed in the study area. Their presence in the study area were reported previously from sighting cruises, bycatch and stranding reports (Harwood, 1980; Leatherwood *et al.*, 1984; Alling *et al.*, 1986; Kumaran, 2003). Risso's dolphin was observed on two occasions in southeastern Arabian Sea between 12°'N-74°'E and 13°'N-74°'E (Fig 4.7) and could be indicative of presence of local population in this region.

Pygmy sperm whale (*Kogia breviceps*), dwarf sperm whale (*Kogia simus*), Cuvier's beaked whale (*Ziphius cavirostris*), killer whale (*Orcinus orca)*, melon-headed whale (*Peponocephala electra)*, rough-toothed dolphin (*Steno bredanensis)* were not seen in the present survey. It is possible that these species may have been included in the unidentified sightings. Over past 200years, many of these species have been reported rarely from the study area (Chantraporsyl *et al.*, 1991; Leatherwood *et al.*, 1991; Kumaran, 2002). Lack of past stranding records and sightings in the present study could be indicative of their rarity in the study area especially in Indian water. But sighting and by-catch of pygmy sperm whale, dwarf sperm whale and melon-headed whale are reported regularly in Sri Lankan waters (Dayarante and Joseph, 1993; Ilangagoon, 1997; Cornelis *et al.*, 2008). Hence, in the present survey, absence of these species in Sri Lankan water, rather than being rare, is a result of their shy and extreme difficulty to observe at sea (Jefferson, 2008).

Irrawady dolphin (*Orcaella brevirostris*), finless porpoise (*Neophocaena phocaenoides*), Ganges river dolphin (*Plantanista gangetica*) and seacow (*Dugong dugon*) were also not sighted due to the operational limitation of survey vessel in their actual habitat. Distributional range of these three species is confined to inshore shallow estuaries and river habitat. Of these, finless porpoise were recorded as incidental catch in fishing gear off Mangalore (southeastern Arabian Sea) during the study period (Yousuf *et al.*, 2008). Few by-catch records are available from northeastern Arabian Sea and southern and northern Bay of Bengal (James *et al.*, 1989; Kumaran and Subramanian, 1993; Sutaria and Jefferson, 2004). The sighting of this species was reported from boat surveys in northern Arabian Sea (Sutaria and Jefferson, 2004).

The occurrence of Irrawady dolphin was noticed in a boat survey in Chilika Lake in northern Bay of Bengal but not included in the present study because of lack of systematic survey effort in assessing its distributional range. This species is also known to occur in Sunderban area in northern Bay of Bengal (Smith *et al.*, 2008). Ganges river dolphin is an endemic population of Ganges River in northern Bay of Bengal and is reported to be a dwindling population due to intense fishing in this area (Lal mohan *et al.*, 1993). Seacow is a resident population of the Gulf of Mannar and Palk Bay, which were not covered in the surveys. Incidental catch of this species has been often reported in these areas (Badrudeen, 2004). Few stranding records are available from Gulf of Kachchh in northeastern Arabian Sea (Frazier and Mundkar, 1990). Similarly, few sightings and strandings of seacow have also been reported in Andaman Sea (Sivaprakasam, 1980; Das and Dey, 1999).

The distribution pattern other species observed in the present study agrees with historical records based on incidental capture. In the present survey, as the surveys were mostly in the fishing grounds, the four predominant delphinids spinner dolphin, bottlenose dolphin, common dolphin and humpback dolphin observed in the study were among the most recorded species in incidental catches in fishing gear (Lalmohan, 1985; Jayaprakash *et al.*, 1995). This suggests that these four species widely occur along the Indian coasts. Sporadic occurrence of false killer whale and pilot whale in both sighting and fishery by-catch confirms their comparatively rare occurrence in Indian coasts. The data generated on species occurrence and distribution will be useful to estimate the abundance of marine mammals in the Indian Seas. For this, the oceanic surveys onboard research vessels need to be supplemented with coastal surveys. The result of the present study indicates the need for further effort in many areas. It is likely that species, which occur in other adjacent sea, would occur in India Seas too.

5.3 Distribution in relation to environmental parameter

Cetacean distribution is mainly influenced by the physiographic (Canada *et al.*, 2002; Macleod *et al.*, 2007) and oceanographic features (Forney, 2000; Baumgartner *et al.*, 2001) of regional ocean environment and prey availability. In the present study, the smaller dataset of these four variables available for few species group have contributed knowledge on relationship between environmental parameter and cetacean distribution. Among the four variables considered for the present study, the physiographic variables (depth and distance from the shore) were primary variables in differentiating the cetacean habitat. The distribution of cetaceans in the study area was mostly partitioned by these two physiographic variables, with each of the five species distinguishable by these two features alone. The difference in depth preference by cetaceans is related to their diving behaviour and its foraging ecology (Schreer and Kovacs, 1997; Stephanis *et al.*, 2008).

Spinner dolphin are generally oceanic cetaceans but it is occasionally found on shelf area too (Jefferson *et al.*, 1993). In the present study, this species was found on continental slope in deeper oceanic water but occasionally found over shelf and shelf break water in coastal and offshore area. The occurrence of this species in shelf and slope area may be related to their predation on diverse range of fish, myctophid and squid, associated with deep scattering layer in different water depth (Fitch and Brownell, 1968; Miyazaki *et al.*, 1973; Ridgway and Harrison, 1994). Stomach content study of spinner dolphin in the surveyed area exhibited occurrence of *Solenocera crassicornis,* which inhabits at 50m depth (Anoop *et al.*, 2008). In other study, presence of carangids and squid has been observed in stomach of spinner dolphin (Karbari *et al.*, 1993). Therefore, occurrence of this shelf water in the present study indicates that this species utilize shallow water in shelf area for feeding.

Bottlenose dolphin showed preference for shelf and shelf break and also occurred on continental slope in offshore area. This distribution pattern is consistent with those observed in northeast Atlantic and Bay of Biscay (Skov *et al.*, 1995; Kiszka, *et al.*, 2007). Bottlenose dolphins occurred within 200 km, predominantly within 87km from the nearest coast, close than the distribution range of spinner dolphins. This suggests possible habitat partitioning of these two species. Bottlenose dolphin is known to feed on wide range prey species (Barros and Odell, 1990). Study on stomach content shows that the diet of bottleose dolphin comprised a diverse range of fish, cuttlefish, *Acetes*, copepods, squilla and cephalopod species (Mohamed *et al.,* 2005). These prey species occur in shallow coastal waters of India. The prevalent preys were *Saurida tumbil, Nemipterus mesoprions,* carangid, anchovy, *Thryssa* and squid. Hence, the wide distribution in shelf area may be result of its opportunistic and wide range of prey preference.

Common dolphin distribution with respect to depth and occurrence range from the nearest shore was intermediate between bottlenose dolphin and spinner dolphin distribution. Most of the sightings were seen over shelf and shelf break area in offshore water and few occurrences on coastal shelf water. There is sparse information on diet habit of this species in study area. According to available information, common dolphins feed on small mesopelagic, cephalopods and myctophids (Blanco *et al.,* 1995; Pusineri *et al.,* 2007; Meynier *et al.,* 2008).

Sperm whale is considered to be oceanic species associated with water deeper than 1000m but it is occasionally found over shelf edge (Davis *et al.,* 2002; Whitehead, 2003). Bathymetry feature of sperm whale habitat is characterised by seamounts and submarine canyon where cephalopods aggregate (Whitehead *et al.,* 1992). In the present study, sperm whale distribution was restricted to deeper oceanic water over slope and rarely over shelf break area which is close to shore. The topographic feature of the southern Bay of Bengal and Andaman Sea regions, from where most sperm whales were observed, is characterized by irregular bathymetry feature with presence of the steep continental slope, seamounts and submarine canyon (Rao and Kessarkar, 2001; Ramasamy, 2007). Bathymetry characterized by submarine canyons and seamonunt has been shown to play an important role in enhancing biological production (Gili *et al.,* 2000). Such area has a strong influence on the biological processes, and it is linked to the sperm whale food chain (Clarke, 1996). Hence, the bathymetry features of these two (southern Bay of Bengal and Andaman) regions probably provides ideal feeding habitat for sperm whale.

Indo-Pacific humpback dolphin sightings, as reported elsewhere (Corkeron *et al.,* 1997; Jefferson and Leatherwood, 1997), prefer nearshore shallow depth in the present study. Most of the sightings were in shallow water with depth < 20m within range of 0.5km from the shore along the southwest coast of India (Fig. 4.23A and B). On one occasion, sighting was observed at shallow depth in offshore. Offshore occurrence of this species has been noted in Madagascar and Hong Kong water (Corkeron *et al.*, 1997; Jefferson, 2000). Jefferson and Karczmarski (2001) postulate that shallow water depth that remains in offshore is main factor in limiting their offshore occurrence. The pattern of distribution observed in the present study is similar to observation of this species in northeastern Arabian Sea (Sutaria and Jefferson, 2004).

The pattern of baleen whale distribution observed in this survey shows that baleen whale appears to prefer offshore deeper water area. Baleen whales preferentially occurred over continental slope and outer slope area in offshore waters, generally <150km. Distribution in coastal water over shelf and shelf break water was very sparse. Few sightings were made in coastal water, where deeper water is close to the shore. Distribution range of baleen whale was closer to the shore than that of sperm whale. Similarly, blue whale and Bryde's whales were also found in deeper slope water within 70km range from the shore.

False killer whale, short-finned pilot whale and Risso's dolphin were found on slope regions. The occurrence of short-finned pilot whale was <110km, closer than that of false killer whale and Risso's dolphin. All the four false killer whale sightings in this study were found over slope, generally between 228km and 274km (Table 4.12 and 4.13). Risso's dolphins were seen generally in oceanic slope water, but on one occasion, it was found in coastal shelf water. This may be explained by the fact that Risso's dolphin often feed on neritic and oceanic squid (González *et al.*, 1994; Kruse *et al.*, 1999). Short-finned pilot whales were also found in deeper slope oceanic water. One sighting was made in shelf break water, closer to the shore. Oceanic occurrence of these three species is related to their oceanic cephalopod feeding habits (Wurtz *et al.*, 1992; Carwardine, 1995; Davis *et al.*, 1998). The distributional range from the shore and depth occurrence exhibited similar pattern as seen in other parts of the ocean (Findlay *et al.*, 1992; Jefferson *et al.*, 1993; Baumgartner, 1997).

Oceanographic variables were secondary factors in differentiating cetacean distribution in the survey areas. The cetacean occurred in the water with relatively narrow range of SST and SSS, similar to those reported for northern Gulf of Mexico (Fritts *et al.*, 1983) and eastern tropical pacific (Au and Perryman, 1985; Perrin and Gilpatrick, 1994). All the cetacean species except humpback dolphin were encountered in water with mean surface temperature of 28°C and mean surface salinity of 33ppt. However, occurrence of *Balaenoptera* sp, *Stenella* sp and humpback dolphin showed preference for narrow range of salinity, which may be attributed to their depth of occurrence. Sperm whale, spinner dolphin, bottlenose dolphin and common dolphin were recorded in water with relatively wide variation in salinity. This may be due to their distribution on both shelf and slope regions. Humpback dolphin sighted area was characterised by low surface temperature and surface salinity, which agree with observation off Bangladesh (Smith *et al.*, 2008).

Surface temperature and salinity of all the species observed in this survey was within range reported elsewhere in tropical water. Nevertheless, the average SST and salinity of animal sighted area are greater than that for Gulf of Mexico and Eastern tropical Pacific (Au and Perryman, 1985; Baumgartner, 2000). A weak influence of SST in differentiating the species distribution may have resulted from the fact that the SST of the study area, mainly offshore area subject to minimum seasonal variation. Davis *et al.* (1998) hypothesized that being large, warm-blooded mammals, cetacean distribution in Gulf of Mexico is not limited by hydrographic features but probably determined by the availability of prey, which may be influenced secondarily by oceanographic features. The oceanographic variables varied with the depth and therefore, the influence of oceanographic variables on distribution of cetacean may be consequence of their distribution with depth. Hence, these two oceanographic variables might probably be secondary environmental factors to distinguish the cetacean habitat, in particular, for oceanic species. However, the limited sample size represents that the habitat characteristics examined in this study are not absolute and need to be further studied with more sample frequency.

SUMMARY

- India has an Exclusive Economic Zone of 2.02 million km^2, which supports 25 species of cetacean and one species of sirenian. Of the 25 species of cetaceans six species are mysticeti and the rest are Odontoceti, which includes three families of dolphins, porpoise and toothed whale.

- Distribution of marine mammal in the Indian Sea is poorly understood. The coastal waters of northeast Arabian Sea and oceanic water of eastern Arabian Sea of India have been subjected to a few investigations on occurrence and distribution of cetaceans. Nevertheless, there have been no systematic studies to map distribution of cetacean in Indian Seas. Hence, status of diversity of Indian cetacean remains ambiguous and there is uncertainty as to exact number of cetacean species occurring in Indian water. Lack of information on the distribution is disturbing, as Indian coast is located within the Indian Ocean Sanctuary.

- The purpose of this study was to examine the distribution of cetacean species, using the visual sighting survey in the Indian seas and the contiguous sea. This thesis provides information on species diversity and distribution of cetacean in the Indian and the contiguous seas. The relation between cetacean distribution and environmental features is also discussed.

- Opportunistic visual survey method (passing mood) was conducted following standard method to assess distribution and relative abundance. Surveys were conducted from 2003 to 2007 for the continuous period in different Zones. The survey was designed to cover three regions of zone of Indian EEZ such as of west coast of India (eastern Arabian Sea), east coast of India (Bay of Bengal) and Andaman water. Apart from these three regions, Sri Lankan water, the contiguous sea of India was also covered.

- A total of 35 cruises were conducted in the six geographical regions. The number of observation days was 657 of 5254 observation hours and cetaceans were sighted on 299 days.

Species diversity

- Species diversity of Indian cetacean community appears similar to other cetacean communities in northern Indian Ocean. A total of 473 cetacean encounters of 5865 individual cetaceans, representing 13 species of confirmed identities belonging to three families from two suborders were recorded. Eleven species were found in Indian waters, which is only 50% of the species reported earlier for the Indian waters.

- Of 13 identified species, three were from Mysticeti group and 10 were from Odontoceti, which includes two families. The four whale species include 3 species of baleen whales from Balaenopteridae family (Mysticeti) and one species of toothed whale from Physeteridae family (Odontoceti). All the other 9 species belonged to 7 genera from the family Delphinidae (dolphins), which consisted of 6 smaller delphinids and 3 larger delphinids.

- Delphinids were sighted more frequently than *Balaenoptera* sp. The bottlenose dolphin, *Tursiops aduncus* was the most abundant species in terms of number of sightings, whereas the spinner dolphin, *Stenella longirostris* (spinner dolphin) was the most abundant in terms of number of individuals. *Delphinus capensis* (common dolphin) and *Sousa chinensis* (Indopacific humpbacked dolphin) were also found abundant. *Physeter macrocephalus* (sperm whale) was the most frequently sighted species among larger whales.

- False killer whale, short-finned pilot whale, Risso's dolphin and striped dolphin were less frequently observed in the study area. Pygmy sperm whale, dwarf sperm whale, Cuvier's beaked whale, killer whale, melon-headed whale, rough-toothed dolphin were not seen in the present survey. However, over past 200years, many of these species have been reported rarely from the study area. Lack of stranding records in the past and sightings in the present study could be indicative of their rarity in the study area especially in Indian water.

- Irrawady dolphin, finless porpoise, Ganges river dolphin and sea cow (*Dugong dugon*) were also not sighted due to their distributional range, which is beyond operation limit of FORV *Sagar Sampada*. However, frequent bycatch and stranding reports substantiate their factual distribution in Indian water.

Geographical distribution

- Cetaceans are found to have a very wide geographical distribution in the Indian EEZ and the contiguous seas. Species richness are greater in the southeastern Arabian Sea and southern Sri-Lankan waters whereas and relatively sparse in other surveyed area, in particular, in the northern parts of Indian Sea.

- Sri Lanka Sea was the richest diverse area with contribution of 87 sightings of seven species, accounting for 687 individuals with the sighting frequency of 0.21/hr. Species composition in the Sri Lankan water was of *Balaenoptera* sp. Delphinids was found less in the present study due to fact that the present survey was restricted to slope area of the Sri Lanka water and the coastal area and western part of Sri Lanka were not covered.

- Among entire survey area, the southeastern Arabian Sea was the second most diverse area and first among the Indian Seas with sighting frequency of 0.10/hr. There were ten species recorded with dominant occurrence of *Stenella longirostris, Tursiops aduncus, Delphinus capensis* and *Sousa chinensis* in southeastern Arabian Sea. The greater diversity of cetacean in this regions may be attributed to the fact that the southern Arabian Sea water are one of the most biologically productive ocean regions and dense prey availability through out all the seasons.

- The southern Bay of Bengal is the third most diverse area, representing two species of baleen whales, one species of sperm whale and five species of delphinids were encountered on continental slope and shelf water. The sighting frequency was 0.08/hr. The southern Bay of Bengal was dominated by *Stenella longirostris, Tursiops aduncus* and *Balaenoptera* sp. *Megaptera* *novaeanglia* from Balaenopteridae family and *Physeter macrocephalus* from Physeteridae family were the larger whale observed in this region.

- The northeastern Arabian Sea and northern Bay of Bengal were the less surveyed areas. Hence, cetacean diversity and number of sightings observed in these areas were very sparse. There were 4 species in the northeastern Arabian Sea and northern Bay of Bengal with sighting frequency of 0.05/hr and 0.06/hr respectively. Species composition in northeastern Arabian Sea was made up of *Grampus griseus, S. longirostris, T. aduncus* and *S. chinensis.* In northern Bay of Bengal, *Pseudorca crassidens, S. longirostris, T. aduncus* and *Delphinus capensis.*

- The present study represents probably underestimated species composition and abundance for northeastern Arabian region due to lack of survey in broader shelf area between 20°-23°'N latitude, further northeast of Arabian Sea. Low sea surface salinity and less productivity might contribute to sparse diversity in north of 20°N- 87°E in the northern Bay of Bengal.

- The Andaman Sea was also one of the less surveyed areas representing five species of 46 sightings and 514 individuals with sighting frequency of 0.08/hr. Observed species composition in this area was dominated sighting by *Stenella* sp from delphinids and *Physeter macrocephalus* from physetridae. *Globicephala machrorhyncus, D. capensis* and *T. aduncus* were sighted less frequently.

Seasonal Distribution

- Between the different surveyed regions, there was not much seasonal variability in species composition and distribution.

- In southeastern Arabian Sea, species composition was diverse in winter and inter monsoon seasons, accounting for 8 species in each season and comprising of 82 (42.3%) and 53 (27.3%) sightings respectively.

- Cetacean diversity was very scanty in all the seasons in northeastern Arabian Sea. Sightings were high in winter (37.8%) and fall monsoons (28.9%).

- In southern Bay of Bengal, maximum diversity was found in summer and winter monsoons. A total of six species of 22 encounters (33.3%) and 471 individuals (47.3%) were recorded in winter monsoon whereas seven species of 18 sightings (27.8%) of 247 individuals (24.8%) were in summer monsoon.

- Among the six surveyed regions, northern Bay of Bengal and Andaman Sea showed poor diversity during the entire seasons. In northern Bay of Bengal diversity was high in both summer and winter monsoon which accounted for five species consisted of 346 (46.5%) individuals.

- In Andaman Sea, maximum of 4 species of 27sightings (58.7%), accounting for 285 individuals (55.4%) were recorded in winter monsoon. This is followed by summer monsoon with three species of 12 sightings (26.1%) consisted of 121 (23.5%).

- The occurrence of spinner and bottlenose dolphins was common in all the seasons. The spinner dolphin was more predominant in winter monsoon season, followed by inter monsoon season. The bottlenose dolphin and common dolphin was most commonly found in winter season.

- The larger whale encounters were also considerably high in winter and inter monsoons. The sperm whale was found more in winter monsoon.

Distribution in relation with environmental parameters

- The relationship between the environmental parameters and distribution of *Physeter macrocephalus, Tursiops aduncus, Stenella longirostris, Delphinus capensis* and *Sousa chinensis* cetaceans were examined to characterize their habitat.

- Among the four variables considered for the present study, the physiographic variables (depth and distance from the shore) were primary variables in differentiating the cetacean habitat. The distribution of cetaceans in the study area was mostly partitioned by these two physiographic variables, with each of the five species distinguishable by these two features alone.

- Spinner dolphin was found on continental slope in deeper oceanic water but occasionally found over shelf and shelf break in coastal and offshore area. The occurrence of this species in shelf and slope area may be related to their predation on diverse range of fish in different water depth.

- Bottlenose dolphin showed preference for shelf and shelf break and also occurred on continental slope in offshore area, predominantly within 100km from the nearest coast, which is closer than the distribution range of spinner dolphins. This suggests possible habitat partitioning of these two species.

- Common dolphin distribution with respect to depth and occurrence range from the shore was intermediate between bottlenose dolphin and spinner dolphin distribution. Most of the sightings were seen over slope area in offshore water and few occurrences in coastal shelf water.

- Sperm whale distribution was restricted to deeper oceanic water over slope and rarely over shelf break area, which is close to shore. The topographic feature of the southern Bay of Bengal and Andaman Sea regions, from where most sperm whales were observed, is characterized by irregular bathymetry feature with presence of the steep continental slope, seamounts and submarine canyon.

- Indo-Pacific humpback dolphin sightings prefer nearshore shallow depth water <20m within range of 0.5km from the shore along the southwest coast of India.

- The pattern of baleen whale distribution observed in this survey shows that baleen whale appears to prefer offshore deeper area. Baleen whales preferentially occurred over continental slope and outer slope area in offshore waters, generally <150km. Distribution in coastal water over shelf and shelf break water was very sparse. Distribution range of baleen whale was closer to the shore than that of sperm whale.

- False killer whale, short-finned pilot whale and Risso's dolphin were found on slope region. Occurrence of short finned killer whale was <110km, closer than that of false killer whale and Risso's dolphin.

- Oceanographic variables were secondary factors in differentiating cetacean distribution in the survey areas. The cetacean occurred in the water with relatively narrow range of SST and SSS. Surface temperature and salinity of all the species observed in this survey was within range reported elsewhere in tropical water.

- All the cetacean species except humpback dolphin were encountered in water with mean surface temperature of 28°C and mean surface salinity of 33ppt. However, oceanic species differ in their preference for surface salinity. Occurrence of *Balaenoptera* sp, *Stenella* sp and humpback dolphin was restricted to water with narrow range of salinity. Sperm whale, spinner dolphin, bottlenose dolphin and common dolphin were recorded in water with relatively wide variation in salinity. Humpback dolphin sighted area was characterized by low surface temperature and surface salinity

Conclusion

- The distribution pattern other species observed in the present study agrees with historical records based on incidental capture. The data generated on species occurrence and distribution will be useful to estimate the abundance of marine mammals in the Indian Seas.

- The oceanic surveys onboard research vessels need to be supplemented with coastal surveys to assess the distribution of missing coastal species in the present study. Seasonal distribution of different marine mammal species in different geographical regions also needs to be studied extensively.

- The result of the present study indicates the need for further effort in many areas such as northern part of Indian coast and Andaman Sea. It is likely that species, which occur in other adjacent seas, would occur in India Seas too. The limited sample size for examining the habitat characteristics in the present study are not absolute and need to be further studied for missing species in the present study.

REFERENCES

Acevedo-Gutierrez, A. 2002. Interactions between marine predators: dolphin food intake is related to number of sharks. *Marine Ecology Progress Series*, **240**: 267-271.

Alagarswami, K., P. Bensam, M.E. Rajapandian and A. Bastian Fernando. 1973. Mass stranding of Pilot Whales in the Gulf of Mannar. *Indian Journal of Fisheries*, **20**: 269-279.

Allaby, M. 1998. *A Dictionary of Ecology*. Second Edition. Oxford University Press: 440pp.

Alling, A. 1986. Records of odontocetes in the northern Indian Ocean and off Sri Lanka. *Journal of the Bombay natural History Society*, **83**(2): 376-394.

Alling, A., E.M. Dorsey and J.C.D. Gordon. 1991. Blue whales *Balaenoptera musculus* off the northeast coast of Sri Lanka: Distribution, feeding and individual identification. *UNEP Marine Mammal Technical Repoer*, **3**:247-258.

Amano, M. 2002. Finless porpoise *Neophocaena phocaenoids* (G.Cuvier, 1829). In "*Encyclopedia of Marine Mammals*" (Perrin, W.F., B. Wursig and J.G.M.Thewissen, eds) Academic press San Dieago CA. pp 432-434.

Amir, O.A., P. Berggren and N.S. Jiddawi. 2002. The incidental catch of dolphins in gillnets fisheries in Zanzibar, Tanzania. *Western Indian Ocean Journal of Marine Science*, **1**: 155-162.

Amir, O.A., N.S. Jiddawi and P. Berggren. 2005. The occurrence and distribution of dolphins in Zanzibar, Tanzania with comments on the differences between two species of *Tursiops*. *Western Indian Ocean Journal of Marine Science*, **4**: 85-93.

Anoop, A., K.S. Yousuf, P.L Kumaran, H. Nayak, B. Anoop, V.V. Afsal, M. Rajagopalan, E. Vivekanandan, P.K. Krishnakumar and P. Jayasankar. 2008. Stomach content of cetaceans incidentally caught along Mangalore and Chennai coasts of India. *Estuarine Coastal & Shelf Science*, **76**: 909–913.

Aragoness, L.V., T.A. Jefferson and H. Marsh. 1997. Marine mammal survey techniques applicable in developing countries. *Asian Marine Biology*, **14**:15-39.

Arnold, P., H. Marsh, and G. Heinsohn. 1987. The occurrence of two forms of minke whales in east Australian waters with a description of external characters and skeleton of the diminutive or dwarf form. *Scientific Reports of the Whales Research Institute* Tokyo **38**:1-46.

Arumugam, G., T.S. Balasubramaniam and M. Chellappa. 1995. A note on the foetus of the Hump-back Dolphin from Tuticorin coast, Gulf of Mannar. *Marine Fisheries Information Service Technical & Extension Series,* **138**: 14-15.

Au, D.W.K. and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. *Fishery Bulletin,* US. **83**: 623-643.

Au, D.W.K. and R.L. Pitman. 1986. Seabird interactions with dolphins and tuna in the eastern tropical Pacific. *Condor,* **88**:304-317.

Badurdeen, M., P. Nammalwar and K. Dorairaj. 2004 Status of Sea-Cow *Dugong dugon* (Muller) along the southeast coast of India. *Journal of the Bombay natural History Society,* **101**(3): 381-387.

Baird, R.W., A.D. Ligon, S.K. Hooker, and A.M. Gorgone. 2001. Subsurface and nighttime behaviour of pan-tropical spotted dolphins in Hawaii. *Canadian Journal of Zoology,* **79**: 988–996.

Baldwin, R., K. Van Waerebeek and M. Gallagher. 1998. A review of small cetaceans from waters off the Arabian Peninsula. Paper SC/50/SM6 presented to the IWC Scientific Committee.

Ballance, L.T., R.L. Pitmans, B. Reilly and M.P. Force. 1996. Report of a cetacean, seabird, marine turtle and flying fish survey of the western tropical Indian Ocean aboard the research vessel *Malcolm Baldrige,* March *2* 1-July 26, 1995. U.S. Department of Commerce, NOAA *TM-NMFS-SWFSC*-224. 132 pp.

Ballance, L.T. and R.L. Pitman. 1998. Cetaceans of the western tropical Indian Ocean: distribution, relative abundance, and comparisons with cetacean communities of two other tropical ecosystems. *Marine Mammal Science,* **14**:429-459.

Ballance, L.T. and R.L Pitman. 1999. Foraging ecology of tropical seabirds. In *Proceeding of International symposium on Ornithology* (Adams, N.J. and R.H. Slotow, eds). Congress, Durban: 2057-2071. Johannesburg: Bird Life South Africa.

Ballance, L.T., R.C. Anderson, R.L. Pitman, K. Stafford, A. Shaan, Z. Waheed and R.L. Brownell Jr. 2001. Cetacean sightings around the Republic of the Maldives, April 1998. *Journal of Cetacean Research and Management,* **3**: 213-218.

Bannister, J.L. and S.L. Hedley. 2001. Southern hemisphere group IV humpback whales: their status from recent aerial survey. *Memoirs of the Queensland Museum,* **47**(2): 587-598.

Barco S.G., W.M. Swingle, W.A. McLellan, R.N. Harris and D.A. Pabst. 1999. Local abundance and distribution of bottlenose dolphins (*Tursiops* *truncatus*) in the nearshore waters of Virginia Beach, Virginia. *Marine Mammal Science,* **15** (2): 394 – 408.

Barlow, J. 1995. The abundance of cetaceans in California waters. Part 1: Ship surveys in summer and fall 1991. *Fishery Bulletin US,* **93**:1–14.

Barros, N.B. and D.K. Odell. Food habits of bottlenose dolphins in the southeastern united states In "*The bottlenose dolphin*" (Leatherwood S. and R.R Reeves eds) Academic Press, San Diego, CA, P 309-328.

Baumgartner, M.F. 1997. The distribution of Risso's dolphins (*Grampus griseus*) with respect to the physiography of the northern Gulf of Mexico. *Marine Mammal Science,* **13**:614–638.

Baumgartner, M.F., K.D. Mullin, L.N. May and T.D. Leming. 2001. Cetacean habitats in the northern Gulf of Mexico. *Fishery Bulletin US,* **99**: 219–239.

Baumgartner M.F., T.V.N. Cole, P.J. Clapham and B. Mate .2003. North Atlantic right whale habitat in the lower Bay of Fundy and on the SW Scotian Shelf during 1999–2001. *Marine Ecological Progress Series,* **264**: 137–154.

Beadon, J.J. 1991. A note on cetaceans seen and live-captured in the Gulf of Aquaba and Gulf of Suez. United Nations Environment Program, *Marine Mammal Technical Report,* **3**:111–114.

Bearzi, M. 2005. Habitat partitioning by three species of Dolphins in Santa Monica Bay, *California Bulletin, Southern California Academy of Sciences,* **104**(3):113-124.

Bellison, N.B. 1966. Fauna Marina Antarctica. Republica Argentina Secretaria de Marina, Servicio de hidrografia Naval, Publicio H.907, Buenos Aires. 91 pp. (*Cross reference).*

Benson S.R., C. Donald, M. Baldo, C.P. Francisco and T.H. James. 2002 Changes in the cetacean assemblage of a coastal upwelling ecosystem during El Niño 1997-98 and La Niña 1999. *Progress in oceanography,* **54**(1-4):279-291

Best, P.B. 1985. External characters of southern minke whales and the existence of a diminutive form. *Scientific Reports of the Whales Research Institute* Tokyo, **36**:1-33.

Berggren, P., O.A. Amir, A. Guissamulo, N.S. Jiddawi, Z. Ngazy, E. Stensland, A. Sarnblad and V.G. Cockroft. 2007. Sustainable Dolphin Tourism in East Africa. MASMA Technical Report. WIOMSA Book Series No 7, ix+72pp.

Best, P.B., K. Sekiguchi, B.P. Rakotonirina and A. Rossouw. 1996. The distribution and abundance of humpback whales off southern Madagascar, August-September 1994. *Report International Whaling Commission,* **46**: 323-331.

Biggs, D.C., R.R. Leben and J.G. Ortega-Ortiz. 2000. Ship and satellite studies of mesoscale circulation and sperm whale habitats in the northeast Gulf of Mexico during Gulf Cet II. *Gulf of Mexico Science* **18**:15–22.

Blanco C., J. Aznar and J.A. Raga.1995. Cephalopods in the diet of the striped dolphin *Stenella coeruleoalba* from the western Mediterranean during an epizootic in 1990. *Journal of Zoology, London,* **237**: 151-158.

Blaylock, R.A., J.W. Hain, L.J. Hansen, D.L. Palka, and G.T. Waring. 1995. U.S Atlantic and Gulf of Mexico marine mammal stock assessments. U.S. Dep. Commer., *NOAA Tech. Memo.NMFS-SEFSC*-363, 211.

Borsa, P. 1997. Seasonal trends in the occurrence of marine mammals in the Golfe du Morbihan, Kerguelen Islands. *Marine Mammal Science,* **13**(2):314-316.

Bowen, W.D. 1997. Role of marine mammals in aquatic ecosystems. *Marine Ecology Progress Series,* **158**:267–274.

Bourreau, S. and A. Gannier. 2003. Distribution of Delphinus delphis in the Mediterranean Sea: competition with striped dolphin or fisheries? Annual Meeting of the European Cetacean Society, Tenerife, Spain.

Braeger S. and K. Schneider. 1998. Near-shore distribution and abundance of dolphins along the West Coast of the South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research,* **32** (1):105-112

Branch, T.A., K.M. Stafford, D.M. Palacios, C. Allison, J.L. Bannister, C.L.K Burton, E. Cabrera, C. Carlson, B. Galletti Vernazzani, P.C. Gill, R. Hucke-Gaete, K.C.S. Jenner, M.N.M Jenner, K. Matsuoka, Y.A. Mikhalev, T. Miyashita, M.G. Morrice, S. Nishiwaki, V.J. Sturrock, D. Tormosov, R.C. Anderson, A.N Baker, P.B. Best, P. Borsa, R.L. Brownell Jr, S. Childerhouse, K.P .Findlay, T. Gerrodette, A.D. Ilangakoon,, M. Joergensen, B. Kahn, D.K. Ljunglad, B. Maughn, R.D. McCauley, S. McKay, T.F. Norris, Rankin, S., Samaran, F., D. Thiele, K. Van Waerebeek, and Warneke, R.M. 2007. Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. *Mammal Review,* **37**(2): 116-175.

Brown C.W. and H.E. Winn. 1989. Relationship between the distribution pattern of right whales, *Eubalaena glacialis*, and satellite-derived sea surface thermal structure in the Great South Channel. *Continental Shelf Research,* **9**:247-260.

Burton, R.W. 1940. A visit to the Laccadive Islands. *Journal of the Bombay Natural History Society,* **41**(4): 489-513.

Burton, C.L.K. 1991. Sighting analysis and photo identification of humpback whales off Western Australia, 1989. *Memoirs Queensland Museaum,* **30**(2): 259-270

Burton, C.L.K. 2001. Historical and recent distribution of humpback whales in Shark Bay, Western Australia. *Memoirs of the Queensland Museum,* **47**(2): 599-611.

Burton, C.L.K., J. Colman, C. Serginson and C. Green. 2001. Dedicated marine fauna monitoring program during the Flinders Deepwater 2D Seismic survey in the Great Australian Bight: December 2000 – May 2001. Unpublished report to Woodside Energy Ltd., November, 2001. 110pp.

Burtenshawa, J.C., E.M. Olesona, J.A. Hildebranda, M. McDonalda, R. K. Andrewb, B. M. Howeb and J.A. Mercerb.2004.Acoustic and satellite remote sensing of blue whale seasonality and habitat in the Northeast Pacific *Deep-Sea Research* II, **51**: 967–986.

Caldwell, D.K and M.C. Caldwell. 1989. Pygmy sperm whale Kogia breuiceps (de Blainville, 1838): Dwarf sperm whale Kogia simus Owen, 1866. Pages 235- 260 in S. Ridgway H. and R. Harrison, eds. Handbook of marine mammals. Vol. 4. River dolphins and the larger toothed whales. Academic Press, London.

Calambokidis, J. and J. Barlow. 2004. Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. *Marine Mammal Science.* **20**:63–85.

Canadas, A., R. Sagarminaga and S.G. Tiscar. 2002. Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. *Deep-Sea Research I,* **49**:2053-2073.

Cartes, J.E. 1998. Feeding strategies and partition of food resources in deep-water decapod crustaceans in relation to depth (between 400–2300 m). *Journal of the Marine Biological Association UK,* **78**: 509–524.

Carwardine, M. 1995. Whales, Dolphins and Porpoises. Dorling Kindersley, London, UK, 257 pp.

Chandrasekar, M., K. Chittibabu, P. Achayya, R.V.D. Prabhakar and K. Vijayakumaran. 1993. On the landing of a young Bottlenose Dolphin at Visakhapatnam. *Marine Fisheries Information Service Technical & Extension Series,* **122**: 24-25.

Chandrakumar, N.P. 1998. Mass entanglement of dolphins in a shore seine near Balaramapuram, Srikakulam district, Andhra Pradesh. *Marine Fisheries Information Service Technical & Extension Series,* **155**: 19.

Chantrapornsyl, S., S. Kinze, S. Leatherwood and W.P. Prematunga. 1991. Notes on the *Kogia sp* in the Northern Indian Ocean. *UNEP Marine Mammal Technical Report,* **3**: 79-88.

Chase, J.M. and M.A. Leibold. 2002. Spatial scale dictates the productivity biodiversity relationship. *Nature,* **416:** 427-430.

Chittleborough, R.G. 1953. Aerial observations on the humpback whale, with notes on other species. *Australian Journal of marine and Freshwater Research,* 4:219-226.

Chittleborough, R.G. 1959. Australian marking of humpback whales. *Norsk hvalfangst tidende,* **2**: 47-55. (*Cross reference*).

Clarke, R. 1982. An index of sighting conditions for surveys of whales and dolphins. *Report of the International Whaling Commission,* **32**: 559-61.

Clarke, M.R Cephalopods as prey, III: Cetaceans. *Biological Science,* **351**:1053-1065.

Clark, C.W. and R.H. Lamberson. 1982. An Economic History and Analysis of Pelagic Whaling. *Marine Policy,* **6**: 103-120.

Clarke K.R. and R.N. Gorley. 2001. PRIMER v5: User manual. PRIMER- E Ltd, Plymouth, United Kingdom .

Clarke K.R. and R.M. Warwick .1994. Similarity-based testing for community pattern: The two-way layout with no replication. *Marine Biology,* **118**(1): 167-176.

Clarke K.R. and R.M .Warwick. 1998. A taxonomic distinctness index and its statistical properties. *Journal of Applied Ecology,* **35:** 523-531.

Clarke K.R. and R.M Warwick. 1999. The taxonomic distinctness measure of biodiversity: weighting of step lengths between hierarchical levels. *Marine Ecological Progress Series,* **184**: 21-29.

CMFRI, 2006. Marine Fisheries Census 2005, Part 1. Kochi: Central Marine Fisheries Research Institute, pp. 104.

CMFRI, 2007. Studies on Marine Mammals of Indian EEZ and the contiguous Seas. Final Report submitted to Ministry of Earth Sciences, New Delhi. 1-212.

Cockcroft, V.G. and G.J.B. Ross. 1990. *Food and feeding of the Indian Ocean Bottlenose dolphin off Southern natal, South Africa.* The Bottlenose dolphin. Academic press. Chapter 15.

Cole, F.R., D.M. Reeder and D.E. Wilson. 1994. A synopsis of distribution patterns and the conservation of mammal species. *Journal of Mammalogy,* **75:** 266-277.

Compton, R., A. Banks, L. Goodwin and S.K. Hooker. 2007. Pilot cetacean survey of the sub- Arctic North Atlantic utilizing a cruise- ship platform *Journal of the Marine Biological Association UK,* **87**: 321-325.

Corkeron, P.J., N.M. Morisette, L. Porter and H. Marsh. 1997. Distribution and status of hump-backed dolphins in Australian waters. *Asian Marine Biology,* **14**:49-59.

Cornelis, K., A. Broker and A. Ilankakoon. 2008. Occurrence and conservation needs of cetaceans in and around the Bar Reef Marine Sanctuary, Sri Lanka. *Oryx,* **42**(2): 286-291.

Croll, D.A. and B.R. Tershy. 1998. Estimation of the energy and prey requirements of penguins and fur seals breeding on the South Shetland Islands and potential commercial fisheries interactions. *Polar Biology,* **19**:365-374.

Croll D.A., B. Marinovic, S. Benson, F.B. Chavez, N. Black, R. Ternullo and B.R. Tershy. 2005. From wind to whales: trophic links in a coastal upwelling system. *Marine Ecology Progress Series,* **289**:117-130.

Croll, D. A., B. R. Tershy, R. P. Hewitt, D. A. Demer, P. C. Fiedler, S. E. Smith, W. Armstrong, J. M. Popp, T. Kiekhefer, V. R. Lopez, J. Urban and D. Gendron. 1998. An integrated approach to the foraging ecology of marine birds and mammals. *Deep- Sea Research II,* **45**:1353-1371.

Das, H.S. and S.C. Dey. 1999 Observations on the Dugong, *Dugong dugon* (Muller) in the Andaman and Nicobar Islands, India. *Journal of the Bombay Natural History Society,* **96**(2): 195-198.

Davis, R.W and G.S. Fargion, eds. 1996. Distribution and abundance of cetaceans in the north-central and western Gulf of Mexico: Final report. Vol. 11. Technical report. OCS Study MMS 96-0027. Texas Institute of Oceanography and the National Marine Fisheries Service. US. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA.

Davis, R. W., G.S. Fargion, L.N. May, T.D. Leming, M.F. Baumgartner, W.E. Evans, L.J. Hansen and K. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. *Marine Mammal Science,* **14**:490–507.

Davis, R.W., J.G. Ortega-Ortiz, C.A. Ribic, W.E. Evans, D.C Biggs, P.H. Ressler, R.B.Cady, R.R. Leben, K.D.Mullin and B. Wursig. 2002. Cetacean habitat in the northern oceanic Gulf of Mexico. *Deep-Sea Research I*, **49**: 121-142.

Dhandapani, P. 1992. Status of Irrawady River Dolphin *Orcaella brevirostris* in Chilka Lake. *Journal of the Marine Biological Association of India*, **34**: 90-93.

Dawson, S., P. Wade, E. Slooten and J. Barlow. 2008. Design and field methods for sighting surveys of cetacean in coastal and riverine habitats. *Mammal Review*, **38** (1):19-49.

Dayaratne, P. and L. Joseph. 1993. A study on dolphin catches in Sri Lanka. Bay of Bengal Programme, Madras, India.

De Boer, M.N. 2000. Observations on Occurrence and Distribution of Cetaceans in the Southern Ocean Sanctuary and Southern part of the Indian Ocean Sanctuary. Paper SC/52/O9 presented to the IWC Scientific Committee.

De Boer, M.N. 2001. A note on cetacean observations in the Indian Ocean Sanctuary and the South China Sea, Mauritius to the Philippines, April 1999. *Journal* of *Cetacean Research Management*, **2**(3):197-200

De Lestang, J.N. 1993. Status of marine mammals in the eastern African region. Report to UNEP; *Regional Seas Reports and studies series.*

De Silva, P.H.D.H. 1987. Cetaceans (whales, dolphins and porpoises) recorded off Sri Lanka, India, from the Arabian Sea and Gulf, Gulf of Aden and from the Red Sea. *Journal of the Bombay Natural History Society*, **84**(3): 505-525.

Devaraj, M. and P. S. Bennett. 1974. Occurrence of *Xenobalanus globicipitis* (Steenstrup) on the Finless Black Porpoise, *Neomeris phocoenoides* in Indian Sea. *Indian Journal of Fisheries*, **21**: 579-581.

Dolar M.L.L, W.F. Perrin, A.A.S.P. Yaptinchay, S.A.B.H, Jaaman, M.D Santos, M.N. S.M.S.B. Alava. 1997. Preliminary investigation of marine mammal distribution, abundance, and interactions with humans in the southern Sulu Sea. *Asian Marine Biology*, **14**: 61- 81.

Durham, B. 1994. The distribution and abundance of the humpback dolphin (*Sousa chinensis*) along the Natal coast, South Africa. M.S. thesis, University of Natal, Pietermaritzburg, South Africa, 83 pp.

Dwivedi, S.N. 1995. Long- Term Variability in the Food Chains Biomass Yield, and Oceanography of the Bay of Bengal Ecosystem pp 43-52. In "*Larger Ocean Ecosystem: Stress, mitigation and sustainability*"

(Kenneth Sherman, Lewis Alexander and Gold, eds)AAAS Press, Washington.

Evans, P.G.H. 1987. The natural history of whales and dolphins. Facts on File, London.

Evans, W.E. 1994. Common Dolphin, White-bellied Porpoise – *Delphinus delphis* Linnaeus, 1758. Pp. 191-225. In *Handbook of Marine Mammals.* Vol. 5. *The First Book of Dolphins.* (Ridgway, S. H. and R. Harrison, eds)Academic Press, London and San Diego. 416pp.

Evans, P.G.H. 2008. Habitat pressure pp 545-548.In "*Encyclopedia of Marine mammal*" (Perrin, W F., B. Würsig and J. G. M. Thewissen, eds) Academic Press.

Evans, P.G.H and P.S. Hammond. 2004. Monitoring cetaceans in European waters. *Mammal Review,* **34**:131-156.

Eyre, E.J. 1995. Observation of cetaceans in the Indian Ocean whale Sanctuary, May-July 1993. *Report of the International Whaling Commission,* **45**:*419*-26.

Eyre, E.J. 1997. Preliminary composite cetacean survey in the Indian Ocean Sanctuary, April 1995. Paper SC/49/O28 submitted to the Scientific Committee of the International Whaling Commission.

Eyre, E.J. 2000. Observations of cetaceans in the Indian Ocean Sanctuary, Mauritius to Singapore, April 2000. Paper SC/52/O16 submitted to the Scientific Committee of the International Whaling Commission.

Ferguson, M. C., J. Barlow, S. B. Reilly and T. Gerrodette. 2006. Predicting Cuvier's (*Ziphius cavirostris*) and Mesoplodon beaked whale population density from habitat characteristics in the eastern tropical Pacific Ocean. *Journal of Cetacean Research Management*, 7(3):287–299.

Fiedler, P.C. and S. B. Reilly. 1994. Interannual variability of dolphin habitats in the eastern tropical Pacific. 11: Effects on abundances estimated from tuna vessel sightings, 1975-1990. *Fishery Bulletin*, U.S. **92**:451-463.

Fiedler, P., S. Reilly, R. Hewitt, D. Demer, V. Philbrick, S. Smith, W. Armstrong, D. Croll, B.R. Tershy and B. Mate. 1998. Blue whale habitat and prey in the Channel Islands. *Deep Sea Research II*, **45**:1781-1801.

Findlay, K.P. and P.B. Best. 1996. Assessment of heterogeneity in sighting probabilities of humpback whales within viewing range of Cape Vidal, South Africa. *Marine Mammal Science*, **12**(3): 335-353.

Findlay, K.P. P.B. Best, G.J.B. Ross and V.G. Cockcroft. 1992: The distribution of small odontocete cetaceans off the coasts of South Africa and Namibia. *South African Journal of Marine Science,* **12**: 237–270.

Fitch, J.E. and R.L. Brownell. 1968. Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits. *Journal of the Fisheries Research Board of Canada,* **25**:2561-2574.

Forcada, J., A. Aguilar, P.G.H. Evans and W.F. Perrin. 1990. Distribution of common and striped dolphins in the temperate waters of the eastern North Atlantic. *European Research on Cetaceans,* **4**:64-68.

Forcada, J. and P. Hammond. 1998. Geographical variation in density and numbers of striped and common dolphins of the western Mediterranean. *Journal of Sea Research,* **39** (3-4): 318-325.

Forcada, J., A. Aguilar, P. Hammond, X. Pastor and R. Aguilar. 1996. Distribution and abundance of fin whales (*Balaenoptera physalus*) in the western Mediterranean sea during the summer. *Journal of Zoology London,* **238**: 23–34.

Forney K.A. and J. Barlow. 1998. Seasonal patterns in the abundance and distribution of California cetaceans, 1991–1992. *Marine Mammal Science,* **14**:460–489.

Forney, K.A. 2000. Environmental models of cetacean abundance: reducing uncertainty in population trends. *Conservation Biology,* **14**:1271-1286.

Frazier, J.G. and T. Mundkur. 1990. Dugong *Dugong dugon* Muller in the Gulf of Kutch, Gujarat. *Journal of the Bombay Natural History Society,* **87**(3): 368-379.

Fritts, T.H., A.B. Irvinre, D. Jennings, L.A. Collum, W. Hoffman and M.A. McGehee. 1983. Turtles, birds, and mammals in the northern Gulf of Mexico and nearby Atlantic waters. Report FWS/OBS-82/65. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. 455 pp

Fulling, G.L., K.D. Mullin and C.W. Hubard. 2003. Abundance and distribution of cetaceans in outer continental shelf waters of the U.S. Gulf of Mexico. *Fishery Bulletin, U.S,* **101**:923–932.

Galindo, J.A., A. Serrano, L. Vazquez-Castán, C. Gonzalez-Gandara, M. Lopez-Ortega. 2009. Cetacean Diversity, Distribution, and Abundance in Northern Veracruz, Mexico. *Aquatic Mammals,* **35**(1): 12-18.

Gannier, A. 1999. Distribution of cetaceans in the Marquesas Islands (French Polynesia) as obtained from a dedicated survey. In Abstracts of the

Thirteenth Biennial Conference on the Biology of Marine Mammals, Maui, HI, December 1999.

Gannier, A. 2005. Summer distribution and relative abundance of delphinids in the Mediterranean Sea. Revue d'Ecologie (Terre et Vie), **60**: 223–238.

Gaston, J. 2000. Global patterns in biodiversity. *Nature*, **405**: 220-227.

Gedamke, J., N. Gales, J. Hildebrand and S. Wiggins. 2006. Seasonal occurrence of low frequency whale vocalizations in waters of East Antarctica, February 2005-February 2006. SC/58/017 presented to the IWC Scientific Committee, 2006. [available from the Office of the IWC].

Gerrodette, T., W. Perryman and J. Barlow. 2002. Calibrating group size estimates of dolphins in the eastern tropical Pacific Ocean. SWFSC Admin. Rep. No. LJ-02-08. 25pp. [Available from SWFSC, PO Box 271, La Jolla, CA]

Gerrodette, T. and P. R. Wade. 1991. Monitoring trends in dolphin abundance in the eastern tropical Pacific: Analyses of 1989 data. *Report of the International Whaling Commission,* **41**: 511-515.

Gili, J.M., F. Pages, J. Bouillon, A. Palanques, P. Puig, S. Heussner, A. Calafat, M. Canals and A. Monaco. 2000. A multidisciplinary approach to the understanding of hydromedusan populations inhabiting Mediterranean submarine canyons. *Deep Sea Research I*, **47**(8):1513–1533

Gill, P.C. 1997. A yacht-based cetacean research cruise to Antarctic waters south of Australia. In: M. Hindell and C. Kemper (eds). *Marine Mammal research in the Southern hemisphere,* Volume 1: Status, Ecology and medicine. Surray Beatty & Sons, Chipping Norton, 1997. Pp 30-39.

Goes, J.I., P.G. Thoppil, H.R. Gomes and J.T. Fasullo. 2005. Warmig of the Eurasian land mass is making the Arabian Sea more productive. *Science*, **308**: 545-547.

Gonzalez, A.F., A. Lopez, A. Guerra and A. Barreiro. 1994. Diets of marine mammals stranded on the northwestern Spanish Atlantic coast with special reference Cephalopoda. *Fisheries Research*, **21**: 179-191.

Gopalakrishna, V.V. and J.S. Sastry. 1985. Surface circulation over the shelf off the coast of India during the southwest monsoon. *Indian Journal Marine Science*, **14**: 62– 66.

Gordon, J.C.D. 1990. The World Wildlife Fund's Indian Ocean Sperm Whale Project: An example of cetacean research within the Indian Ocean Sanctuary. Pp 219-239. In: *Cetaceans and cetacean research in the*

Indian Ocean Sanctuary (Leatherwood S. and G.P. Donovan, eds). Nairobi, Kenya. United Nations Environment Programme, *Marine Mammal Technical Report Number* 3.

Gordon, J.C.D. and P. Tyack. 2002. Acoustic techniques for studying cetaceans. In *Marine Mammals: Biology and Conservation* (Evans, P.G.H. and J.A. Raga, eds), pp. 293–324. Kluwer Academic, London and New York.

Gowans, S. and H. Whitehead.1995. Distribution and habitat partitioning by small odontocetes in the Gully, a submarine canyon on the Scotian Shelf. *Canadian Journal of Zoology*, **73**(9): 1599-1608.

Gowans, S., H. Whitehead, J.K. Arch and S.K. Hooker. 2000. Population size and residency patterns of northern bottlenose whales (*Hyperoodon ampullatus*) using the Gully, Nova Scotia. *Journal of Cetacean Research Management*, **2**(3): 201-210.

Grace, R.V. 1994. Oceanic debris observations in the Indian Ocean Whale Sanctuary and eastern Mediterranean Sea. Paper *SC/46/O26* presented to the International Whaling Commission, May 1994. 18p.

Griffin, R.B. 1997. Relationships Between Odontocete Distributions and Zooplankton Community Structure Along the Southern Edge of Georges Bank. *Journal of Northwest Atlantic Fisheries Science*, **22**: 27-36.

Griffin, R.B. 1999. Sperm whale distributions and community ecology associated with a warm-core ring off Georges Bank. *Marine Mammal Science*, **15**:33–51.

Griffin, R.B. and N.J. Griffin. 2003. Distribution, Habitat Partitioning, and Abundance of Atlantic Spotted Dolphins, Bottlenose Dolphins, and Loggerhead Sea Turtles on the Eastern Gulf of Mexico Continental Shelf. *Gulf of Mexico Science*, **1**: 23–34.

Guissamulo, A.T. 2000. Ecological studies of bottlenose and humpback dolphins of Maputo Bay, southern Mozambique. Ph.D. dissertation, University of Natal, Pietermaritzburg, South Africa, 258 pp. (*Cross reference*)

Gulland, J.A. 1974. Distribution and abundance of whales in relation to basic productivity. In "*The whale problem*" (Schevill, W.E ed) Harvard University Press, Cambridge, MA, p 27–51.

Hafeezullah, M. 1984. Record of a foetus of the finless black porpoise from Goa coast. *Journal of the Bombay Natural History Society*, **81**(1):183-186.

Hain, J. H.W., M.A.M. Hyman, R.D. Kenney and H.E. Winn. 1985. The role of cetaceans in the shelf-edge region of the northeastern United States. *Marine Fisheries Review,* **47**:13–17.

Hale P.T., A.S. Barreto and G.J.B Ross. 2000. Comparative morphology and distribution of the *aduncus* and *truncatus* forms of bottlenose dolphin *Tursiops* in the Indian and Western Pacific Oceans. *Aquatic Mammals,* **26**(2): 101-110.

Hamazaki, T. 2002. Spatiotemporal prediction models of cetacean habitats in the Midwestern North Atlantic Ocean (From Cape Hatteras, North Carolina, U.S.A. to NovaScotia, Canada). *Marine Mammal Science,* **18**:1920-939.

Hammond, P.S. 1986. Estimating the size of naturally marked whale populations using capture–recapture techniques. *Reports of the International Whaling Commission,* Special Issue, **8**: 253–282.

Hammond, P.S., P. Berggren, H. Benke, D.L. Borchers, A. Collet, M.P. Heide-Jorgensen, S. Heimlich, A.R. Hiby, M.F. Leopold, and N. Oien. 2002. Abundance of harbour porpoises and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology,* **39**: 361-376.

Hansen, L.J., K.D. Mullin and C.L. Roden. 1995. Estimates of cetacean abundance in the northern Gulf of Mexico from vessel surveys. Southeast Fisheries Science Center, Miami Laboratory Contribution No. MIA-94/5-25 (unpublished). 20 pp. Available from NOAA, NMFS, SEFSC, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL 33149. (*Cross reference*)

Harwood, J. 1981. Observations of cetaceans in the Arabian Sea, November-December 1980. Doc 7 presented to workshop to Plan a Programme of Scientific Research on Cetacean in the Indian Ocean Sanctuary, Zeist, Netherlands, 1981 (*Cross reference)*

Hashmi D.D.K. and B. Adloff. 1991. Surface frequency of cetaceans in the Strait of Gibraltar. In: P. G. H. Evans (ed.), *European research on cetaceans,* **5**: 16-17.

Hastie, G.D., R. Swift, J.C.D. Gordon, G. Slesser and W.R. Turrell. 2003. Sperm whale distribution and seasonal density in the Faroe Shetland Channel. *Journal of Cetacean Research and Management,* **5**(3): 247-252.

Hastie, G.D., R.J. Swift, G. Slesser, P.M. Thompson, and W.R. Turrell. 2005. Environmental models for predicting oceanicdolphin habitat in the Northeast Atlantic. *ICES Journal of Marine Science,* **62**: 760-770.

Hastie, G.D., B. Wilson, L.J. Wilson, and K.M. Parsons. 2004. Functional mechanisms underlying cetacean distribution patterns: hotspots for bottlenose dolphins are linked to foraging. *Marine Biology*, **144**:397-403.

Hawkins E.R. and D.F. Gartside. 2008. Social and Behavioural Characteristics of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) in northern New South Wales, Australia. *Australian Mammalogy*, **30**(2):71 – 82.

Heyning, J.E. and W.F. Perrin. 1994. Evidence for two species of common dolphins (genus Delphinus) from the eastern North Pacific. *Los Angeles County Museum of Natural History Contributions in Science*, **442**: 1-35.

Hoelzel, A.R., E.M. Dorsey and S.J. Stern. 1989. The foraging specializations of individual minke whales. *Animal Behaviour*, 38: 786–794

Hooker, S. K., H. Whitehead and S. Gowans. 1999. Marine protected area design and the spatial and temporal distribution of cetaceans in a submarine canyon. *Conservation Biology*, **13**:592-602.

Holt, R.S. and S.N. Sexton. 1990. Monitoring trends in dolphin abundance in the eastern tropical Pacific using research vessels over a long sampling period: Analyses of 1986 data, the first year. *Fishery Bulletin*, U.S, **88**:105-111.

Holt, A.R., T. Gerrodette and J.B. Cologne. 1987. Research vessel survey design for monitoring dolphins abundance in the eastern tropical Pacific. *Fishery Bulletin*, U.S, **85**: 433-446.

Hui, C.A. 1979. Undersea topography and distribution of dolphins of the genus *Delphinus* in the southern California Bight. *Journal of Mammalogy*, **60**:521–527.

Ilangakoon, A. 1997. Species composition, seasonal variation, sex ratio and body length of small cetaceans caught off west, south-west and south coast of Sri Lanka. *Journal of the Bombay Natural History Society*, **94** (2): 298-306.

Ilangakoon, A. 2002 Whales and dolphins of Sri Lanka: A Guide to the Cetacecans in the Waters around Sri Lanka. WHT Publication. Colombo, Sri Lanka.

Jacob, P.K. and M.D. Menon. 1947. The piscivorous habits of the Rorqual or Fin Whale *Balaenoptera* sp. *Journal of the Bombay Natural History Society*, **47**(1): 156-158.

James, D.B. 1984. Capture of a false killer whale *Pseudorca crassidens* at Port Blair, Andamans. *Marine Fisheries Information Service Technical & Extension Series*, **55**: 17.

James, D.B. 1990. On a Sperm Whale landed at Kalpeni Island with notes on Ambergris. *Marine Fisheries Information Service Technical & Extension Series,* **104**: 11-14.

James, P.S.B.R. and R. Soundararajan. 1979. On a Sperm Whale *Physeter macrocephalus* (Linnaeus) stranded at Krusadai Island in the Gulf of Mannar, with an up-to-date list and diagnostic features of whales stranded along the Indian coast. *Journal of the Marine Biological Association of India,* **21**: 17-40.

James, P.S.B.R. and R. Soundararajan. 1981. An osteological study on the Sperm Whale *Physeter macrocephalus* Linnaeus from Indian Ocean. *Indian Journal of Fisheries,* **28**: 217-232.

James, D.B. and K.C.S. Panicker. 1994. On the recovery of a foetus from a Sperm whale *Physeter macrocephalus* Linnaeus stranded at Chetland Island, Lakshadweep. *Journal of the Bombay Natural History Society,* **91**(3): 451-452.

James, P.S.B.R. and R.S. Lal Mohan. 1987. The Marine Mammals of India. *Marine Fisheries Information Service Technical & Extension Series,* **71**: 1-13.

James, P.S.B.R., M. Rajagopalan, S.S. Dan, A.B. Fernando and V. Selvaraj. 1989. On the mortality and stranding of marine mammals and turtles at Gahirmatha, Orissa from 1983 to 1987.*Journal of the Marine Biological Association of India,* **31**(1 & 2): 28-35.

Jayaprakash, A.A., P. Nammalwar, S. Krishna Pillai and M.N.K. Elayath.1995. Incidental by-catch of dolphins at Fisheries Harbour, Cochin, with a note on their conservation and management in India. *Journal of the Marine Biological Association of India,* **37**:126-133.

Jayasankar, P., A.K. Anoop, M.Rajagopalan and P.K.Krishnakumar. 2007. A note on observations on cetaceans in the western Indian sector of Southern ocean (20-56°S and 45°57°E), January to March 2004. *Journal Cetacean Research Management,* **9**(3): 263-267.

Jadhav, D.G. and R.B. Rao. 1998. On the stranding of the Common Dolphin *Delphinus delphis* at Murud Janjira. *Marine Fisheries Information Service Technical & Extension Series,* **152**: 17.

Jaquet, N. 1996. How spatial and temporal scales influence understanding of sperm whale distribution: a review. *Mammal Review,* **26**:51–65.

Jaquet, N. and D. Gendron. 2002. Distribution and relative abundance of sperm whales in relation to key environmental features, squid landings and the distribution of other cetacean species in the Gulf of California, Mexico. *Marine Biology,* **141**: 591–601.

Jaquet, N. and H. Whitehead. 1996. Scale-dependent correlation of sperm whale distribution with environmental features and productivity in the South Pacific. *Marine Ecological Progress Series,* **135**:1- 9.

Jayasankar, P., A.K. Anoop, M. Rajagopalan and P.K Krishnakumar. 2007. A note on observations on cetaceans in the western Indian sector of the Southern Ocean (20-56°S and 45-57°30'E), January to March 2004. *Journal Cetacean Research Management,* **9**(3):263–267.

Jefferson TA, S. Leatherwood and M.A Webber. 1993. FAO Species identification guide. Marine mammals of the world. UNEP / FAO, Rome, 320 pp.

Jefferson, T.A. 1996. Estimates of abundance of cetaceans in offshore waters of the northwestern Gulf of Mexico, 1992-1993. *Southwestern Naturalist,* **41**:279-287.

Jefferson, T.A. 2000. Population biology of the Indo-Pacific hump-backed dolphin in Hong Kong waters. *Wildlife Monographs,* **144**:1–67.

Jefferson, T.A. and S. Leatherwood. 1997. Distribution and abundance of Indo-Pacific hump-backed dolphins (*Sousa chinensis*, Osbeck, 1765) in Hong Kong waters. *Asian Marine Biology,* **14**:93–110.

Jefferson, T.A and A.J. Schiro. 1997. Distribution of cetaceans in the offshore Gulf of Mexico. *Mammal Review,* **27**:27-50.

Jefferson T.A. and L. Karczmarski. 2001. *Sousa chinensis. Mammal Species* **655**:1-9.

Jefferson, T.A. and K. Van Waerebeek. 2002. The taxonomic status of the nominal dolphin species *Delphinus tropicais* Van Bree, 1971. *Marine Mammal Science*. **18**:787-818.

Jefferson, T. A., M.A. Webber and R. L. Pitman. 2008. Marine mammals of the World: A Comprehensive Guide to their identification Elsevier Academic Press.pp1-592

Kannan, K., R.K. Sinha, S. Tanabe, H.Ichihashi and R. Tatsukawa. 1993. Heavy metal and Organochlorine residues in Ganges River Dolphin from India. *Marine Pollution Bulletin,* **26**:159-162.

Karbhari, J.P., M. Aravindakshan, K.B. Wagmare and R. Gandhi. 1985. Note on the food of the spinner dolphin Stenella longirostris Gray, caught off Maharashtra coast. *Journal of the Marine Biological Association of India,* **27**:193-195.

Karczmarski, L. 1996. Ecological studies of humpback dolphins *Sousa chinensis* in the Algoa Bay region, Eastern Cape, South Africa. Ph.D.

dissertation, University of Port Elizabeth, South Africa, 202 pp. (*Cross reference*)

Karczmarski, L. 2000. Conservation and management of humpback dolphins: the South African perspective. *Oryx,* **34**: 207–216.

Karuppiah, S., A. Subramanian and J.P. Obbard. 2005. Organochlorie residues in odontocede species from the southeast coast of India. *Chemosphere*, **60**(7): 891-897.

Kasamatsu F., P. Ensor and G.G. Joyce. 1998. Clustering and aggregations of minke whales in the Antarctic feeding grounds. *Marine Ecological Progress Series,* **168**:1-11.

Kasamatsu, F. and G. Joyce. 1995. Current status of odontocetes in the Antarctic. *Antarctic Science,* 7:365-79.

Kasamatsu, F., D. Hembree, G. Joyce, L. Tsunoda, R. Rowlett and T. Nakano. 1988. Distribution of cetacean sightings in the Antarctic; results obtained from the IWC/IDCR minke whale assessment cruises. 1978/79-1983/84. *Report of the International Whaling Commission,* **38**: 449-487.

Kasamatsu, F. 2000. Species diversity of the whale community in Antarctic. *Marine Ecological Progress Series*, **200**: 297.-301.

Kasim, H.M., K.M.S.A. Hamsa and T.S. Balasubramanian. 1993. On an accidental landing of False Killer Whale *Pseudorca crassidens* by drift gillnet off Veerapandianpatnam, Gulf of Mannar. *Marine Fisheries Information Service Technical & Extension Series,* **120**: 18-19.

Kasuya, T. 1999. Finless porpoise *Neophocaena phocaenoids* (G.Cuvier, 1829) In *"Handbook of marine mammals"* (Ridgeway, S.H. and R. Harrison, eds) the second book of dolphins and porpoises Academic press San Dieago CA. vol. 6, pp 411-442.

Kasuya, T. and S. Wada. 1990. Distribution of large cetaceans in the Indian Ocean: Data from Japanese sighting records, November-March. Pages 139-170 In. *Cetaceans and cetacean research in the Indian Ocean Sanctuary*. (Leatherwood, S. and G. P. Donovan, eds) Nairobi, Kenya. United Nations Environment Programme, *Marine Mammal Technical Report Number* 3.

Kasuyo, T. and S. Wada. 1991. Distribution of large cetaceans in the Indian Ocean: data from Japanese sighting records, November-March. In: S. Leatherwood and G. P. Donovan, eds. *Cetaceans and cetacean research in the Indian Ocean sanctuary. Marine Mammal Technical Report No. 3*. UNEP, Nairobi, Kenya. pp 139-170.

Katona, S. and H. Whitehead. 1988. Are cetacean ecologically important? *Oceanography and Marine Biology: An Annual Review*, **26**:553–568.

Kato, H., J. Bannister, C. Burton, D. Ljungblad, K. Matsuoka and H. Shimada. 1996. Report on the Japan/IWC blue whale cruise 1995-96 off the southern coast of Australia. Paper *SC/48/SH9* submitted to the Scientific Committee of the International Whaling Commission.

Kawamura, A. 1994. A review of baleen whale feeding in the Southern Ocean. *Report of the International Whaling Commission*, **44**:261-71.

Keller, R.W., S. Leatherwood and S.J. Holt. 1982. Indian Ocean cetacean survey, Seychelle Islands, April through June 1980. *Report of the International Whaling Commission*, **32**:503-5 13.

Kinzey, D., P. Olson and T. Gerrodette. 2000 Marine mammal Data collection Procedure on Research Ship Line transect surveys by the Southwest Fisheries Science Centre. Southwest Fisheries Science Center, Administrative Report LJ-00-08:1-32.

Kiszka, J., O. Breysse, K. Boinali and M. Vely. 2006. Marine mammals around the Union of the Comoros (Mozambique Channel): recent records and review of available information. Report SC/58/O6 submitted to the Scientific Committee of the International Whaling Commission. 5p.

Kiszka, J., P.J. Ersts and V. Ridoux. 2007. Cetacean diversity around the Mozambique Channel island of Mayotte (Comoros archipelago). *Journal of Cetacean Research and Management*, **9**(2): 105-109.

Kiszka, J., S. Hassani and S. Pezeril. 2004. Distribution and status of small cetaceans along the French Channel coasts: using opportunistic records for a preliminary assessment. *Lutra*, **47**(1): 33-46.

Kiszka, J., K. Macleod, O. Van Canneyt, D. Walker and V. Ridoux. 2007. Distribution, encounter rates, and habitat characteristics of toothed cetaceans in the Bay of Biscay and adjacent waters from platform-of-opportunity data. *ICES Journal of Marine Science*, **64**:1-11.

Krey, J. and B. Babenerd. 1976. Phytoplankton production. Atlas of International Indian Ocean expedition. Universital Kiel. Institute fur Meereskunde, Kiel.

Klinowska, M. 1991.Dolphins, Porpoises and Whales of the World: The IUCN Red Data Book, Gland, p. 429.

Krishna Pillai, S., A.A. Jayaprakash, C. Kasinathan and N. Ramamoorthy. 1995. On the Sei whale *Balaenoptera borealis* Lesson stranded along Palk Bay coast near Pamban light house. *Marine Fisheries Information Service Technical & Extension Series*, **139**: 11.

Krishna Pillai, S. and C. Kasinathan. 1987. Some observations on dolphins in Mandapam area with a note on their food. *Marine Fisheries Information Service Technical & Extension Series,* **71**: 13-16.

Kruse S., D.K. Caldwell and M.C. Caldwell.1999. Risso's dolphin - *Grampus griseus* (G. Cuvier, 1812) In: Handbook of Marine Mammals (Ridgway SH, Harrison SR Eds.) Vol. 6: The second book of dolphins and porpoises. pp. 183 – 212.

Kruse, S., S. Leatherwood, W. Prematunga, C. Mendes and A. Gamage. 1991. Records of Risso's Dolphins, *Grampus griseus*, in the Indian Ocean, 1891-1986. In "*Cetaceans and cetacean research in the Indian Ocean sanctuary*" (Leatherwood, S. and G. P. Donovan, eds) *Marine Mammal Technical Report No. 3*. UNEP, Nairobi, Kenya. 67-77.

Kumar, S.P., M. Muraleedharan, T.G. Prasad, M. Gauns, N. Ramaiah, S.N. de Souza, S. Sardeshi and M. Madhupradap. 2002. Why is the Bay of Bengal less productive during summer monsoon compare to Arabian Sea?. *Geophysics Research Letter,* **29** (D24): 2235.

Kumaran, P.L. 2002. Marine Mammal research in India-a review and critique of the methods. *Current Science.* **83**: 1210-1220.

Kumaran, P.L. 2003. First confirmed record of Striped dolphin, *Stenella coeruleoalba* (Meyen, 1883) from India. *Journal of the Marine Biological Association of India,* **4**(4): 115-120.

Kumaran, P.L. and A.N. Subramanian. 1993. First record of an endangered Finless Porpoise *Neophocaena phocaenoides* from Porto Novo, southeast coast of India. *Journal of the Marine Biological Association of India,* **35**: 207-209.

Kumarran, R.P., J. Rani and K.S.S.M. Yousuf. 2008. Marine mammals inventory for India. In Milton, Training manual on GIS and Marine Mammal Bio diversity. Loyola college publication, 437-444.

Lal Mohan, R.S. 1985. Observations on the by-catch of dolphins *Stenella longirostris, Tursiops aduncus, Sousa chinensis* and *Delphinus delphis tropicalis* in the gillnets off Calicut coast, India. *Proceedings of Symposium on Endangered Marine Animals and Marine Parks*, 1985, MBAI, Cochin. **1**:78-83.

Lal Mohan, R.S. 1996. *Rivdolphinews,* **1**(1): 8.

Lal Mohan, R.S. 1995. Age determination of dolphins entangled in gillnets along the Kerala coast. *Journal of the Bombay Natural History Society,* **92**(1): 77-80.

Lal Mohan, R.S., S.C. Dey, S.P. Dairasi and S. Roy. 1994. Studies on the population of Ganges river dolphin, *Platanista gangetica* of Brahmaputra, Assam. Annual Report (1992-1993).

Leatherwood, S. 1980. Whales, dolphins and porpoises of the Indian Ocean Sanctuary: A catalogue of available information. Hubbs Marine Research Center Technical Report, San Diego 206pp.

Leatherwood, S. 1984. Further notes on cetaceans of Sri Lanka. Paper No.SC/36/06 presented to the International Whaling Commission Scientific Committee.12 pages.

Leatherwood, S. 1985. Further notes on cetaceans of Sri Lanka. *Cetology,* **50**: 1-12.

Leatherwood, S. and J. Clarke. 1983. Cetaceans in the Strait of Malacca, Andaman Sea, and Bay of Bengal, April 1982, with a preliminary review of marine mammal records from those regions. (Unpublished report).

Leatherwood, S. and G.P. Donovan, eds. 1991. Cetaceans and cetacean research in the Indian Ocean Sanctuary. Nairobi, Kenya. United Nations Environment Programme, *Marine Mammal Technical Report* Number 3.

Leatherwood, S., R. Peters, R. Santerre, M. Santerre and J.C. Clarke. 1984 Observation of cetaceans in the northern Indian Ocean Sanctuary, November 1980- May 1983. *Report of the International Whaling Commission,* **34**:509-520.

Leatherwood, S. and R.R Reeves. 1989. Marine mammal research and conservation in Sri Lanka 1985-1986. *UNEP Marine Mammal Techical Report,* **1**(vi):1-138.

Lindstrom U., T. Haug and I. Rottingen. 2002. Predation on herring, Clupea harengus, by minke whales, *Balaenoptera acutorostrata,* in the Barents Sea. *ICES Journal of Marine Science*, **59**: 58-70.

Liret, C. and V. Ridoux. 1998. Patchy home range in coastal bottlenose dolphins. *European Research on Cetaceans,* **12**: 161-164.

Ljungblad, D.K., C.W. Clark and H. Shimada. 1997. Sounds attributed to pygmy blue whales recorded south of Madagascar, December 1996. Paper SC/49/SH17 presented to the International Whaling Commission.

Longhurst, A.R. and D. Pauly. 1987. Ecology of tropical oceans. San Diego; Academic Press.

Madhupratap, M., K.N.V. Nair, T.C. Gopalakrishnan, P. Haridas, K.K.C. Nair, P. Venugopal and M. Gauns. 2001 Arabian Sea oceanography and fisheries of the west coast of India. *Current Science*, **81**(4): 355-361.

Macleod, C.D., S.M. Bannon, G.J. Pierce C. Schweder, J.A. Learmonth, J.S Herman and R.J. Reid. 2005. Climate change and the cetacean community of north-west Scotland. *Biological Conservation,* **124**: 477-483.

Macleod, K., R. Fairbairns, B. Fairbairns, A. Gill, J. Gordon, C. Blair-Myers and E. C.M. Parsons. 2004. The seasonal distribution of the minke whale (*Balaenoptera acutorostrata)* in relation to physiographic factors and potential prey off the Isle of Mull, Scotland. *Marine Ecology Progress Series,* **277**: 263–274.

Macleod, K., M.P. Simmonds and E. Murray. 2003. Summer distribution and relative abundance of cetacean populations off northwest Scotland. *Journal of the Marine Biological Association of the UK,* **83**: 1187–1192.

Macleod., C.D., C.R. Weir, C. Pierpoint and E.J. Harland. 2007. The habitat preference of marine mammals west of Scotland (UK). *Journal of the Marine Biological Association U K,* **87**:157-164.

Mahadevanpillai, P.K. and S.B. Chandrangathan. 1990. On the drift-net entangled dolphins landed at Sakthikulangara. *Marine Fisheries Information Service Technical & Extension Series,* **104**: 16-17.

Manikfan, A.M. 1991. A Note on the Capture of the Smaller Cetaceans for Food in the Laccadive Island. In Leatherwood and Donovan Cetacean and Cetacean Research in the Indian Ocean. *Marine Mammal Technical Report,* **3**:107-109.

Meiyappan, M.M. and K.S. Mohamed.2003. Cephalopods. In Mohan Joseph and A.A. Jayapraksah. "*Status of Marine Fishery resources in India*" Central Marine Fisheries Research Institute, Special publication, 221-227.

McCauley, R.D., C. Jenner, J.L. Bannister, D.H. Cato and A. Duncan. 2001. Blue whale calling in the Rottnest Trench, Western Australia, and low frequency sea noise. Paper presented at the November 2000 Conference of the Australian Acoustical Society, Perth. (*Cross reference*).

McCreary, J.P., P.K. Kundu and R.L. Molinari. 1993. A numerical investigation of dynamics, thermodynamics and mixed-layer processes in the Indian Ocean. *Progress in Oceanography,* **31**(3): 181-244.

Mendolia, C. 1990. Reproductive biology of common dolphins (*Delphinus delphis*, Linnaeus) off the south east coast of southern Africa. M.Sc. thesis, University of Port Elizabeth, 75pp (*cross reference*).

Meynier, L., C. Pusineri, J. Spitz, M.B. Santos, G.J. Pierce and V. Ridoux. 2008. Diet and feeding ecology of the common dolphin, *Delphinus delphis*, in the Bay of Biscay: importance of fat fish. *Marine Ecology Progress Series*, **354**: 267-276

Michel, C. and P.J.H. Van Bree. 1976. On two strandings of the beaked whale *Mesoplodon densirostris* on Mauritius. *Z. Saugetierkd*, **41**(3):194-196.

Mikhalev, Y. 1997. Humpback whales *Megaptera novaeangliae* in the Arabian Sea. *Marine Ecology Progress Series,* **149**: 13-21.

Minton, G., T. Collins, K. Findlay, R. Baldwin, H.C. Rosenbaum, F. Kennedy and V. Cockcroft. 2002. Preliminary investigations of humpback whales (*Megaptera novaeangliae*) distribution and habitat use off the coast of Oman. Paper SC/54/H3 presented to the IWC Scientific Committee.

Mobley, J. R. Jr., S. S. Spitz, K. A. Forney, R. Grotenfendt and P. H. Forestell. 2000. Distribution and abundance of odontocete species in Hawaiian waters: preliminary results of 1993–98 aerial surveys. Administrative Report LJ-00–14C. Available from the NOAA Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037. 26 pp.

Mobley, J. R. Jr., S. S. Spitz, R. Grotenfendt, P. Forestell, A. Frankel and G. Bauer. 2001. Abundance of humpback whales in Hawaiian waters: Results of 1993–2000 aerial surveys. *Report to the Hawaiian Islands Humpback Whale National Marine Sanctuary.* 16 pp.

Mohammed, K.S., P.U. Zacharia, C. Muthiah, K.P. Abdurahiman, T.H. Nayak. 2006. A Trophic Model of the Arabian Sea Ecosystem off Karnataka and Simulation of Fishery Yields for its Multigear Marine Fisheries. *Central Marine Fisheries Research Institute publication,* pp. 1-83.

Mohanraj, G., M.V. Somaraju and C.V. Seshagiri Rao. 1995. A Blue Whale *Balaenoptera musculus* landed at Mangamaripeta, north of Visakhapatnam. *Marine Fisheries Information Service Technical & Extension Series,* **137**: 17.

Moore, S.E. and D.P. DeMaster. 1988. Cetacean Habitats in the Alaskan Arctic. *Journal of the Northwest Atlantic Fisheries Science,* **22**: 55–69.

Moore S.E. 2000. Variability of cetacean distribution and habitat selection in the Alaskan Arctic, autumn 1982–1991. *Arctic,* **53**: 448–460.

Moore SE, J.M. Waite, N.A. Friday and T. Honkalehto. 2002. Cetacean distribution and relative abundance on the central- eastern and the southeastern Bering Sea shelf with reference to oceanographic domains. *Progress in Oceanography,* **55**: 249–261.

Moses, S.T. 1940. Whales in Baroda, with notes on the anatomy of the Fin-Whale *Balaenoptera indica* stranded at Mulvel in March 1939. *Journal of the Bombay Natural History Society,* **41**(4): 895-897.

Moses, S.T. 1947. Stranding of whales on the coasts of India. *Journal of the Bombay Natural History Society,* **47**(2): 377-379.

Mullin, K.D. and L.J. Hansen. 1999. Marine mammals of the northern Gulf of Mexico. In "*The Gulf of Mexico large marine ecosystem: assessment*" Baumgartner et al.: Cetacean habitats in the northern Gulf of Mexico 239 sustainability and management (Kumpf, H., K. Steidinger, and K. Sherman, eds) Blackwell Science, London. p. 269–277

Mullin, K.D. and G.L. Fulling. 2004. Abundance OF Cetaceans in the oceanic Northern Gulf of Mexico, 1996–2001. *Marine Mammal Science,* **20**(4):787–807.

Mullin, K.D. and W. Hoggard. 2000. Visual surveys of cetaceans and sea turtles from aircraft and ships. In. "*Cetaceans, sea turtles and seabirds in the northern Gulf of Mexico: Distribution, abundance and habitat associations*" (Davis, R.W., W. E. Evans, and B. Wursig, eds)Vol.II. Technical report. OCS Study MMS 96 0027. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. P. 111–172

Mullin, K.D., W. Hoggard, C.L. Roden, R.R. Lohoefener, C.M. Rogers and B. Taggart. 1994. Cetaceans on the upper continental slope in the north central Gulf of Mexico. *Fishery Bulletin US,* **92**:773–786.

Mullin, K.D., W. Hoggard and L.J. Hansen. 2004. Abundance and seasonal occurrence of cetaceans in outer continental shelf and slope waters of the north-central and northwestern Gulf of Mexico. *Gulf of Mexico Science,* **22**:62–73.

Murase H., K. Matsuoka, T. Ichii and S. Nishiwaki. 2002. Relationship between the distribution of euphausiids and baleen whales in the Antarctic (35° E–145° W). *Polar Biology,* **25**: 135–145.

Miyazaki, N., T. Kusaka and M. Nishiwaki. 1973. Food of *Stenella coerulleoalba. Scientific Reports of the Whales Research Institute,* **25**:265-275.

Nageswara Rao, T. and P. Venkataramana. 1994. On the landing of Bottlenose Dolphin *Tursiops truncatus* at Kakinada. *Marine Fisheries Information Service Technical & Extension Series,* **127**: 16.

Nair, R.V. and R.S. Lal Mohan. 1975. Studies on the vocalisation of the Sea Cow *Dugong dugon* in captivity. *Indian Journal of Fisheries,* **22**: 277-282.

Nammalwar, P., S. Srinivasarangan and S. Mohan. 1989. On a Sperm Whale stranded at Madras. *Marine Fisheries Information Service Technical & Extension Series,* **95**: 10-11.

Nammalwar, P., A.P. Lipton, S. Krishna Pillai, G. Maheswarudu, C. Kasinathan, M. Bose, N. Ramamoorthy, and P. Thillairajan. 1994. Instances of Finless Black Porpoise *Neophocaena phocaenoides* caught in Mandapam region along the Palk Bay coast in Tamilnadu. *Marine Fisheries Information Service Technical & Extension Series,* **127**: 16-17.

Neumann, D.R. 2001. Seasonal movements of short-beaked common dolphins (*Delphinus delphis*) in the north-western Bay of Plenty, New Zealand: influence of sea surface temperature and El Nino/La Nina. *New Zealand Journal of the Marine Freshwater Research,* **35**: 371-374.

Northridge, S.P., M.L. Tasker, A. Webb and J.M. Williams. 1995. Distribution and relative abundance of harbor porpoises (*Phocoena phocoena*), white-beaked dolphins (*Lagenorhynchus albirostris* Gray), and minke whales (*Balaenoptera acutorostrata* lacepede) around the British Isles. *ICES Journal of Marine Science*, **52**: 55–66.

Norris, K.S., B. Wursig, R.S. Wells and M. Wursig, (eds). 1994. The Hawaiian spinner dolphin. University of California Press, Berkeley.

Notarbartolo di Sciara, G., M.C. Venturino, M. Zanardelli, G.Bearzi, F.J. Borsani and B. Cavalloni. 1993. Cetacean in the central Mediterranean Sea: Distribution and sighting frequencies. *Boll.Zoology,* **60**: 131-138.

Ortega-Ortiz, J.G. 2002. Multi scale analysis of cetacean distribution in the Gulf of Mexico. Dissertation. Texas A&M University, College Station, Texas, USA *(Cross reference).*

Parsons, E.C.M. 1998. Observations of Indo-Pacific humpbacked dolphins, *Sousa chinensis*, from Goa, Western India. *Marine Mammal Science,* **14:** 166-170.

Payne, P.M., D.N. Wiley, S.B. Young, S. Pittman, P.J. Clapham and J.W. Jossi. 1990. Recent fluctuations in the abundance of baleen whales in the southern Gulf of Maine in relation to changes in selected prey. *Fishery Bulletin, US,* **88**: 687–696.

Payne, P.M., J.R. Nicolas, L. O'Brien and K.D. Powers. 1986. The distribution of the humpback whale, *Megaptera novaeangliae,* on George bank and in the Gulf of Maine, USA, in relation to densities of the sand eel, Imitates Americans. *National Marine Fisheries Bulletin,* **84**(2): 271-278.

Peddemors, V.M. 1993. Use of commercial flights to census inshore marine mammals off Natal, South Africa. *Lammergeyer,* **42**: 43-47

Peddemors, V.M. 1999. Delphinids of southern Africa: a review of their distribution, status and life history. *Journal of Cetacean Research Management,* **1**(2): 157-165.

Peddemors, V.M., P.B. Best, K.P. Findley, D. Gove, B. Rakotonirina, A. Rossauw and K. Sekiguchi. 1997. Small cetaceans of the Southwest Indian Ocean. Paper SC49/SM33 presented to the IWC Scientific Committee.

Perrin, W.F. 1990. Subspecies of *Stenella longirostris* (Mammalia: Cetacea: Delphinidae). *Proceedings of the Biological Society of Washington,* **103**:453-463.

Perrin, W.F., T.A. Aquino, M.L. Dolar and M.N. Alava. 2007. External appearance of the dwarf spinner dolphin *Stenella longirostris roseiventris*. *Marine Mammal Science,* **23**(**2**): 464-67.

Perrin, W.F., W.E. Evans and D.B. Holts. 1979. Movements of pelagic dolphins (*Stenella* spp.) in the eastern tropical Pacific as indicated by results of tagging, with summary of tagging operations, 1969–76. *NOAA Technical. Report. NMFS No. SSRF*-737.

Perrin, W.F., M.L.L. Dolar and D. Robineau. 1999. Spinner dolphins (*Stenella longirostris*) of the western Pacific and southeast Asia: pelagic and shallow-water forms. *Marine Mammal Science,* **15**(4): 1029-1053.

Perrin, W. F., G.P. Donovan and J. Barlow (eds). 1994. Gillnets and cetaceans. *Reports of the International Whaling Commission* Special Issue 15.

Perrin, W.F. and J.W. Gilpatrick, Jr. 1994. Spinner dolphin *Stenella longirostris* (Gray, 1828). In: S. H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals, Vol.5: The First Book of Dolphins, pp. 99-128. Academic Press, 416 pp.

Perrin, W F., B. Wursig and J.G.M. Thewissen, (eds). 2002. Encyclopedia of Marine mammal, Academic Press. pp 1-1316.

Piatt, J.F., D.A. Metheven, A.E. Burger, R.L. McLagan, V. Mercer and E. Creelman, 1989. Baleen whales and their prey in a coastal environment. *Canadian Journal of Zoology,* **67**: 1523-1530.

Pillay, R.S.N. 1926. List of cetaceans taken in Travancore from 1902 to 1925. *Journal of the Bombay Natural History Society,* **31**(3): 815-817.

Pilleri, G. and M. Gihr. 1974. Contribution to the knowledge of the cetaceans of southwest and monsoon Asia (Persian Gulf, Indus Delta, Malabar, Andaman Sea andGulf of Siam). In G. Pilleri (Ed.), Investigations on cetacea, Volume 5 (pp. 95-150). Berne, Switzerland: Institute of Brain Anatomy, University of Berne.

Pitman R.L. and P. Ensor. 2003. Three forms of killer whales (*Orcinus orca*) in Antarctic waters. *Journal Cetacean Research Management*, **5**:131–139.

Prakash, S. and R. Ramesh. 2007. Is the Arabian Sea getting more productive? *Current Science,* **92**(5):667-671.

Prematunga, D., P. Girton, A. Ilangakoon and D. McBrearty. 1991. Records of the Blackfish (killer, false killer, pilot pygmy killer and melon headed whales) in the Indian Ocean, 1772-1986 In *"Cetaceans and cetacean research in the Indian Ocean sanctuary"* (Leatherwood S. and G. P. Donovan, eds). Marine Mammal Technical Report No. 3. UNEP, Nairobi, Kenya. pp 33-65.

Pusineri, C., V. Magnin, L. Meynier, J. Spitz, S. Hassani and V. Ridoux. 2007. Food and feeding ecology of the common dolphin (*Delphinus delphis*) in the oceanic northeast Atlantic and comparison with its diet in neritic areas. *Marine Mammal Science,* **23**:30-47.

Rajaguru, A. and R. Natarajan, 1985. Systematics and organ weights of two dolphins, *Stenella longirostris* (Gray, 1928) and *Tursiops truncatus* (Montagu, 1821) of Porto Novo, southeast coast of India. *Proceeding of Symposium on Endangered Marine Animals and Marine Parks,* 1985, MBAI, Cochin, **1**:72-77.

Ramasamy. R. 2007. A submarine trench along the eastern coast of Peninsular India. *Current Science,* **93**(12): 1650-1651.

Rao, V.P and P.M. Kessarkar. 2001. Geomorphology and Geology of the Bay of Bengal and the Andaman Sea In: The Indian Ocean (Ed. By. R. Sengupta and E. Desa) Oxford IBH publishers, 817-868.

Razafindrakoto, Y., N. Andrianarivelo and H.C. Rosenbaum. 2004. Sightings, catches and other records of Indo- Pacific humpback dolphins in the coastal waters of Madagascar. *Aquatic Mammals,* **130**: 103-110.

Reeves, R.R., B.S. Stewart, P.J. Clapham and J.A. Powell. 2002. Sea Mammals of the World: A Complete Guide to Whales, Dolphins, Seals, Sea lions and Sea Cows. A & C Black, London.

Reijnders, P.J.H., A. Aguilar and G.P Donovan. 1999. Chemical Pollutants and Cetacean. *Journal Cetacean Research Management* Special Issue, **1**: 1-273.

Reilly, S.B. 1990. Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. *Marine Ecological Progress Series,* **66**:1–11.

Reillys, B. and P.C. Fiedler. 1994. Interannual variability of dolphin habitats in the eastern tropical Pacific. I: Research vessel surveys, 1986-1990. *Fishery Bulletin,* U.S., **92**:434–450.

Reyes J.C. 1991. The conservation of small cetaceans: A review. Report prepared for the Secretariat of the Convention on the Conservation of Migratory Species of Wild Animals. UNEP / CMS Secretariat, Bonn, Germany

Richard, K.R. and M.A. Barbeau. 1994. Observations of spotted dolphins feeding nocturnally on flying fish. *Marine Mammal Science,* **10**: 473–477.

Ridgway, S.H. and R. Harrison, eds. 1994. Handbook of marine mammals. vol. 5. The first book of dolphins. Academic Press, San Diego, CA.

Ritter, F. 2003. Interactions of cetaceans with whale watching boats-implications for the management of whale watching tourism. M.E.E.R. e.V., Berlin, Germany. 91 pp. Available from M.E.E.R. e.V., Bundesallee 123, 12161 Berlin, Germany.

Robertson, K.M. and S.J. Chivers. 1997. Prey occurrence in pan-tropical spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific. *Fishery Bulletin,* **95**: 334–348.

Robbins, J., C. Carlson and J. Palazzo Jr. 2006. Preliminary worldwide index of cetacean data collection from opportunistic platforms. Paper SC/58/WW3 presented to the IWC Scientific Committee, May 2006, St. Kitts and Nevis, West Indies (unpublished). 1pp. [Paper available at the Office of this Journal].

Robineau, D. 1991. Balaenopterid sightings in the western tropical Indian Ocean (Seychelles Area), 1982-1986. In: S. Leatherwood and G.P. Donovan (eds). *Cetaceans and cetacean research in the Indian Ocean sanctuary. Marine Mammal Technical Report* No. 3. UNEP, Nairobi, Kenya. pp 171-179.

Rosenbaum, H.C. 2003. Marine mammals of Madagascar. Pp. 213-216. In: S. Goodman & J. Bengston (Eds.). The Natural History of Madagascar. University of Chicago Press, Chicago, Illinois.

Rosenbaum, H.C., P.E. Ersts and K. Findlay. 2001. Regional planning workshop on collaborative research and conservation of humpback whales in the Indian and South Atlantic Oceans. Paper SC/53/IA23 presented to the IWC Scientific Committee.

Sawant, S.S. and M. Madhupratap. 1996. Seasonality and composition of phytoplankton in the Arabian Sea. *Current Science,* **71**: 869-873.

Schreer, J.F. and K.M. Kovacs. 1997. Allometry of diving capacity in air-breathing vertebrates. *Canadian Journal of Zoology,* **75**: 339-358.

Scott, M.D. and K.L. Cattanach. 1998. Diel patterns in aggregations of pelagic dolphins and tuna in the eastern Pacific. *Marine Mammal Science,* **14**: 401–428.

Scott, M.D., S.J. Chivers, R.J. Olson and R.J. Lindsay. 1993. Radio tracking of spotted dolphins associated with tuna in the eastern tropical Pacific. In Abstracts of the 10th Biennial Conference on the Biology of Marine Mammals, Galveston, Texas, 11–15 November 1993. Society for Marine Mammalogy, Lawrence, Kans. p. 97.

Selzer, L.A and P.M. Payne. 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeasternUnited States. *Marine Mammal Science,* **4**:141–153.

Seshagiri Rao, C.V. and K. Narayana Rao. 1993. On the landing of a large sized Bottle-nose dolphin *Tursiops aduncus* at Visakhapatnam, along Andhra coast. *Marine Fisheries Information Service Technical & Extension Series,* **120**: 18.

Shannon, E.R. and W. Wiener. 1963. The mathematical theory of communication University of Illinois press Urbana Illions. pp. 117.

Shetye, S. R., A.D. Gouveia, D. Shankar, S.S.C. Shenoi, P.N. Vinayachandran, D. Sundar, G.S. Michael, G. Nampoothiri. 1996a. Hydrography and circulation off the west coast of India during the southwest monsoon. *Journal of Marine Research,* **48**: 359-378.

Shetye, S.R., A.D. Gouveia, D. Shankar, S.S.C. Shenoi, P.N Vinayachandran, D. Sundar, G.S .Michael and G. Nampoothiri. 1996b. Hydrography and circulation in the western Bay of Bengal during the northeast monsoon. *Journal of Geophysics Research,* **101**: 14011-14025.

Shetye, S.R., A.D. Gouveia, S.S.C. Shenoi, G.S. Michael, D. Sundar, A.M.A.K. Santanam. 1991. The coastal current off western India during the northeast monsoon, *Deep Sea Research,* **38**: 1517-1529.

Shcott, F., J. Reppin, J. Fischer and D. Quadfasel. 1994. Currents and transports of the monsoon current south of Sri Lank. *Journal of Geophysics Research,* **99**(C12): 25,127-25,141.

Sigurjonsson, J., T. Gunnlaugsson, P. Ensor, M. Newcomer and G. Víkingsson. 1991. North Atlantic Sightings Survey 1989 (NASS-89):

shipboard surveys in Icelandic and adjacent waters July-August1989. *Report of the International Whaling Commission,* **41**: 559-572.

Silas, E.G. and A. Bastian Fernando. 1985. The Dugong in India - is it going the way of the Dodo. *Proceedings of. Symposium on Endangered Marine Animals and Marine Parks*,1985 MBAI, Cochin, **1**:167-176.

Silas, E.G., P.P. Pillai, A.A. Jayaprakash and M. Ayyappan Pillai. 1984. Focus on small scale fisheries drift gillnet fishery off Cochin, 1981 and 1982. *Marine Fisheries Information Service Technical & Extension Series,* **55**: 1-12.

Silas, E.G., P. Nammalwar and R. Sarvesan. 1985. On the food of Sperm Whale *Physeter macrocephalus* Linnaeus at Tranquebar with a note on the food habits of Sperm Whales. *Proceedings of. Symposium on Endangered Marine Animals and Marine Parks*, 1985, MBAI, Cochin, **1**: 65-71.

Sivadas, M., S. Krishna Pillai and M.R. Arputharaj. 1987. Report on a sperm whale *Physeter macrocephalus* Linn. stranded along the Gulf of Mannar coast. *Marine Fisheries Information Service Technical & Extension Series,* **71**: 16-17.

Sivaprakasam, T.E. 1980. On the unusual occurrence of the Common Dolphin *Delphinus delphis*Linnaeus in longline catches at Port Blair, Andaman. *Journal of the Bombay Natural History Society,* **77**(2): 320-321.

Skov, H., J. Durink, F. Danielsen and D. Bloch, 1995. Co-occurrence of cetaceans and seabirds in the north-east Atlantic. *Journal of Biogeography*, **22**: 71–88.

Small J.A. and G.J. Small. 1991. Cetacean Observations from the Somali Democratic Republic, September 1985 through May 1987. *In:* S. Leatherwood and G. P. Donovan (eds). *Cetaceans and cetacean research in the Indian Ocean sanctuary. Marine Mammal Technical Report* No. 3. UNEP, Nairobi, Kenya. pp 180-210.

Smeenk, C., M.J. Addink, A.B. Van den Berg, C.A.W. Bosman and G.C. Cadee. 1996. Sightings of *Delphinus tropicalis* in the Red Sea. Bonn. *Zoology of Beitr*, **46**: 389-398.

Smith, B.D., B. Ahmed, R.M. Mowgli and S. Strindberg. 2009. Species occurrence and distributional ecology of nearshore cetaceans in the Bay of Bengal, Bangladesh, with abundance estimates for Irrawaddy dolphins *Orcaella brevirostris* and finless porpoises *Neophocaena phocaenoides*. Aquatic Conserv. *Marine and Freshwater Ecosystem,* **19**: 209–225.

Smith, B.D., G. Braulik, S. Strindberg, B. Ahmed and R. Mansur. 2006. Abundance of Irrawaddy dolphins (*Orcaella brevirostris*) and Ganges river dolphins (*Platanista gangetica*) estimated using concurrent counts made by independent teams in waterways of the Sundarbans mangrove forest in Bangladesh. *Marine Mammal Science,* **22**: 527-47.

Smith, B.D., G. Braulik, S. Strindberg, R. Mansur, M.A.A. Diyan and B. Ahmed. 2009. Habitat selection of freshwater-dependent cetaceans and the potential effects of declining freshwater flows and sea-level rise in waterways of the Sundarbans mangrove forest, Bangladesh, *Aquatic Conservation: Marine and Freshwater Ecosystem,* **19**: 209–225.

Smith, R.C, R. Dustan, D. Au, K.S. Baker and E.A. Dunlap. 1986. Distribution of cetaceans and sea-surface chlorophyll concentrations in the California Current. *Marine Biology,* **91**:385–402.

Smith, B.D., U.H. Thant, J.M. Lwin and C.D. Shaw. 1997. Investigation of cetaceans in the Ayeyarwady River and northern coastal waters of Myanmar. *Asian Marine Biology,* **14**: 173-94.

Smith, S.C. and H. Whitehead. 2000. The diet of Galapagos sperm whales *Physeter macrocephalus* as indicated by fecal sample analysis. *Marine Mammal Science*, **16** (2): 315-325.

Smith, B.D. and M. Than Tun, 2008. Species occurrence, distributional ecology and fisheries interactions of cetaceans in the Mergui (Meik) Archipelago, Myanmar. *Journal of Cetacean Research Management,* **10**(1): 37-44.

SPSS, Inc. 2007. SPSS for Windows: Statistics, version 13. SPSS, Inc Chicago II

Stensland, E., P. Berggren, R. Johnstone and N. Jiddawi. 1998. Marine mammals in Tanzanian waters: urgent need for status assessment. *Ambio.* **27**: 771-774.

Stephanis, R.D., T. Cornulier, P. Verborgh, J.S. Sierra, N.P. Glimeno and C. Guinet. 2008. Summer distribution of cetaceans in the Strait of Gibraltor in relation to the oceanographic context. *Marine Ecological Progress Series,* **353:** 275-288.

Stensland, E., A. Sarnblad, I. Carlén, A. Bignert and P. Berggren. 2006. Abundance, distribution and behavioral ecology of Indo-Pacific bottlenose (*Tursiops aduncus*) and humpback (*Sousa chinensis*) dolphins off the south coast of Zanzibar. *Marine Mammal Science*, **22**: 667-82.

Sykes, R., J. Allen and C. Owens. 2003. Factors influencing the seasonal distribution of Bottlenose Dolphins (*Tursiops truncatus*) along the Dorset coast. Annual Meeting of the European Cetacean Society, Tenerife, Spain.

Sutaria, D. and T.K. Jefferson. 2004. Records of Indo-Pacific humpback dolphins (*Sousa chinensis*, Osbeck, 1765) along the coasts of India and Sri Lanka: an overview. *Aquatic Mammals,* **30(1)**: 125-36.

The Wildlife Protection Amendment Act, Govt. of India, Min. of Law, Justice and Company Affairs, 1991, pp. 1–76.

Tananbe, S., H. Iwata, and R. Tatsukawa. 1994. Global contamination by persistent organochlorine and their ecotoxicological impact on marine mammals. *Science of the Total Environmet,* **154**. 263-234.

Thomas, D. 1966. Natural history of Dugong in Rameswaram waters. *Madras Journal of Fisheries,* 80-82.

Thiele, D., E.T. Chester and P.C. Gill. 2000. Cetacean distribution off Eastern Antarctica (80°E-150°E) during the Austral Summer of 1995/96. *Deep-Sea Research .II,* **47**:2543-2572.

Tynan, C. 1996. Characterisation of Oceanographic habitat of cetaceans in the southern Indian Ocean between 82°-115°E: *cruise report from World Ocean Circulation Experiment* (WOCE) 18S and 19S. *(Cross reference)*

Tynan, C.T., D.G. Ainley, J.A. Barth, T.J. Cowles, S.D. Pierce and L.B. Spear. 2005. Cetacean distributions relative to ocean processes in the northern California Current system. *Deep-Sea Research II*: 145-167.

Van Bree, P.J.H and M.D. Gallagher. 1978. On the taxonomic status of *Delphinus tropicalis,* Van Bree, 1971 (Notes on Cetacea, Delphinoidea IX). *Beaufortia,* **28**: 1-8.

Venkataramana, P. and P. Achayya. 1998. On the capture of a bottlenose dolphin off Kakinada. *Marine Fisheries Information Service Technical & Extension Series,* **155**: 20.

Velayutham,P., K. Venkataramanujam and V. Ramadhas. Distribution of Mercury in different organs of the spinner dolphin, *Stenella logirostris*

Wade, P.R. and T. Gerrodette. 1992. Estimates of dolphin abundance in the eastern tropical Pacific: preliminary analysis of five years of data. *Report of the International Whaling Commission,* **42**:533-9.

Wade, P.R. and T. Gerrodette. 1993. Estimates of cetacean abundance and distribution in the eastern tropical pacific. *Report of the International Whaling Commission,* **43**:477-493.

Walker, D and K. Macleod. 2004. Procedding of the workshop on Biscay cetacean research and conservation. Held at European cetaceans society's 17th Annual Conference, University of Las Palamas de Gran Canaria, Canary Islands, Spain 9th March 2003. ECS Newsletter No. 43 Special issue, September 2004. (*Cross reference).*

Warwick R.M. and K.R. Clarke. 1995. New 'biodiversity' measures reveal a decrease in taxonomic distinctness with increasing stress. *Marine Ecological Progress Series,* **129**(1-3): 301-305.

Waring G.T, J.M. Quintal and S.L. Swartz, eds. 2000. US Atlantic and Gulf of Mexico marine mammal stock assessments -- 2000. US Dep Commer, *NOAA Technical Memorandum* NMFS NE 162; 298 p.

Watson, L. 1981. Sea Guide to Whales of the World, Hutchinson, 302 pages.

Weinrich, M., M. Martin, R. Griffiths, J. Bove and M. Schilling. 1997. A shift in distribution of humpback whales, Megaptera novaeangliae, in response to prey in the southern Gulf of Maine. *Fishery Bulletin,* **95**: 826-836.

Weitkowitz, W. 1992. Sightings of whales and dolphins in the Middle East (Cetacea). *Zoology in the Middle East,* **6**: 5-12.

Whitehead, H. 2003. *Sperm Whales Social Evolution in the Ocean.* University of Chicago Press. p. 3.

Whitehead, H. and J.E. Carcadden. 1985. Predicting inshore whale abundance: Whales and capelin off the Newfoundland coast. *Canadian Journal Fisheries and Aquatic Science,* **42**(5): 976-981.

Whitehead, H., S. Brennan and D. Grover. 1992. Distribution and behaviour of male sperm whales on the Scotian Shelf, Canada. *Canadian Journal of Zoology,* **70**: 912–918.

Williams, R., S.L. Hedley and P.S. Hammond. 2006. Modelling distribution and abundance of Antarctic baleen whales using ships of opportunity. *Ecology and Society,* **11.** [online0URL: http//www.ecologyand society.org/vol1/iss1/art1/.

Wishner, K.F., J.R. Schoenherr, R. Beardsley and C. Chen. 1995. Abundance, distribution and population structure of the copepod Calanus finmarchicus in a springtime right whale feeding area in the southwestern Gulf of Maine. *Continental Shelf Research,* **15**: 475–507.

Weir, C.R., C.M. Pollock, C. Cronin and S. Taylor. 2001. Cetaceans of the Atlantic Frontier, north and west of Scotland. *Continental Shelf Research,* **21**:1047-1071.

Whitehead H, S. Brennan and D. Grover. 1992. Distribution and behaviour of male sperm whales on the Scotian Shelf, Canada. *Canadian Journal of Zoology,* **70**:912-918.

Wood, C.J. 1998. Movement of bottlenose dolphins around the south-west coast of Britain. *Journal of Zoology, London,* **246**:155-163.

Woodley, T.H and D.E. Gaskin. 1996. Environmental characteristics of north Atlantic right and fin whale habitat in the lower Bay of Fundy, Canada. *Canadian Journal of Zoology,* **74**:75-84.

Wurtz, M., R. Poggi and M.R. Clarke. 1992. Cephalopods from the stomachs of a Risso's dolphin (*Grampus griseus*) from the Mediterranean. *Journal of the Marine Biological Association.* U.K, **72**:861–867.

Wyrtki, K. 1973. *Physical oceanography of the Indian Ocean: The Biology of the Indian Ocean*, B. Zeitzschel, Ed., Springer-Verlag, Berlin, 18-36.

Yen, P.P.W., W.J. Sydeman and K.D. Hyrenbach. 2004. Marine bird and cetacean associations with bathymetric habitats and shallow-water topographies: implications for trophic transfer and conservation. *Journal of Marine Systems,* **50**: 79-99.

Yousuf, K.S.S.M., A.K. Anoop, B. Anoop, V.V. Afsal, E. Vivekanandan, R.P. Kumarran, M. Rajagopalan, P.K. Krishnakumar and P. Jayasankar. 2008. Observations on incidental catch of cetaceans in three landing centres along the Indian coast. *Journal of Marine Biological Association.* U.K. [Biodiversity Records. Published online].