CONSERVATION ACTION SERIES 20140712

GUJARAT'S GENTLE GIANT

Conservation of Whale Shark (*Rhincodon typus*) in Gujarat

Wildlife Trust of India
www.wti.org.in

FOREST DEPARTMENT GOVT. OF GUJARAT

TATA CHEMICALS LIMITED

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TATA CHEMICALS LIMITED

Wildlife Trust of India (WTI) is a non-profit conservation organisation, committed to help conserve nature, especially endangered species and threatened habitats, in partnership with communities and governments. Our principal objectives include managing or preventing wildlife crises and mitigating threats to individual wild animals, their populations and habitats through holistic strategies and practical interventions.

Established in 1939, Tata Chemicals Limited (TCL) is India's leading manufacturer of inorganic chemicals, fertilisers and food additives. Part of the US$ 22 billion Tata group, the company owns and operates the largest and most integrated inorganic chemicals complex in the country at Mithapur, Gujarat. The company's state-of-the-art fertiliser complex at Babrala, Uttar Pradesh, is known for its world-class energy efficiency standards, and has won several awards in the fields of environmental conservation, community development and safety. TCL's phosphatic fertiliser complex at Haldia in West Bengal is currently the only manufacturing unit for DAP/NPK complexes in West Bengal. The acquisition of an equal partnership in Indo Maroc Phosphore S.A. (imacid) along with Chambal Fertilisers and the global phosphate major, OCP of Morocco recently, is the first step that TCL took towards globalisation. In early 2006, TCL acquired the UK based Brunner Mond Group (BM). This acquisition makes TCL one of the most diversified companies with manufacturing facilities in three continents and markets across the world. Tata Chemicals Society for Rural Development (TCSRD) was established by Tata Chemicals in 1980 for the benefit of the rural population in an around the company's plants and township. Over the years it has initiated a number of development, welfare and relief activities. 2004 onwards, WTI with support of Tata Chemicals has worked hard and turned the hunters of whale shark into its protectors. Whale shark is now called *Vhali* "the dear one" and people celebrate whale shark day at the local level. Tata Chemicals won the Green Governance Award 2005 for the Whale Shark Conservation Project. The award was given by Dr Manmohan Singh, former Prime Minister of India on November 10, 2005 in New Delhi.

The Gujarat Forest Department is entrusted with the prime responsibility of protection, conservation and development of forests and wildlife of the state. They have extended support to the Whale Shark campaign even beyond the shores of the state.

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Message

Dr. C. N. Pandey, IFS
Principal Chief Conservator of Forests and
Chief Wildlife Warden (WL)
Gujarat.

It is gratifying to see the Whale Shark Conservation Project, initiated in the year 2003 through initiative of the Gujarat Forest Department, the Wildlife Trust of India and corporate houses come of age.

The project began with a massive awareness campaign (see Turning the Tide) followed by a scientific study initiated in 2008 to find answers to specific questions. However, what I am particularly pleased about is that the project has allowed the main stakeholders – the fishing community to take a lead in conserving this magnificent animal by releasing the whale shark accidentally caught in their net.

Recently, a self-documentation scheme introduced by WTI, with the forest department which essentially entails giving the fishermen water-proof cameras to document cutting the net themselves, resulted in greatly reducing the stress on the fish and increasing its chances of survival, as the amount of time it spent in the net came down. This project has now become a well- tested model of conservation.

I am also happy that the world also has acknowledged the success of this project in the form of the recent UNDP award to this project. There is still a long way to go as more fishermen need to be empowered to save the fish. However, I am sure with Gujarat Forest Department's commitment to facilitate the initiative this goal shall soon be met too.

The first successful satellite tagging of the whale shark in India by WTI and the Gujarat Forest Department has paved the way forward to understand the whale shark movement in Indian waters. Genetic studies and research have yielded interesting data which support previous findings of high genetic diversity in whale shark populations.

This report captures all the scientific initiative that have been taken from 2008 to 2013 for this species through this project and will create the much needed awareness to manage this species and other marine life better.

Date: 20th June, 2014 **(Dr. C.N. Pandey)**

FOREWORD

Whale sharks are the world's largest fish. Yet, they remained unknown, hidden underneath the ocean depths, to all except the fishing communities in India until about two decades ago.

In Gujarat where most sightings were recorded, the fishing communities called it 'barrel' — an indication to the tool used to hunt this species. The fish was hunted in hundreds for liver oil used in water-proofing boats and the by-product meat was exported.

In 2001, the whale shark was brought under protection of Indian laws, making it the first fish to be listed in Schedule I of the Indian Wildlife (Protection) Act, 1972. However, awareness was low, mandating a campaign to let people know its legal status, and to change perceptions about this fish in itself.

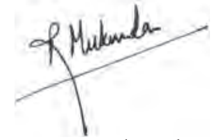
In 2004, the Gujarat Forest Department joined hands with International Fund for Animal Welfare – Wildlife Trust of India (IFAW—WTI) and Tata Chemicals Limited to begin the widely acclaimed Whale Shark Campaign.

The campaign brought about unprecedented change in the mindset of the people of Gujarat regarding the whale shark. The fishermen began releasing whale sharks accidentally trapped in their nets; local authorities in eight cities declared the fish as city mascots; a whale shark day was declared and many others. The campaign had converted the quarry to an icon, from 'barrel' to Vhali – the dear one.

At Tata Chemicals many employees also volunteered their effort towards the "Save the Whale Shark" campaign. Following on the success of the campaign, we started scientific efforts to learn more about this fish. This has included establishing a camp office at Mithapur for the study and initiatives like photo-identification, satellite or physical tagging, genetic studies, even as freeing the whale shark by the fishing communities continued in Gujarat.

The activities carried out have not just helped save whale sharks in Gujarat but has become a role model for the conservation of this species across the country.

Of course, there is more work required to unravel the mysteries of this unique fish – also known as the gentle giants of the sea. As we recommit ourselves to continued efforts in conservation of whale sharks in the country, we are happy to come out with this publication that chronicles the activities carried out over the past five years through our collaborative project.



R. Mukundan
Managing Director,
Tata Chemicals Limited

PREFACE

The whale shark is indubitably the largest fish in the world. The conservation of the whale shark is debatably the most successful conservation project undertaken by WTI in its history. This project in collaboration with Tata Chemicals Limited and the Forest Department of Gujarat has won several conservation laurels. These include the BNHS Green Governance Award in 2005, as well as the Gujarat Ecology Commission (GEC) Award for 18 environment friendly practices of Gujarat for whale shark rescues in 2012, both for Tata Chemicals Limited. The UNDP-MoEF Indian Biodiversity Award was also recently awarded to the Gujarat Forest Department for co-management in the Whale Shark Conservation Project in 2014.

For us at WTI, these awards given to our partners are the culmination of eleven years of hard work, first in designing and implementing an on ground campaign, then in the policy work that followed at centre and state, then in the rescue of the sharks themselves and finally in entering the domain of science to know more about this wondrous creature.

This report documents those eleven years and the many milestones that come with it. For me personally the memories of first distributing Mike Pandey's film at the CITES conference in Santiago in 2002, my very first visit with my then Vice Chair Sujit Gupta to the coast of Gujarat to see the location of the whale shark Arribadas and attending the Whale Shark Day celebrations at Porbander with thousands of school children thronging the streets are all equally vivid. That from those early days, using the charismatic appeal of the social activist and guru Morari Bapu, so much has been achieved is testimony to a well-planned and choreographed campaign. Eight cities adopting the whale shark as a mascot, the Gujarat government announcing a relief scheme for fishermen who cut their nets and freed the shark, the popular movement that christened the hitherto un-named fish as Vhali or the loved one were all unprecedented. And what was even more interesting was that all this was being done, not for the tiger, not for the elephant, not even for Gujarat's own symbol of wildlife the lion, but for a fish.

Within one year of launching the campaign in 2004, it was won. Nobody in Gujarat killed the whale shark anymore. Yes, we had to do much more to ensure that the policy was in line with the campaign findings. Most certainly much had to be learnt about the movements, behaviour and demography of whale sharks off our coasts. But the conservation imperative of stopping the killing of hundreds of sharks annually had come to a grinding halt. There could not have been a more spectacular and swift ending to a conservation campaign.

And thus, with this report we document the planning, acknowledge the partners and popular support and celebrate a great conservation victory. May more happen in the whale sharks wake, especially in the marine realm where conservation success is a rare creature.

Vivek Menon
Executive Director & CEO
Wildlife Trust of India

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We wish to express our gratitude to Dr. S. K. Nanda, Additional Chief Secretary, Home Department, Government of Gujarat, Mr. Pradeep Khanna (Former Principal Chief Conservator of Forests, Gujarat), Mr. Satish K. Goyal, (Former Principal Chief Conservator of Forests (WL), Gujarat), Mr. C. N. Pandey (Principal Chief Conservator of Forests and Chief Wildlife Warden, Gujarat) for their support in providing permission to undertake this work. Mr. G. Yadaiah (Chief Conservator of Forests), Ms. Aradhana Sahu (Deputy Conservator of Forests), Mr. B. V. Padshala, (Former Range Forest Officer), Mr. N. B. Dodiya (Range Forest Officer) and Mr. M. M. Goswami (Forester) for their help throughout the project.

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We would like to thank Scientist-in-Charge, Mr. Koya Mohammed from CMFRI, Veraval for analyzing physico-chemical parameters to study the whale shark habitat in Gujarat waters. We are thankful to the Principal Scientist & Head, Dr. K. K. Vijayan from CMFRI, Cochin for analyzing whale shark tissue sample for studying whale shark genetics in Gujarat waters.

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We appreciate the technical support given by the Wildlife Institute of India for the project. Our sincere thanks to all the staff and students of Choksi College and Fisheries College, Veraval for their undeterred support in campaign activities.

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Last but not the least we are sincerely thankful to Siddique Adham, Hameed, Imran, Altaf and all the Fishermen Patels (Heads) and Fishermen of Sutrapada, Veraval, Dhamlej and Mangrol for their sincere support in conserving and studying this magnificent animal.

EXECUTIVE SUMMARY

The largest fish on earth, the whale shark *(Rhincodon typus)* is a large, plankton-feeding, ovoviviparous and highly migratory shark species. Although widely distributed across tropical and warm temperate seas, limited information is available on the population status of this species, especially along the Indian coastline. Catch statistics and anecdotal reports suggest that this unique species along the Indian coast is in severe decline. The species is mainly threatened by unregulated and unsustainable capture to meet international trade demands for shark fins, liver oil, skin and meat. Other threats include accidental entanglement in trawl nets and set nets, collision with boats, as well as extensive coastal pollution.

Prior to 2001, due to the lack of legal protection, whale sharks were ritually, brutally and extensively hunted across the shores of Gujarat state in western India. This was brought to light by the documentary film, “Shores of Silence” by Mike Pandey. The film highlighted the plight of the whale shark, and went on to not only win the Green Oscar Award but also attract large-scale attention of policymakers and conservationists alike, towards this species. Following this, the Wildlife Trust of India (WTI), along with Mike Pandey, actively lobbied with the Ministry of Environment and Forests (MoEF), for legal protection of the species by placing it in the Schedule I of the Wildlife (Protection) Act, 1972. In the year 2002, due to the efforts by India and the Philippines, the fish was included under (Appendix II) of the Convention on International Trade in Endangered Species (CITES). WTI further escalated its lobbying in Santiago, Chile, to garner more attention on the species’ conservation status. It subsequently conducted a brief survey in 2004 along the coastal town of Veraval and the inland city of Ahmedabad, in Gujarat. The survey revealed low awareness level (19%) on poaching and the protection status of whale shark among the people of Veraval, the hub of the whale shark slaughter.

From whale shark campaign and rescue to whale shark science

Following the survey, WTI launched a large-scale whale shark awareness campaign in 2004 in Gujarat, with special focus on Veraval and Ahmedabad. The widely-acclaimed whale shark campaign spread awareness on the plight of the species and its protected status in Gujarat. It not only helped convert Gujarat fishermen into protectors of the whale shark by bringing about a major change in the perception and attitude of local people, but also helped in local protection of the species. Since its inception and by the end of 2013, over 372 whale sharks had been rescued and voluntarily released by fishermen.

The campaign also led to a model relief programme that offered monetary support to fishermen whose nets were damaged or had to be cut open during the rescue and release of whale sharks. Despite the efforts of the rescue team, a large number of whale sharks were still dying due to entanglement and stress induced mainly by the extensive travel time taken by the rescue team to reach the site and address the situation. To speed up the release and reduce stress on the sharks, a self-photo documentation process started. 1200 water proof cameras were distributed to fishermen in Sutrapada, Dhamlej and Veraval. The captured images of a rescue by fisher folk served as evidence to prove the damage to nets. The photos also helped fishermen claim financial relief from the government scheme to repair/ buy nets.

Although large-scale hunting of whale sharks in Gujarat has been curbed, a greater understanding

of the species ecology is still required. Due to the dearth of scientific information on whale sharks in India, the generation of baseline data/ information on its population, ecology and migration across the entire Indian coastline is necessary to plan conservation measures and aid the recovery of the species along India's coastline.

Whale shark science

Acknowledging this need, WTI with support from Tata Chemicals Limited launched the Whale Shark Conservation Project in November 2008. The project was initiated after constituting the Scientific Advisory Council (SAC) and a Governing Council (GC) to facilitate its implementation. While the SAC included Indian and international marine experts, the GC included the project implementers and senior Gujarat Forest Department officials.

The thrust of the project was to :

a) Enhance the efficacy of rescue and the release of whale sharks through community participation

b) Identify whale sharks through photo identification for migration studies

c) Create a genetic profile of the whale shark population across Indian waters in relation to global waters

d) Mark whale sharks with markers and satellite tags, to understand their migration patterns and habitat utilisation

e) Explore the prospect of community based whale shark tourism to provide alternate livelihood options to fishing communities

Photo-identification

Implemented with the aim of contributing to population estimates as well as studies on whale shark migration, photo-identification entails underwater photography and comparison of the photographs with the global database. The photo-identification carried out under the project, contributed whale shark photographs to the database managed by ECOCEAN. Whale sharks are identified using the pattern of spots, which are unique (equivalent to stripes in tigers) for each individual. India began contributing to global whale shark research with the initiation of photo-identification in 2010. The first individual from Indian shores was identified in April, 2010. It was labelled as I-001 and was a new entry to ECOCEAN's global database. After this, only one more individual was added to the database.

Genetic analysis

Whale sharks also occur in the off shore waters of India. It is believed there are discrete whale shark population in the different seas with varied genetic signature. Therefore, genetic analysis of whale shark along the Gurajat coast has shed light on the genetic varied diversity of whale sharks as well as helped establish the relationship between whale sharks along the Indian coast with different populations across the globe, In addition, it has also contributed to understanding the species' long term migratory patterns, to some extent.

Migration studies

After tagging the whale sharks with marker tags and satellite tags, and through the use of online tracking portals, WTI was able to track whale shark movement along the west coast of India and their migratory patterns, and also understanding the habitats preferred by the species.

Whale shark tourism

The value of whale sharks in terms of the revenue generated through tourism is much higher compared to that generated from whale shark hunting. This has been established in Australia, which is among the few countries with best-known whale shark tourism practices in the globe. This project has explored the possibility of establishing whale shark tourism in India with an aim to provide incentives to coastal communities for contributing to conservation of marine wildlife and their habitats, as well as to garner greater public support and awareness towards the conservation of this species.

Whale shark recovery plan development

A whale shark status survey was started in 2008 along India's west and east coast to identify whale shark aggregations and develop state-level recovery plans for the species. As of today, whale shark aggregation sites have been identified along India's west coast and draft recovery plans have been developed.

The Wildlife Trust of India intends that the Whale Shark Conservation Project will generate voluminous information on the species distribution, ecology and migratory patterns, which will provide the basis for the development of a whale shark management strategy that takes into account both the conservation needs of the species and the economic needs of fishermen, the direct stakeholders of this project.

Since the initiation of the project in late 2008, till the project tenure of September 2013, several milestones have been achieved and WTI is confident of extending the whale shark conservation project beyond the Gujarat coast to other states along India's west coast and hopes to join global efforts in whale shark conservation, research and management. It also hopes to pursue enhanced conservation science and field action with corporate and community support to make the whale shark population in the Arabian Sea a global hotspot.

MoU signing between (left to right) Vivek Menon (WTI), Homi Khusrokhan (TCL), Dr. S. K. Nanda and Pradeep Khanna (Gujarat Forest Department)

RECOGNITIONS

Former Prime Minister Shri Manmohan Singh presenting the BNHS - Green Governance Award to TCL, 2005

The project team at the BNHS Green Governance Award Ceremony, 2005

Junagadh Forest Division of Gujarat receiving Indian Biodiversity Award, 2014 for co-management of whale shark conservation with fishing community

CHAPTER 1

Project background and objectives

> **Globally, the best documented whale shark sites are in the Gulf of Mexico, Gulf of California, Belize, Honduras, Western Australia, the Galapagos, New Zealand, Philippines, Indonesia, Madagascar, Mozambique, Kenya, India, Pakistan, Maldives, Seychelles, Indonesia and Thailand**

The whale shark belongs to the order *Orectolobiformes* and is the only species in the family *Rhincodontidae*. Although it does not have close relation with other sharks, it shares some features with sharks belonging to the order *Orectolobiformes,* such as the nurse shark (*Ginglymostoma cirratum*) and the zebra shark (*Stegostoma fasciatum*). The whale shark (*Rhincodon typus*) is a slow-moving filter-feeding shark and the largest known extant fish species. There are two other large filter-feeding sharks, the basking shark (*Cetorhinus maximus*) and megamouth shark (*Megachasma pelagios*), but they are in the mackerel shark order and are not closely related to the whale shark.

Whale sharks lives in all tropic and warm-temperate seas, except the Mediterranean. They are thought to be primarily pelagic (preferring an open-ocean habitat) but seasonal feeding aggregations are also known to occur at several coastal sites throughout the tropics. The whale shark is known to occur in the waters of over 130 countries (Turnbull and Randell 2006 a), and the best-documented whale shark sites are in the Gulf of Mexico, Gulf of California, Belize, Honduras, Western Australia, the Galapagos, New Zealand, Philippines, Indonesia, Madagascar, Mozambique, Kenya, India, Pakistan, Maldives, Seychelles, Indonesia, and Thailand. The first historic account describing a whale shark was from Seychelles waters, in an entry in the ship's log of the Marion Dufresne expedition in 1768, just 12 years after the first settlement of these islands (Lionnet, 1984). The first record of a whale shark being fished is also from these waters, in the 1805 log of Captain Philip Beaver (Smith, 1829), and foretells the fate of the species in the Indian Ocean. Despite these early records and the first scientific recording of the species from the Indian Ocean by Andrew Smith in 1828 and 1829 (Smith, 1829), remarkably little is known about the whale sharks' range and status in this region (Fowler, 2000). Targeted fisheries in the northern Indian Ocean show a dramatic decline of the species (Hanfee, 2001) calling for an urgent review of the species status in this region.

Whale shark is generally of limited value to traditional fisheries. However, since the early 1990s, an increase in demand for whale shark flesh and fins in some Southeast Asian countries, especially Taiwan (Chen *et al.* 1997), led to localised targeted increase in

fishery landings in some regions, especially the Philippines, India and Taiwan. Artisanal fishing for whale sharks has existed in a number of countries, e.g. Indonesia, the Philippines, Iran, Maldives, India and Pakistan (Anderson and Ahmed (1993), Hanfee (2001), Compagno (2002), Rowat (2007), White and Cavanagh (2007)). The surface swimming behaviour of whale sharks has also led to mortality from collisions with boats, which are not often reported but presumably are a regular occurrence in some areas (Rowat 2010). Strandings are also relatively common in some areas, e.g. off South Africa where it is thought that the whale sharks may be killed or stunned by sudden chilling due to cold water masses (Beckley *et al.* 1997).

Over the last two decades, a number of countries have banned fishing of whale sharks, e.g. Maldives in 1993 (Anderson and Ahmed 1993), the Philippines in 1998 (Pine *et al.* 2007), Honduras in 1999 (Compagno 2002), Thailand in 2000 (Fishing Act B.E. 2490), India in 2001 (Wildlife Protection Act, 1972), Palau (2003), Belize in 2003 (Graham 2007), Seychelles in 2004 (Wild Animals Bill), and Taiwan in 2008. The increase in fishing effort and targeted fishing for elasmobranchs in the world oceans led to concerns over the sustainability of vulnerable species, including whale sharks, given their low productivity. International policies relating to conservation and protection of whale sharks, include Appendix II of Convention for the Conservation of Migratory Species of Wild Animals in 1999 (CMS 1999), Appendix II of CITES (Convention on International Trade in Endangered Species) (CITES 2002) (Fowler 2000), Annex 1 (Highly Migratory Species) of the United Nations Convention on the Law of the Sea (UNCLOS), and the Convention on Biological Diversity. Despite its protected status in many countries, illegal and incidental capture of the species continues to be reported (Kasinathan *et al.* 2006; Riley *et al.* 2009).

In spite of the ban on the fishing or killing of whale sharks or possession of whale shark products in India, incidental catch of the species has continued along the coastline (Romanov (2002), Chaudhary *et al.* (2008), Sajeela *et al.* (2010)), where some cases go unreported due to the large area covered. This is in part due to the lack of awareness of the imposed law, lack of education on vulnerability of the species and the high cost incurred when rescuing and releasing an accidentally netted whale shark, including a stranding and rescue operation network.

In view of this plight of the species, WTI, in partnership with the Gujarat Forest Department (GFD) and Tata Chemicals Limited (TCL), felt the need to initiate a whale shark conservation project along the west coast of India.

A better understanding of the ecology of the whale shark and defining critical habitats off the west coast of India would help in the long term conservation of the species globally

The broad objectives of the conservation action project are to :

- Rescue and release the incidentally captured whale sharks
- Track whale shark migration in the marine environment
- Understand whale sharks relationship with its marine habitat
- Genetically profile whale sharks in Indian waters
- Assess whale shark aggregation areas on the Gujarat coast
- Create awareness through campaigns
- Explore the prospect of whale shark tourism in Gujarat

CHAPTER 2

Project area

The state of Gujarat along India's west coast has a 1600 km coastline with a continental shelf extending over an area of 1,84,000 km^2. The state comprises 13 coastal districts, with 263 fishing villages. A total of 123 fish landing centres are spread across the 13 coastal districts. The landing centres support 24,152 fishing crafts, of which 13,047 are mechanised craft, 7,376 motorised and 3,729 traditional crafts. Based on the State fisheries statistics 2012, the total fishing population in Gujarat is 3,23,215, which depends heavily on marine resources for their livelihood.

The study area and base station for the project activities were selected based on the following criteria:

> **The project area comprising of four villages along the Gujarat coast, was chosen, taking into account historical whale shark landing and sighting records and accessibility to the landing centres and the sea**

- **Historical whale shark landing records:** Gujarat has the highest recorded landings of 279 sharks in Dec 1999 alone, with nearly 40 whale shark landings in a single day (Hanfee. 2001). This was the primary reason for initiating a conservation action programme in the state. A review of the landing records of Gujarat revealed that Gujarat coast had the highest hunting records of whale sharks before the ban. The data also provides the whale shark abundance in the targeted locality.
- **Whale shark historical sighting:** Whale sighting records off the coastal villages in Gujarat were collected by interviewing fisherfolk. This information provided the team possible whale shark aggregation sites along the Gujarat coast, where the team could focus their attention.
- **Community involvement:** As the project objectives also required the involvement of local communities in the conservation programme, assisting and empowering them, the fishing villages along the Gujarat coast which were earlier involved in whale shark hunting and trade were chosen to be WTI's main focus of attention. While the local government authorities were willing to collaborate, Tata Chemicals Limited who supported the project, was also located in Gujarat, hence, the project was initiated along the Porbandar coast.

- **Accessibility:** A focal point with access to maximum landing centres and to the sea was also considered for setting up of a base station. Based on these criteria, the following sites were selected for implementing the project.

2.1. Project area

Based on the past records of whale shark landing and hunting along the coastal areas of Gujarat, four major fishing villages i.e. Veraval, Sutrapada, Dhamlej and Mangrol in Junagadh district, were found to be most sensitive sites, as they had the maximum number of incidental capture of whale sharks, and had active fishing ports and landing centres. The following four sites were chosen as the project area:

2.1.1. Veraval

Veraval town, situated along the Saurashtra coast, is one of the largest fish landing zones of Gujarat. It has three fish landing centres: Jaleshwar, Bhidiya and Veraval port which accounts for 20 to 30% of fishermen of the total population of the three towns. As per provisional reports of Census India, the population of Veraval in 2011 was 153,696; comprising 78,1661 males and 75,535 females. The fishermen of Veraval and Bhidiya port mostly belong to Kharva samaj (community) and Koli samaj, whereas more than 90% of Jaleshwar fishermen belong to Machhiyara samaj. There are about 5000 IBM (in board motor) trawler boat operators at Veraval, including Bhidiya port and at least 1500 OBM (board motor) small fibre boats (locally called 'peelani' boat) operate from Veraval port, including Jaleshwar fishing point. Veraval was also selected for setting up the base station as it was strategically a good location for accessibility into the sea and other project sites.

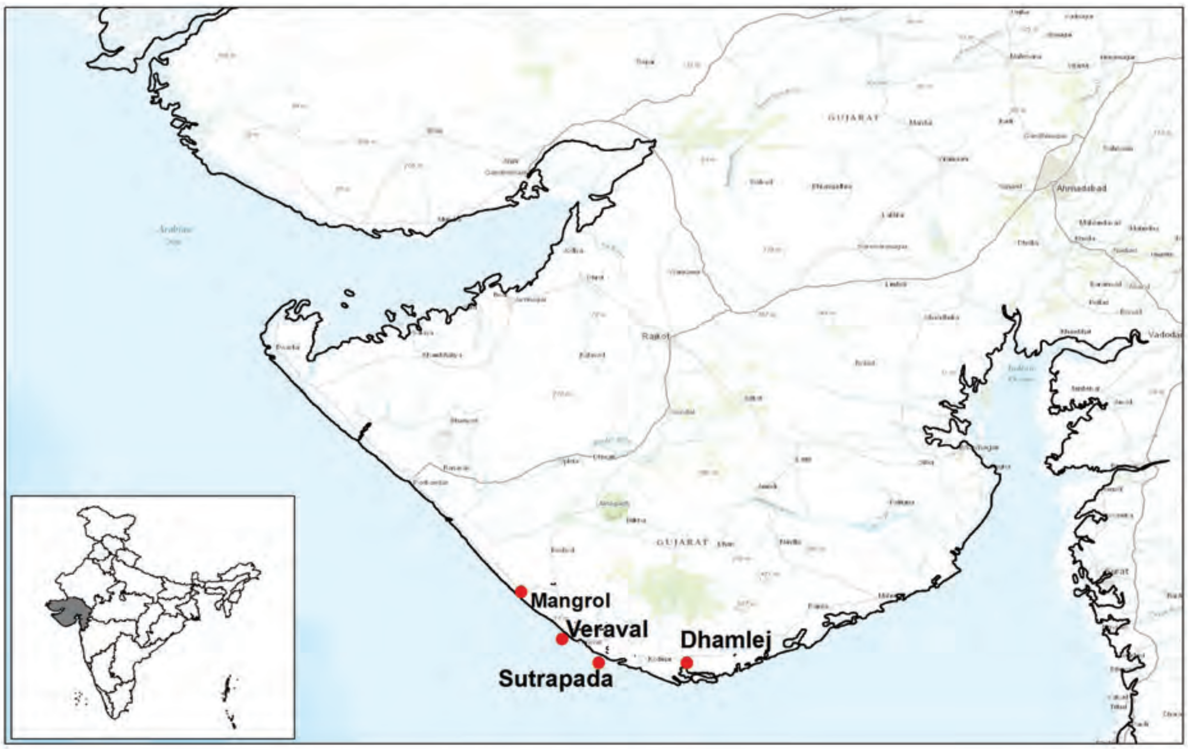

Fig. 1: Project area along the Gujarat coast

2.1.2. Sutrapada

Sutrapada is 20 kms south of Veraval, towards Kodinar. Sutrapada has a total population of 1,22,406, of which 62,435 are male and 59,971 female. About 20% of the population comprises fishermen who are isolated from the rest of the population and inhabit the Sutrapada coast. In Sutrapada, there are 60 IBM (comparatively smaller than a trawler and locally called '*bethada*') and 800 OBM small fibre boats operated by fishermen.

2.1.3. Dhamlej

Twenty kilometres north of Sutrapada is Dhamlej, a previous whale shark landing village, which also has a considerable number of fishermen who depend on daily fishing for their livelihood. The total population of Dhamlej is about 70000, of which 30-40% are fishermen, who live separately along the coast of Dhamlej. There are 600 to 700 OBM (Out Board Motor) boats operated by the Dhamlej fishermen. It has only two *bethada*, but does not have any trawler.

2.1.4. Mangrol

Mangrol is situated 50 km north off Veraval, towards Dwaraka and is one of the most important fish landing centres along Gujarat's Saurashtra coast. The total population of Mangrol is 1,32,733, which comprises of 68,186 males and 64,547 females. The fishermen comprise 15-20% of Mangrol's population. Like Veraval, Mangrol also has a considerable number of trawler boats, in addition to '*peelani*' fibre boats. There are over-1500 trawler boats and 500 small fibre '*peelani*' boats operating at Mangrol fishing port. Mangrol has emerged as one of the well-known fishing boat building centre in Gujarat, in addition to Veraval.

2.2. Demography of the selected project sites

As interaction with the fishing community was an essential component of the project. A demographic understanding of the locations was compiled by the project sociologist. A literature survey, community interaction and a field survey by the sociologist revealed the following,

Gujarat fishermen community comprise of four different castes; Rajput Kharwa, Koli Kharwa, Ghoghala samaj, Machhiyara samaj (the only Muslim fishing community).

2.2.1. Rajput Kharwa

Rajput Kharwa is the largest fishing community among the four. Members of the community are Hindus by religion and Rajputs by caste. They are based largely on the Veraval coast. Rajput Kharwas are comparatively more literate and economically better off than the other communities of fishermen.

2.2.2. Koli Kharwa

The second major community of Hindu fishermen is Koli Kharwa, concentrated in Bhidiya site of Veraval coastland, but also based in several village settlements in Saurashtra and a few other parts of coastal Gujarat. They are also known by their sub-castes, such as, Moila Koli, Ghedia Koli, Ghoghaliya Koli etc.

2.2.3. Ghoghala

Also Hindus, this community is mostly based in Sutrapada, Dhamlej and Muldwarka fishermen villages.

2.2.4. Machhiyara

Machhiyaras are the only Muslim fishermen community, concentrated mostly in Jaleshwer area, adjacent to Veraval. A few Machhiyara families also inhabit Muldwarka, Dhamlej, Hirakot, Chorwad and Mangrol Bara regions of Saurashtra coast of Gujarat.

CHAPTER 3

Historical whale shark occurrence and distribution along the coast of Gujarat: A survey

Owing to colossal hunting globally, whale shark numbers dwindled and they needed legal protection. It was unlikely that they could tolerate intensive fishing pressures as they grow slowly and mature late in life

Despite their size and ranging patterns, whale shark (*Rhincodon typus)* is among the most threatened species of the world. People have hunted whale sharks for years for their meat and fins and bones for use in delicacies and medicines, skin as an abrasive and mostly for their massive livers for extraction of oil. The World Conservation Union (IUCN 2013) lists the whale shark as vulnerable to extinction, as a result of directed fisheries, high value in international trade, a highly migratory nature, a K-selected life history and generally low abundance (Norman 2000). Owing to this colossal hunting globally, their numbers have dwindled and they are hence given legal protection by various countries, among which the Indian Government had given the highest possible legal protection under the Schedule–I of the Indian Wildlife (Protection) Act, 1972 as amended in 2002.

It is unlikely that whale sharks can tolerate intensive fishing pressures because they are thought to share the typical elasmobranchs' life-history patterns of slow growth and late maturity (Colman 1997). The effects of overfishing of this species may be manifested in other parts of the world since these are reported to be highly migratory with some individuals travelling thousands of kilometres across oceans (Eckert and Stewart, 2001).

Whale shark abundance in Taiwan (Chen and Phipps, 2002), India (Hanfee 2001), Philippines (Alava *et al.* 1997) has been inferred from fisheries dependent data. Although catch independent population estimates of marine mammals are commonly available, in part due to their need to surface and breathe, most population estimates of large migratory fish, particularly sharks, remain primarily based on catch-dependent/by catch data. These surveys are, therefore, linked to fishing areas/zones as opposed to the species' activity spaces or full habitat range and, therefore, may not adequately represent the studied populations (Graham and Roberts, 2007). However, very little is known about their occurrence, numbers and home range. Though whale sharks were reported from all

along the Indian coast, majority of the reports are from the north western maritime state of Gujarat from where, 1,866 whale sharks were reported between 1989 to 1998 (Pravin, 2000). A staggering 591 whale sharks were reportedly caught and slaughtered during 1999-2000 alone along the Gujarat coast (Hanfee. 2001). After the launch of awareness programmes by the Wildlife Trust of India (WTI) in 2004, supported by Tata Chemicals Limited (TCL) and in collaboration with the Gujarat Forest Department and the local fishing communities (Chaudhary *et al.* 2008), it was felt necessary to have some knowledge of their historical occurrences in the off-shore waters off the state of Gujarat where nearly 187 whale sharks were released from fishing gears during 2004-2005. The survey aimed to find whether there was any change in the seasonality and place of occurrence, numbers and associations of whale sharks if any, with marine mammals, over the past 50 years along the Gujarat coast.

3.1. Survey area

The state of Gujarat is located on the north-western side of the Indian peninsula, with a coast line of 1600 km, with an estimated 3,23,215 fishermen from 263 marine fishing villages dependent on marine and coastal fishery resources. The survey was undertaken from September−October 2008, covering 31 key fishing villages across the coast of Gujarat, starting from Jakau in the north and extending up to Nargol in the south (Fig. 2).

Based on the prevailing fishing practices and also for the benefit of analysis and presentation, the entire coastline of Gujarat was divided into three regions, Region-I, starting from Jakau in the north to Salaya in the south; Region-II, starting from Rupen in the north to Jafrabad in the south; and Region-III, starting from Hajira in the north up to Nargol in the south (Fig. 2).

3.2. Methodology

The survey was done in three phases, covering one region at a time. Fishermen above the age of 55 and who have already retired from active fishing were selected for the survey. 151 fishermen from 31 villages were interviewed for the survey (Appendix I). The questionnaire was developed following Maynou *et al.* 2011, except

Fig. 2. Map showing survey area

that the time period was not further divided into any segments owing to the stress put on interviewees' memory.

A questionnaire was circulated to 151 fishermen who were 50-95 years old and have been fishing, as their traditional means of livelihood, since they were 12-15 years old

After recording the name, age and place, the questions asked during the interview included: 1) the age at which the interviewee started fishing, 2) the age at which he stopped fishing, 3) whether he had seen a whale shark during his fishing career, 4) if, yes, the frequency, 5) the season in which most of the sightings occurred, 6) whether they observed any change in the seasonality of occurrences during their fishing career, 7) the number of whale sharks seen together mostly, 8) the location of frequent sightings, such as the distance and direction from the shore, depth at sightings, 9) the estimated number of encounters during their career, 10) whether they had seen any mammals such as whales, fin-less porpoises and dolphins, 11) if so, their frequency, 12) and their location 13) whether they observed any association between whale sharks and mammals and/or sea turtles etc.

Questions one and two were asked to calculate the time period from which the fishermen reported their observations. For questions, four and eleven, the interviewees were asked to rate frequency as frequent, occasional and rare. Pictures of mammals were shown for easy and accurate identification.

3.3. Results

Since the respondents were between 50-95 years old and they took to fishing as a traditional source of livelihood since they were 12-15-years-old, the results were based on observations made by them over a period of 54 years, from 1926 to 1980, going back to 82 years in time (Table 1) since the beginning of the present study. For the ease of presentation and understanding, the results are presented separately for the three regions viz., Region–I (Kachchh), Region–II (Saurashtra) and Region–III (Khambhat).

3.3.1. Region – I

The northern coast of Jamnagar and Rajkot districts were also included in the Kachchh region during the survey, keeping in mind the prevailing fishing practices. A total of 66 fishermen were interviewed from eight fishing villages, namely, Salaya, Sikka, Bedi, Tuna, Bhadreshwar, Mundra, Mandvi and Jakhau. The fishermen interviewed were between 60 and 92 years of age (Fig. 3).

A total of 66 fishermen were surveyed from various fishing villages from this region, among whom, 37.8% reported to have seen whale sharks during fishing operations for more than two decades, and about 62.2% reported not having seen a whale shark during their fishing life (Fig. 4).

The likelihood of sighting a whale shark had shown a gradual decline from Salaya towards Jakhau in the northern most part of Gujarat (Fig. 5). Among the 37.8% (n=25)of respondents who reported to have seen a whale shark, 24% (n=6) reported to have sighted them frequently and 76% (n=19) reported occassional sightings off the coast of Rupen and Okha (Fig. 6).

Table 1. Age class and average age of the fishermen interviewed from the three regions surveyed

Region of survey	No. of interviews	Age range of interviewees	Average age
Region – I (Kachchh)	66	60 – 92	70.7
Region – II (Saurashtra)	66	50 – 95	63.4
Region – III (Khambhat)	19	55 – 80	62.1

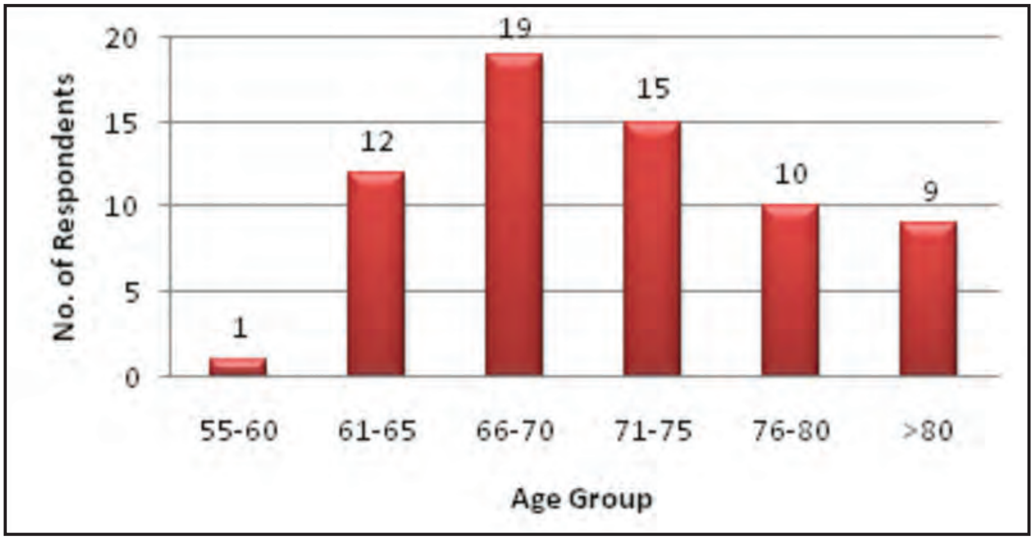

Fig. 3. Distribution of respondents across various age groups

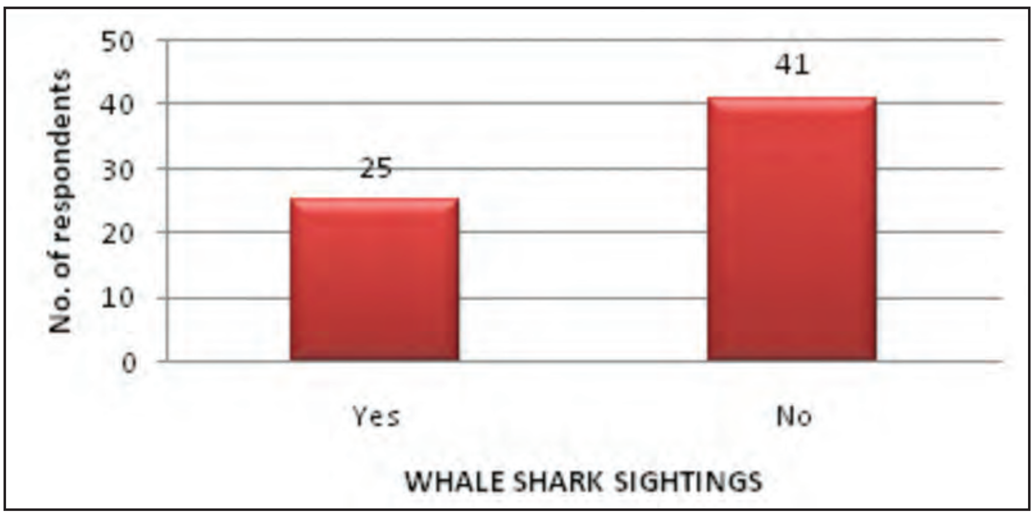

Fig. 4. Whale shark sightings in the Kachchh region

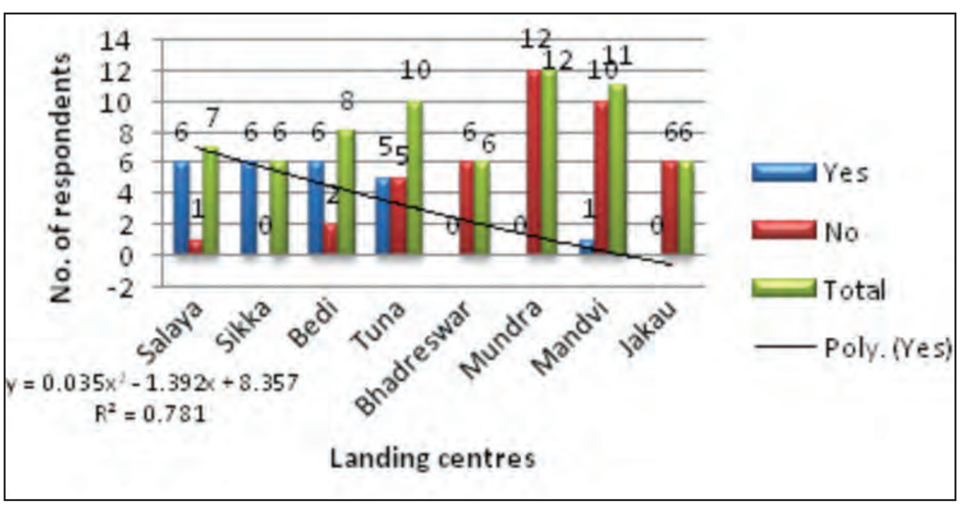

Fig. 5. Whale shark sightings across various landing centres in Kachchh region

The seasonality of sightings began in October, attaining a peak during November-March and lasting up to April, and sometimes even till May. However, most sightings reportedly occurred between November and April (Fig. 7).

Among the respondents, 36% (n=9) claimed to have had less than 50 whale shark encounters during fishing, 24% (n=6) had 50 to 100 enconters, and 40% (n=10) had more than 100 encounters during their fishing lives (Fig. 8).

About 36.9% of the total respondents reported to have sighted whales, 18.4% had seen fin-less porpoises and 69.2% had seen dolphins during their fishing operations. However, no one had reported seeing a dugong even once. Dolphins were reported to have been sighted frequently by 60% of the respondents, 33.3% have reported to had seen them occassionally, and only 2 of the respondents said that they rarely saw them during a fishing operation. With respect to other marine mammals, 58% of the respondents reported occassional sightings of fin-less porpoises, 50% of the respondents had reported to have sighted whales occassionally, and 41.6% reported rare sightings of whales (Fig. 9).

3.3.2. Region – II

The Saurashtra coast has long been an abode for whale shark congregations and fishermen from this region are known to have caught whale sharks in staggering numbers before legal protection for the species came into force. Fifteen fishing villages starting from Okha in the north and extending up to Jafrabad in the

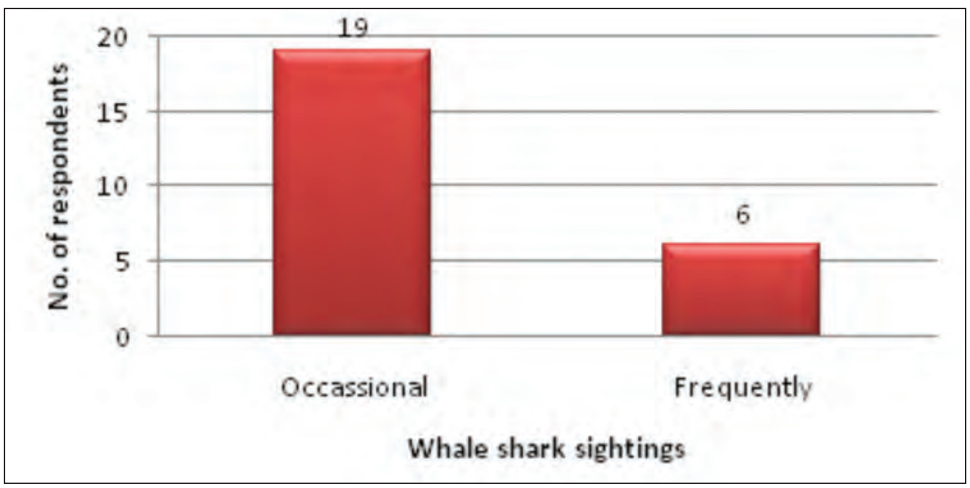

Fig. 6. Frequency of whale shark sightings

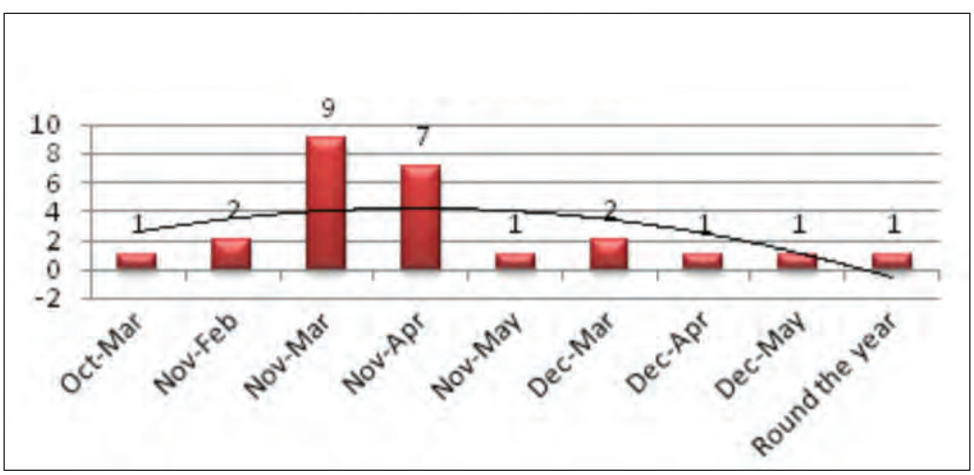

Fig. 7. Responses indicating seasonality of whale shark sightings

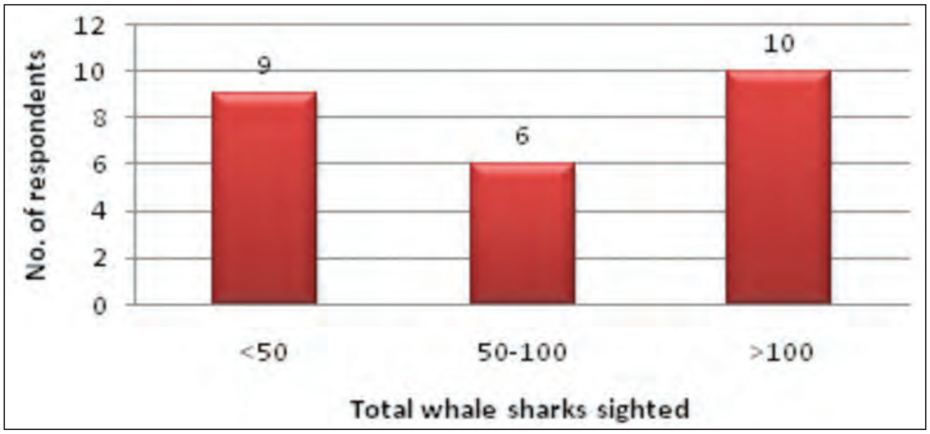

Fig. 8. Distribution of whale shark encounters along Saurashtra coast

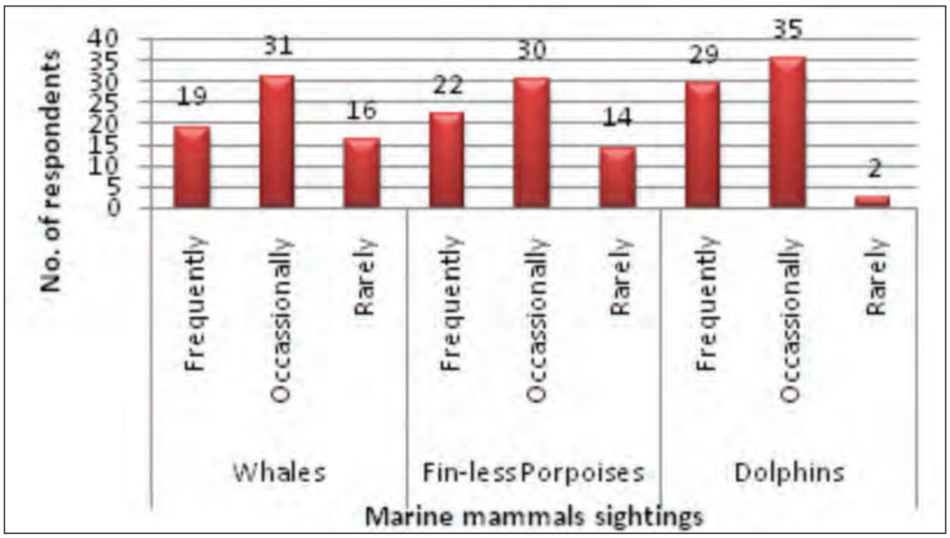

Fig. 9. Frequency of marine mammal sightings during fishing operations along Saurashtra coast

south were covered under this region, and 66 fishermen between the age of 50 and 95 years were interviewed (Fig. 10). Everybody except one respondent reported to have seen a whale shark during fishing operations and 95% reported the sightings are frequent (Fig. 11 and 12).

The seasonality of sightings of whale sharks was similar to that reported from the Kachchh region (Fig.6). Though 6% of the respondents claimed to have seen whale sharks throughout the year, the seasonality of sightings seems to be more

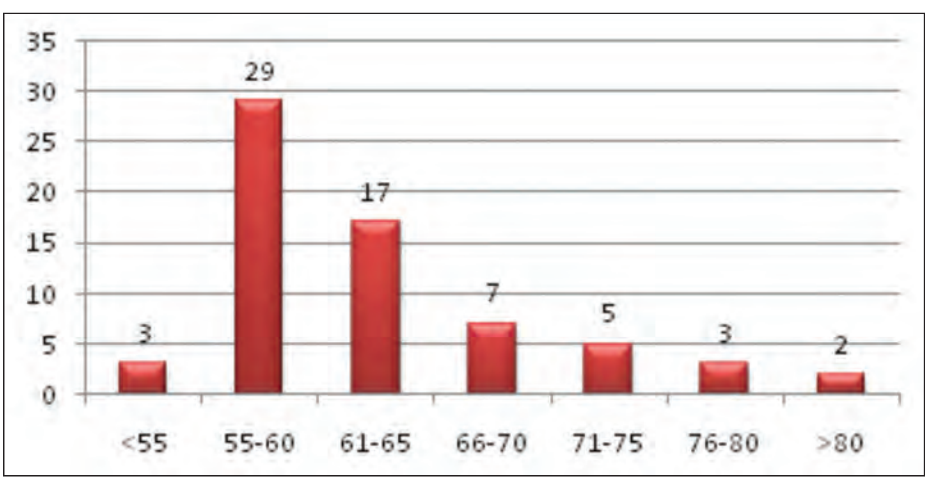

Fig. 10: Distribution of respondents across various age groups along Saurashtra coast

concentrated during the months of November to March, and sometimes extended up to April (Fig. 13).

The possibility of sighting a whale shark during fishing is mostly reported between the depths 20-30 fathoms (1 fathom = 1.822 meters) while they come as close as up to 5 fathom deep waters, and move out as far as up to 60 and sometimes even up to 100 fathom depths during the season.

The group size of the whale sharks sighted varied across the survey area. 40% of the respondents claimed to have seen a group of 2–3 whale sharks during sightings, while 44.6% claimed to have seen them basking solitarily, and 10.7% reported to have seen groups of 3-5 whale sharks together. Such variations in this section may be due to a difference in the time of the day of the sighting, which suggests differing social behavior of the whale sharks at different times of the day (Fig. 14).

When asked about the total number of whale shark sightings observed during their fishing days, 52.3% (n=34) reported to have seen 50–100 whale sharks, 29.2% (n=19) reported 25–50 sightings and 15.3% (n=10) reported to have seen more than 100 whale sharks (Fig. 15). 62.12% (n=41) of the repondents have reported to have sighted whales, 8.66% (n=8) had seen fin-less porpoises and every one (100%; n=66) saw dolphins during fishing (Fig. 16). However, no one had seen a dugong. Among the repondents

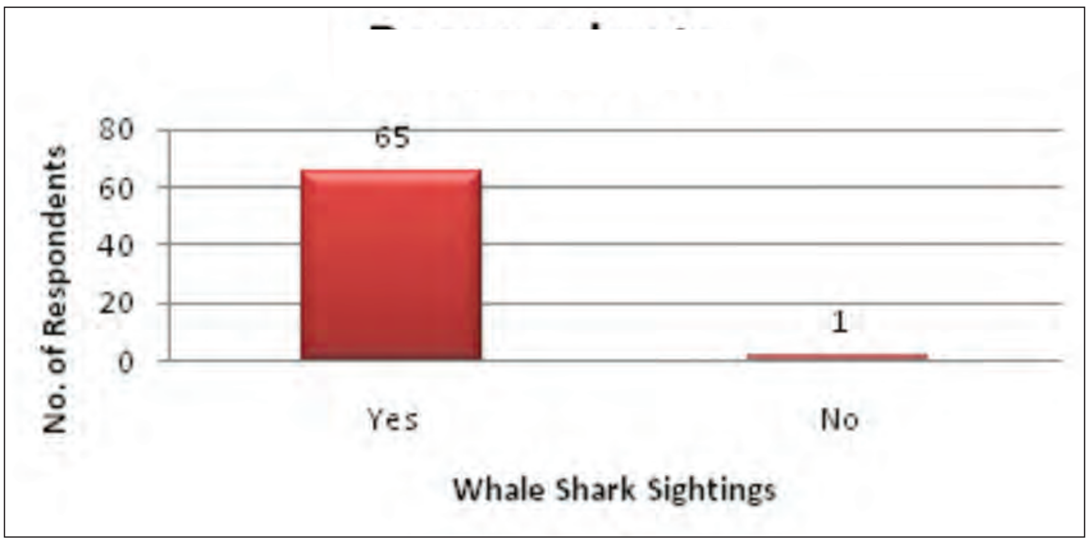

Fig. 11. Whale shark sightings along Saurashtra coast

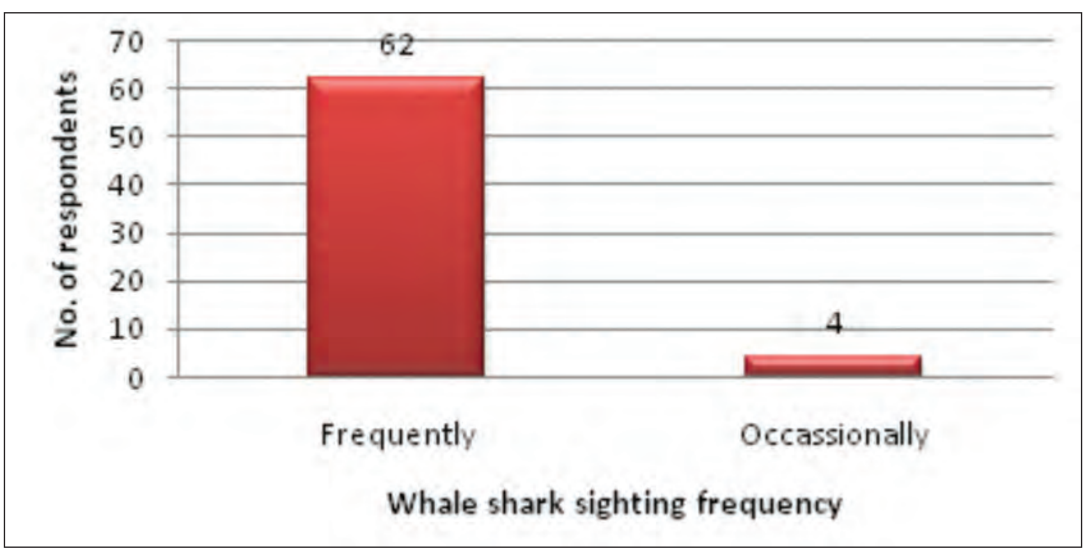

Fig. 12. Frequency of whale shark sightings along Saurashtra coast

who had sighted these marine mammals, 53.6% (n=22) had reported occassional sightings of whales, and 12% (n=5) reported to have sighted them rarely. Fin-less porpoises were sighted occassionally by 50% (n=4) of the respondents, and rarely by 12.5% (n=1) of the respondents.

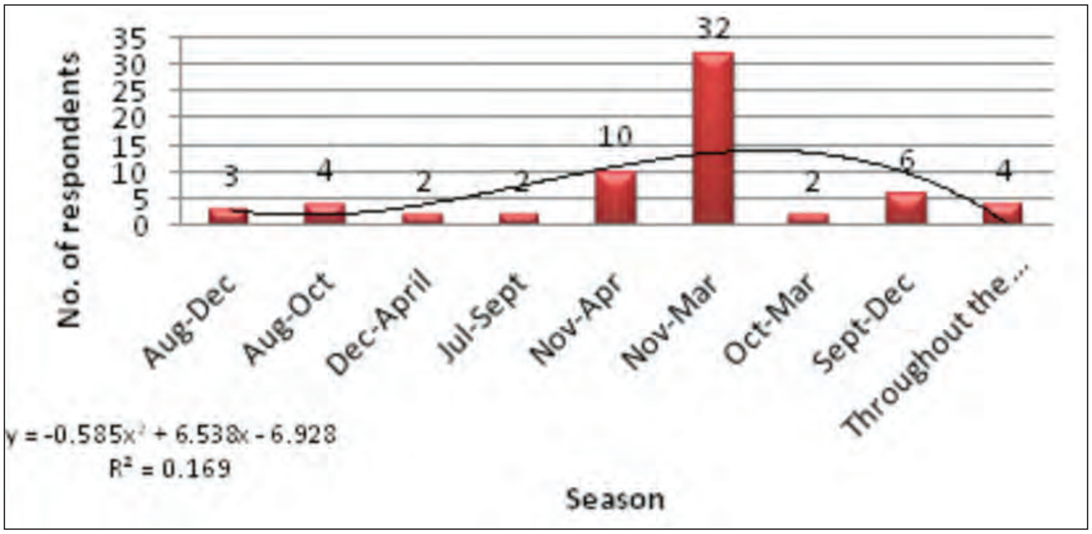

Fig. 13: Seasonality of whale shark sightings along Saurashtra coast

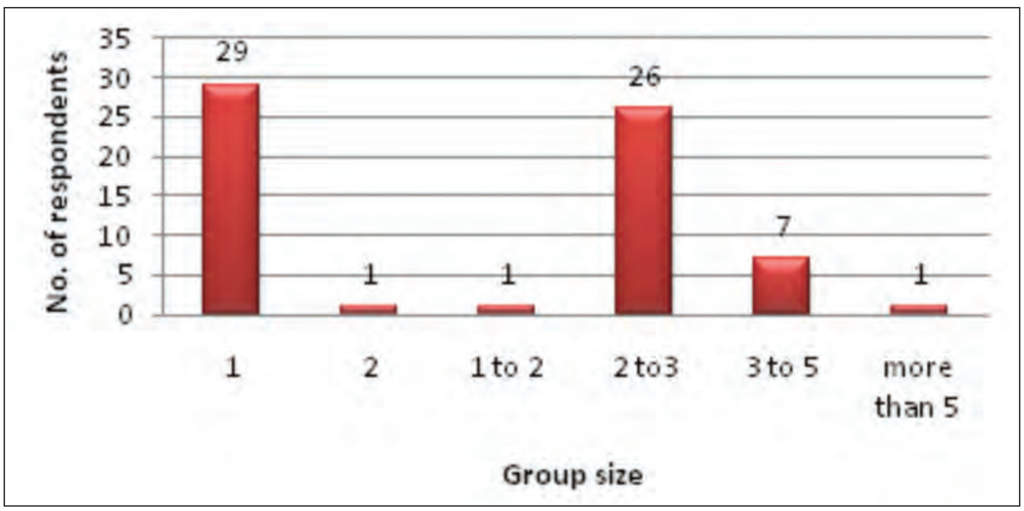

Fig. 14: Group size of whale sharks along Saurashtra coast

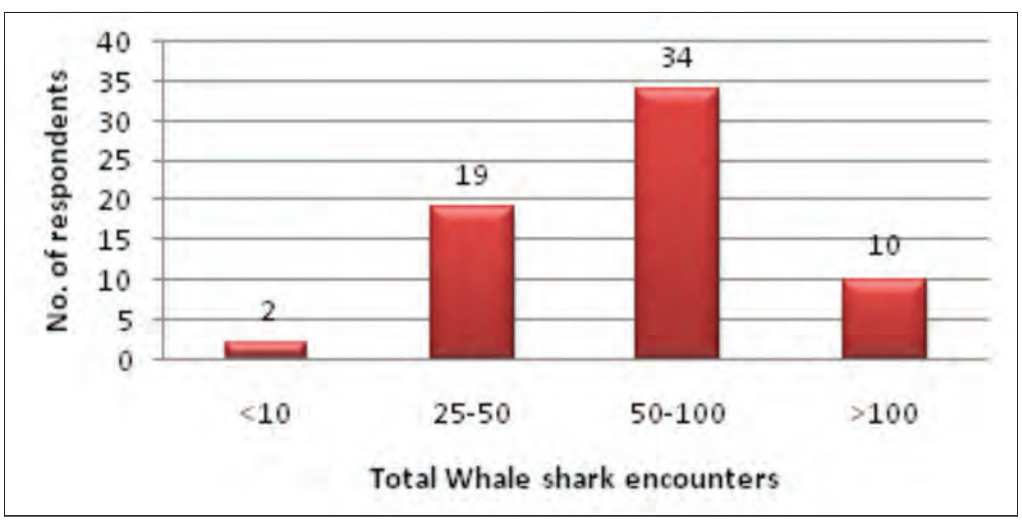

Fig. 15: Total whale shark encounters along Saurashtra coast

However, dolphins seem to be more in numbers since 65% (n=43) of the respondents have reported to have seen them frequently during their fishing operations, and as close as 2–3 nautical miles away from the shore.

3.3.3. Region – III

The marine fishermen from this region fish within the mud banks and creeks of the Gulf of Khambhat and most of them were engaged in mud-skipper fishing during the older days. Very few fishermen ventured into the sea towards the shores of Saurashtra. Seven fishing villages were surveyed and 19 fishermen between the age of 55 and 80 were interviewed (Fig.17).

Of the 19 fishermen interviewed, 14 respondents reported to have seen a whale shark during fishing, of these 42.1% (n=8) had reported to see them rarely and 28.5% (n=4) had seen them occassionally while fishing off the shores of Saurashtra (Fig. 18). The reported seasonality of whale shark sightings were similar to that reported from Kachchh and Saurashtra regions. Though they tend to start congregating as early as July, the sightings peaked between the months of November and March to April (Fig. 19).

The whale shark sighted during fishing had been reported to be solitary by 57.14% (n=8) of the respondents; 21.42% (n=3) reported seeing two

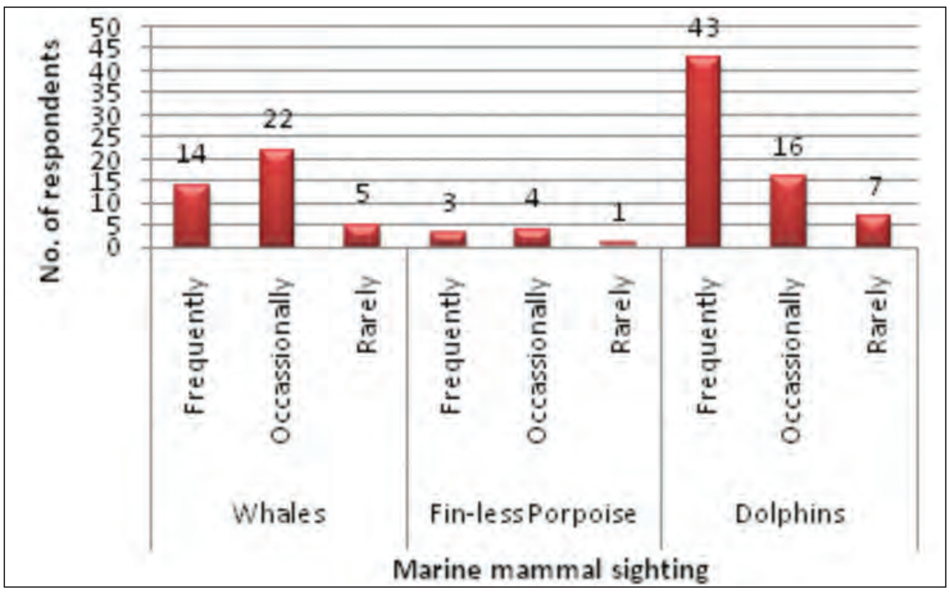

Fig. 16: Frequency of occurrences of marine mammal sightings in Gulf of Khambhat

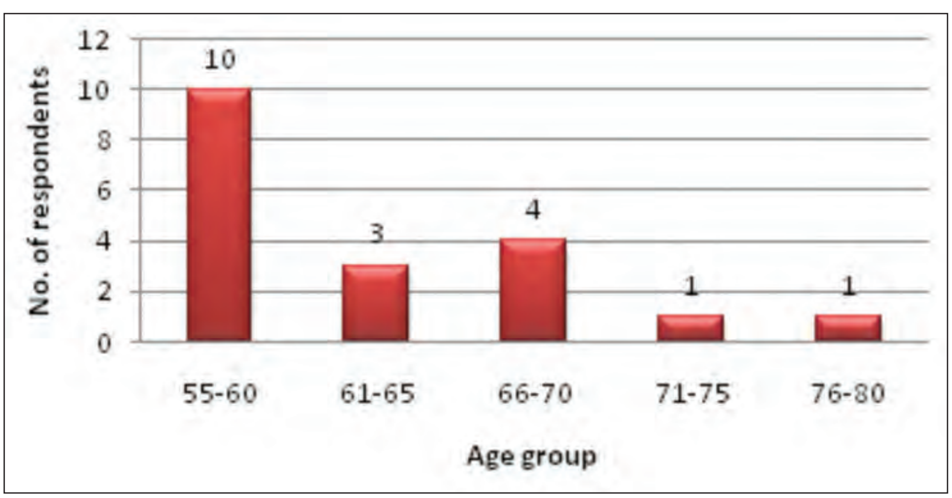

Fig. 17: Distribution of respondents across various age groups in Gulf of Khambhat

whale sharks together, and 14.28% (n=2) reported to have seen two to three whale sharks together (Fig. 20). Nine out of 14 respondents had seen 10-50 whale sharks during fishing, three had seen below 10, while two have seen between 51 and 100 (Fig. 21). Of the total respondents, seven had rarely sighted whales, 11 had seen finless porpoises rarely and 13 had seen dolphins frequently (Fig. 22) and as close as 2–3 nautical miles from the coast.

3.4. Conclusion

A total of 151 fishermen, between 50 and 95 years of age, were interviewed from 31 fishing villages along the coast of Gujarat. Of these, 68% (n=105) reported to have seen whale sharks during fishing operations for more than two decades. Among them, 72% (n=106) claimed to have seen whale sharks frequently, and 27% (n=48) saw them occassionally during their fishing trips. The numbers of respondents who had seen whale sharks varied across the fishing villages and their information on their fishing grounds has revealed that the probability of sighting a whale shark is higher towards the coast of Dhamlej and Muldwaraka villages, and that the maximum

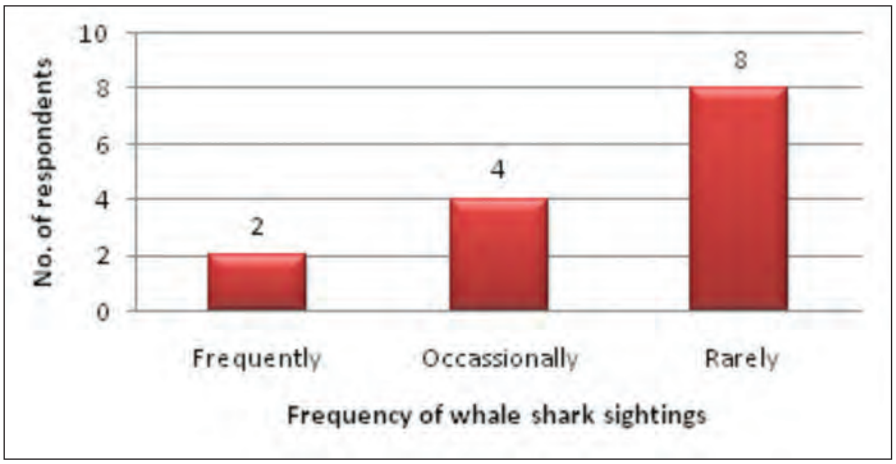

Fig. 18. Frequency of whale shark sighting in Gulf of Khambhat

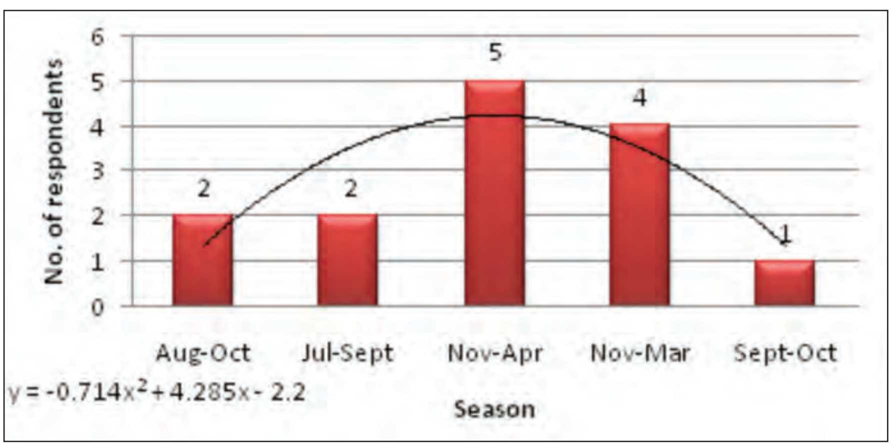

Fig. 19. Seasonality of whale shark sighting in Gulf of Khambhat

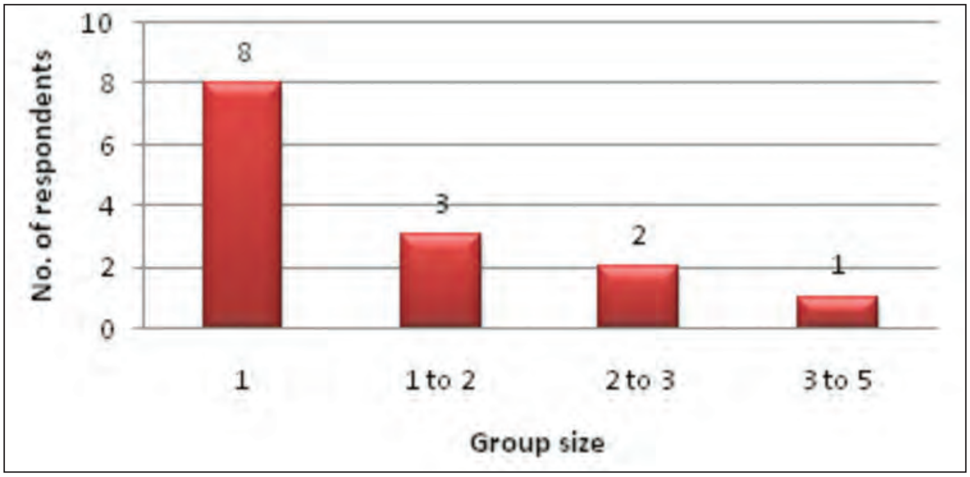

Fig. 20: Group size of whale sharks sighted in Gulf of Khambhat

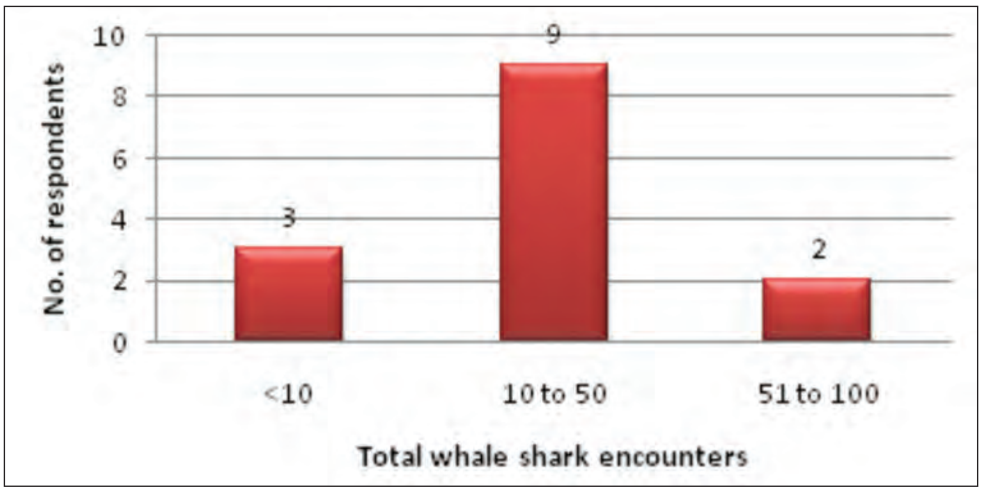

Fig. 21: Total whale shark encounters in Gulf of Khambhat

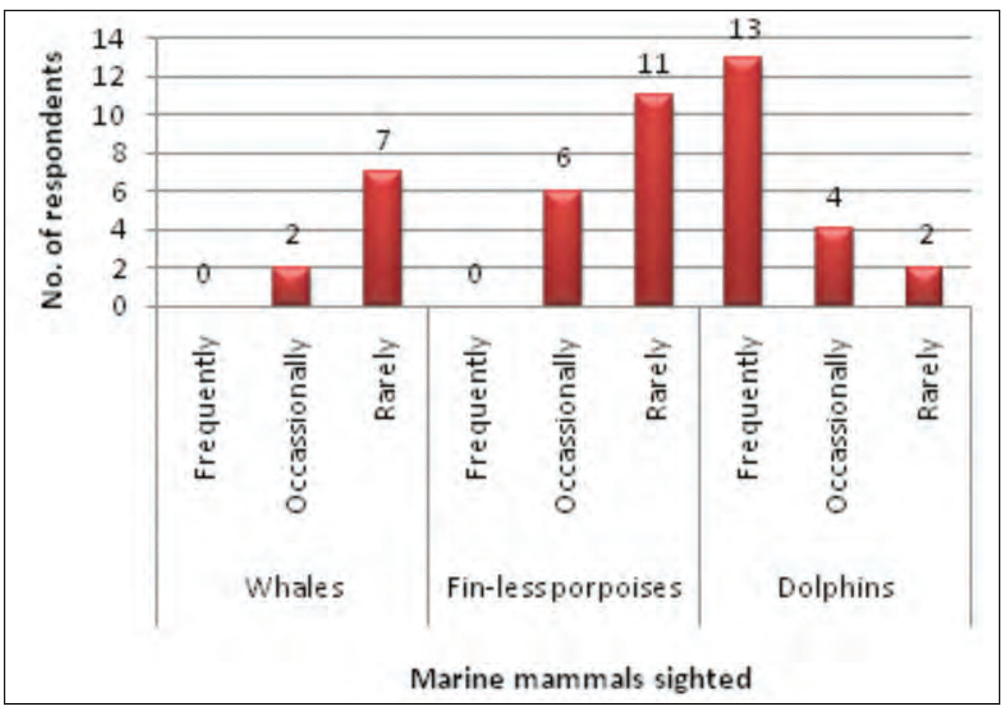

Fig. 22: Occurrences of marine mammals along the coast of South Gujarat in Gulf of Khambhat

concentration of whale sharks occured along the Saurashtra coast (Fig. 23) from November to April and some times till May.

Only one of the repondents reported any change in the numbers, or seasonality or the location of sightings throughout these years. However, most fishermen reported to have seen whale sharks at depths of 20-40 fathoms off the coast from Porbandar to Diu. This and the present information on whale shark rescue suggest that there is no change in the whale shark's habitat and the season of occurrence for the past 80-85 years. Whale sharks also do not exhibit a continual association with other marine mammals and reptiles such as sea turtles.

The fishermen's responses suggest that there is no change in the whale shark's habitat and the season of occurrence for the past 80-85 years along the Gujarat coast

It can be inferred from the above observations on their past abundance and distribition that there are no natural threats to the whale shark populations along the coast of Gujarat. Though their population was threatened to a major extent by fishing and trade, recent conservation efforts by WTI and the local forest department, with support from the local fishing communities, has abated the threat to some extent, as is evident from the voluntary rescue of the animals caught accidentally.

Only a better understanding of their habitat and migratory patterns, along with estimates of their population can help formulate long-term species recovery programmes along the coastal waters of Gujarat, and perhaps India

However, it cannot be ascertained that whale shark populations and distribution are immune to human activities in the state's offshore waters. There is a need to regulate fishing along the coastal waters to create safer waters for this species. Only a better understanding of their habitat and migratory patterns, along with estimates of their population can help formulate long-term species recovery programmes along the coastal waters of Gujarat and perhaps India.

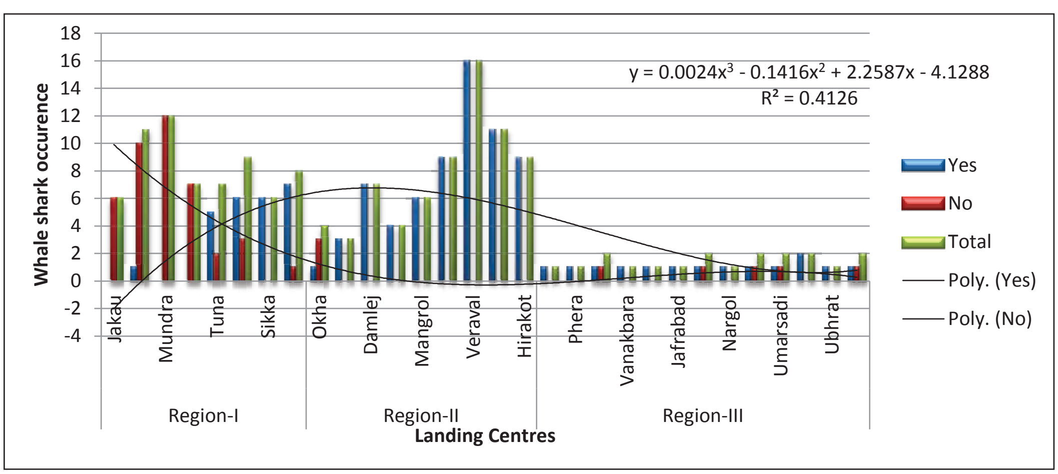

Fig. 23: Whale shark sightings across various fishing villages along the coast of Gujarat

CHAPTER 4

Whale shark rescue analysis

Providing relief to fisherfolks, who voluntarily cut their fishing nets to release incidentally caught whale shark was the basis of community involved rescue of a vulnerable species

Launched in 2004, the Save the Whale Shark Campaign led to the creation of *Vhali* (or "dear one") – a whale shark depicted by a local popular religious leader Morari Bapu as an incarnate of God. Bapu also correlated it with the long-standing Indian tradition of '*Atithi Devo Bhavo*' in which guests are likened to gods, and he described the whale shark as a guest who deserves equal respect. It proved to be a people-friendly method to reach out to the masses and spread awareness: now not only do most fishermen realise the implications of whale shark hunting, but they also have started to contribute to the cause by agreeing to release accidentlly caught whale sharks.

This, however, also meant heavy losses incurred by the fishermen when their nets had to be cut in order to free any trapped whale sharks and paved the way for a new policy implemented by the Gujarat Forest Department in 2006 to provide compensation to the affected fishermen whose nets were destroyed in the process. The Wildlife Trust of India's marine team on the Whale Shark Conservation project started assisting such rescues from January 2010 onwards to analyse their efficiency and improve the rescue operation methods.

Since 2005, the Forest Department of Gujarat, Wildlife Trust of India, Tata Chemicals Ltd. jointly started the Whale Shark Conservation Project. Since that time fishermen along the Gujarat coast are releasing incidentally-caught whale sharks from their nets. In return, they are provided compensation by the Forest Department for the loss of their nets.

A total of 372 whale sharks (Fig. 24) have been rescued until 7th May 2013 in Gujarat waters, which shows the success of the whale shark campaign that led to the Gujarat fishing community to regard the whale shark as a daughter of the state, a concept popularised by the spiritual leader Morari Bapu.

4.1. Year-wise whale shark rescue

Based on the seven year data of whale shark rescue, the highest number of whale sharks were rescued in Sutrapada, Veraval and Dhamlej locality fishing villages in Gujarat. A self-documentation scheme that was initiated in the villages is discussed in detail in the forthcoming section of this report. From 2012 till June 2013, a total of 57 whale sharks have been rescued in Sutrapada, Veraval and Dhamlej under this new method (Fig. 25 and 26).

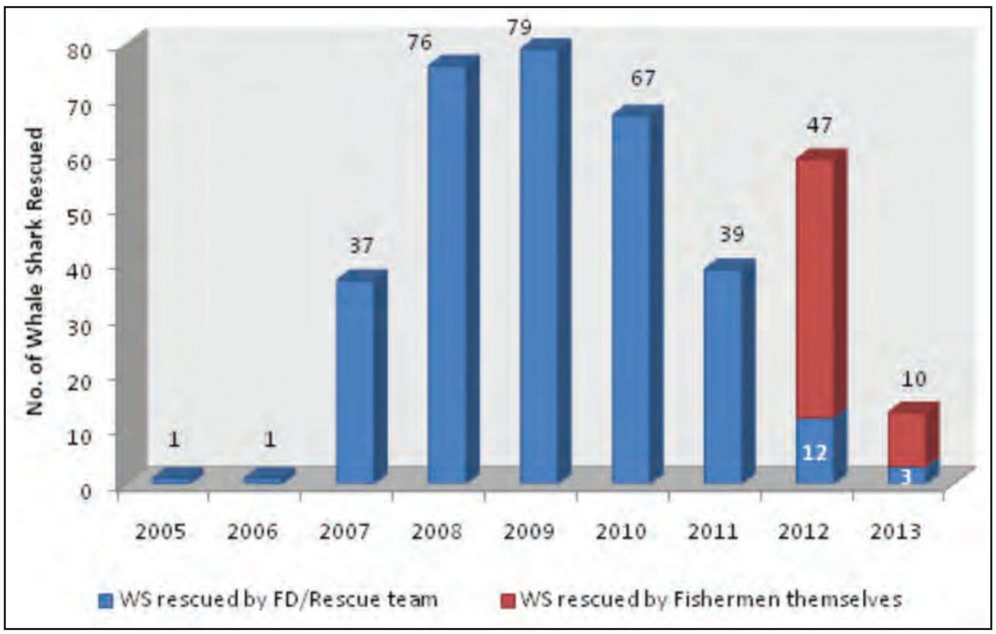

Fig. 24: Total number of whale sharks rescued in Gujarat waters (year-wise)

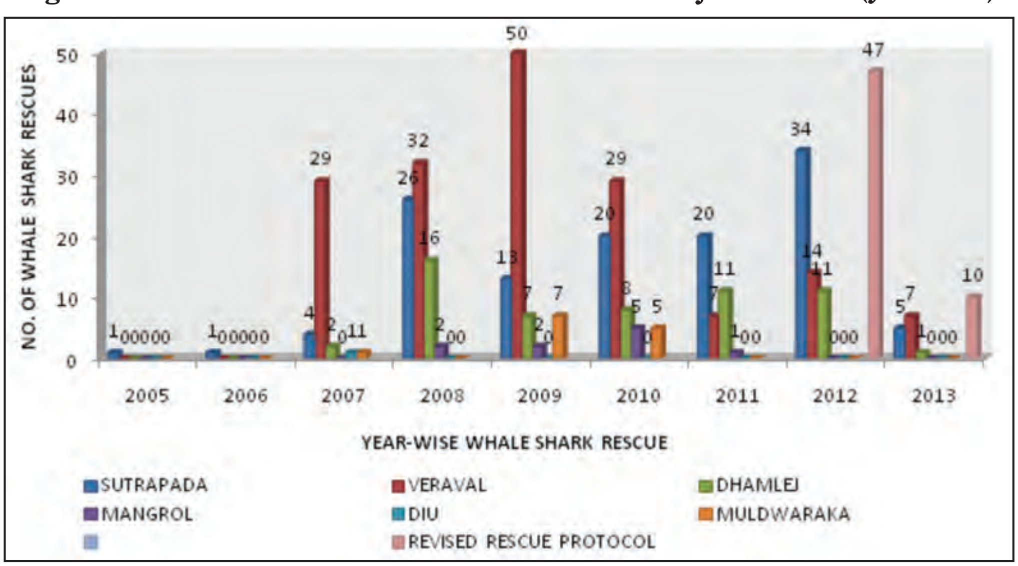

Fig. 25: Number of whale sharks rescued in different fishing villages in Gujarat

Table 2 : Overall whale shark rescue data in Gujarat waters

Fishing villages	2005	2006	2007	2008	2009	2010	2011	2012	2013
Sutrapada	1	1	4	26	13	20	20	34	5
Veraval	0	0	29	32	50	29	7	14	7
Dhamlej	0	0	2	16	7	8	11	11	1
Mangrol	0	0	0	2	2	5	1	0	0
Diu	0	0	1	0	0	0	0	0	0
Muldwaraka	0	0	1	0	7	5	0	0	0
Total rescue	**1**	**1**	**37**	**76**	**79**	**67**	**39**	**59**	**13**
Overall rescue	**372**								

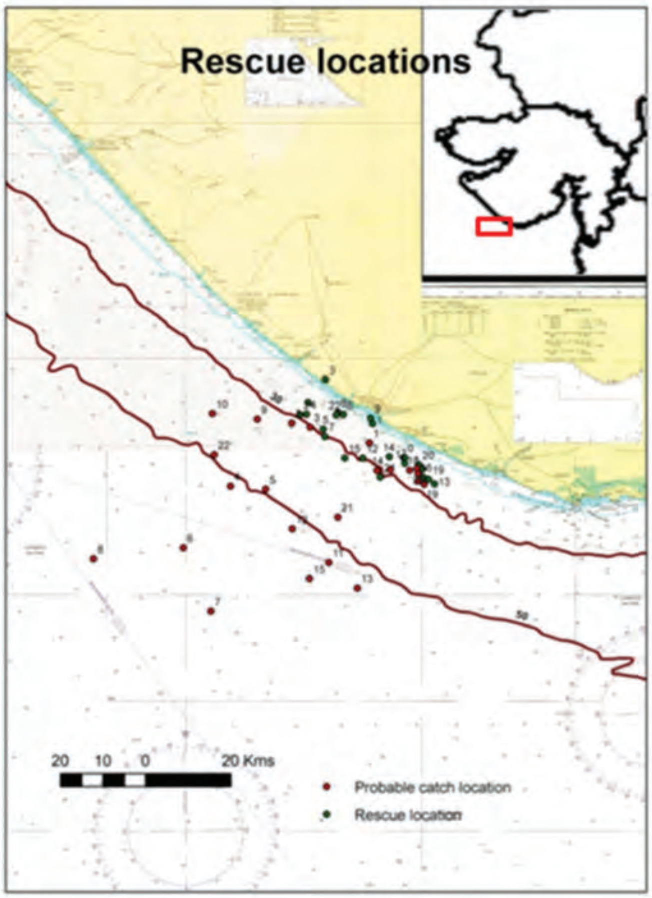

Fig. 26: Map showing whale shark capture and rescue locations in Saurashtra coast

4.2. Review of the rescue methods

By the year 2010, a review of the whale shark rescue methodology and release operation was considered in an attempt to make it simplified and much less time consuming, keeping in mind the reaction of the rescued after release whale shark to stress and possible mortality.

4.3. Fish stress and mortality- A brief review:

4.3.1. Sharks have negative buoyancy

Sharks do not have an air bladder as other fishes do; but they have a large liver with fats and oils which help them to get some buoyancy. This still does not help them remain totally buoyant and so they move their bodies regularly, else they

would sink. (Weihs 1981). In case they die and internal decomposition starts, or air gets trapped in the gut, they may start floating.

4.3.2. Sharks and their osmoregulation

Every marine fish has to drink water to retain osmoregularity and release excess salt through their gills or skin. It is just the opposite case with fresh water fishes which continuously release water, as the fluids concentration is higher in the body compared to surrounding fresh water. In marine fishes, the concentration of outside water is higher and so they drink water.

> **Dragging a shark against its gills can kill it in minutes, while entanglement with nets ruptures their gills, fins and skin. Roping around its gills and keel causes injuries and rashes, and blocks blood flow**

4.3.3. Exposure to air and dragging

Exposure to air for any marine fish is fatal. Dragging a shark against its gills can kill it in minutes. The gill lamellae may get impaired, making sharks susceptible to breathe normally.

4.3.4. Netting, roping and hooking

Accidentally caught sharks are prone to get injuries and internal haemorrhage. Entanglement of the fish with nets ruptures gills, fins and skin. Roping around its gills and keel causes injuries and rashes, and also blocks blood flow, causing internal haemorrhage. Hooking directly injures tissues and cause blood loss.

4.3.5. Discussion

Fish react to the acute stress of capture, exhaustive exercise and handling, with greater disruptions to their physiology and biochemistry than higher vertebrates (Pickering 1981; Adams 1990; Wood 1991; Milligan 1996; Kieffer 2000). Myotomal muscle mass of nearly all species of fish is dominated by anaerobic white muscle (80–95%), which allows high work output in short bursts (Driedzic & Hochachka 1978). Most fishing techniques cause high anaerobic activity and muscular fatigue, resulting in physiological disruptions of the internal milieu of fish (Wells *et al.* 1984). As the body mass of fish comprises more than 30% white muscle and only 3–6% blood, changes in muscle biochemistry are strongly reflected in the blood (Wells *et al.* 1986).

Wells *et al.* (1986) sampled the post-mortem blood chemistry of a limited number of tunas, marlins and sharks after tournament capture and concluded that elevated levels of plasma electrolytes, osmoregularity, blood metabolites (glucose, lactate), plasma enzymes and haematocrit were useful indicators of capture stress. Manire *et al.* (2001) quantified serological changes associated with gillnet capture in bonnet head sharks (*Sphyrna tiburo),* black tip sharks (*Carcharhinus limbatus),* and bull sharks (*Carcharhinus leucas).* They concluded that species-specific differences in gill-net mortality were likely associated with the animal's respiratory physiology and the degree of struggling.

Piiper *et al.* (1972) and Holeton & Heisler (1978) found that spotted dogfish, *Scyliorhinus stellaris* (Linnaeus), required up to 24 hrs physiologically to recover from exhaustive activity. Barham & Schwartz (1992) reported that blood glucose and haematocrit levels required 24 hrs to return to normal in neonatal smooth dogfish, *Mustelus canis* (Mitchill). Similarly, capture-induced blood chemistry changes in the dusky shark (*Carcharhinus obscurus*), required 24 hrs for recovery (Cliff & Thurman 1984). However, Spargo (2001) and Skomal (2006) found that acid–base blood chemistry in rod-and-reel-caught sandbar sharks (*Carcharhinus plumbeus*), recovered to pre-stress levels in less than three hours, thereby emphasising the need for species-specific studies.

Francis (1989) found that recapture rates of the gummy shark (*Mustelus lenticulatus),* were less in sharks taken in trawls than in nets, which suggests that trawl-caught fish had significantly greater release mortality.

In the Skomal & Chase (2002) and Skomal (2006) studies, the single Bluefin tuna that died immediately after release had low blood pH and high blood lactate levels indicative of a severe acidemia. Muscular fatigue associated with the angling bout precluded obligatory ram ventilation after release, leading to respiratory failure Skomal & Chase (2002) and Skomal (2006).

Gill-net capture and restraint probably involve respiratory and metabolic acidosis and hypoglycaemia as well as cellular damage. Species-specific and individual differences in the mortality of sharks caught in gill nets are likely related to an animal's respiratory physiology and degree of struggling upon capture as well as to the extent of net entanglement around the gill area (Manire *et al.* 2001).

Trawling created an upward spike in pCO^2 and a massive drop in pH relative to presumed basal (T3) values in dogfish. These responses were presumably a combined function of net constriction, exhaustive activity and the brief periods on deck following capture. Inversely related pCO2 increases and blood pH decreases have also been reported for other elasmobranchs (Piiper *et al.* (1972), Holeton and Heisler (1983), Cliff and Thurman, (1984)), and teleosts (e.g. (Wood *et al.* (1977 and 1983), Schwalme and Mackay, (1985), Milligan and Wood, (1986), Ferguson and Tufts, (1992))

Given the large size and pelagic nature of these fishes, assessing post-release mortality is difficult and should include multiple approaches that quantify the extent of physical damage and the level of physiological disruption. These fishes interact with multiple gear types, which impose varying levels of stress. Hence, studies must be conducted on a fishery-specific basis.

4.4. Efficacy of whale shark rescues

In order to review the current and past rescues, WTI prepared a report in 2011, based on past rescue video documentation analysis and on the levels of stress to the rescued whale sharks, and suggested a new rescue protocol for the future rescues. To understand the level of whale shark stress during rescue it was felt necessary to prepare a similar report based on the rescues attended to, and underwater videos and photographs for the 40 rescues that marine team of WTI had participated in the analysis was based on close encounters between the marine team and the gentle giants. The purpose of the investigation was to study the condition of the rescued sharks at the time of release and to assess the efficiency of the rescue mechanism.

Between 2005-2010, a total of 261 whale sharks had been rescued and released and a review of the efficiency of operation was felt a necessity

All whale shark rescue operations undertaken by the Gujarat Forest Department have been photo and/or video documented. Details of the fishermen and vessels at the time of rescue were also noted down. In the current review, the rescue documentation footage was used to assess the condition of sharks during the rescue and using different indices of measurement, WTI tried to speculate their fate during and after release.

4.5. Methodology for stress assessment

All the videos were reviewed at the office of the Gujarat Forest Department in Veraval. The condition of sharks was ranked on a scale of 0–3, no values indicating impaired function, condition of whale sharks were rated based on breathing rate (0-3), body movement 0–3; injuries and internal haemorrhage: 0–3 (Plate 1), Association of other fishes (P-a) and draggfing (P-a) (Plate 2), ropes around its gills or keel to control it (Plate 3); hooked (Plate 4).

The overall health condition of the shark was assessed as normal, impaired (moribund with high chances of delayed mortality), and no signs of life.

Plate 1. Injuries and internal hemorrhage

Plate 2. Dragging the whale shark

Plate 3. Ropes around its gills

Plate 4. Hooked

All videos were analysed and rated in the presence of officials of the Forest Department, Gujarat who were implementing the compensation scheme.

Till October 2010, a total of 216 rescue operations were conducted by the Forest Department at Veraval and 156 videos were available with the Gujarat Forest Department during the time of video analysis. The analysis focused on assessing factors such as:

a. Breathing rate / internal haemorrhage / body movement
b. Fish association, dragging, hook and roped
c. Time factor
d. Overall assessment

Each has been discussed in detail ahead:

4.5.1. Breathing rate / Internal hemorrhage / Body movement

An analysis of the 156 videos resulted in 58 cases (37.1%) showed no gill or mouth movement; 34 cases (21.7 %) showed occasional movement and only seven cases (4.48%) showed some frequent movements. It was difficult to place individuals into any category in 57 cases (36.53%). Extreme internal haemorrhage was found in five cases (3.2 %), while it was high and clearly visible in 22 cases (14.1%). In 26 cases (16.6 %) there were mild injuries and in 18 cases (11.5%) sharks were seen without injury or haemorrhage. Eighty five cases (54.4 %) were difficult to analyse.

In 75 cases (48%) no body movement was detected. Some signs of movement were found in 43 (27.5%) cases and 19 cases (12.1 %) showed frequent movements. Only in three cases (1.9 %) some strong movements were noticed. (Fig 27); 16 cases (10.2%) were difficult to categorise.

4.5.2. Fish association, dragging, hooking and roping

Fish association with the shark is an indicator of its health. Out of 156 videos, in 23 cases (14.7 %) no other fish were seen associated with the

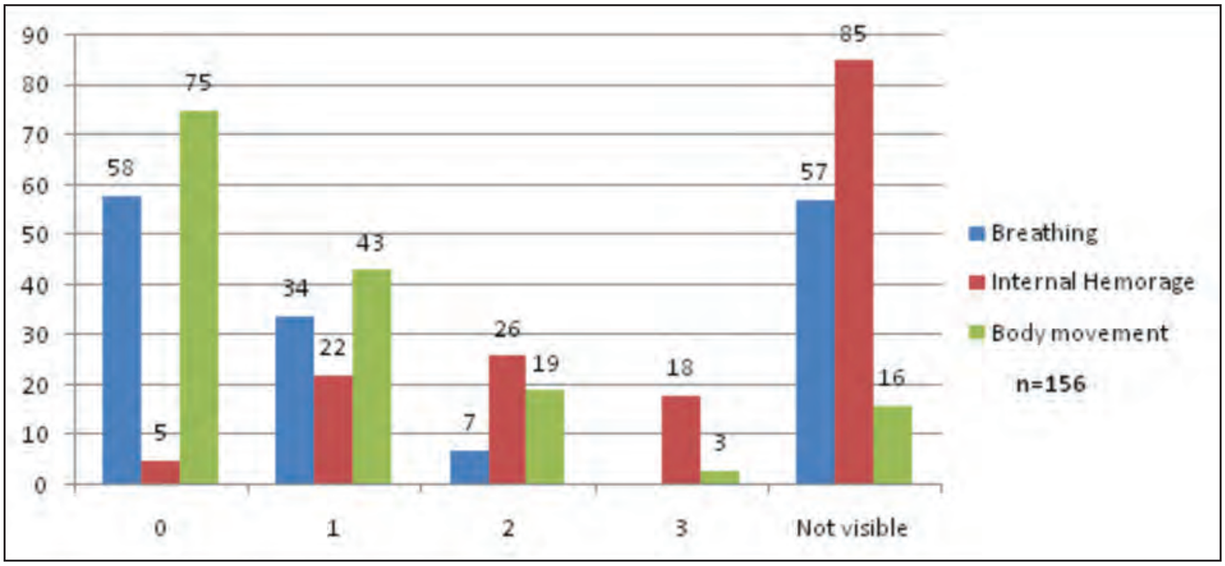

Fig. 27. Graph showing number of cases in each grade of health indices of shark (0= Poorest, 1= Bad, 2=Good, 3= Normal)

netted whale shark. In the remaining 133 (85.25 %), it was difficult to make out any association. Whale sharks were towed in 35 cases (22.4 %) against its gills at the time of rescue. In117 (75%), no dragging was visible at the time of rescue and in the remaining 4 cases (2.56 %) it was difficult to assess how the animal was dragged.

Whale sharks were hooked in 15 cases (9.16%), whereas in 135 cases (86.5%) no hook was visible to control the fish. In 6 cases (3.84%), the video quality did not allow a proper assessment (Fig 28). Whale sharks were roped around its gills, keel and caudal peduncle in 154 cases (98.71 %). In 2 cases (1.28 %) it was difficult to make anything out from video.

4.5.3. Time factor

An attempt to assess the time taken to complete each rescue was also carried out. Only the time of receiving a rescue call and the time of

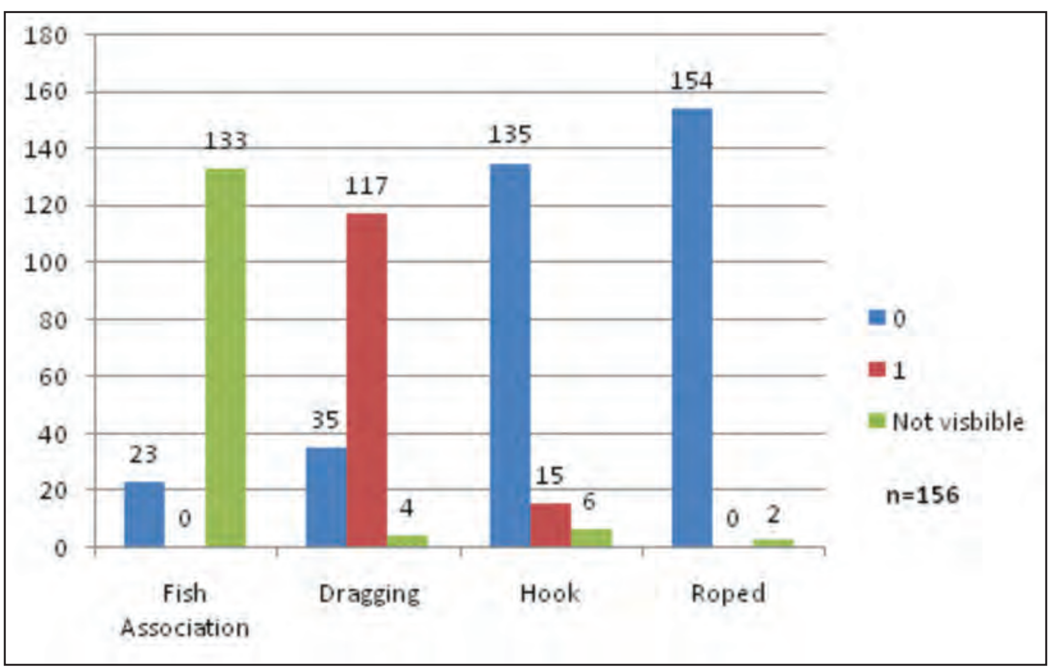

Fig. 28. Graph showing number of cases with presence and absence status with different indices

completing a rescue was available with the Forest Department. Therefore, it was not possible to account for the time between the actual time of fish entanglement with the net and its release. Out of 156 videos, 146 rescue videos were available with the time code.

The rescues were completed on an average time of 1 hour and 53 minutes (SD ±63.10 min), with a shortest time of 20 minutes to longest duration of 6 hours. The frequency distribution showed a mode at 1:30 – 2:30 hrs (Fig. 29).

The total time for the rescue, in the 19 rescues which had WTI involvement was also calculated. The average time between the actual catch (time the fishermen discover the trapped whale shark) and release was within 5 hours 12 min (SD± 132 min). The mode of the frequency distribution was 4-8 hrs, much higher than calculated earlier with the data from the Forest Department (Fig. 30).

4.5.4. Assessment results

Based on the analysis carried out through video recordings, 38 cases (24.35 %), were in comatose condition, 108 cases (69%) were found with high risk of possible delayed mortality and only five cases (3.2%) were found in normal condition before release (Fig. 31).

In five cases (3.2 %), the videos were corrupted and no assessment was possible.

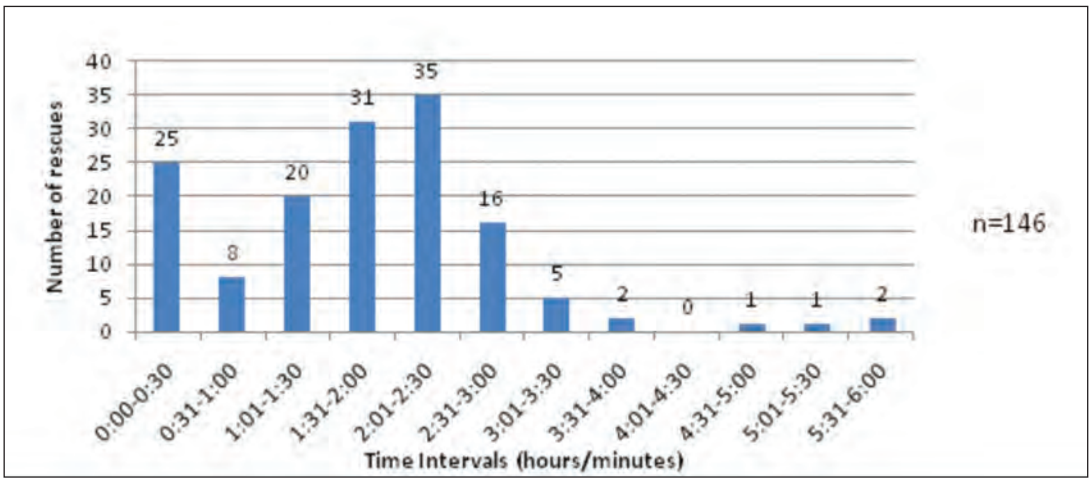

Fig. 29. Number of rescues at different time intervals

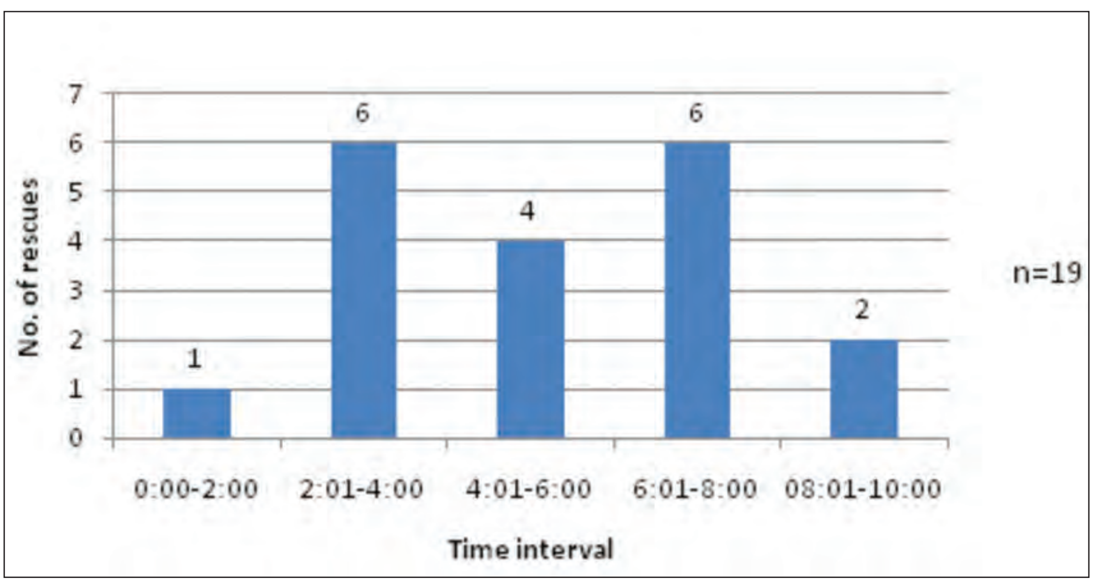

Fig. 30. Number of rescues at different time intervals

4.6. Discussion

Little is known about the post-release mortality associated with the catch and release of sharks, tunas and marlins. Regardless of the fishing gear, captured fish are exposed to varying degrees of stress, which includes the cumulative impacts of physical trauma and physiological stress. Although the magnitude of stress depends on the capture method and handling, studies on fishes show that they all react to the acute stress of capture, exhaustive exercise and handling with more exaggerated disruptions to their physiology and biochemistry than higher vertebrates (reviewed by Pickering 1981; Adams 1990; Wood 1991; Milligan 1996; Kieffer 2000).

In elasmosbranchs too, it appears that no phylogenetic predisposition occurs as even very closely-related sharks species respond differently to capture. For example, Morgan and Burgess (2004), reported that at-vessel mortality was 36% for the sandbar shark (*Carcharhinus plumbeus*), less than half of those for the cogeneric black tip shark (*Carcharhinus limbatus*, 88% mortality) and dusky shark (*Carcharhinus obscures*, 81% mortality). There appear to be no references available on studies conducted on stress level and post release mortality of whale sharks or similarly-sized sharks. The video reviews are, therefore, an extremely important tool for the conservation of this species. Though whale sharks are big and are known to have a great healing capacity, anaerobic conditions for long durations, internal haemorrhage, dragging, hooking and roping can kill the animals.

> **Review of videos of rescue operations that WTI was engaged in showed 23.5% of the sharks with no signs of life and 69% with high chances of delayed mortality**

Time is a critical factor for any kind of rescue: the greater the delay for any rescue lesser is the chances of survival. The average time of 1 hour and 53 minutes obtained from the data set was actually the time taken by the rescue team to complete the operation after the call from the fishermen was received. The fish could be caught in the net during the night or early hours of the morning. Data from 19 rescues in which WTI participated revealed the total rescue time increased to 4–8 hrs when the actual time of fish being caught was added. Even a delay of 1–2 hrs negatively impacts the fish's survival.

The video review showed a significant percentage (23.35 %) of individuals with no signs of life, and an alarming 69 % with high chances of delayed

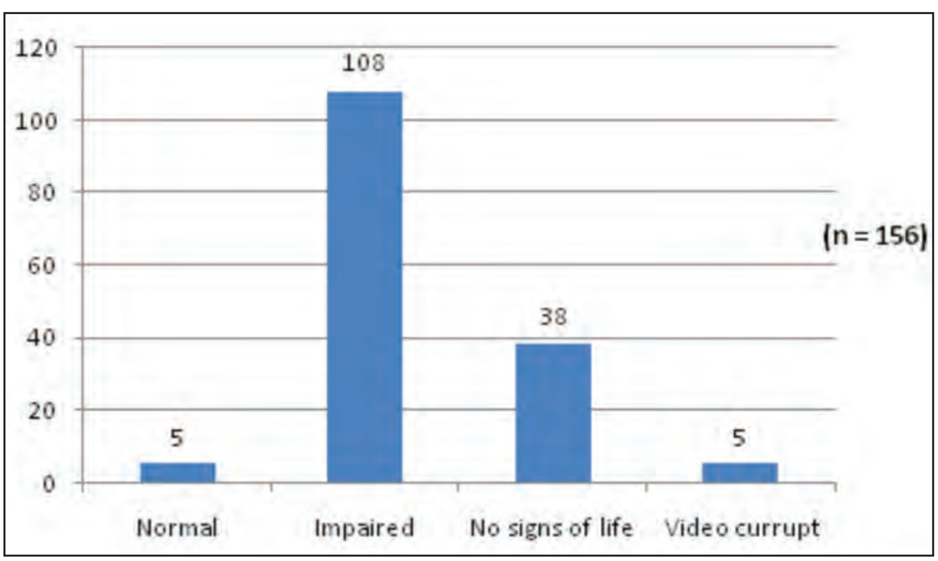

Fig 31. Overall health assessment of whale shark recued

mortality. In 35 cases, it was found that the fish was dragged even during the rescues, which would harm the fish the most. Significantly in 154 cases, it was found that fish was roped from its keel (before tail) and on its gills, mostly to control it and prevent net tearing. This would harm the fish by inflicting internal injuries to gills and blocking the continuous flow of blood (over tightening), causing internal haemorrhage.

Severe and high injuries and internal haemorrhage, which were visible in 17.3% cases is a major risk factor causing instant or delayed mortality. The cause for the internal haemorrhage appears to be anaerobic conditions, dragging, hooking and over-tight ropes used to restrain whale sharks. Direct injuries due to hooking on mouth were found in 9.16 % of the cases, resulting in local tissue damage and bleeding. 37.1 % cases were found with no gill or mouth movement, indicating anaerobic and tiring conditions. In 36.6 % of cases it was difficult to make out such movements, due to the fish position in the videos.

Though no significant difference was found between the timing of suspected dead, impaired and normal sharks tested (Mann-Whitney U test) at 95 % confidence level (impaired vs normal (z=-.370, p=.711), suspected dead vs impaired (z=-.799, p=.424), normal vs suspected dead (z=.883, p=.887). It seems that lack of data on the actual time of entanglement plays a critical function here.

As mentioned before, the chances of survival of a whale shark decrease with an increase in the time taken for rescues. Therefore, it becomes imperative that time of rescues must be curtailed substantially. The most desirable situation is to release a trapped whale shark as soon as possible.

This review resulted in redefining the whale shark rescue operation (Plate 5) on the Gujarat coast.

Plate 5: Fishermen rescuing whale shark at Veraval

CHAPTER 5

Redefining whale shark rescue operation: Development of self-documentation scheme

To cut time wasted in notifying the relevant authorities about an accidental capture of a whale shark and waiting for them to arrive on the spot and release it, local fishermen were trained to release the shark quickly and photograph the process, using water-proof cameras, for evidence

The initial rescue protocol dictated that if a whale shark was caught in a net, the fisherman had to report it to the authorities and a rescue team would reach the spot to cut it loose, mainly for documentation. But it led to a significant amount of time and transportation expenses. The stress of being captive, at times for hours, was quite intense on the whale sharks (leading to stress and high chances of immediate or delayed mortality), with some of them even dying because of it.

The 2011 assessment of the rescue video showed that the stress caused to the fish needed to be reduced, if not eliminated completely and that is when the idea of self-documentation arose. It essentially involved providing the fisherman with cameras, training them to use them and allowing them to document the release operation while cutting the whale shark loose without any assistance. Theoretically, by allowing fisherman to document the capture and release of the big fish, the time taken for it to be released would be drastically reduced. The fisherman would not have to wait around for the rescue team to arrive and would also get adequate compensation in a shorter period of time.

The conceptual refinement rescue method was discussed in consultative meetings with Forest Department, fishing communities, researchers and local stakeholders to explore the feasibility of the method. The Governing Council meeting held in December 2011 chaired by Secretary Dr. S. K. Nanda, agreed to recommend the changes in the relevant Government Rule of rescue in March 2012. The government of Gujarat made the necessary changes recommended by the Governing Council. Under the Rapid Action Projects of WTI, the conceptual model was executed at Sutrapada, Dhamlej and Veraval to equip and train several fishing communities in self-documentation of a whale shark rescue operation using the revised methodology.

5.1. Methodology of new rescue protocols

Using water-proof cameras provided by WTI or their mobile camera

the fishermen were advised to photograph the incidentally-caught whale sharks along with their boat number (usually written on the sides of their boat) in a single frame to stake claims for monetary relief against their damaged nets.

5.2. Empowering fishing communities to use photo documentation

Several demonstrations on operating the water-proof camera was conducted in Jaleshwar, Veraval, Dhamlej and Sutrapada. For wider understanding of the method, street plays, dance dramas and other methods were used. Immediately after the training programme, cameras were distributed to the fishermen, through their respective fishing community heads. A total of 1159 cameras were distributed. The coverage of such programmes through print and electronic media enhanced interest in the self-documentation scheme in other fishing villages as well.

On a request of the village head, additional 16 cameras were later distributed in Mangrol. Mangrol fishing port having 500 small OBM boats and about 1500 boat operators. Based on the Patel's (community head) recommendation, WTI arranged for a small gathering of fishermen with forest officials, where 16 water-proof cameras were distributed and training was provided to them on using the cameras.

5.3. Train the trainers programme

In order to train the fishermen on how to use the cameras and the kind of photographs needed to claim relief money, a "Train the trainers programme" was organised in each fishing village. In this training programme, 10-15 fishermen were trained, who would further train the rest of the fishermen.

5.4. Media hits

The awareness drive and self-documentation scheme was well supported by local and national media. It was also popularised through social networking sites such as Facebook and Twitter (Plate 7).

Plate 6. Volunteers and WTI Marine team conducting workshops for fishermen.

વેરાવળ બંદરમાં વેલશાર્ક માછલીની જાળવણી અંગે શેરી નાટક રજૂ કરાયું

માછીમારોને સેલ્ફ ડોક્યુમેન્ટેશન અને કેમેરા અપાયા

Plate 7: Story in local print media

5.5. Results of the self-documentation scheme

Soon after the camera distribution, the first rescue happened on 2nd October, 2012, where a whale shark was accidentally caught in a gill net near Veraval. No rescue team ventured into sea to document it; the fisherman used his mobile camera (Plate 8) for documentation and reported to have released the whale shark immediately.

Plate 8: The first rescue under the self-documentation scheme on 2nd October, 2012. This picture was taken using a mobile phone.

After this, 111 more rescues happened under the self-documentation scheme, from Veraval, Sutrapada and Dhamlej (Plate 9). Details about the rescues have been given in Appendix III. The new method has drastically reduced the rescue duration, as it eliminated the time taken for informing the concerned departments after an incidental catch by the fishermen and the time taken for a rescue team to reach the location. Analyses of the pictures obtained in the self-documentation scheme are under process, which will provide us with the data on the efficiency of the new method.

Plate 9: Sample photos of whale shark rescue documented using the water—proof camera.

5.6. Other concerns of whale shark rescue

Rescuing the netted whale shark by fishermen, using a camera under the self documentation scheme has shown admirable results for whale shark conservation project in terms of the number of rescues. It has developed a good understanding among fishermen to rescue the whale shark on their own and as soon as possible.

Certain factors that need to be looked into for making the scheme more effective include:

1. Fishermen deploy their nets in the late evening and start retrieving them early morning, and if a whale shark gets entangled in their net, the fishermen have to wait for sunrise to get sufficient light as they do not have cameras to take photographs.

   Solution: They should be given training in using torch light along with the camera to give suffcient light for a decent-quality photo and/or provide them with improved cameras with flash units.

2. Forest officials who undertake rescue documentation work report that fishermen are unable to provide rescue photographs of the qualtiy recommended and required by the forest department, which leads to rejection of their relief claim. This has been found mainly due to two reasons;

   i. Fishermen have not received suffcient training as complaints on camera operation is the common reason for bad pictures.

ii. Cameras are handled by untrained fishermen while the trained fishermen are engaged in retrieving nets.

Solution: Effective hands-on training needed for the each indivdual fisherman, who recieved the waterproof camera. The training should cover all the activities such as,

a) How to rotate the roll manually after taking one picture

b) Documenting rescue pictures as per forest deparment requirements which are:

   1. An entangled whale shark in the net.
   2. Cutting the net, without harming the whale shark.
   3. Releasing the entangled whale shark from the net.
   4. Taking a snap of both the whale shark and boat number for Forest Department documentation purpose. It's easier for the department to process the document for net damage compensation.

c) Fishermen heads to inform their fishermen to replace the used roll in the water proof camera with a new roll after each whale shark rescue documentation.

For effective rescue records, the date and time are required to be printed on the clicked photos, but the current cameras do not have this feature, which needs to considered for future work.

School and college students also strived to sensitise communities through street plays and spread awareness on the whale shark conservation campaign

Most whale sharks are accidentally caught in the gill nets that are laid out. In the first instance, Dinesh Khoraba had spread his maul net to catch tuna fish and ended up catching the majestic whale shark instead. The endeavour of trying to save whale sharks, and give them a fighting chance for survival would not have been possible without the cooperation of the local fishing communities in Gujarat. Students from schools and colleges such as the Choksi College and Fisheries College (under the Junagadh Agriculture University) also strived to sensitise the communities through street plays and spreading awareness about the stress to the whale shark, the change in the government ruling, and the benefits to the fishermen, with respect to time and finances.

While local fishermen of Gujarat have voluntarily released the accidentally-captured whale sharks, the ingenious self-documentation process cut the time lost in reaching and releasing the sharks, making it a pivotal point in the history of the conservation effort to save the whale shark.

CHAPTER 6

Whale shark habitat preference

In general, occurrences of whale sharks appear to be sporadic and unpredictable, which is partly a reflection of the lack of knowledge about the animal's habitat and ecology

The accessibility of the seasonal aggregation of whale sharks in the Veraval regions provides an excellent opportunity for researchers to undertake studies on this rarely-encountered and poorly-understood shark. Initial research efforts lacked clearly-defined objectives and were often hampered by limited scientific research on whale shark biology and ecology. Some aspects of the research should seek to provide information to environmental management bodies to minimise possible detrimental impacts. In general, occurrences of whale sharks appear to be sporadic and unpredictable, which is partly a reflection of the lack of knowledge about the animal's habitat and ecology.

6.1. Methodology

WTI aimed to study the habitat and ecology of whale shark along the Saurashtra coast. Three experimental sites were selected based on the information available on the whale shark citations. The experimental sites included: 1.Veraval - A (0 km), B (5 km), C (10 km), D (20 km); 2. Diu - A (0 km), B (5 km), C (10 km), D (20 km); and 3. Mangrol - A (0 km), B (5 km), C (10 km), D (20 km) (Plate 10). Sampling was done in the fishing season, which fell in three categoriehs: post monsoon (September to October), winter (November to February), and pre-summer (March to April).

All water sampling and water quality analyses were carried out according to the standard sea water analysing protocols (Strickland & Parsons, 1968) at the regional centre of the Central Marine Fishery Research Institute, Veraval (Appendix II). The methods used for the analysis of various parameters are tabulated in Table-4. Parameters such as sea surface temperature, salinity, pH, visibility, DO, gross and net primary productivity, ammonia, nitrate, phosphate, silicate, chlorophyll concentration, photos, and zooplankton biomass and diversity were recorded from September 2010 (post monsoon) to April 2011 (pre-summer).

The study analysed water samples for sea surface temperature, salinity, pH, visibility, gross and net primary productivity, ammonia, nitrate, phosphate, silicate, chlorophyll concentration, photosynthesis, zooplankton biomass and diversity

Zooplankton samples were collected (Pate 11) from surface hauls by employing standard plankton nets. The plankton net is towed horizontally from the boat for 10 minutes using three bridles (suspension lines), which are tied to the ring at equal distance from each other. While making the collections the speed of the vessel is maintained at 1 to 2 nautical miles per hour. After the 10 minutes haul, the net is taken out of water and is washed from outside by jetting seawater to bring down all the plankton into a collecting bucket. After the excess water is drained off from the net and through the window of the collecting bucket, the bucket is carefully removed from the net and the plankton, along with the water, is poured into a wide-mouthed 500-ml polythene bottle. The collected samples were preserved in 5% formaldehyde solution. With regard to phytoplankton, one litre of water from each station is collected in a wide-mouthed 1000-ml polythene bottle and preserved in 5% formaldehyde solution.

The gross and net primary production rates were calculated, using the light and dark bottle oxygen technique (Gaarder & Gran, 1927). The chlorophyll content of the water was estimated following the methods of Strickland & Parsons (1968). A sample of one litre water with phytoplankton was collected from the surface of the stations. The phytoplankton organisms were enumerated by the settling method and qualitative and quantitative evaluation of the flora. For the quantitative estimation of zooplankton in the samples, displacement method was used and the zooplankton volume was determined. As it is not possible to analyse the entire zooplankton sample collected during a haul, sub-samples of minimum 2 ml of zooplankton were used for qualitative analysis of plankton groups. The sub-sampled planktons were analysed by counting in a plankton-counting chamber under a microscope (Plate 12).

The analysis of all data was done using NCSS software package for statistical analysis (ver. 8).

6.2. Results

Auto-correlation was checked between various habitat parameters (e.g. pH, ammonia etc). None of the variables seemed to be strongly correlated. Strong para correlation was found among the variables.

Only two variables – depth and visibility – showed a significant correlation (r=0.644614).

The correlation matrix is given in Table 5. Difference in the readings of various habitat variables (e.g. pH, ammonia etc) between different sites were analyzed by applying ANOVA.

Based on the locations (places), among all parameters studied, the pH values showed a significant difference (F=3.44, P=0.043902). Visibility also showed a significant difference (F= 9.39, P= 0.000592). Other factors such as gross productivity, nitrate and silicates also showed a significant difference between Veraval, Mangrol and Diu (F=3.53, P=0.040715), (F=4.56, P=0.017909) and (F ratio=3.68, P=0.036080) respectively.

Table 4. Various parameters measured

SL. NO.	PARAMETERS	METHODS	INSTRUMENTS
1.	Temperature	-	Thermometer
2.	pH	-	pH meter
3.	Salinity	-	Salinometer
4.	Dissolved Oxygen	Winkler's	-
5.	Visibility	-	Secchi Disk
6.	Nitrate	Strickland & Parsons (1968)	Spectrophotometer
7.	Phosphate	Strickland & Parsons (1968)	Spectrophotometer
8.	Ammonia	Strickland & Parsons (1968)	Spectrophotometer
9.	Silicate	Strickland & Parsons (1968)	Spectrophotometer
10.	Chlorophyll	Strickland & Parsons (1968)	Spectrophotometer
11.	Primary productivity	Gaarder & Gran, 1927 (Light & Dark Bottle)	
12.	Phyto- and Zooplankton analyses	Standard phyto- and zooplankton sample collection and analysis method	Hemocytometer, Microscope

Plate 10: Project area at Mangrol, Veraval and Diu (in yellow) and sampling sites (in red)

Plate 11: On board fixing of water samples

Plate 12: Zooplankton collection through planktonic net

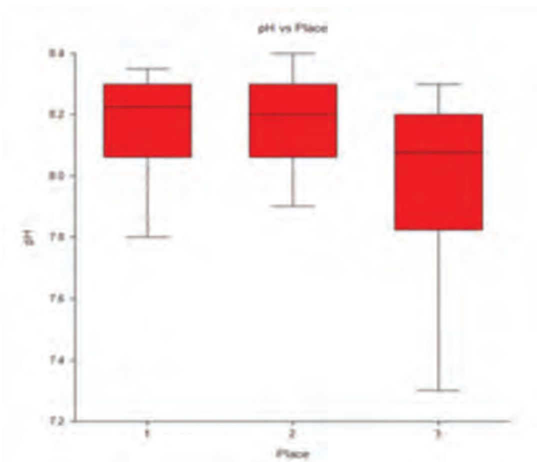

Fig. 32. Response of pH between different places

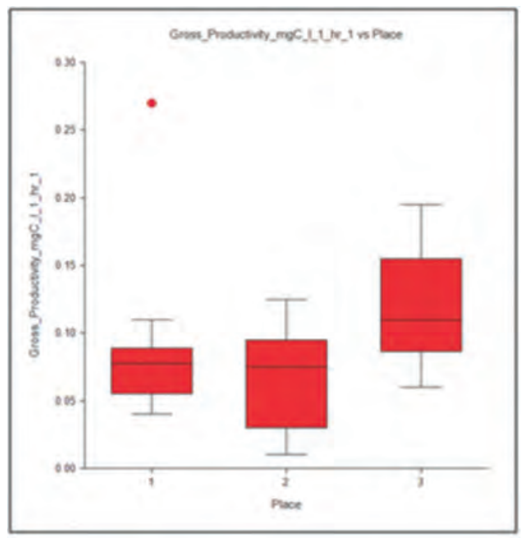

Fig. 34. Response of Gross Productivity

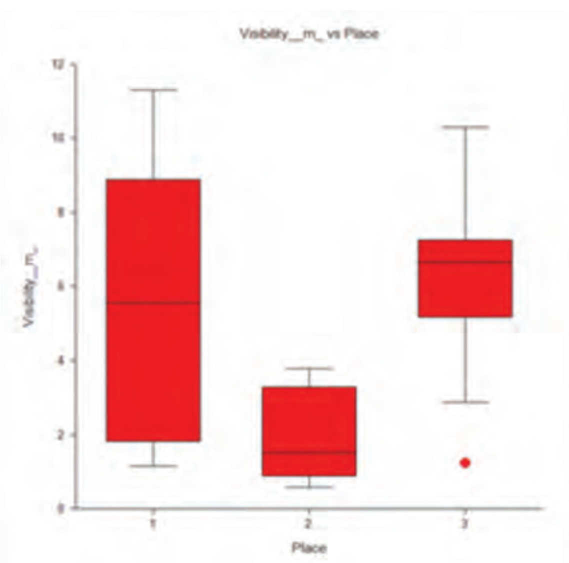

Fig. 33. Response of visibility between different places

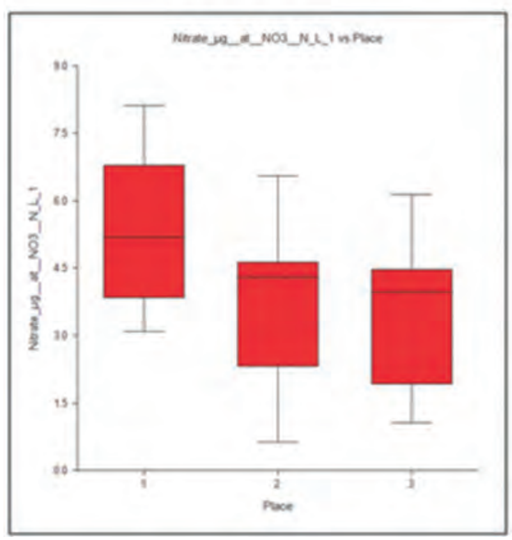

Fig. 35. Response of Nitrate (Veraval=1, Diu=2, Mangrol=3)

Table 5. Correlation matrix showing correlation coefficients (r) of only significantly correlated habitat parameters

	Depth (m)	Visibility (m)	DO (ml/L)	Net Productivity (mg C/L/hr)	Ammonia (µg /L)	Nitrate(µg /L)	Silicate(µg at /L)
Temperature (°C)					0.42		
pH	0.41		0.42				
Depth (m)		0.64					-0.40
Visibility (m)							-0.39
Gross Productivity (mg C/L/hr)				0.51			
Phosphate(µg/L)						0.45	

Auto-correlation was checked among different habitat variables and the significantly correlated habitat parameters are indicated in Table 5. Among them, only two variables- depth and visibility-showed a strong positive correlation (r= 0.64), this may be explained as with increasing depth, concentration of silicate decreased (r=-0.40).

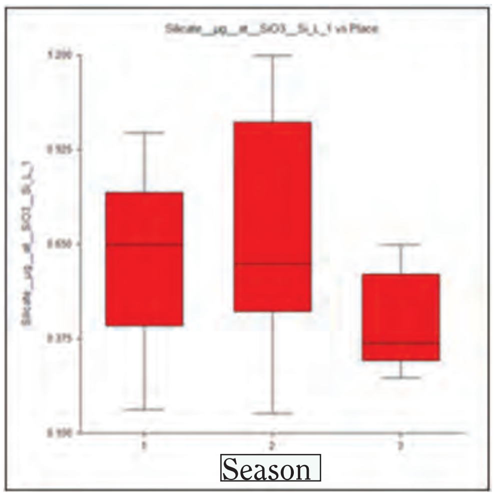

Fig. 36 . Response of silicate between different places
(Post-monsoon=1, Winter=2, Pre Summer=3)

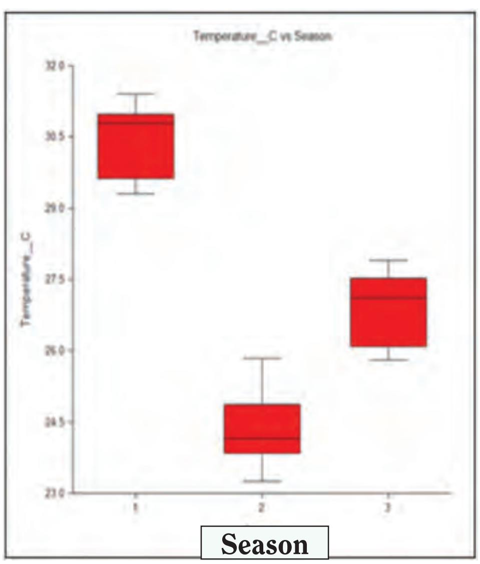

Fig. 37. Response of temperature

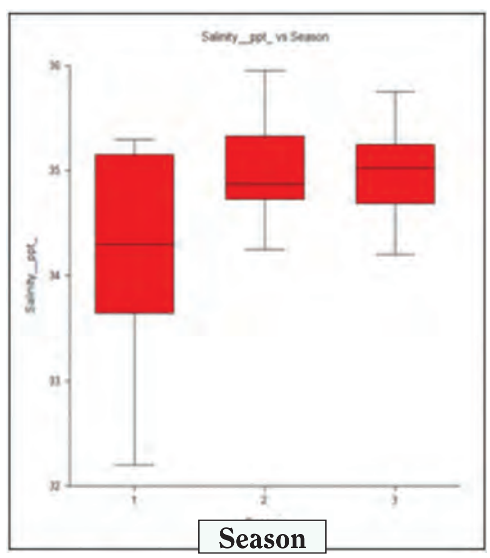

Fig. 38 Response of salinity

(Post-monsoon=1, Winter=2, Pre Summer=3)

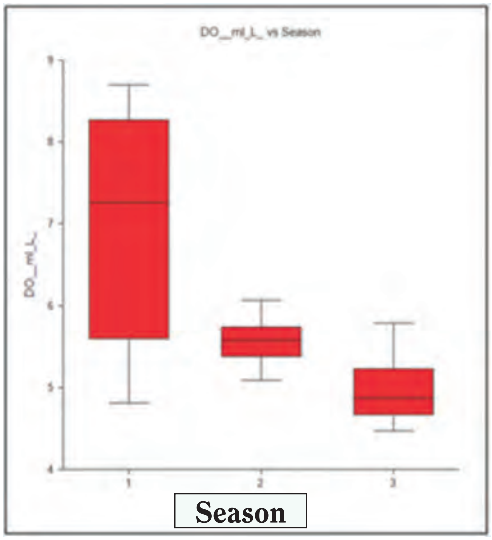

Fig. 39. Response of DO between different seasons

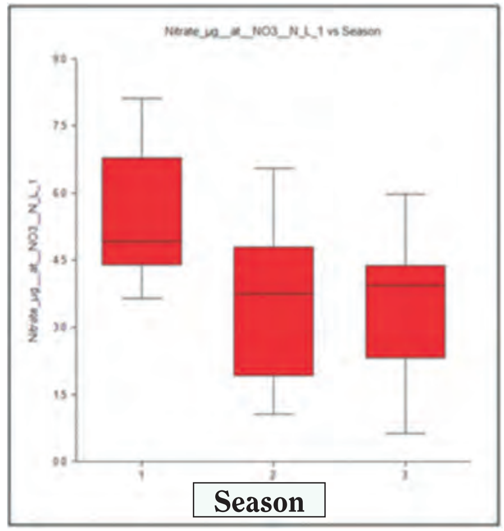

Fig. 40. Response of Nitrate different seasons

Post-monsoon=1, Winter=2, Pre Summer=3

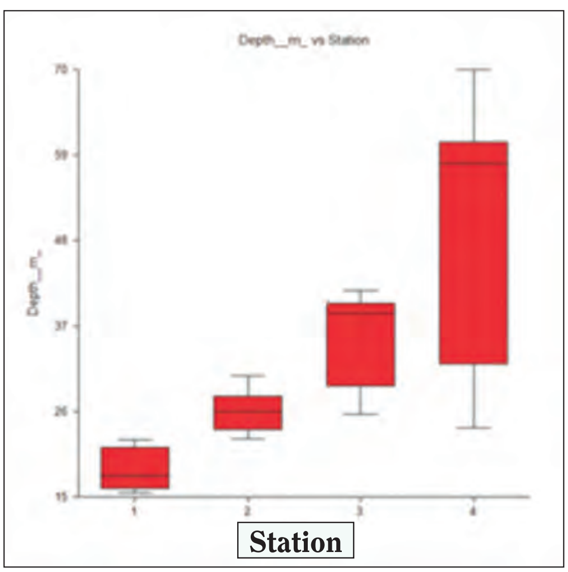

Fig. 41. Response of Depth

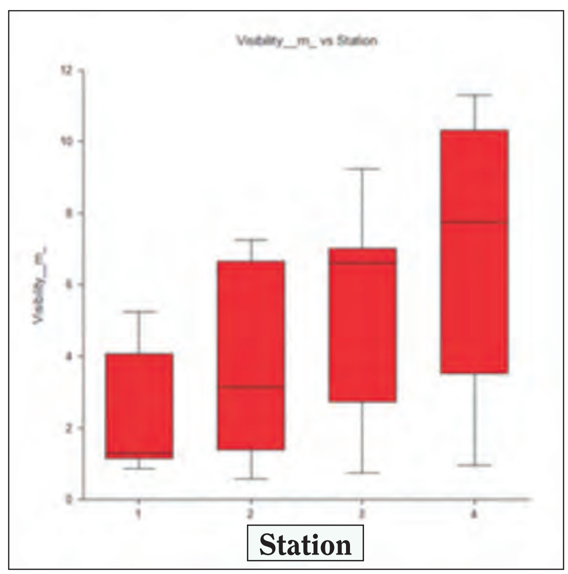

Fig. 42. Response of Visibility

Station (A=1=0 km, B=2=5 km, C=3= 10 km, D=4=20 km)

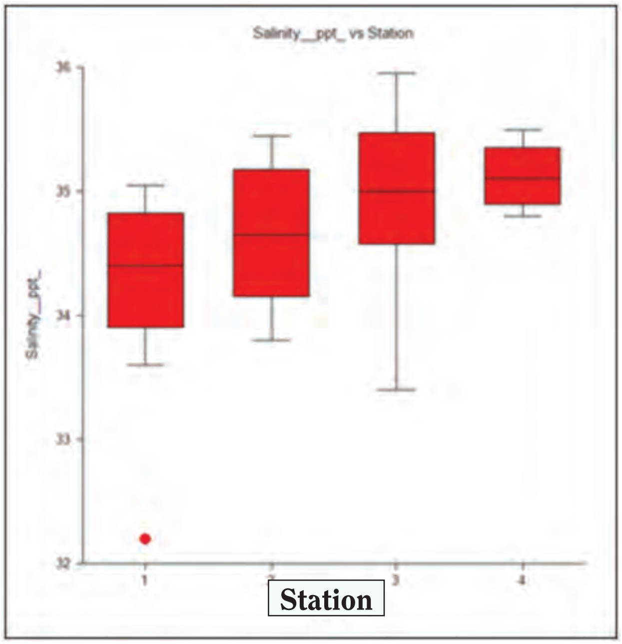

Fig. 43. Response of salinity based on distance from shore

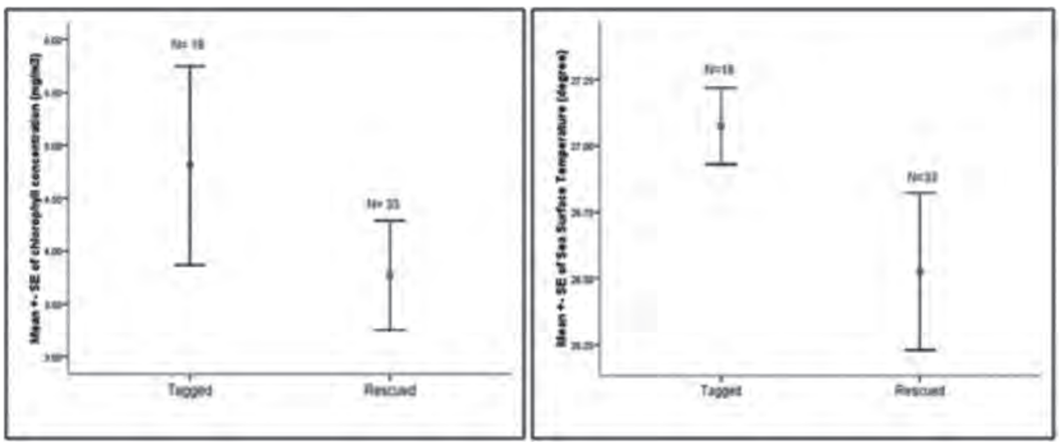

Fig. 44(a). Variable= X1 = Diu_field_temp, X2 = Diu_Sat_temp. for confidence limits = 2.1009

Table 6. Data acquired from MODIS

Chlorophyll	SST
March 2010 (8 day composites)	March 2010 (Monthly)
April 2010 (Monthly)	April 2010 (Monthly)
May 2010 (Monthly)	May 2010 (8 day composites)
December 2010 (Monthly)	December 2010 (Monthly)
October 2010 (Monthly)	October 2010 (Monthly)
February 2011 (Monthly)	February 2011 (Monthly)
April 2011 (Monthly)	April 2011 (Monthly)

6.4. Whale shark habitat analysis with free source satellite data

An overlay of satellite image data available for various parameters for the whale shark rescue and tagged locations was prepared to analyse habitat preferences of whale sharks off the Gujarat coast.

6.4.1. Data acquisition and methodology

Monthly and eight-day composites of SST and chlorophyll MODIS images having 4 km resolution

were downloaded from http://oceancolor.gsfc.nasa.gov/cgi/l3?per=DAY. Level-3 from MODIS products were produced for several time period composites. In general, longer time periods fill in more of the naturally occurring data gaps (caused by, for example, clouds, sun glint, inter-orbits gaps, ice, low light, etc.) at the expense of short-lived features which tend to get smoothed out in longer-period composites.

Sea surface temperature (SST) and chlorophyll data was acquired on the different dates when signals were acquired for tagged whale sharks as well as rescue locations. Both data sets were processed. HDF files downloaded were converted to ASCII using HDFView, and edited to remove the null values using ConText. The SST was linearly stretched using SAGA GIS. Chlorophyll data did not require any stretching. Values of the tagged shark locations and rescue locations was extracted using ArcGIS

6.4.2. Analysis

Sea surface temperature and chlorophyll

The mean SST was 27.0737°C (±14°C) at the tagged whale shark locations and the mean temprature for rescued whale shark location was 26.5264°C (±0.29°C). But a number of the whale shark rescue locations were found to be around 25°C (Table 7).

Table 7. Mean SST

	N	Mean	Std. Deviation	Std. Error Mean
SST (Tagged)	18	27.0737	0.61405	0.14473
SST (Rescued)	33	26.5264	1.702241	0.296322

The mean chlorophyll was 4.8072 mg/cubic m for tagged whale shark locations and 3.769849 for whale shark rescue locations (Table 8). The chlorophyll value for whales shark locations varied drastically among the locations, leading to no conclusion about weather chlorophyll goverened whale shark movement.

Table 8. Mean chlorophyll

	N	Mean	Std. Deviation	Std. Error Mean
Chlorophyll (Tagged)	18	4.8072	3.9974	0.9422
Chlorophyll (Rescued)	33	3.769849	2.973909	0.517691

6.5. Comparative study of satellite data with field data on sampling location

In order to check the reliability of satellite data, a test run was conducted between data gathered from field and satellite data.

6.5.1. Temperature

Paired T-test was applied to the data. There appears a selective bias in the data originated from satellite, which might be caused by many factors. For temperature, data collected in field was found higher than satellite data (Table 9).

Field data of Diu was compared with the satellite data. Against a null hypothesis i.e. field data was similar to satellite data, three alternative hypotheses were tested, and it was found that temperature data from the field was elevated as compared with satellite data.

Table 9. Temp. test for difference between temperature means section

Alternative hypothesis	T-Value	Prob. Level	Reject HO at 0.050
Diu_field_temp-Diu_Sat_temp<>0	2.2071	0.040534	Yes
Diu_field_temp-Diu_Sat_temp<0	2.2071	0.979733	NO
Diu_field_temp-Diu_Sat_temp<0	2.2071	0.020267	Yes

Variable= X1 = Diu_field_temp, X2 = Diu_Sat_temp for confidence limits = 2.1009

6.5.2. Chlorophyll

The chlorophyll data was not normally distributed. Against a null hypothesis, ie. field data is similar to satellite data, three alternative hypothesis were tested, and it was found that the chlorophyll data from field was lower than satellite data.

Table 10. Tests of assumptions about different sections

Tests of assumptions about differenct sections		
Assumption	Value	Probability
Skewness Normality	-3.4381	0.000586
Kurtosis Normality	2.6648	0.007702
Omnibus Normality	18.9223	0.000078

6.5.3. Seasonal variation in temperature and chlorophyll content with correlation to whale shark rescue and migration location of tagged whale shark using satellite data:

The satellite data was analysed to find the seasonal variation in temperature and chlorophyll content with correlation to whale shark rescue and migration location of tagged whale sharks.

The analysed data did not yield any correlation between the seasonal variation in temperature and chlorophyll content; this could be due to the low sample size or due to the previously discussed errors in the deviation of satellite data and actual field data. Further analysis is needed for any possible correlation to be identified.

Table 11: T-Test for difference between means section			
Alternative hypothesis	T-Value	Prob. Level	Reject HO at 0.050
Chloro_field-Chloro_Sat<>0	-2.8005	0.012827	Yes
Chloro_field-Chloro_Sat<0	-2.8005	0.006414	Yes
Chloro_field-Chloro_Sat>0	-2.8005	0.993586	No

Variable= X1 = Chloro_field, X2 = chloro_sat temp. for confidence limits = 2.1199

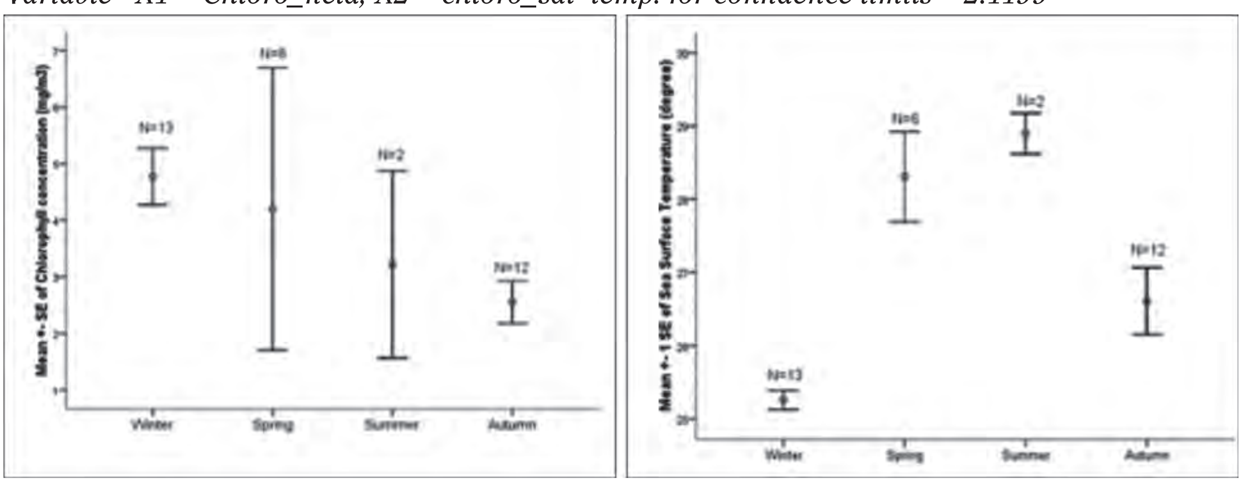

Fig. 44(b). Seasona-wise mean chlorophyll concentration and (c) season-wise mean SST variation

6.5.4. Seasonal variation in whale shark sighting or rescues:

With the available data it was not possible to run any analysis, but the graphs below show some higher whale shark sightings/rescues in some specific season (Fig 45 a, b).

6.6. Whale shark occurrence with reference to depth

When whale shark catch locations (of rescued whale sharks) were plotted in a map, not much difference was found between the numbers of whale sharks accidently caught in shallow

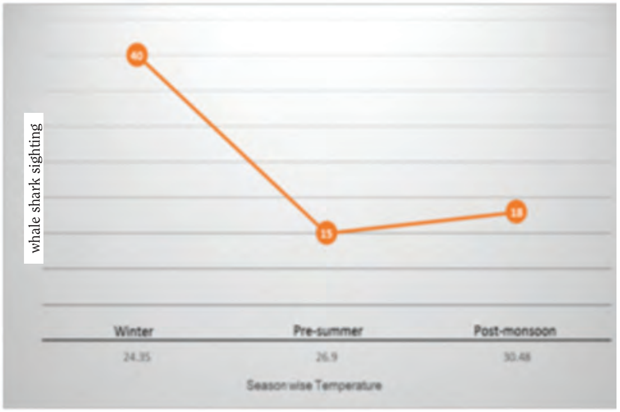

Fig.45 a. Temperature vs whale shark sightings/rescues

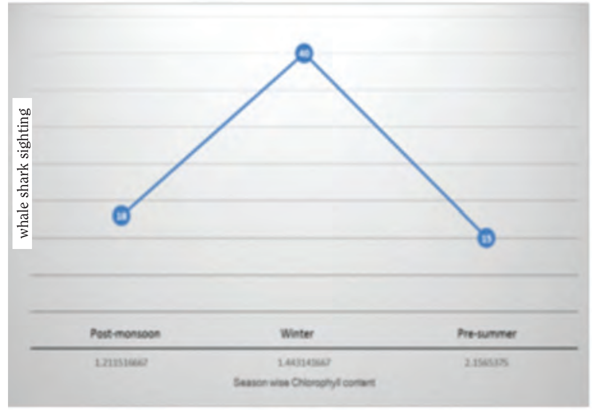

Fig 45 b. Chlorophyll vs whale shark sightings/rescues

and deeper areas. Eleven catch locations were reported from deeper areas (50 m or > 50 m) and almost similar number of 12 whale sharks were caught in shallow areas (30 or less than 30 m).

6.6.1. Zooplankton community analysis

Hierarchical Cluster analysis was applied to analyse how the community structure of zooplanktons, phytoplankton, diatoms, dinoflagellates, silicoflagellates, blue green algae and nannoplanktons at three study sites varies with seasons. The results are depicted as cluster dendrograms of three seasons, post monsoon, winter and pre-summer.

Among the zooplanktons (Table 12), Hydromedusae and copepods were most distantly associated (Fig. 46) for all the seasons except winter. Hydromedusae and Siphonophora were most closely associated zooplanktons throughout the year (Fig. 46, 47, 48, 49).

Table 12. List of zooplankton community analysis in dendrogram.

1	Hydromedusae
2	Siphonophora
3	Chaetognatha
4	Copepod
5	Sergestidae
6	Invertebrate larvae
7	Thaliacea
8	Fish eggs
9	Fish larvae

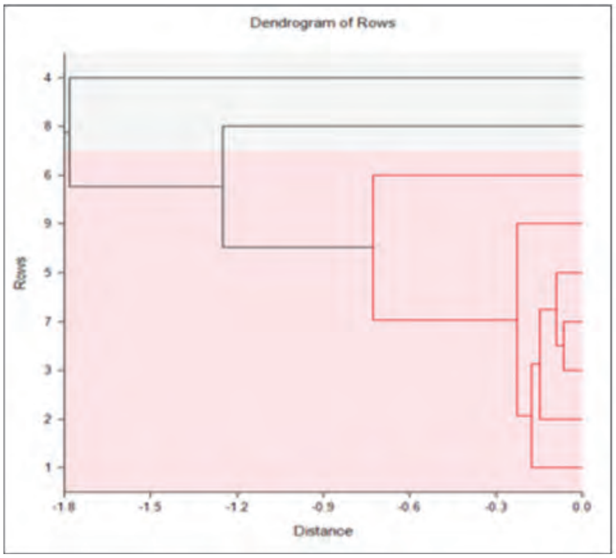

Fig. 46. All season

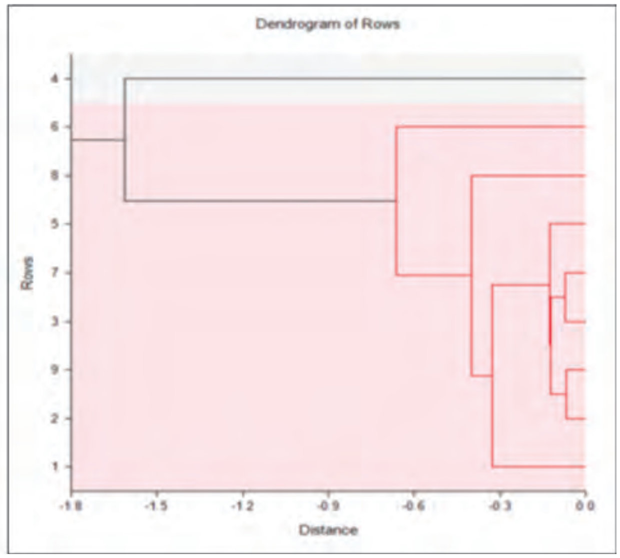

Fig. 47. Post-monsoon

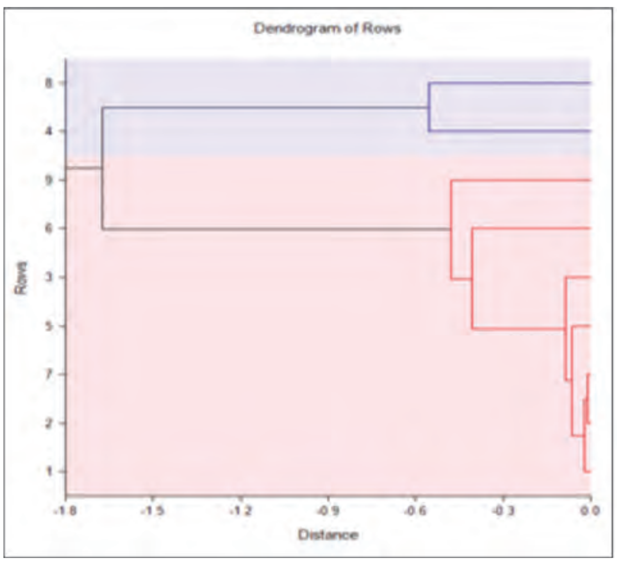

Fig. 48. Winter

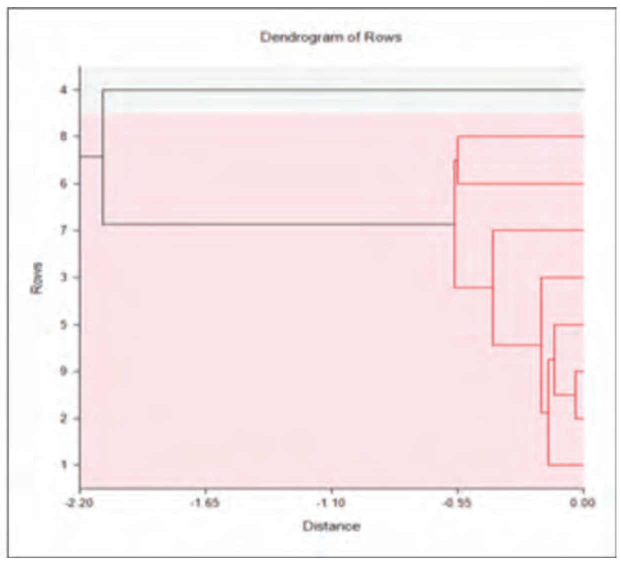

Fig. 49. Pre-summer

Table 13. List of species in dendrogram

1	*Skeletonema costatum*
2	*Thallassiophyxix palmeriana*
3	*Thallassiosira subtilis*
4	*Coscinodiscus excentricus*
5	*Planktoniella sol*
6	*Rhizosolenia robusta*
7	*Eucampia cornuta*
8	*Biddulphia mobiliensis*
9	*Ditylum brightwelli*
10	*Biddulphia sinensis*
11	*Cerataulina bergonii*
12	*Cyclotella sp*
13	*Chaetoceros sp*
14	*Lithodesmium sp*

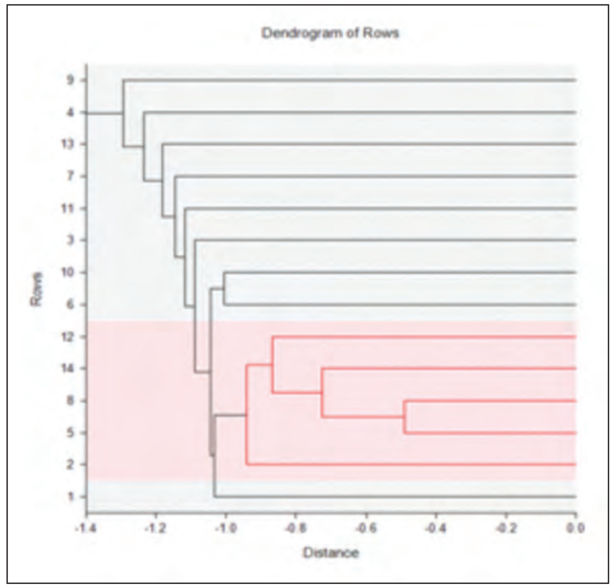

Fig. 51. Winter

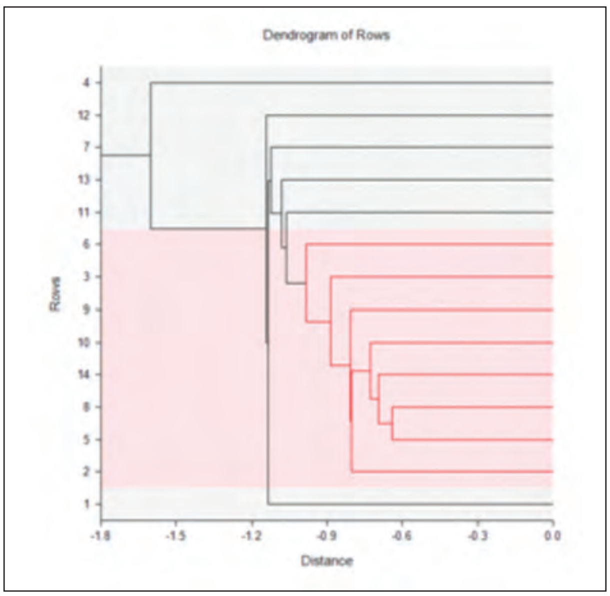

Fig. 50. Post-monsoon

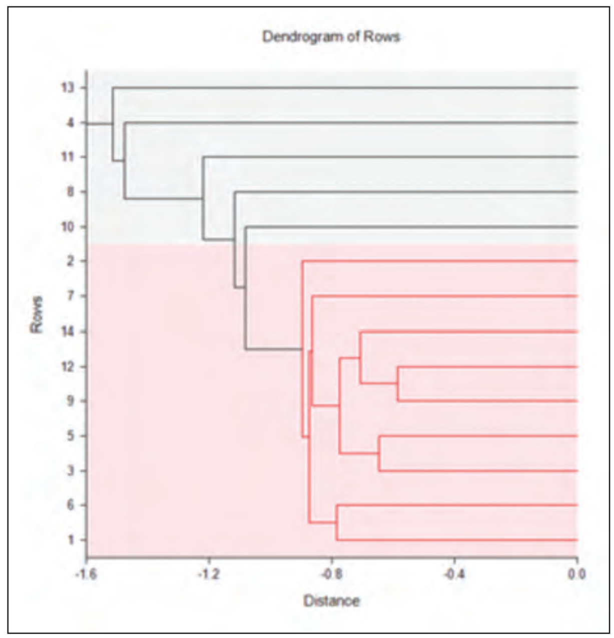

Fig. 52. Pre-summer

6.6.2. Phytoplankton community analysis

Phytoplankton community analysis was carried out in two phases, one for Diatom centrales (Figure 50, 51, 52) and other for Diatom pennales (Figure 53, 54, 55). *Skeletonema costatum* and *Thallassiiophyxix palmeriana* were very closely related during post monsoon and winter, however, in pre-summer, *Skeletonema* costatum and *Rhizosolenia robusta* were closely associated.

6.6.3 Diatoms pennales

In case of diatom pennales, three separate assemblages were evident in post monsoon (Fig. 53) whereas only two community associations were depicted in winter and pre-summer (Fig. 54 and 55) (Table 14).

Table 14. List of species in dendrogram

1	*Grammatophora undulate*
2	*Licmophora delicatula*
3	*Fragilaria oceanic*
4	*Rhaphoneis discoides*
5	*Thallasiothrix frauenfeldii*
6	*Asterionella japonica*
7	*Mastogloia exilis*
8	*Cocconeis littoralis*
9	*Gyrosigma balticum*
10	*Bacillaria paradoxa*
11	*Nitzschia closterium*
12	*Nitzschia sp*
13	*Surirella fluminensis*
14	*Campylodiscusi yengarii*
15	*Navicula sp*
16	*Thalassionemanitz schioides*

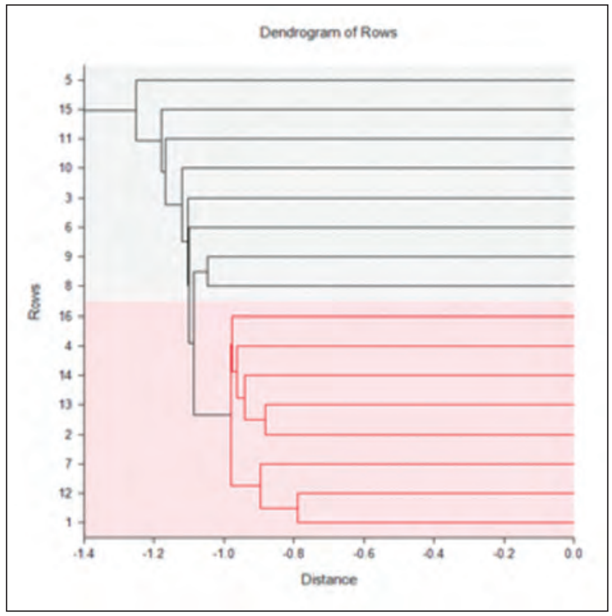

Fig. 54. Winter

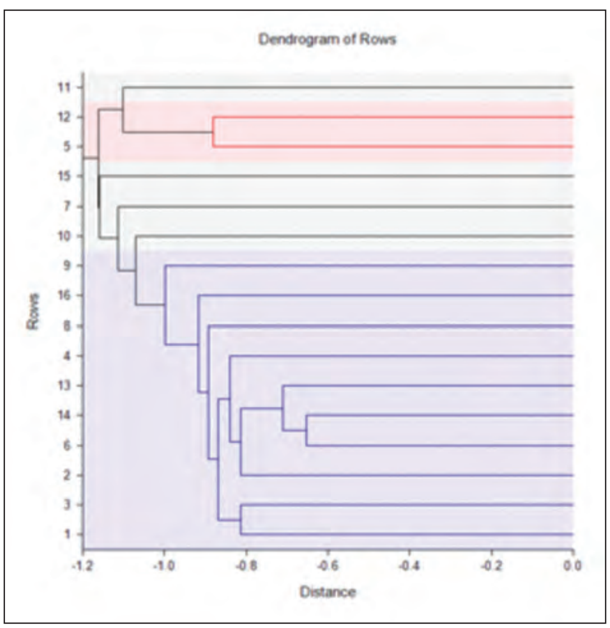

Fig. 53. Post-monsoon

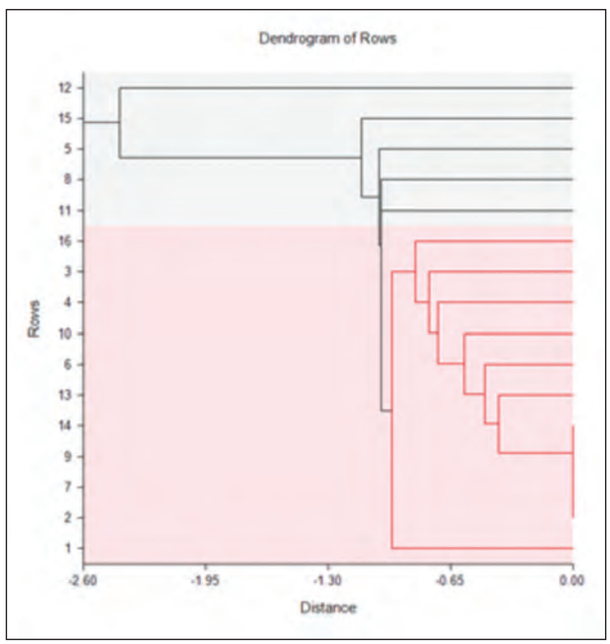

Fig. 55. Pre-summer

6.6.4 Dinoflagellates

In case of Dinoflagellates, close association was depicted for *Ceratium sp*. and C*ochlodinium citron* for all the three seasons (Fig. 56, 57 and 58). However, several changes in community composition were also depicted between winter and pre-summer.

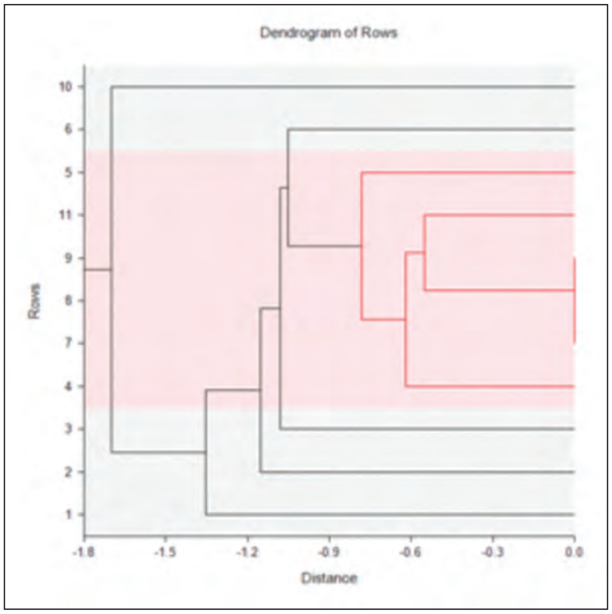

Fig. 56. Post-monsoon

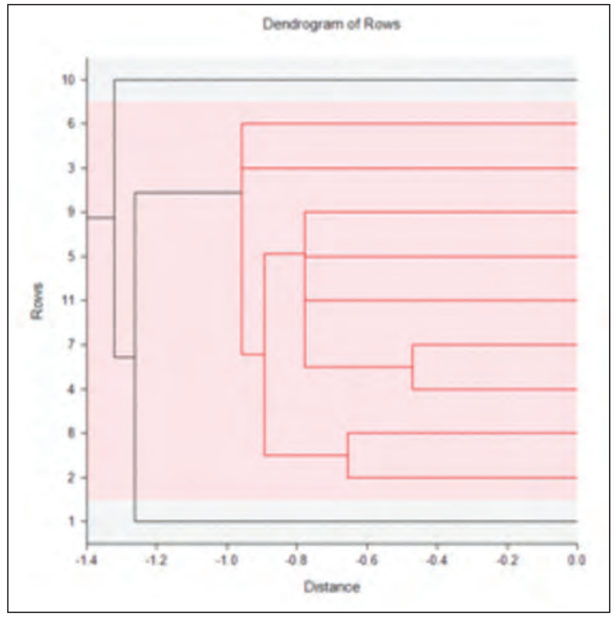

Fig. 57. Winter

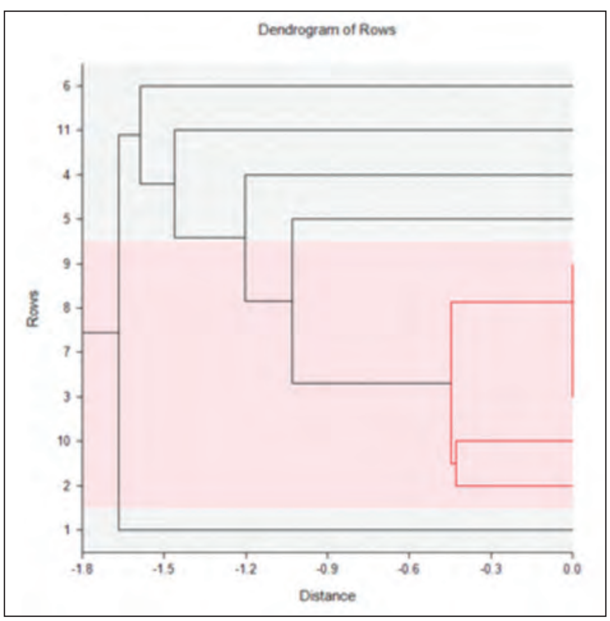

Fig. 58. Pre-summers

Table 15. List of species in dendrogram.

1	*Ceratium sp*
2	*Cochlodinium citron*
3	*Amphisolenia bifurcata*
4	*Ceratium declinatum*
5	*Dinophysis caudata*
6	*Peridinium claudicans*
7	*Podolampas bipes*
8	*Pyrophacus horologium*
9	*Diplopsalis sp*
10	*Ornithocercus magnificus*
11	*Prorocentrum sp*

6.6.5. Silicoflagellates, blue-green algae & nannoplankton

For this group, blue-green algae and *Nanno chloropsis* were not at all associated for all the three seasons (Fig. 59, 60, 61) and were part of two different communities for all the seasons.

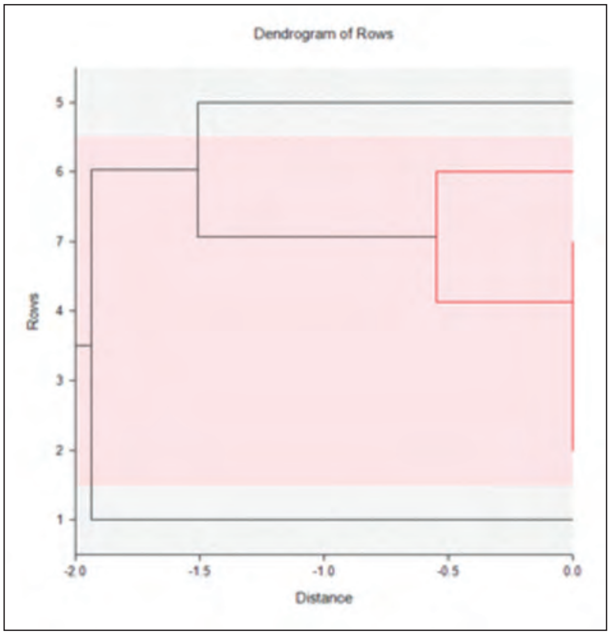

Fig. 59. Post-monsoon

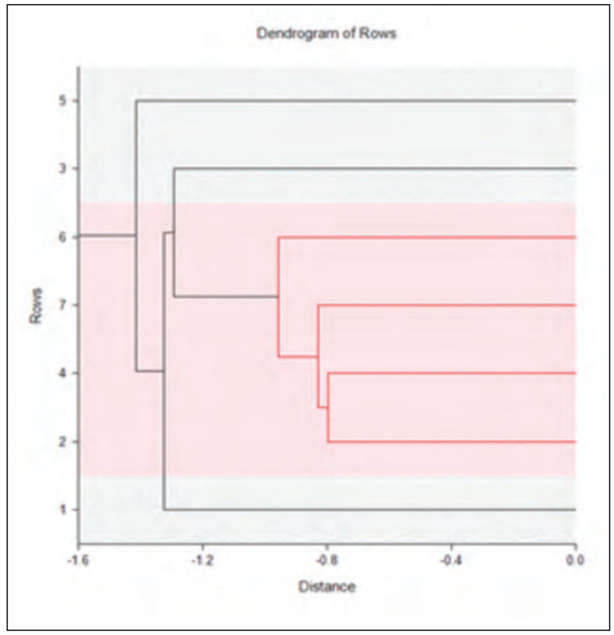

Fig. 60. Winter

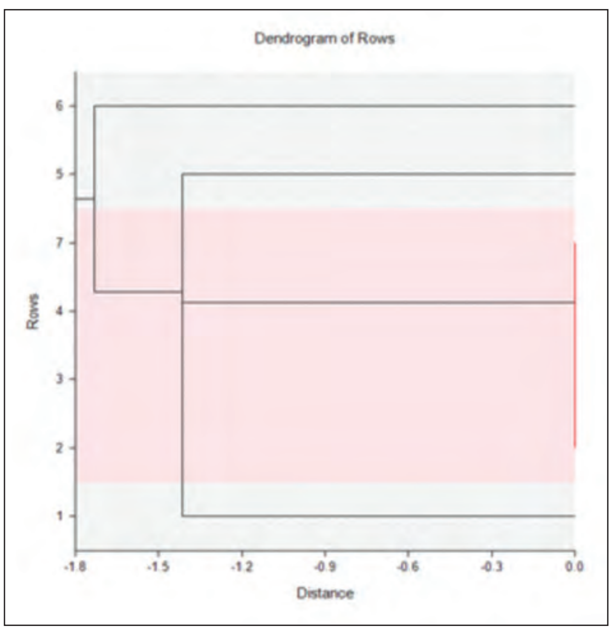

Fig. 61. Pre-summer

Table 16. List of taxon in dendrogram

1	Blue green algae
2	*Spirulina sp*
3	*Pavlova sp*
4	*Dunaliena sp*
5	*Nanno chloropsis*
6	*Chlorella sp*
7	*Tetraselmis sp*

6.7. Conclusion

6.7.1. Various habitat parameters their relation and responses to places, seasons and distance from shore

Among all habitat parameters, only depth and visibility showed some relation, which was expected as visibility often improves with depth. The rest of the parameters were weakly or not correlated at all and so nothing could be inferred.

Whale shark tourism depends on good visibility and current studies show that only the deeper areas which are far from shore show a visibility range of 2.5 m to 10 m (mean = 6.5m). Among the three study sites, Mangrol showed good visibility compared to Veraval which showed a broad range of visibility. Diu had the lowest visibility. This suggests that deeper areas in Mangrol and Veraval are good for initiating whale shark tourism and satellite tagging studies. The low visibility in Diu may be due to heavy land runoffs and shallow seas compared to Veraval and Mangrol.

> **Analysis of various parameters indicated that deeper areas in Mangrol and Veraval are good for initiating whale shark tourism and satellite tagging studies**

The pH values of all three habitats did not show significant changes and were within normal ranges. But further studies are needed specifically in areas near Veraval where heavy industrial runoffs are discharged directly into sea by fish- processing units.

Gross productivity, nitrates and silicates showed a significant difference among three study sites. The Veraval area, where maximum number of whale sharks sightings and rescues were reported, showed a greater range and mean values for these parameters, which are important to support zooplankton and phytoplankton growth (whale shark food). Further studies are needed to confirm whether areas near Veraval are highly productive compared to the rest, as the present study was limited to one seasonal cycle. It is speculated that the high numbers of recues from Veraval may also be due to increased fishing efforts, compared to Mangrol and Diu.

Different seasons showed a marked difference in temperature changes in water. In winter, when the maximum number of rescues was reported, the mean water temperature was 24.35°C (±0.58°C SD). But more studies are needed to confirm the seasonal temperature preference for whale sharks at Saurashtra coast.

A significant difference of DO and Nitrate during post-monsoon suggests heavy runoffs from lands into the sea and churning due to heavy water currents and monsoon.

The depth and visibility revealed a significant difference from shore which was expected. Low visibility closer to shore areas may be due to the heavy disturbance factors of too many boats operating.

6.7.2.Satellite field data and comparison with field data

Satellite data is reliable to study various marine species' habitat and their distribution. In the current studies, when temperature and chlorophyll data from satellite studies and the field were compared, a significant difference was found, which suggests the need to either refine the field protocols and sample analysis, or need further studies to understand satellite data.

6.7.3. Temperature and chlorophyll preference by satellite tagged whale shark

However, when the satellite data was analysed for temperature and chlorophyll at the locations where tagged animals migrated, it was found that the temperature variations between these places were small, indicating that the tagged whale shark preferred a specific temperature of 27.07°C (± 0.61°C SD). Probably this was

because the data was only for two months (13 March 2011- 24 April 2011). Chlorophyll had a wide variations (Mean 4.80 ± 3.99 SD), indicating that there was probably no relation.

6.7.4. Whale shark locations with respect to depth

No difference was found between the number of whale sharks caught in shallow and deeper areas. It shows that irrespective of the depth, whale sharks search for productive feeding grounds. In the case of tagged whale sharks also, frequent switching between deeper and shallow areas was observed. The team could not come to a definite conclusion as the present data size is limited.

6.7.5. Comparison of whale shark rescues/ sightings with seasonal temperature and chlorophyll field data

When the numbers of whale shark sightings/ rescues are compared with the seasonal water quality changes, the maximum number of rescues were recorded in winter, followed by -monsoon and -summer. If the mean temperature value of pre summer time and satellite tagged animal location temperature data (satellite data) which was during pre-summers (March and April), are compared, there is only a difference of 0.1°C, which suggests that during pre-summers of 2011 whale shark preferred this temperature. However further studies are needed to confirm such preferences for specific temperature range by whale shark for specific seasons.

6.7.6. Zooplankton community analysis

Samples collected from the study sites listed the presence of Hydromedusae, Siphorophora, Chaetognatha, Copepod, Sergestidae, invertebrate larvae, Thaliacea, fish eggs and fish larvae.

Chaetognatha, Sergestidae and Siphonophora were found continuously, forming clusters during all three seasons. During post-monsoon, fish larvae were found in close association with these species. The high density of fish larvae during post-monsoon is expected as most fish breed during monsoon. Hydromedusae and Thaliacea were found abundantly during winters.

Fish eggs and copepods were also found forming a specific cluster during winters. It is important to note that copepods and fish eggs form a major part of whale shark diet. So their increased growth during winters might be the reason for whale sharks sightings in winters.

6.7.7. Phytoplankton analysis

Phytoplanktons are the base of a marine ecosystem: they serve as food not only for many small and big marine organisms, but also for whale sharks. Their enormous growth is also known as food capsules of oceans, which attracts whale sharks.

6.7.8. Diatoms centrales

Samples collected from three sites showed the presence of *Skeletonemaco statum, Thallassiophyxix palmeriana, Thallassiosira subtilis, Coscinodiscus excentricus, Planktoniella sol, Rhizosolenia robusta, Eucampia cornuta, Biddulphia mobiliensis, Ditylum brightwelli, Biddulphia sinensis, Cerataulina bergonii, Cyclotella sp., Chaetoceros sp. and LIthodesmium sp.*

Species such as *Lithodesmium* sp. and *Planktoniella* sol showed a consistent grouping throughout all seasons. Two other species, *Biddulphia mobiliensis* and *Cyclotella* sp., were also found high in numbers during winters, especially when whale shark sighting is at its peak. The consistent presence of some species of diatom centrals throughout the seasons and the specific presence of some during winters might be the reason for consistent whale shark sightings and more specific sightings in winters.

6.7.9. Diatoms pennales

The analysis of water samples revealed the presence of 16 diatom pennales species viz. *Grammatophora undulata, Licmophora delicatula, Fragilaria oceanica, Rhaphoneis discoides, Thallasiothrix frauenfeldii,*

Asterionella japonica, Mastogloia exilis, Cocconeis littoralis, Gyrosigma balticum, Bacillaria paradoxa, Nitzschia closterium, Nitzschia sp, *Surirella fluminensis, Campylodiscus iyengarii, Navicula sp. and Thalassionema nitzschioides.*

Among diatoms pennales species, *Surirella fluminensis, Campylodiscus iyengarii* and *Asterionella japonica* which are specific community structure during post monsoon and pre-summer season are replaced by species like *Nitzschia sp, Grammatophora undulate* and *Mastogloia exilis* while during winters forming a different community structure.

6.7.9.1 Dinoflagellates

Ceratium sp, *Cochlodinium citron, Amphisolenia bifurcata, Ceratium declinatum, Dinophysis caudata, Peridinium claudicans, Podolampas bipes, Pyrophacus horologium, Diplopsalis* sp, *Ornithocercus magnificus* and *Prorocentrum* sp were reported from the analysed samples.

Diplop salis sp, podolampas bipes, prorocentrum sp, ceratium declinatum and *dinophysis caudata* are consistent for post-monsoon and winter. During pre-summer three of these species are replaced by *Amphisolenia bifurcatea Ornithocercusmagnificus* and *Prorocentrum sp.*

6.7.9.2 Silicoflagellates, blue-green algae and nanoplankton

Blue-green algae *Spirulina sp, Pavlova sp, Dunaliena sp, Nanno chloropsis, chlorella sp* and *Tetraselmis sp* have been reported from the three study sites.

Four species, *Spirulina* sp, *Tetraselmis* sp, *Nanno chloropsis* and *Dunaliena* sp are consistent during post monsoon and winters, but during pre- summers *Dunaliena* sp and *Nanno chloropsis,* are replaced by *Nanno chloropsis* and blue green algae.

With data available from only one seasonal cycle, it is difficult to arrive at a definite conclusion for whale shark habitat preferences at the Saurashtra coast. In current studies, various habitat parameters showed some differences between the three study sites, which could be a reason for increased sightings specifically near Veraval, though it could also be directly related to more intensified fishing as Veraval port has the maximum number of operational fishing vessels compared to Diu and Mangrol. Further studies are needed to understand the reasons.

Similarly it is imperative to conduct further research on the status of quantum of zooplankton and phytoplankton in the sites. The current study has shown that these areas are rich in copepods and other species which are the preferred food for whale sharks.

It is also important to refine either the field protocols of sampling and analysis, or data extraction techniques from satellite images, because the current studies showed a significant difference between the two sources. Once it is done, satellite data may help considerably in understanding the whale shark habitat. Similar efforts are needed in satellite tagging of whale sharks, as their movement data will be a great source of information on the reasons behind these migrations.

During all three seasons, a continuous heavy untreated discharge from fish processing units of Veraval was noticed. It is also important to study the impact of such discharges on the coastal waters of Gujarat, including possible alterations to the marine environment.

CHAPTER 7

Whale shark migration

Whale sharks are believed to migrate between feeding grounds. Preliminary results from various tagging studies and other observations appear to indicate that this species migrate in response to seasonal concentrations of food. Whale sharks returns regularly to certain locations to feed on blooms of zooplankton (i.e., concentrations of eggs and larvae from the synchronous spawning of fish, crabs or coral) that occur for a few months each year. Whale sharks in the Indian Ocean is highly migratory, as indicated by Rowat (2007). The tracking information from GPS data and anecdotes from fishermen and tour operators in the Indian Ocean have shown that shark migrate annually east towards continental Africa, then both south into the Mozambique area and to the north off Somalia, after which they migrate west towards Sri Lanka. The pattern of temporal occurrence shows that the whale sharks are generally seen on a regular basis during specific periods. The movements have been also linked with the monsoon wind seasons (Anderson and Ahmed 1993). Sleeman (2010) found that surface geostrophic currents did not affect the movements of whale sharks. The tracked individuals confirmed that whale sharks can effectively swim against prevailing surface currents and they did not seem to utilise the currents to get to productive areas.

Photographic identification has several advantages over conventional tagging, as it is non-invasive

Whale sharks travel long distances and the timing of their movements are typically associated with localised blooms of planktonic organisms and water temperature changes (Compagno 2002). In the Gulf of California (GOC), Eckert and Stewart (2001) used towed satellite tags to demonstrate extensive movement of whale sharks into the north Pacific Ocean. Using towed tags off Southeast Asia, Eckert *et al.* (2002) reported two whale sharks that travelled 4,567 and 8,025 km with an overall mean travel rate of 24.7 km/day. By applying PSATs to whale sharks at Ningaloo Reef, Western Australia, Wilson *et al.* (2005) documented long-term movements characterised by both in-shore and off-shore habitat utilisation, north-easterly travels into the Indian Ocean. Collectively these studies indicate that whale shark is capable of transoceanic movements, crossing numerous geopolitical

boundaries, which highlights the need for both regional and multinational levels of management for this species. Whether the migrations (i.e. the seasonal movements of animals from one region to another) of several thousand kilometres are solely driven by feeding events or linked to other aspects of their life history is yet to be determined. Although the whale shark has been documented in various parts of the Gulf of Mexico (GOM) (Burks *et al.* 2006 and Hoffmayer *et al.* 2007) and Caribbean Sea (Gudger 1939 and Heyman *et al.* 2001), the team know very little about the movement and migration patterns of this species.

Conventional tagging is increasingly used to estimate and assess shark populations and movements and since 1962 the National Oceanographic and Atmospheric Administration's National Marine Fisheries Service Laboratory (NOAA-NMFS) has implemented a cooperative shark tagging programme with recreational anglers and commercial fishers, leading to the tagging of over 87,000 sharks (Kohler *et al.* 1998). However tag shedding appears common in a range of shark species, undermining viable population estimates (Davies and Joubert, (1967), Gruber, (1982), Carrier, (1985), Heupel and Bennett, (1997). Graham *et al.* (2007) has also reported conventional tagging efforts off Gladden Spit, Belize has resulted in very few re-sightings outside the study area.

By comparison, photo identification is a non-invasive method of identifying individuals that relies on cataloguing distinctive scars or markings originally developed to identify terrestrial animals and marine mammals that can be clearly seen (Katona *et al.* (1979) and Arnbom, (1987 b)). In elasmobranchs, photo-identification has been adapted to identify basking sharks in Britain (Sims *et al.* 2000), white sharks at California's Farallon Islands (Klimley, 1996), nurse sharks in Brazil's Atol das Rocas (Castro and Rosa, 2005) and whale sharks worldwide including Ningaloo Reef, Australia (Arzoumanian *et al.* 2005), Belize (Graham, 2003) and more recently in combination with tagging in the Isla Contoy in Mexico, the Bay Islands of Honduras, the Seychelles and Djibouti.

Whale sharks are born with unique body pigmentation that is retained throughout their lives (Norman 2004). This natural patterning of lines and spots shows no evidence of significant change over years and may, therefore, be used to identify individual sharks (Taylor 1994; Norman 1999): its uniqueness has been corroborated by traditional tagging and identifications made based on scarring and other visual markers. By combining photographed encounters and spot-pattern matching, a shark may be 'tagged' without physical contact or interference with the animal. In an early effort, Norman (1999) established a photo-identification library of whale sharks at Ningaloo Reef, Western Australia, with photographs of individual sharks examined by eye for identifying characteristics, including spot patterns.

Photographic identification as several advantages over conventional tagging, particularly for a large threatened species like the whale shark. Photo-ID is non-invasive, reducing both the potential for detrimental impacts from the tags or a behavioural response to tagging, which may bias future re-sighting. Given that underwater digital cameras are now ubiquitous within the diving and marine tourism industry, it is easy to obtain ID shots from tourism operators or interested clients themselves as well as from within the scientific community.

It is vital to gather more information through scientific studies on whale shark movement, so that better conservation models can be developed in collaboration with other range states and countries. The project has used all the three techniques i.e. photo- identification, marker tagging and satellite tagging technique, to trace and understand the migration route of whale shark in the Arabian Sea. All techniques have shown varying levels of success in spite

of the challenges faced due to extreme natural conditions of the coastal waters of Gujarat.

7.1. Photo identification

Whale sharks are easily distinguishable from other species due to their large size and distinctive white-spotted dorsal coloration. The spot patterns are individually unique and appear to be consistent over time, enabling long-term re-sighting of individuals and the application of standard sighting re-sighting based population estimation methods (Meekan *et al.* 2006).

The flanks of the shark are the areas used for identification, based on other successful studies. Photographs should be taken from right angles to the shark. The important areas to include in the photograph are the upper and lower fifth gill slit and the inner trailing edge of the pectoral fin. The flank areas approximate a two-dimensional surface, containing large distinctive spots and include suitable reference points for comparison between images (Plate 13).

A platform like ECOCEAN (www.whaleshark.org) provides a global platform for the submission of whale sharks photographs, where these photographs are processed and IDs are given to individual animals. ECOCEAN was incorporated in India on January 2010 for the joint research work of Wildlife Trust of India, Tata Chemicals Ltd, and Forest Department, Gujarat.

7.1.1. Photo ID of the whale sharks of Gujarat coast

All photographs used for the photo ID were taken during the rescue operations. Though a number of photographs were documented during the project period, only two were of acceptable quality. They were uploaded on to the global online whale shark photo ID directory, ECOCEAN. The whale sharks were identified as new individuals, not previously photographed/ photo identified, and, therefore, are new additions to the ECOCEAN global directory.

Some of the hurdles for the a good-quality photo ID in Gujarat are:

- **Visibility** is one of the prime requirements for a good photo ID. But poor water visibility in the Gujarat waters has been a major hurdle for photo ID. In 40 rescues, an average visibility of 2.01m (SD±1.37) was recorded
- **Position** of the rescued whale shark is also a major hurdle for photo ID. As photographs of the sides of the sharks (specifically near the gills), need to be taken for identification, the position of the trapped sharks is sometimes unsuitable for documentation for a photo Id.
- **Net entanglement** is a third major problem, as the trapped whale sharks are completely

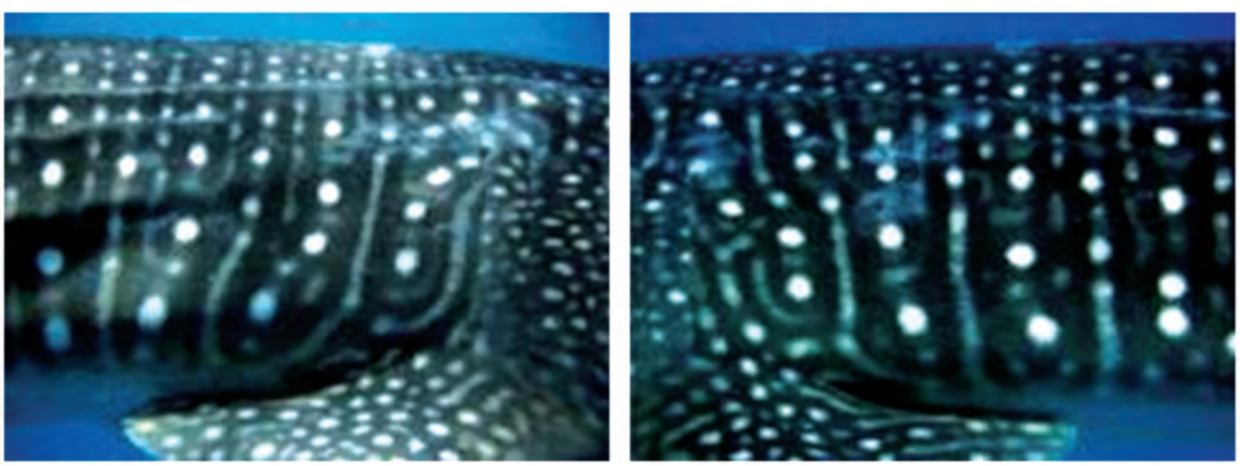

Plate 13: Photographs for a perfect photo ID

covered in net, to an extent that the spots are not visible. In such cases a photo Id is not possible.

- **Post-release** from the entangled net, the rescued whale shark immediately dives into deeper waters, making photo ID impossible in such situations.

Considering all of the above factors, it seems logical not to depend exclusively on photo ID for migration or whale shark population studies off the coast of Gujarat.

> **External marker tags carry an individual code, batch code,and visible instructions for reporting. They include ribbons, threads, wires, plates, disks, dangling tags and straps. They are usually attached to the dorsal fin**

7.2. Marker tags

Conventional external tags are another way to mark the whale sharks; the tags are applied externally on the animal. It follows that the tag is easily detectable and no special equipment is required for detection. The tags may carry an individual code, a batch code and/or visible instructions for reporting. Examples of these types of tags include ribbons, threads, wires, plates, disks, SSD, dangling tags and straps (McFarlane *et al.* 2009).

7.2.1. Tag Used

The stainless steel head dart (SSD tags) tags (Plate 14) were used to mark the animals. Each SSC tag is labelled with the project name, specific number and email id and contact number of the project leader to maximise the chances of reporting in cases of recapture.

7.2.2. Protocol

During rescue, the tags are deployed with the help of an applicator. The preferable area for inserting tags is the base of dorsal fin. At an angle of 45 degrees, the tags are harpooned into the dorsal muscle where the tag will anchor itself without locking to any specific bony structure.

The upper denticles are slightly removed using a drill, which serves as an easy insertion point for the tag to move in with the help of an applicator. This reduces the chances of secondary injuries to the animal, as using a harpoon at the close end may cause injuries. This method also further helps to take samples for genetic studies.

7.2.3. Marker tags on the whale sharks of Gujarat coast

Four marker tags have been successfully deployed during rescues operation, and no recapture of these sharks have been reported till date.

Plate 14. A standard SSD tag

Table 17. Details of deployed marker tags

S. No	Date	Place	Marker Tag Number	GPS location
1	14/12/2010	Sutrapada	001	N 20°46'377" E 70°29'637"
2	05/03/2011	Veraval	002	N 20°52'376" E 70°16'366"
3	09/03/2011	Sutrapada	003	N 20°47'592" E 70°21'528"
4	13/03/2011	Sutrapada	004	N 20°44'495" E 70°29'349"

A major hurdle in deploying the marker tags is the position of the sharks during rescue, as marker tags are required to be inserted below the dorsal fin, and in many instances the position of the sharks makes it unreachable.

7.3. Satellite tagging

Satellite tags help study animal movements and their migration patterns through transmitted signals

Satellite tags across the world are used in various wildlife conservation organisations to track and study the movement of a targeted animal, thereby, helping them not only to understand the animal's migration pattern, but also to conserve and secure the habitat the targeted animal uses. Similarly, to understand the migration pattern and also, if required, to extend the conservation activities for whale sharks, satellite tags were used in the project.

7.3.1. Tag used

Two fin mount SPOT 5 (Smart Position or Temperature Transmitting Tag) tag supplied by Wildlife Computers were used to monitor the whale shark movement in the project. The transmitted signals data location was obtained through ARGOS service provider, which is accurate up to ±350m. The tags can measure temperatures from -40°C to +60°C, with a resolution of approximately 0.2° C. The temperature is reported in "time-at-temperature" histograms. Several battery configurations are available for the SPOT5 tag. For position-only deployments, a single "AA" battery is capable of providing approximately 70,000 transmissions; a single C-cell provides 180,000 transmissions. As a general rule, a budget of 250 transmissions per day is sufficient to provide daily location calculations via ARGOS. Therefore, a single AA cell provides locations for approximately 280 days; a single C-cell provides locations for 700 days, though the actual results depend on animal behaviour and other environmental temperatures (Plate 15).

Plate 15. Fin mount SPOT tag

Additionally, the Government of Gujarat has supported in purchasing 10 tow (SPOT 5) tags supplied by Wildlife Computers. The fin mount tags need to be bolted onto the dorsal fin, while the tow tags are needed to be speared onto the base of the dorsal fin (Plate 16).

7.3.2. Tag configuration and testing

Each tag can be configured, using a computer system using SPOT5 host v5.50.2003 software. Transmission intervals and temperature ranges for up to 12 bins, as well as the number of hours over which the temperature histograms are collected (1 to 24), were set by using the SPOT5 Host v 5.50.2003 programme. Based on information available at www.satscape.co.uk satellite pass was predicted and tag transmission was tested. A WTI research team continuously practised on a dummy fin made of hard cardboard and fibre, before setting out for actual deployment.

7.3.3. First tag deployment in India

During a rescue call at Sutrapada on 13th March 2011, the first satellite tag was deployed on a rescued male whale shark (Plate 17). WTI's

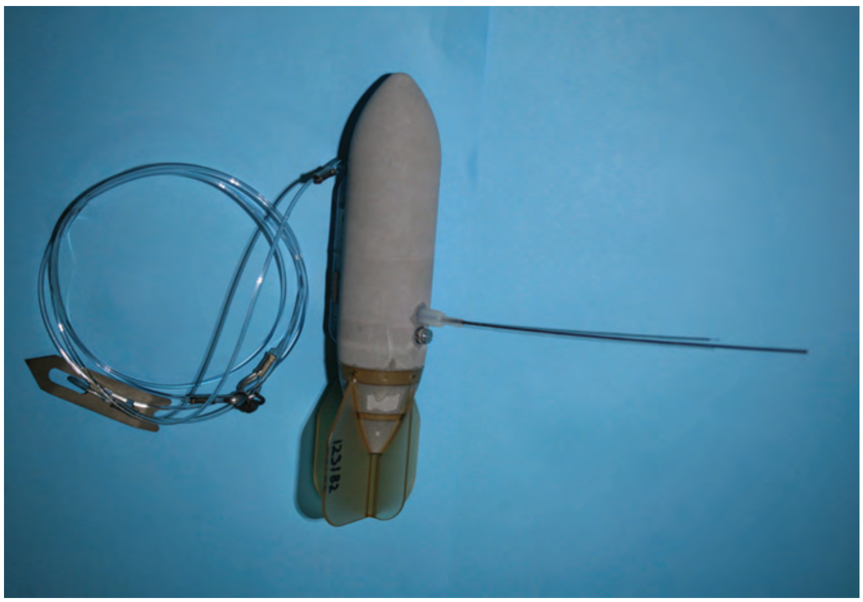

Plate 16: Floating buoy SPOT tag

Plate 17: First satellite tagging of the whale shark in India

research team and officials from the Gujarat Forest Department were involved in the tagging. On reaching the rescue spot, the health of the whale shark was assessed, after which the tag deployment was initiated.

Prior discussions with fishermen and several international whale shark experts revealed that the tail portion is the most visible part of the body above the water when a whale shark surfaces and they suggested placing the tag on the caudal fin of whale shark. The suggested protocols were followed and the tag was deployed on the tail. Plastic bolts and plastic washers along with stainless steel nuts provided with the satellite tag were used to fix the tag firmly onto the top end tail. The whole tagging process was completed within 10 min. During release, the whale shark showed no symptoms of over- stress or turmoil.

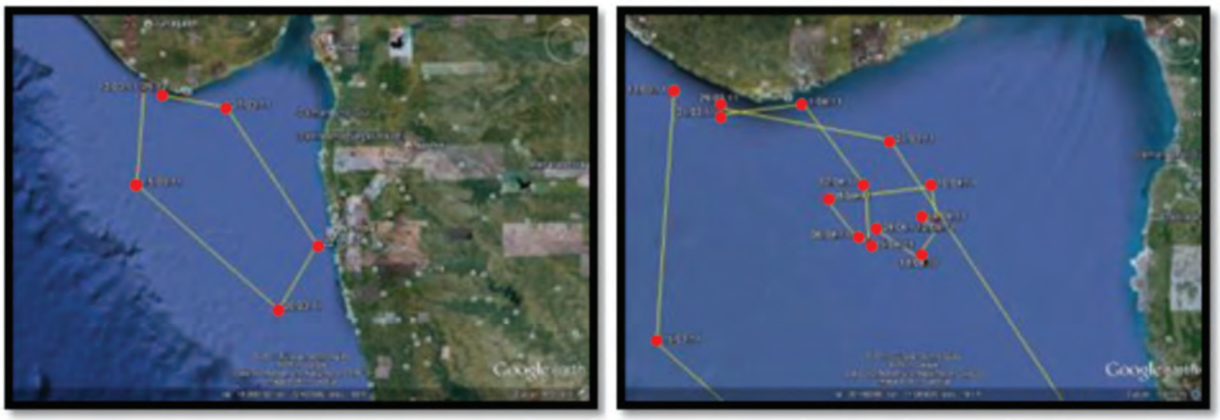

Plate 18: First satellite tagged whale shark's movement in Arabian sea

Plate 19: Tagged WS with migrating potential fishing zone (red dot- whale shark position / blue dot -potential fishing zone)

Plate 20: Tagged whale shark with migrating potential fishing zone (red dot- whale shark position/blue dot -potential fishing zone)

7.3.4. Tag transmission

For the first two days, no transmission signal was received from the tag. On 15 March 2011, the first signal was received through ARGOS satellite tag monitoring system. After the first transmission, regular transmissions were received every two or three days. The project received the tag's location data for 41 days after which the transmission stopped.

7.3.5. Tagged whale shark movement

After three days, the data revealed that the whale shark was located some 130 km away from the release location. Thereafter, the transmission signals received showed a gradual movement towards the waters of south Maharashtra, Mumbai and Gulf of Khambhat, followed by Diu. Later it was located 25 km away from the location where it was released. The whale shark moved back to Gulf of Khambhat where it spent a longer time compared to the rest of locations during the 41 days of observation (Plate 18).

On several occasions, the whale shark was found close to PFZ (Potential Fishing Zones), a forecast done by INCOIS (Indian National Centre for Ocean Information Services) based on optimum temperature and chlorophyll–content sensed through satellite imagery (Plates 19 & 20).

7.3.6. A second attempt of satellite tagging

In May 2013, a second attempt to satellite tag a rescued female whale shark (10 ft) was attempted. (Plate 21) Due to high turbidity and unsuitable weather conditions, the procedure was cancelled and the whale shark was released.

Plate 21: Attempt to tag the rescued whale shark

7.3.7. Second satellite tagging

On 27th December 2013, a recipient of a camera under the self-documentation scheme informed the local forest range officer that a whale shark was caught in his fishing net approximately 4.73 nautical miles from Sutrapada coast. The forest department in turn informed the WTI whale shark research camp at Sutrapada. The WTI whale shark rescue team immediately set off to the sea along with all required tagging instruments and reached the fishing vessel with the captured whale shark around 10.25 am. On reaching the rescue spot, the health of the whale shark was assessed, after which the tag deployment process was initiated (Plate 22).

Plate 22. Second satellite tagging

Plate 23: Second whale shark satellite tagged location

Plate 24. Tagged whale shark movement between 28 December, 2013 to 7 January, 2014 – had travelled 287 NM from tagged location

After examining the condition of the whale shark the team deployed a SPOT Tag bearing the following details (Plate 23).

- SPOT Tag Argos PTT number: 102680 or 0A7A298B
- Tagging Location: Latitude - 20°46'40.30"N Longitude - 70°32'13.50"E

7.3.8. Tag transmission from second tag

On 1st January 2014, the first signal was received through the ARGOS satellite tag monitoring system. After the first set of transmissions were received for seven days, the transmission stopped (Plate 24).

7.3.9. Tagged whale shark movement

The first signal was received on 28th December 2013 from the tagged whale shark, but the quality of the signals was poor and we were unable to plot the location. The second signal was received on 1st January 2014 from the tagged whale shark. The quality of the signal was good and the location was plotted. The whale shark had travelled around 208 nautical miles from the tagged location.The third signal was received on 3rd January 2014 from the tagged whale shark. The total distance the whale shark travelled from the tagged location was around 287 nautical miles.

Based on the transmission from the tag it was deduced that the tagged whale shark has gone in to depths ranging from 24 - 3800 m during the seven days. It is believed that the satellite tag may have stopped signalling due to high pressure during a deep dive of the whale shark.

> **The first successful satellite tagging of whale shark in India has paved the way for understanding the tagging process and monitoring whale shark movements in Indian waters**

7.4. Discussion

The first successful satellite tagging of whale sharks in India has paved the way for understanding the tagging process and monitoring whale shark movement in Indian waters. Interesting movement patterns were shown by the tagged individuals, restricted to the west coast of India. One is that it moved closer to the shore, especially during its longer stay of 41 days in the Gulf of Khambhat. There is a need to understand the water conditions around the movement locations during the particular periods.

To understand the sudden move southwards after the release and then the gradual migration back, along with some interesting movement towards PFZ and increased amount of time spent in Gulf of Khambhat, habitat-related studies are required in these areas. The failure of tag transmission after 41 days is another issue that needs to be studied as it could be because of the failure of tag's wet and dry sensor, or some other technical reason. This may require some modification on the tag to avoid such short survival of the tag in future.

In the future actitivies of the project, eight satellite tags procured with support from the Gujarat Forest Department will be used to monitor whale shark movements along the Gujarat coast, of which two have been deployed already.

CHAPTER 8

Genetic study of whale sharks in Gujarat

Preliminary analysis of the five mitochondrial control region sequences has yielded interesting data and contributed new haplotypes not yet found in whale sharks. The data support previous findings of high genetic diversity in whale shark populations

Quantification of inter-specific and intra-specific sequence variations within the mitochondrial (mtDNA) genome is a powerful tool for examining the population genetic structure, gene flow and migratory movements within and among different populations of fish and sharks (Heist *et al.* 1996; Rosel and Block, 1996; Haig, 1998). It is important to select a locus or loci with a relatively high mutation rate to detect sufficient polymorphism for population-level studies (Heist *et al.* 1996). Various studies have shown that the rate of mutation is greater in mtDNA than in coding regions of nuclear DNA (Heist *et al.* 1996; Parker *et al.* 1998). The mtDNA genome also includes a small non-coding region known as the control region or displacement loop (D-loop), which serves as the origin of replication for the mitochondrial genome, and is usually more variable than other coding genes (Parker *et al.* 1998; Avise, 1994). As maternal inheritance and in a haploid condition, mitochondrial genes have an effective size that is one-fourth that of nuclear genes, Nf = 1/4Ne (Randi, 2000), and therefore, mtDNA variability is sensitive to random drift in small populations and an ideal marker for assessing genetic structure of recently-diverged or closely related populations or species (Avise, 1994; Randi, 2000).

Sequencing of the mitochondrial control region has been suggested as a useful tool to evaluate genetic structure in sharks (Heist *et al.* 1996; Keeney *et al.* 2003). Pardini *et al.* (2001) analysed the control region in white shark *Carcharodon carcharias,* which revealed significant differences between Australian/New Zealand and South African populations. Keeney *et al.* (2003) analysed the entire control region sequence of black tip shark *Carcharhinus limbatus* and detected significant partitioning of haplotypes between Gulf and Atlantic nurseries.

The use of microsatellites as a tool to understand the population genetics of a species has revolutionised the field of conservation biology. These repetitive sequences undergo mutations that add or subtract repeat units, and they are, therefore, highly polymorphic. They provide excellent resolution for assessing intra-specific genetic variability and differentiation. Here scientists employ microsatellite analysis to evaluate levels of genetic variability across

a global panel of whale sharks, and to determine whether sharks from different regions comprise geographically restricted breeding populations. The first identification and analysis of whale shark microsatellites demonstrated moderate levels of genetic diversity within the species as a whole, but little evidence for population structure between different geographic regions (Schmidt *et al.* 2009).

8.1. Objective of the project

Whale sharks tissue biopsies were collected for DNA extraction, and then the DNA analysed using mitochondrial and nuclear genetic markers. This component of the project was carried out in collaboration with Central Marine Fisheries Research Institute, CMFRI, Cochin (Table 18).

8.2. Genetic sample collection

A small piece of tissue is scraped out using a sharp object. The whale shark tissue samples (Plate 25) collected from rescued animals is preserved in alcohol and processed later in the lab using DMSO tissue buffer. The DNA is extracted and the extracted DNA is compared to the genomic sequences available in the genomic library of whale sharks. Tissue biopsies were collected from 12 whale sharks, when the entangled animals were being freed from fishing nets.

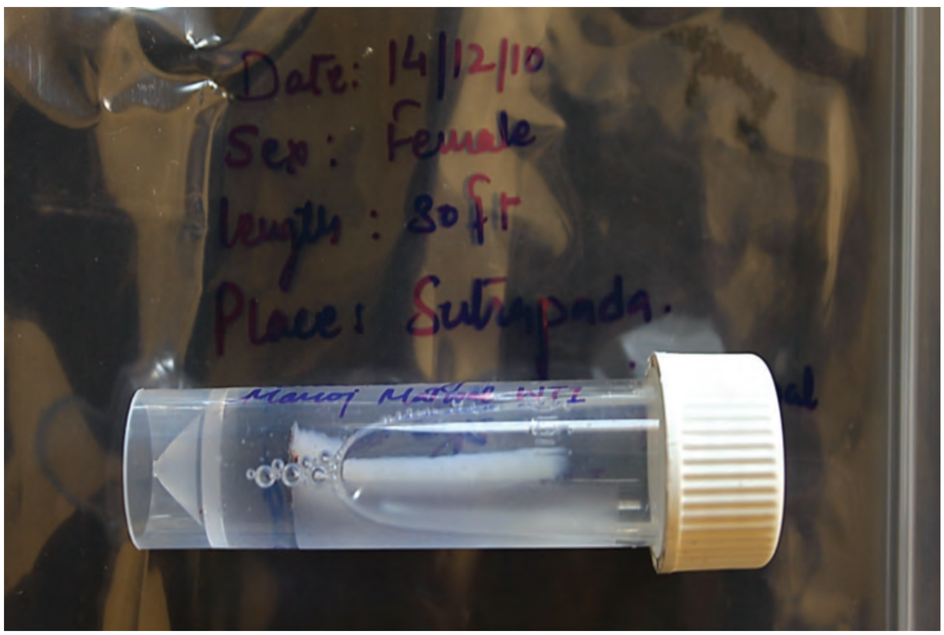

Plate 25. Whale shark tissue sample in sterile vial for genetic analysis

Table 18. Details of whale shark tissue sample submitted for DNA analysis

Sl. No	Date	Whale shark tissue sample		
		No. of Sample	Sex	Length (feet)
1	25/09/10	1	Female	15
2	20/10/10	1	Female	12.4
3	30/11/10	1	Male	23
4	13/12/10	1	Male	13
5	14/12/10	1	Female	28
6	13/01/11	1	Female	8
7	05/03/11	1	Female	19.6

8	09/03/11	1	Unidentified	20
9	13/03/11	1	Male	21.3
10	10/10/11	1	Male	20
11	13/01/12	1	Female	10
12	16/5/13	1	Female	20

DNA from five of these samples has so far been subjected to mitochondrial DNA sequence analysis, by amplifying a characteristic portion of the mitochondrial control region. So far five samples were analysed and seven more samples is under process. Microsatellite analysis of all samples is planned for the future and will serve to extend the population genetic analysis initiated through control region sequencing.

8.3. Results and disscussion

Tissue samples of whale shark preserved in alcohol sent to CMFRI were used for analysis

8.3.1. DNA extraction and PCR

DNA was extracted from the tissue preserved in ethanol using standard phenol/chloroform protocol followed by ethanol precipitation (Sambrook *et al.* 1989). PCR amplifications were carried out using the primers WSCR1F (5'-TTGGCTCCCAAAGCCAAGATTCTTC-3') and (5'-GCATGTataATTTTGGTTACAA-3') WSCR1R following the instruction given by Dr. Jennifer V. Schmidt.

8.3.2. Cloning and Analysis

The amplified PCR products (~1400 bp) were purified and ligated into pJET 1.2/blunt cloning vector, and cloned using CloneJETTM PCR Cloning Kit (Fermentas Life Sciences, EU) according to manufacturer's instruction.

Sequencing was performed using pJET 1.2 forward and pJET 1.2 reverse sequencing primers (vector primers) and the contigs were assembled using BioEdit sequence alignment editor version 7.0.5.2 (Hall, 1999).

BLAST analysis showed 98-100% identity with different haplotypes of whale shark mitochondrial DNA control region reported by Castro *et al.* (2007), The whale shark *Rhincodon typus* (Smith 1828).

Rty-2 (1397 bp) showed 100% similarity with haplotype 14 (Northwest Pacific) and haplotype 20 (western Indian) with a query coverage of 88%.

Rty-3 (1404 bp) showed 98-99% similarity with most of the haplotypes with a query coverage of 88% and showed 100% similarity with a few haplotypes (including Indian) with query coverage of 47—48% (Appendix IV).

Preliminary analysis of the five mitochondrial control region sequences has yielded interesting data, and contributed new haplotypes not yet found in whale sharks. The data support previous findings of high genetic diversity in whale shark populations. There are currently seven more samples available for analysis. To draw conclusions on population levels of Gujarat whale sharks, more genetic samples are required.

Table 19. Details of whale shark subjected to DNA analysis

Sl. No.	Sample ID	Date of collection	Sex	Sampling location	Other details
1	Rty-02	25/09/2010	F	Veraval (Adri)	–
2	Rty-03	20/10/2010	F	Veraval	Length - 3.8 m

CHAPTER 9

New records of neonatal (pup) whale sharks from the Gujarat coast

The discovery and reporting of four neonatal (pups) whale sharks confirms that the Gujarat coast is indeed a breeding area of the aggregating whale sharks

Globally, a number of areas are now known to have seasonal populations of whale sharks and most of the populations comprise sharks from 3 to 12 m in size. These include studies from the Sulu Sea, Asia (Eckert *et al.* 2002), Ningaloo in Western Australia (Taylor (1989), Taylor (1994), Meekan *et al.* (2006), South Africa (Beckley *et al.* (1997), Belize (Heyman *et al.* 2001), Sea of Cortez (Eckert and Stewart 2001), La Paz, Mexico (Clarke and Nelson 1997), the Gulf of Mexico (Hoffmayer *et al.* 2005; Hueter *et al.* 2005) and from the Indian Ocean (Anderson and Ahmed, (1993), Rowat, (1997), Pravin (2000), Hanfee (2001). While the number of occurrence records of whale shark has increased there is, however, concern that these populations are decreasing in size as noted from areas with targeted fisheries (Pravin 2000; Hanfee 2001) and more recently from areas where there have never been targeted fisheries (Meekan *et al.* 2006; Bradshaw *et al.* 2007). Despite an increase in the known areas of occurrences, few records exist of neonatal whale sharks or juveniles less than 3 m in length. This is of particular concern in the development of national and regional conservation initiatives, as potential pupping and nursery areas may unknowingly be impacted by anthropogenic activities. The paucity of such information makes the reporting of any such sightings extremely valuable.

9.1. Discovery of neonatal whale sharks across the world

The first discovery of a live and almost fully developed embryonic whale shark was from an egg case trawled from a depth of 57 m in the Gulf of Mexico (Breuer 1954; Baughman 1955). This 35-cm total length (TL) embryo was found to have absorbed a large mass of yolk into the abdomen thought sufficient to support the young shark for some time (Reid 1957; Garrick 1964). Wolfson described a further seven juvenile whale shark specimens ranging in size from 55 to 93 cm TL (Wolfson 1983), all caught in pelagic purse seine fishery operations. Three were found in the Atlantic and four in the Pacific oceans where the sea bed ranges from 2600 m to 4750 m. Three of the specimens, ranging from 55 to 63 cm TL had a faint vitelline scar marking the attachment of the yolk-sac that disappears within a few months of birth in other elasmobranchs (D'Aubrey 1964).

Wolfson also remarked that while her description of the seven juvenile sharks helped provide information on the size at birth, there were no records of sharks between 1 and 4 m TL (Wolfson 1983). The capture in 1995 of a gravid female shark off Taiwan coast (Joung *et al.* 1996) confirmed that the species is ovoviparous, retaining the lecithotrophic young within the uteri, allowing further development. Of the three size classes of prenatal sharks recorded, the largest (58 to 64 cm TL) was a free-swimming pup which was without a yolk-sac but which did exhibit a vitelline scar; so the authors suggested that these prenates were ready to be birthed. There are a few other reports of very young whale sharks: one was a 61 cm TL specimen found alive in the stomach of a blue marlin, *Makaira mazara,* off Mauritius in 1993 (D. Goorah, personal communication and cited in Colman 1997). Two others were reported from the tropical Atlantic (Kukuyev 1995), one trawled from water deeper than 2000 m and the other in the stomach of a blue shark, *Prionace glauca.* Taylor 1994 reported from Ningaloo, Western Australia, sighting of 14 young whale sharks.

In Bangladesh, the Marine Life Alliance, Comilla, was informed of the capture of an unusually small whale shark in March 2006. The specimen was seen at the local fish market at the town of Cox's Bazar, but by the time researchers arrived, the specimen had been sold. Interviews with the fishers revealed that the pup had been caught during a fishing expedition from 15–17 March 2006, in a set bag-net 140 km offshore of the town of Cox's Bazar. The specimen was already dead when the net was recovered and was measured at 1.13 m TL. The area where the net was set was in shallow waters of 10 to 20 m depth but was close to the 30- m contour where the sea bed falls steeply to depths of over 100 m.

In the south western Indian Ocean, the Marine Conservation Society, Seychelles, has recorded three sightings of less-than3- m whale sharks off Seychelles. The first was c.a. 1.5 m in September 1998, off of N.E. Mahe (Rowat, 1998); a second pup of 1.8 m was recorded by aerial survey off S.W. Mahe in October 2005, the length being confirmed by reference to an object measured shortly afterwards; and the third sighting of a less-than-2-m pup was in May 2007, off of Isle Farquar (Henn, 2007).

Table 20. Historical record of whale shark pup or juvenile (< 3 m) and past sightings published across the globe

Location of Whale Shark sighting information	Total Length of the Embryo/ Pup/ Juvenile	Year of Sighting	Details of the information	Source of information
Gulf of Mexico	35 cm	Not Mentioned	Fully developed embryonic whale shark in landing center	Reid 1957; Garrick 1964
Atlantic and Pacific Ocean	55 to 93 cm	1983	Seven, juvenile whale shark caught in pelagic purse seine fishery operations.	Wolfson 1983
Taiwan	58 to 64 cm	1995	First pregnant female whale shark, 10.6 m TL female caught in Taiwan carried 304 embryos in the uteri	Joung *et al.* 1996, Chang *et al.* 1997, Leu *et al.* 1997
Mauritius	61 cm	1993	Young whale shark found alive in the stomach of a blue marlin, Makaira mazara	Colman 1997

Ningaloo, Western Australia	1 m	1994	14 young whale sharks freely swimming along Ningaloo Sea	Taylor 1994
Balochistan, Pakistan	58.6 cm	2000	Fishermen observed the two whale shark pup in their gill net, the pup was preserved in formalin by the Fisheries Department, Omara	Rowat *et al.* 2008
North East Mahe, Seychelles	1.5 m	1998	Personal observation by Rowat	Rowat *et al.* 2008
South West Mahe, Seychelles	1.8 m	2005	Pup was recorded by aerial survey off of S.W. Mahe, the length being confirmed by reference to an object measured shortly afterwards.	Rowat *et al.* 2008
North West Mahe, Seychelles	2.5 m	2006	Anecdotal record of a pup of c.a. 2.5 m was reported from a diving trip off of N.W. Mahe.	Rowat *et al.* 2008
Isle Farquar, Seychelles	< 2 m	2007	Personal observation by Henn (one of the author)	Rowat *et al.* 2008
Comilla, Bangladesh	1.13 m	2006	Whale Shark pup had been seen at the local fish market at the town of Cox's Bazar but by the time researchers arrived, the specimen had been sold. Interviews with the fishers revealed that this pup had been caught in a set bag-net 140 km offshore of the town of Cox's Bazar.	Rowat *et al.* 2008
Donsol, Philippines	46 cm	2009	Smallest whale shark ever recorded had been caught on in nearby San Antonio, a barangay of Pilar town, adjacent to Donsol. WWF - Philippines researcher rushed and rescued the pup.	Aca and Schmidt 2011

9.2. Discovery of neonate whale sharks across the Indian coast, Arabian sea and Bay of Bengal

As noted above, of live-born whale sharks, only nine post-natal and no neonatal sharks have been reported previously. The large number of adult whale shark aggregations known from the Indian Ocean (Taylor (1989), Anderson and Ahmed (1993), Taylor (1994), Beckley *et al.* (1997), Hanfee (1997) Rowat (1997), Pravin (2000), Meekan *et al.* (2006) would suggest that there should be a population of neonatal sharks somewhere in this region.

Both India and Bangladesh indicated that January to March were peak months of whale shark occurrence (Rowat 2007). The Indian whale shark fishery, which closed in 2001, had been particularly active from March to May off the northwest coast of Gujarat (Pravin 2000; Hanfee 2001), confirming the presence of high numbers of whale sharks throughout the northern Indian Ocean during this season. A search of public reports revealed that a pup had been caught in India off of the south-west coast of Vizhinjam, Kerala (MFIS, CMFRI 2002). The 95-cm-pup was caught in a net in December 2002 and given to the Central Marine Fisheries Research Institute (CMFRI) at Thiruvananthapuram, where it survived in their aquarium for only a day. In 1998, 16 juveniles of about 1 m were reported to be swimming with an adult whale shark of 5.5 m off Vizhinjam, India (Krishna- Pillai, 1998). The smallest recorded whale shark previously recorded in India has been a 3.15-m specimen caught off of the south-east coast of Mandapam (Nammalvar 1986 cited in Pravin 2000).

Table 21. Historical record of whale shark pup or juvenile (< 3 m) and past sightings published in the Arabian Sea and Bay of Bengal off Indian coast

Location of whale shark sighting informationn (India)	Total length of embryo/ pup/ juvenile	Year of sighting	Details of the information	Source of information
West Coast (Arabian Sea)				
Kaup, Karnataka	2.5 m	1981	Juvenile whale shark observed in landing center	Pai *et al.* 1983
Vizhinjam, Kerala	1 m	1996	16 juveniles of about 1 m were reported to be swimming with a whale shark of 5.5 m off Vizhinjam	Krishna-Pillai 1998
Calicut, Kerala	94 cm	2001	Fishermen reported a young whale shark with yolk sac found swimming away 5 km from the Calicut shores.	Manoj Kumar 2003
Thiruvananthapuram, Kerala	95 cm	2002	Pup whale shark was caught in a net and given to the Central Marine Fisheries Research Institute (CMFRI) at Thiruvananthapuram, where it survived in their aquarium for only a day.	Rowat *et al.* 2008
Vizhinjam, Kerala	97.5 cm	2002	Juvenile whale shark was alive and kept in an aquarium at CMFRI in Vizhinjam for 13 h after being landed at Vizhinjam landing site.	Gopakumar *et al.* 2003
Kochi, Kerala	115 cm	2008	Small juvenile whale sharks observed during landing sites surveys	Akhilesh *et al.* 2012

Kochi, Kerala	148 cm	2010	Small juvenile whale sharks observed during landing sites surveys	Akhilesh *et al.* 2012
Kochi, Kerala	260 cm	2011	Small juvenile whale sharks observed during landing sites surveys	Akhilesh *et al.* 2012
Kochi, Kerala	172 cm	2011	Small juvenile whale sharks observed during landing sites surveys	Akhilesh *et al.* 2012
Kochi, Kerala	95 cm	2011	Small juvenile whale sharks observed during landing sites surveys	Akhilesh *et al.* 2012
Kochi, Kerala	163 cm	2011	Small juvenile whale sharks observed during landing sites surveys	Akhilesh *et al.* 2012
East Coast (Bay of Bengal)				
South East Coast of Mandapam, Tamil Nadu	3.15 m	Not Mentioned	The smallest individual whale shark recorded between 1990 and 1998 by Pravin (2000)	Akhilesh *et al.* 2012
Tuticorin, Tamil Nadu	119 cm	2007	Small juvenile whale sharks observed during landing sites surveys	Akhilesh *et al.* 2012

9.3. Whale shark pup recorded along the Gujarat coast

In March 2013, the WTI research team received the first cogent evidence of whale shark pups being found along the Gujarat coast. A young pup was caught in the net of a local fisherman – Mohan Beem Solanki – in Sutrapada. Following years-long tradition of the fishing community of Gujarat, through the internationally-acclaimed whale shark campaign, Solanki set the whale shark free. When he reported the incident to us, Solanki was unaware of the flutter created by this serendipitous discovery (Plate 26). He had unveiled a treasure-trove, and the fishing community held the key.

Even as our research lead by a sociologist went about asking the fishing communities whether they had seen or – hopefully – photographed a whale shark pup with the cameras provided

Plate 26. Whale shark pup recorded at the Saurashtra coast of Gujarat in the year 2013

to them to facilitate self-documentation during rescues, the fishermen themselves started approaching WTI with information on the pup. Within a month, WTI had reports of four pups spotted off Gujarat coastline (Table 22).

These are significant finds for the project. All caught pups seemed to be between 1 and 3 months old – the size of an arm – indicating that the fish may be breeding, and definitely pupping off the Gujarat coast.

Neonatal whale sharks are thought to have limited swimming abilities compared to juveniles and adults (Martin 2007). Neonatal whale sharks have an elongated body with a strongly heterocercal caudal fin (Garrick 1964; Wolfson 1983; Kukuyev 1995), very similar to neonatal tiger sharks, *Galeocerdo cuvier*, which have an inefficient anguilliform swimming stroke (Branstetter *et al.* 1987). The new records of pups in the Saurashtra Coast, Gujarat, indicate that the region is not just a whale shark aggregating site, but also an important pupping ground.

Identification and recording of whale shark pups may well be the key to the conservation of this species on a regional and global scale (Rowat, 2007). Encouraged by the important findings, the project has launched a reply-paid postcard questionnaire survey along the entire west coast of India, in which the photograph of a whale shark pup is on the postcard is retained by the fishermen, and information about when and/or where the informer has seen one is printed on the reply-paid card. In this way, the project hopes to collect further information of whale shark pupping locations along India's west coast.

Table 22. Whale shark pup and juvenile reported during the project

Location of whale shark sightings	Total length of the embryo/ pup/ juvenile	Year of sighting	Details of the information	Source of information
Sutrapada, Gujarat	< 60 cm	2013	A young pup was caught in the gill net of a local fisherman in Sutrapada. The Pup caught and released immediately into the sea. (Fig. 1a, 1b)	Fisher folk
Sutrapada, Gujarat	< 60 cm	2013	A young pup was caught in the nylon gill net of a local fisherman in Sutrapada. The Pup caught and released immediately into the sea. (Fig. 2a to 2d)	Fisher folk
Sutrapada, Gujarat	< 60 cm	2013	A young pup was shored in the Sutrapada beach. The local fishermen taken picture of the pup and buried near the beach. (Fig. 3a, 3b)	Fisher folk
Sutrapada, Gujarat	< 100 cm	2013	Fishermen reported a young whale shark found swimming away 20 km from the Sutrapada beach.	Fisher folk

CHAPTER 10

Education, Awareness, Communication and Outreach

Although the project focused on whale shark science since 2008, the awarness campaign continued on a smaller scale throughout the duration of the project. A 'Whale Shark Day', continues to be celebrated with great enthusiasm by the fishing community, school children and authorities from the Forest Department, Coast Guard, Navy etc every year. During the project period eight cities (Porbandar, Diu, Dwarka, Okha, Ahmedabad, Veraval, Dwarka and Mangrol) adopted the whale shark as its mascot. (Dwarka adopted it twice).

Other than that, awareness activities were held occasionally among the local communities and educational institutions such as schools and colleges.

Whale Shark Day and Melas are being observed in Gujarat, as part of a statewide awareness campaign to save and conserve the whale shark

Awareness activities were also held to appraise fishermen about the things they should do to reduce the stress on whale sharks during rescues, as part of promoting the self-documentation scheme.

10.1. Whale Shark Day and Whale Shark Mela

Although 30 August is celebtrated as the World Whale Shark day, in Gujarat taking the Hindu calender in to consideration and to conduct the whale shark day in multiple coastal towns and cities different dates have been used as 'Local Whale Shark Day". On February 17, 2007, the state forest minister declared the 'Whale Shark Day', for Gujarat designating Kartik Amas as the annual date. This marked a significant milestone in the campaign, making whale shark the first animal in India with a day designated in its honour.

During this period, five Whale Shark Days and Melas were coordinated by the project in Porbandar, Dwarka, Mangrol, Sutrapada and Veraval.

Thousands of stakeholders including fishermen, school and college students, and government authorities participated in the events. The events saw talks and speeches by experts as well as

street plays on the plight of the fish. Fun activities were also organised for the children and other stakeholders (Plate No. 27, 28, 29 and 30).

10.1.1. Whale Shark Day – Porbandar, November 27, 2008

The event took place at the Chowpatti cricket ground in Porbandar. In addition to the local stakeholders, the event saw participation of international marine experts (Scientific Advisory Council members) and a filming crew from Australia.

'Whale Shark Day 2008 or 'Vhali Utsav' began with a colourful procession, in support of 'Vhali'- the dear one, as the fish is locally known. Led by the campaign's flagship life-size inflatable whale shark mounted on a camel cart, about 1000 students dressed in symbolic whale shark coloured T-shirts, and holding whale shark campaign flags, rallied across Porbandar from Kirti Nagar to Chowpatti cricket ground. At the venue, whale shark coloured balloons brightened up the celebrations in honour of the species. Talks and street plays ensued.

10.1.2. Whale Shark Day – Dwarka, November 27, 2009

The event was held at the Sunset Point ground for the celebration. The event was chaired by Hon'ble Minister of State for Environment and Forests, Shri Kiritsinh Rana. Indian and international marine experts, government officials and conservationists participated in the event, along with hundreds of school students.

The celebrations began with a colourful rally by school children donning the campaign T-shirts and sun visors, waving whale shark flags, and chanting slogans for whale shark. The rally was led by the inflatable. It also witnessed talks and street play on the fish.

Plate 27: Students create a whale shark at the sand art competition, Sutrapada, 2011

Plate 28: School children involved in kite flying in the Whale Shark Mela, Sutrapada, 2011

Plate 29: Members of the Forest Department, Navy, TCL, WTI and the fishing community took part in the rally

Plate 30: Children of the fishing community at the Mela

Plate 31: Students from Choksei College and Fisheries College, along with some volunteers from private banks helping to make a street play enacting whale shark stress under current rescue practices.

Plate 32: Students doing their first show at Sutrapada, which was applauded by all. Support form Forest Department and fishing community helped start this drive. Cameras were also distributed for doing self-documentation.

Plate 33: Street play at Jaleshwar, near Veraval.

Plate 34: Awareness campaign in coastal villages for awareness

10.1.3. Whale Shark Day – Mangrol, January 25 2011

After several delays due to unavoidable circumstances, the whale shark day 2010 was organised on January 25, 2011 in Mangrol.

The whale shark day in Mangrol saw the town adopting the fish as its mascot, making Mangrol the seventh in the state to do so.

The celebrations were kicked off with a rally by hundreds of children, following the 40- foot long whale shark inflatable from Parmeshwar Vidyalaya to the event venue at the Town Jetty, Mangrol. The event was chaired by SK Chaturvedi, Chief Conservator of Forests and was attended by the local member of legislative assembly (MLA) Rajgi Bhai Jatwa along with representatives from WTI and TCL.

10.1.4. Whale Shark Day and Mela – Sutrapada, November 25, 2011

With a number of distinguished guests, including the local MLA of Mangrol, Bhagwanbhai Kargatia; Rajsinh, MLA Somnath; Govindbhai Parmar, ex MLA of Mangrol; Jethabhai Fulbaria, sarpanch, Sutrapada bunder, and TCL Deputy General Manager Paresh Tank; the Whale Shark Day was organized at the Navdurga temple grounds. Over 250 school children from Vivekanand Vinay Mandir and Manas Vidyalaya took part in the event.

A number of fun games on the whale shark theme, including snakes and ladders, and jig saw puzzles, were organised for the children. A signature campaign in which the children drew the outline of their hand and left a message on the screen was also organised.

A short ceremony by the forest department was held where its officials, local NGOs, and other groups shared their views on whale shark conservation. It was followed by a play by girls from the Navodaya school.

Fishermen who rescued whale sharks were given appreciation certificates and cheques for their participation in whale shark conservation, and monetary relief for their net loss.

10.1.5. Whale Shark Day and Mela – Veraval, December 17, 2012

Whale shark day celebration was held at Chokshi College, Veraval, on December 17, 2012, which were organised by the Veraval Forest Department. The event saw participation from local schools and colleges, NGOs and volunteers. The whale shark film was screened during the session and a street play based on the self-documentation scheme street play was performed by volunteers.

10.1.6. Whale Shark Day and Mela – Dwarka, March 6-7, 2013

On March 6, 2013, the annual whale shark mela kicked off in Dwarka, with a cycle rally. Over 30 cyclists from the Rupen fishing community, Tata Chemicals Limited (TCL), Gujarat Forest Department, the Navy, college volunteers, and WTI started off from ISKCON gate. The rally went around the town through the main markets as well as residential areas, crossing the Dwarka temple, and moving 4-5 km to reach the cricket ground, where a cricket tournament was held.

The cricket tournament had six teams participating – two from the fishing community, and one each from TCL, the forest department, Navy and Saradapith College. A fishing community team won the tournament, and the team from the Navy was the runner-up.

Day 2 of the mela saw various activities involving local school children including kite- flying, rangoli, tug-of-war, etc. Interaction with the children indicated a good awareness about the fish and its status.

10.2. Self-documentation scheme campaign

To reduce the stress on the whale shark during rescues, the project suggested and ensured changes in the rescue protocol. This mandated self-documentation by the fishermen to reduce time taken for rescues. A rapid action project was implemented to provide water-proof cameras to over 1000 fishermen to facilitate the implementation of the updated protocol.

The project carried out awareness campaigns to spread the information on the new development, as well as to make the local fishermen aware of the self-documentation scheme and methodology. Numerous meetings and awareness activities were held with the communities on the issue.

The project deployed local volunteers (college students as well as corporate workers) to spread the word. A street play was devised along with the volunteers for o the fishing communities, along with talks (Plate 31, 32, 33 and 34).

Trainings were also held for the local fishermen on the use of the cameras. These focused on making the fishermen aware of the use of the camera, and the kind of photographs needed to claim a refund for their nets damaged during whale shark rescues. A training of trainers was organised in the various fishing villages, with around 15 fishermen participating in each to become ambassadors for the new scheme.

A series of interactive sessions with various schools, colleges and fishermen societies were conducted during the project period in Jaleshwar. In these sessions, the target audience was introduced to the importance of whale sharof whale sharks and their conservation, using power point presentations and active discussions. The school and college students were also urged to be volunteers in the whale shark conservation project, which led to their active participation during whale shark campaigns, with a few helping with whale shark science.

CHAPTER 11

Future plans for whale shark conservation project

A conservation effort leading to the species emerging as one of the flagship species will seal a safe future for the whale sharks not just in Gujarat, but in the whole marine environment of India

The Wildlife Trust of India has been working on the whale shark now for over a decade. This decade saw very effective lobbying and a successful campaign that catapaulted this gentle giant into wildlife conservation agendas both internationally (CITES) and nationally. Such was the campaign that within a year of its initiation, the hunters of this fish (the fishermen) turned conservationists when they cut their nets through to let a captured whale shark go free. This got institutionalised further when the Gujarat Forest Department stepped in and offered compensation for the loss of net in case a fisherman cut his net to set free a trapped whale shark. Tata Chemicals Ltd was recognised for their role in this initiative with the BNHS Green Governance Award by the then prime minister Dr Manmohan Singh. A state-wide 'Whale Shark Day' on ‘Karthik Amas’ was declared by the forest minister Mangubhai Patel on February 17, 2007, making it the first animal with a day in its honour in the state. The Kharva fishing community of the coastal city 'Veraval' also showed their commitment to whale shark conservation by making the life size whale shark inflatable a part of their most important celebration. Eight cities and towns in Gujarat, including a non-coastal city, adopted the fish as their mascot.

WTI also initiated scientific work on the species to find out hotspots of whale shark aggregations within Gujarat waters and figure out population estimates using various contemporary techniques. Marine research in India is still in its infancy and despite the presence of a very august scientific advisory committee, it has taken the team time to find its feet. Information obtained over the last four years has been important and it is time to build on this and the progress is expected to be much more rapid now. One important and landmark piece of research concerned the stress the whale shark suffered from post capture upto its release. Through the initiative of the government of Gujarat, a self documentation scheme has now been introduced where a fisherman does not have to wait for the forest department to document before releasing a whale shark. The fisherman can document the evidence himself using either the camera provided for the purpose by WTI or his mobile phone camera.

Thus in the future, WTI shall concentrate on completing the scientific initiatives, take the whale shark information network forward and continue with the awareness activities. Specifically the activities would include:

11.1. Spatial analysis using satellite imagery

Baseline information on the occurrence and preferred zones of whale sharks is lacking along the Gujarat coast. The information is important to target conservation efforts and potential tourism also. Ocean colour remote sensing is an important tool for detecting regional to global trends and patterns in ocean biology and biogeochemistry. Scientists have made important discoveries during the SeaWiFS/ MODIS , which have drastically transformed the field. Monthly composites of parameters such as sea surface temperature (SST), chlorophyll and salinity are available from Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the National Oceanographic and Atmospheric Administration-Advanced Very High Resolution Radiometer (NOAA-AVHRR), which can be used to find out the preferred zones of whale shark. With the overlay of whale shark rescue location data and oceanographic parameters, it is adviced to identify variables that govern the distribution of whale sharks along the Gujarat coast.

11.1.1 Migration studies

Satellite Tagging: A total of ten tags have been provided by the Gujarat Forest Department, of which two have been deployed so far. The remaining eight shall be deployed on both rescued and free moving whale sharks.

Marker Tag: Marker tags are defined as visible tags applied externally on the fish. It follows that the tag is easily detectable and no special equipment is required for detection. These types of tags may carry an individual code, a batch code and/or visible instructions for reporting. Examples of the tags include ribbons, threads, wires, plates, disks, dangling tags and straps (McFarlane *et al.* 1990). The use of external tags are the oldest and the most widely used technology for identifying individuals or groups of fish. External tags have been used for both scientific and assessment purposes.

The justification for any type of tag on a fish is the future recovery or recapture and the resultant information collected. The more advanced external tags can carry extra information on individual fish together with reporting instructions, information on rewards etc. The best known examples of external tags are probably T-Bar Anchor Tags (Jones, 1979, Morgan & Walsh, 1993) and Carlin tags (Carlin, 1955) and various modifications of these. Several different external tagging methods have been evaluated by Bartel *et al.* (1987), Dunning *et al.* (1987), Mattson *et al.* (1990), McAllister *et al.* (1992), Nielsen (1988), Nakashima & Winters (1984), Weathers *et al.* (1990) and Rasmussen (1980, 1982). These marker tags will be distributed to fishermen who will be formally trained so that they can tag the animals in case of any whale shark encounters. Through this awareness among fishermen, the chances of reporting in cases of recapture will increase.

Archival/Pop-up tags: Additionally pop-up tags will be purchased, which would give us a greater benefit of storing up data (archive) and transmitting it as a whole when a satellite reception is available so that no data is lost. Understanding the movement patterns of large migratory fishes is important for their conservation and management. To investigate these patterns, satellite-linked radio transmitters have been widely used on species that regularly swim in surface waters. However, this technology is less effective when studying species that may remain submerged for long periods as radio signals are rapidly attenuated in seawater, and are also reflected downward at the sea surface. Consequently, the signals either have limited strength or never reach earth-orbiting satellites unless the transmitter's antenna is above the surface of the sea. In recent years, new types of tags have been developed that overcome some of these constraints (Block *et al.* 1998). These ''pop-up'' archival tags store recorded data

until they detach from the fish and float to the surface. They then transmit the information to Argos satellites. The technology has permitted researchers to examine the horizontal and vertical movement patterns of a wide range of fishes, such as tunas (e.g. Wilson *et al.* 2005), billfishes (e.g. Takahashi *et al.* 2003), and sharks (e.g. Sims *et al.* 2003).

11.1.2 Genetic studies

Genealogy: The use of microsatellites as a tool to understand the population genetics of a species has revolutionized the field of conservation biology (Ellegren, 2004 and DeSalle and Amato, 2004). The repetitive sequences undergo mutations that add or subtract repeat units, and they are, therefore, highly polymorphic. They provide excellent resolution for assessing intra-specific genetic variability and differentiation. Here we employ microsatellite analysis to evaluate levels of genetic variability across a global panel of whale sharks, and to determine whether sharks from different regions comprise geographically restricted breeding populations. Thus more genetic samples shall be collected and analysed from both rescued and free-ranging whale sharks.

Bio-makers: In search for biomarkers for health in whale sharks and exploration of metabolomics as a modern tool for understanding animal physiology, the metabolite composition of the serum in whale sharks can explored using 1H nuclear magnetic resonance (NMR) spectroscopy and direct analysis in real time (DART) mass spectrometry (MS). Metabolomics is the study of the low-molecular-weight molecules in a biological sample using bio-analytical and bioinformatics tools (Viant, 2007). The approach has been reinvigorated recently by new technologies, allowing its application to understand metabolic perturbations such as those occurring during disease and exposure to toxicants (Viant, 2007, Miller *et al.* 2007, Robertson 2005, Samuelsson *et al.* 2006, Viant 2003). In metabolomic studies, the progression of a disease can be observed as a trajectory deviating away from a ''normal'' state in principal component space (Hines *et al.* 2007). Using NMR and MS metabolomic approaches, we can seek to characterise variations in the metabolism of healthy and unhealthy whale sharks over a period of several months and, thereby, identify biomarkers of health in this elasmobranch species. The team can succeed in distinguishing healthy and unhealthy animals and in identifying several promising biomarker compounds.

11.1.3 Feeding biology

The whale shark (Smith, 1828) is the world's largest fish as well as the largest filter feeding fish, yet its feeding biology is still under studied. Better understood, but still controversial, is the diet of this circum global giant. Early scientists recognised that, despite its size, it had a unique filtering apparatus and subsisted on plankton near the surface (Gill, 1905). Gudger (1941a) noted that in addition to planktonic crustaceans, Rhincodon had been conclusively demonstrated to feed on squid and cuttle fish. He postulated that an invertebrate diet is insufficient to maintain this species, and summarised observations of whale sharks purportedly ingesting schooling clupeids. Since those early, and often anecdotal, studies, numerous dietary analyses have been conducted at whale shark aggregation sites. These analyses based on stomach contents, faecal samples, behavioural observations and plankton tows, indicated that whale sharks primarily feed on a variety of planktonic organisms. These include euphausids, copepods, chaetognaths, crab larvae, molluscs, siphonophores, salps, sergestids, isopods, amphipods, stomatopods, coral spawn, and fish eggs. In addition, they also feed on small squid and fish (Silas and Rajagopalan, (1963), Taylor, (1994, 1996, 2007), Clark and Nelson, (1997), Taylor and Pearce, (1999), Heyman *et al.* (2001), Wilson and New bound, (2001), Duffy, (2002), Jarman and Wilson, (2004), Hacohen-Domene *et al.* (2006); Hoffmayer *et al.* (2007); Nelson and Eckert, (2007), Meekan *et al.* (2009). To understand the feeding biology of the shark in Indian waters, the following techniques are proposed to be undertaken.

Collecting faecal sample from live animal: Using Cannulation technique for collecting faecal samples from entangled whale shark (Fig. 5). The collection of faecal samples from animals for individual identification and mark-recapture purposes has been used in a number of circumstances (Lukacs & Burnham 2005). Collection of faecal samples has been used successfully to identify prey species of whale sharks (Jarman & Wilson 2004).

Collecting gut content sample from dead animal: The study of the feeding habits of fish and other animals based upon analysis of stomach content has become a standard practice (Hyslop 1980). Stomach content analysis provides important insights into fish feeding patterns and quantitative assessment of food habits is an important aspect of fisheries management. Lagler (1949) pointed out that the gut contents only indicate what the fish would feed on. Direct observation on the feeding habits of a whale shark in its natural habitats is virtually impossible and thus, to ascertain the exact nature of a fish food, the best way is to examine its gut contents.

Plate 35. Reusable waterproof film camera

11.1.4 Education, awareness and outreach

Administrative measures and scientific knowledge, only when accepted and supported by the society, can lead to greater success of conservation measures.

Whale Shark Mela: A Whale shark mela will be conducted to raise awareness in coastal schools. A possible integration into the Coast Guard and Naval day celebrations shall also be looked into. Assistance in celebrating whale shark day for GFD shall be continued.

Self-documentation scheme: After several complaints that previous rescue methods were biased, new rescue protocols were developed, in which fishermen themselves photograph the accidentally caught whale sharks and release them without the need to wait for the authorities to arrive. Then the photographs are produced for net compensation, reducing the trapped time and hence the stress to the caught animal. So far, 1174 cameras have been distributed with an additional requirement of 4000 cameras. More improved models of water-proof cameras will be distributed to local fishermen (Plate 35).

Rescue: Assistance in rescue of whale sharks in case of accidental catch.

New strategies: A number of new strategies will be adopted to increase awareness among targeted groups:

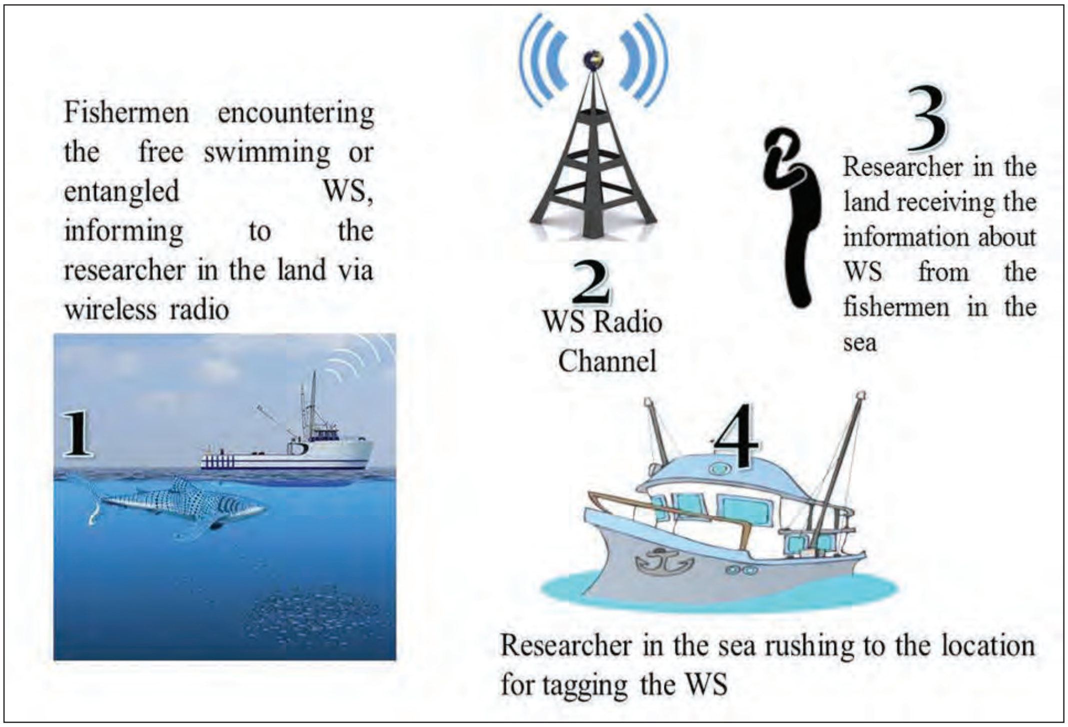

Plate 36. Setting up a whale shark information network

Signboards: Placement of sign boards in strategic areas (landing centres, fishing village squares, markets) on whale sharks, endangered status, rescue methods and other endangered marine fauna.

Friends of whale shark initiative: On trawlers/fishing boats which voluntarily release whale sharks, brass plates with the words 'Friends of the Whale Shark' will be fixed, , thus recognising them and spreading awareness.

Marker tags: The fishermen will be trained in marker tagging technique and will be equipped with marker tags to be deployed during whale shark encounters. A reward scheme will be in place for fishermen who successfully tag the whale sharks.

11.1.5 Whale shark information network

Wireless radio: An exclusive wireless canal for the whale shark will be created and will be intimated to all fishermen and Coast Guard personnel (Plate 35). In case of whale shark sightings, the fishermen or CG will be able to call the wireless canal and provide information. If a team is at sea survey when the information is received, they will also be able to reach the spot and tag the animal. A reward scheme will also be in place for providing information with evidence.

Post cards: Self-addressed post cards with whale shark photos and simple questions on its whereabouts are given to fishermen. In case of sighting a whale shark, the details will be entered and posted, providing us with a sighting record. The exercise will be done in all fish landing centres (Plate 36).

Mobile campaign

A vehicle dedicated for the campaign will travel all along the west coast, spreading awareness on whale sharks. It will hold collaterals, video projectors and the whale shark inflatable which shall be used in targeted area for spreading awareness.

11.2. Anticipated benefits and output

Ecological database on whale shark: Marine habitat use, seasonal movement and migratory patterns of whale sharks in west coast will be established.

Origin traced: Genetic studies will trace the genealogy of the whale sharks in the Indian

waters and compare with other whale shark populations in the world, to end speculation and hypothesis on the whale shark population of India.

Migration mystery revealed : The reasons behind the migration and habitat use of the whale shark to Gujarat will be revealed.

Community involved conservation : Involving the fishing communities for tagging will help bring a sense of ownership of the conservation programme, and also help identify the species as an individual.

Ensure a safe future : A conservation effort leading to the species emerging as one of the flagship species will seal a safe future for the whale sharks not just in Gujarat, but in the whole country.

11.3. Monitoring and evaluation

The Project Investigator and researchers shall review the progress of the project every month. WTI also has a standardised reporting structure followed by the field staff. Activities for the various components of the project are listed as targets for the staff. They are evaluated twice a year to assess the performance of the staff, which is also an indication of success of the project. The Project Investigator and Officer visit the areas of work on a regular basis. An annual report will also be prepared. The field staff are in touch with the concerned representative of TCL, who also evaluate the success of the programme Compilation and analyses of data is carried out every six months. The findings of the project will be submitted for publication in relevant peer-reviewed journals. The publications can serve as scientific and conservation evaluations of the project.

APPENDIX I

Region-wise list of landing centres surveyed during the whale shark historical occurrence survey along the Gujarat coast

REGION	LANDING CENTERS SURVEYED	
Region – I	1.	Salaya
	2.	Sikka
	3.	Bedi
	4.	Tuna
	5.	Badreswar
	6.	Mundra
	7.	Mandvi
	8.	Jakau
Region – II	9.	Rupen
	10.	Okha
	11.	Muldwaraka
	12.	Damlej
	13.	Veraval
	14.	Jaleswar
	15.	Sutrapada
	16.	Hirakot
	17.	Phera
	18.	Mahuva
	19.	Vanakbara
	20.	Goghla
	21.	Jafrabad
	22.	Mangrol
	23.	Madhavpur
	24.	Porbander
Region – III	25.	Dahej
	26.	Nargol
	27.	Hajira
	28.	Umarsadi
	29.	Ojhal
	30.	Ubhrat
	31.	Dumas

APPENDIX II

CONSULTANCY REPORT
ON
WHALE SHARK CONSERVATION

JANUARY-2010 TO DECEMBER-2010

SUBMITTED
TO

WILDLIFE TRUST OF INDIA

F-13, Sector -8, Noida, Uttar Pradesh

BY

Dr. Gulshad Mohammed,

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March 2011

The whale shark (Rhincodon typus) is a relatively recent addition to the human record of the ocean and its inhabitants. However, the ancestry of this shark goes back to the Jurassic and Cretaceous periods 245-65 million years ago, when the present groups of sharks began to appear. It was not until 1828 when the first whale shark specimen known to science was discovered off the South African coast. Like many other shark species, the whale shark has innate biological characteristics, such as large size, slow growth, late maturation and extended longevity, which probably limit recruitment and make it particularly susceptible to exploitation. International conservation status of the species is unclear - it is listed as having an 'Indeterminate' status on the World Conservation Union's Red List of Threatened Animals. This category applies to animals known to be 'Endangered', 'Vulnerable' or 'Rare', but there is not enough information available to say which of these three categories is appropriate.

The accessibility of the seasonal aggregation of whale sharks in the Veraval regions provide an excellent opportunity for researchers to undertake studies of this rarely encountered and poorly understood shark. Initial research efforts lacked clearly defined objectives and were often hampered by limited scientific research of whale shark biology and ecology. Some aspects of this research should seek to provide information to environmental management bodies in order to minimize possible detrimental impacts. In general, occurrences of whale sharks appear to be sporadic and unpredictable, which is partly a reflection of the lack of knowledge about the animal's habitat and ecology.

In order to study the habitat and ecology of whale shark in the Veraval region the present study has been designed (Site selection and Sample collection were carried out by WTI, Sample analysis and data compilation were carried out by Regional Center of CMFRI, Veraval). Three experimental sites were selected based on the information available on the whale shark citation. The experimental sites include 1.Veraval- A (0Km), B (5km), C (10Km), D (20Km), 2. Diu- A (0Km), B (5km), C (10Km), D (20Km) and 3. Mangrol- A (0Km), B (5km), C (10Km), D (20Km). All the sampling stations were clearly plotted in the map (Fig.1). All the water sampling, water quality analyses were carried out according to the standard sea water analyzing protocols (Strickland & Parsons, 1968). The methods used for the analysis of various parameters were tabulated in Table-1. The parameters like Sea surface temperature, Salinity, pH, Visibility, DO, Gross and Net Primary Productivity, Ammonia, Nitrate, Phosphate, Silicate, Chlorophyll concentration, Photo and Zooplankton biomass and diversity were recorded in Veraval for a period of January-2010 to December-2010. The same parameters were started to analyses in the sites of Diu and Mangrol from October-2010 to December-2010.

Result of the analysis is given in Table-2 to Table-51 and Figure-4 to Figure-51. During the sample collection hydrological parameters of the selected sits were also recorded. Sea surface water temperature in the selected study areas were fluctuated with seasons and between stations, it's ranging form 20.50C to 31.0C. The highest temperature during the study period was recorded in Diu and the lowest was recorded in Veraval (Table-2, 13, 24; Fig. 4, 15, 26). Sea water pH in the study areas ranged from 7.11 to 8.65. Except Madhavpur site the level of pH showed a normal trend of fluctuations with very miner changes in all the study areas. During the study period the highest pH level of 8.3 was recorder in Mangrol and lowest pH level was recorded in Diu site during (Table-3, 14, 25; Fig. 5, 16, 27). The salinity in the study areas were ranged from 33.6ppt to 36.3ppt. Fluctuation in salinity level was noticed between stations to station. This deviation from normal pattern can be attributed to the de-linking of the water flow from the sea and the absence of freshwater outflow during the summer period (May, 2010). But this highest deviation in salinity level in this region occurred during October 2010 is due to the mixing of huge volume of fresh water resulted during the

monsoon period. But this case was not occurred in all other sampling location is due to the high mixing rate of sea water with rainy water and also the buffering activity of sea water.

Whale sharks appear to prefer locations with surface water temperatures between 21 -25 degrees, where cool nutrient-rich upwelling mingle with warm surface waters of salinities between 34-34.5%. These conditions may well be optimal for the production of the planktonic and nektonic prey upon which the sharks feed.

The level of Dissolved Oxygen (DO) content during the study period was ranging from 2.13ml/L to 6.27ml/L. In DO level high fluctuation was noticed in the area of Veraval when compare to all other sites ((Table-5, 16, 27; Fig.7, 18, 29)). The high amount of DO level recorded in this site is may resulted due to the activities of Ship breaking yard. In the present investigation the Gross productivity level was ranged from (Table-8, 19, 30; Fig.10, 21, 32) 0.01mg C/L/Hr to 0.22mg C/L/Hr. The productivity level was very low in all the selected study areas except the control site. The Net productivity level was ranged from 0.01 mg C/L/Hr to 0.22 mg C/L/Hr (Table-8, 19, 30; Fig.10, 21, 32). The highest Gross productivity level of 0.22 mg C/L/Hr was recorded in the control site. This results show that the site is fully free from pollution and having enormous primary producers.

In concerned with the nutrient level, the amount of ammonia was ranged from 0.000μg atom to 12.318μg atom. A high value of 12.318μg atom was recorded in the area of Veraval (Table-9, 20, 31; Fig.11, 22, 33). The value was unusual, this may be resulted by the anthropogenic activities leading to discharge of industrial effluents, fertilizers from agricultural farms and domestic sewage causing increase in organic load in the waters have a major influence on the levels of ammonia in this water body. In the present study period, nitrate levels were found to be higher in the areas of Veraval site when compare to all other sites (Table-11, 22, 33; Fig. 13, 24, 35). The domestic sewage mixing in this region is the most important source of nitrates. Phosphate level was varying with 0.001μg atom to 0.217μg atom (Table-10, 21, 32; Fig. 12, 23, 34). Phosphorus particularly in the form of phosphates is an important component of domestic and industrial wastes and is cycled within the environment through aquatic transport. Poor flushing and increased accumulation of industrial, agricultural and domestic wastes in this area results in an imbalance in the relative nutrient levels.

Zooplankton samples were collected from surface hauls by employing standard plankton net. The plankton net is towed horizontally from the boat for 10 minutes using three bridles (suspension lines), which are tied to the ring at equidistance from each other. While making the collections the speed of the vessel is maintained at 1 to 2 nautical miles per hour. After the 10 minutes haul, the net is taken out of water and is washed from outside by jetting seawater to bring down all the plankton into the collecting bucket. After all the excess water is drained off from the net and through the window of the collecting bucket, the bucket is carefully removed from the net and the plankton, along with the water is poured into wide mouthed polythene bottle of 500 ml capacity. The collected sample was preserved in 5% formaldehyde solution. With regard to phytoplankton, one litre of water from each station is collected in wide mouthed 1000 ml capacity polythene bottle and preserved in 5% formaldehyde solution.

The gross and net primary production rate, by the light and dark bottle oxygen technique (Grarder & Gran, 1927). The value of chlorophyll contents of the water studied following the methods of Strickland & Parsons (1968). For the studying phytoplankton , one litre of the water sample were collected from surface of stations studied. The phytoplankton organisms were enumerated by the settling method and qualitative and quantitative evaluation of the flora. For the quantitative estimation of zooplankton in the samples, displacement method was used and the zooplankton volume was determined. As it is not possible to analyze the entire zooplankton

sample collected during a haul, sub sample of the minimum 2 ml of zooplankton was used for qualitative analysis of plankton groups. The sub-sampled plankton was fully analyzed by counting in a plankton counting chamber under a microscope. The results of diversity and density of Phytoplankton were provided in Table- 35 to 37 and 38 (a), (b), (c), and Fig. 37 to 39 .The results of zooplankton Group vise density were provided in the Table- 39 to 50 and Fig.40 to 51. Whale shark rescue data during the study period of February-2010 to February -2011 was provided in Table-51 (a) and (b).

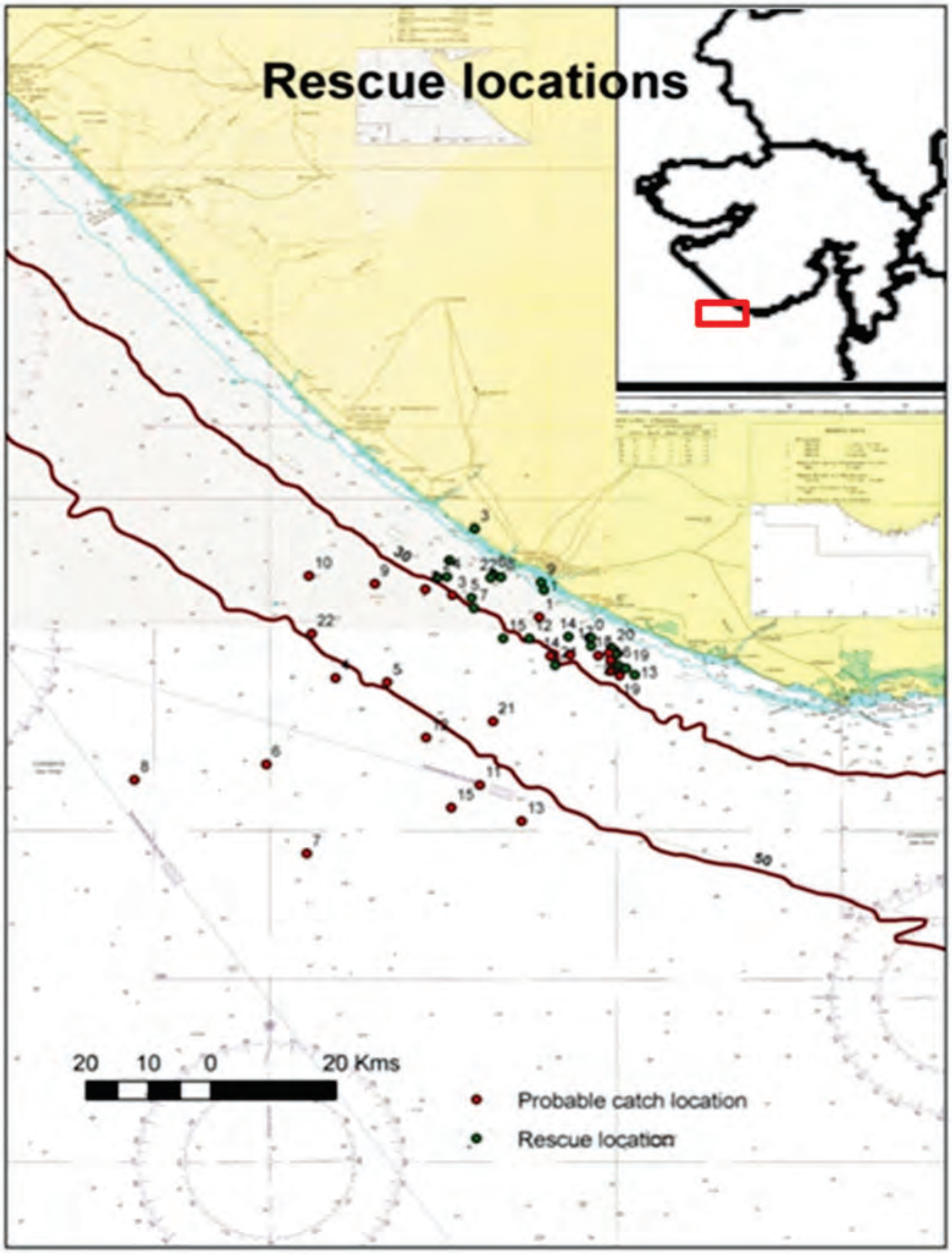
The whale shark is reported as a filter feeder. Although passive filter feeding has been documented and was previously considered characteristic behavior, recent studies now indicate that whale sharks feed primarily at night and at depth. It is under cover of darkness that the deep scattering layer of planktonic and nektonic prey moves up the water column in the densest concentrations. For most of the year, at least during the day, the amount of food taken in during subsurface cruising is equivalent to snacking, while the main meal comes after dark in deeper water.

Comparison of various habitat parameters with the Zooplankton and Phytoplankton biomass and diversity will help in identification of high productive zones with the seasonal Whale shark catch location. Further deep assessment is required to understand the seasonal changes in the nutrient levels and it affect on the primary and secondary productivity in particular attention on the Whale shark arrival in the selected places (Veraval, Diu and Mangrol). Further in-depth study is very essential to predict the seasonal shifts in the productive zones in relation with the whale shark appearance.

Table 1. Methods of analysis of various parameters.

SL. NO.	PARAMETER	METHOD	INSTRUMENT
1.	Temperature	-	Thermometer
2.	pH	-	pH meter
3.	Salinity	-	Salinometer
4.	Dissolved Oxygen	Winkler's	-
5.	Visibility	-	Secchi Disk
6.	Nitrate	Strickland & Parsons (1968)	Spectrophotometer
7.	Phosphate	Strickland & Parsons (1968)	Spectrophotometer
8.	Ammonia	Strickland & Parsons (1968)	Spectrophotometer
9.	Silicate	Strickland & Parsons (1968)	Spectrophotometer
10.	Chlorophyll	Strickland & Parsons (1968)	Spectrophotometer
11.	Primary productivity	Gaarder & Gran, 1927 (Light & Dark Bottle)	-
12.	Phyto and Zooplankton analyses	Standard phyto and zooplankton sample collection and analysis method	Hemocytometer, Microscope

Fig. 1. Map showing the sampling and whale shark rescued locations.



	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	25.20	25.7	25.3	25.5
Mar_2010	26.6	25.60	25.90	25.70
Apr_2010	26.60	26.9	27.8	27.8
May_2010	27.20	28.4	28.6	29.1
Oct_2010	30.00	30.9	30.7	31.1
Dec_2010	24.10	24.9	25.1	25.6

Table- 2. Temperature (°C) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

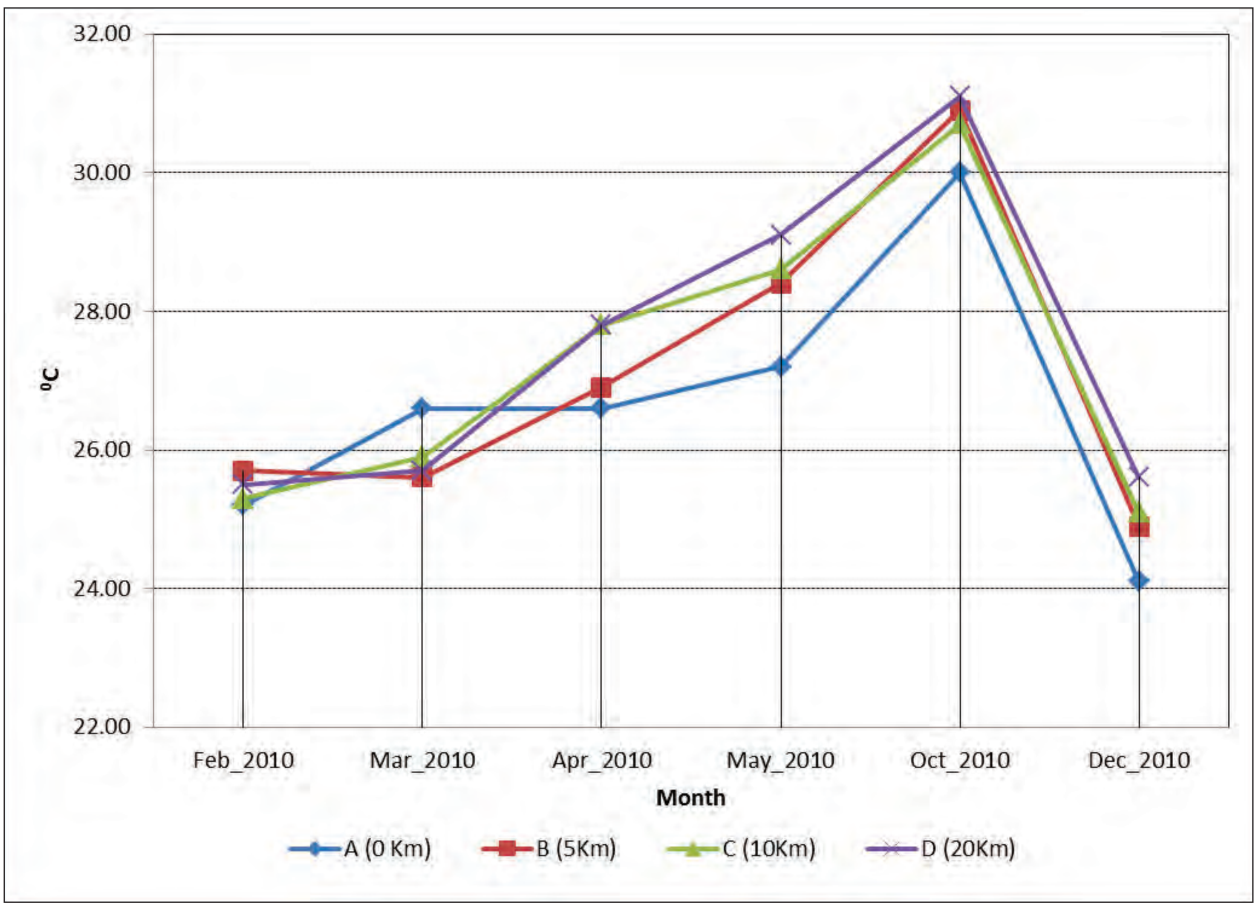


Fig. 4. Temperature (°C) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	6.70	7.40	8.10	7.90
Mar_2010	6.7	6.60	6.70	6.60
Apr_2010	6.70	6.9	7.2	7.1
May_2010	7.60	6.9	7.6	7.3
Oct_2010	7.80	8.2	8.2	8.3
Dec_2010	8.00	8.3	8.3	8.4

Table-3. pH flux in selected sites of Veraval during the Study period January-2010 to December-2010.

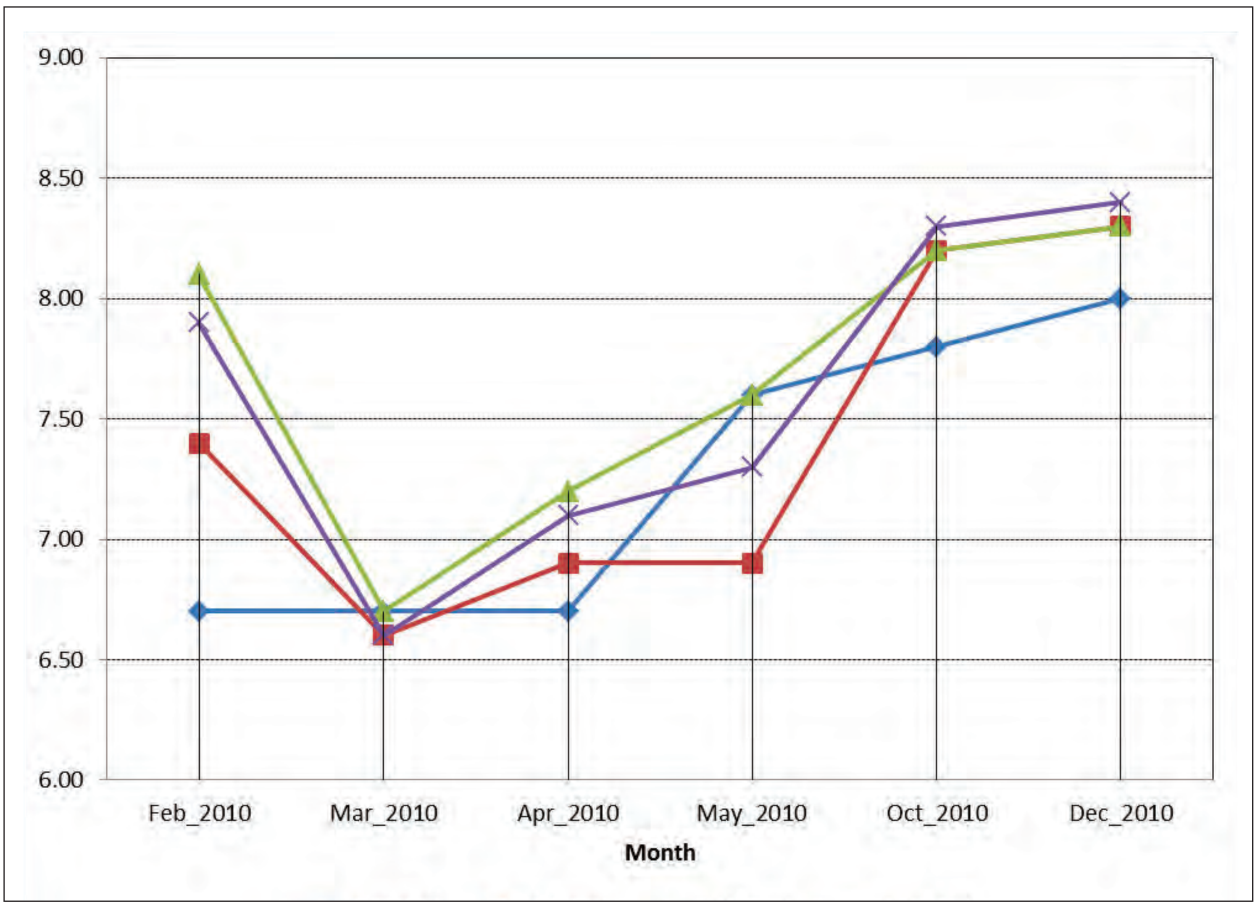


Fig. 5. pH flux in selected sites of Veraval during the Study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	35.30	35.8	35.6	35.4
Mar_2010	34.6	34.8	34.5	34.8
Apr_2010	34.60	35.2	37.1	36.6 error/see hard copy
May_2010	34.10	36.2	36.6	35.4 error/see hard copy
Oct_2010	34.40	34.2	35.2	35.2
Dec_2010	34.90	34.9	34.7	34.7

Table-4. Salinity (ppt) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

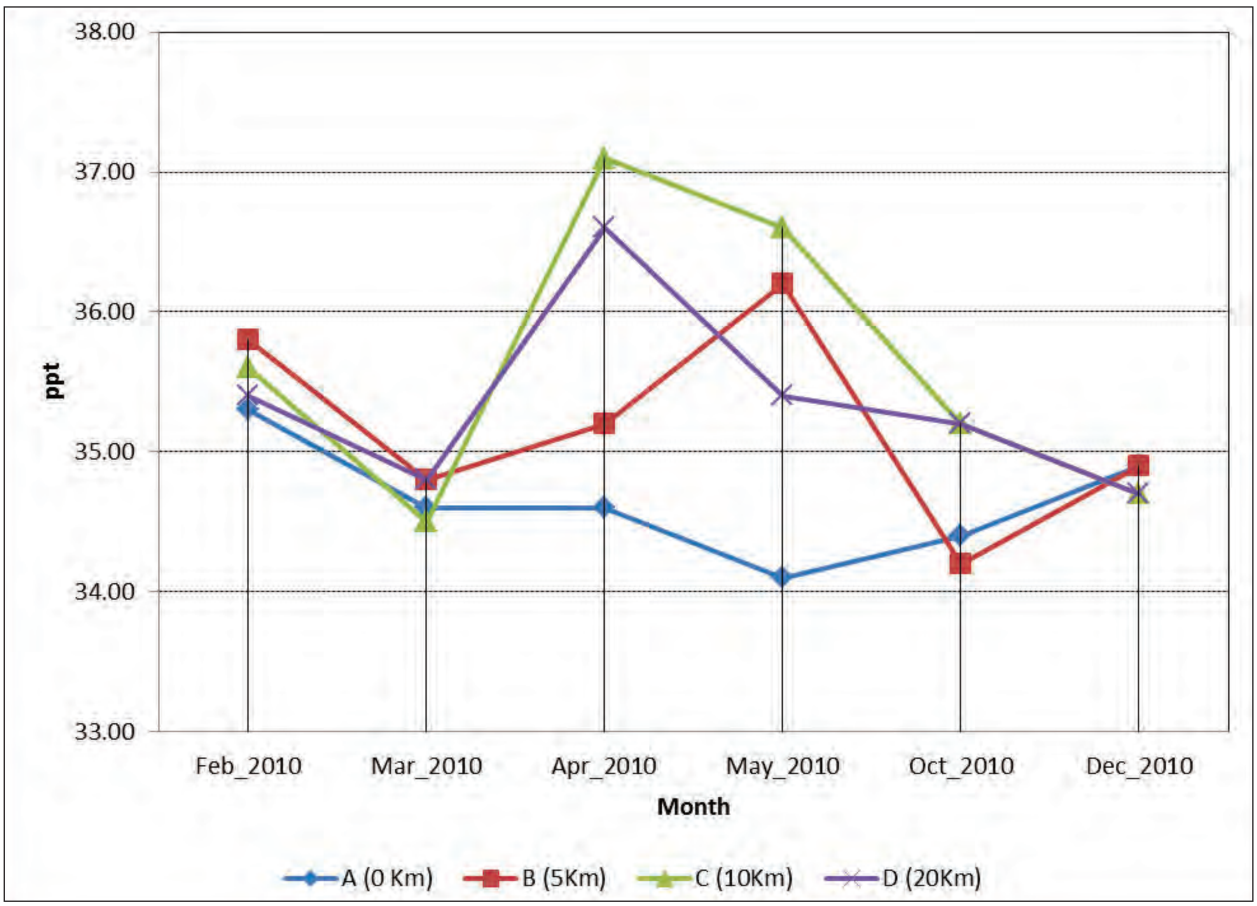


Fig. 6. Salinity (ppt) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	2.430	5.31	6.33	6.39
Mar_2010	3.51	4.89	4.89	4.56
Apr_2010	3.510	4.64	5.26	4.81
May_2010	4.300	5.26	5.71	5.88
Oct_2010	6.440	7.18	7.35	7.46
Dec_2010	5.310	5.71	5.43	5.37

Table-5. Dissolved Oxygen (ml/L) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

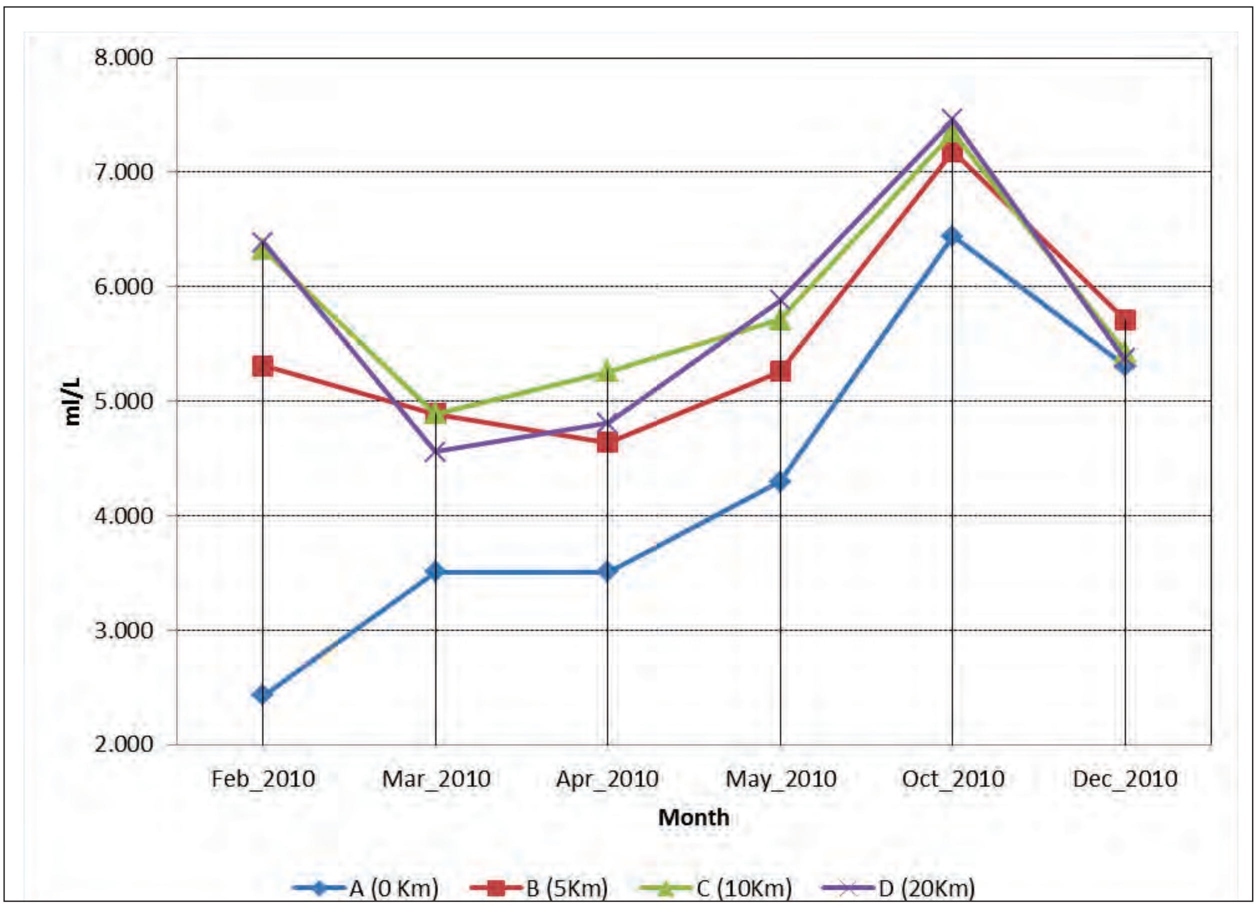


Fig. 7. Dissolved Oxygen (ml/L) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	0.186	0.0986	0.0863	0.0643
Mar_2010	0.2076	0.0512	0.0679	0.0339
Apr_2010	0.208	1.7068	0.2196	0.3124
May_2010	2.887	0.2686	2.2844	1.4196
Oct_2010	1.080	3.0164	1.1476	2.0058
Dec_2010	1.317	3.1592	4.5072	2.0082

Table-6. Chlorophyll (mg m-3) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

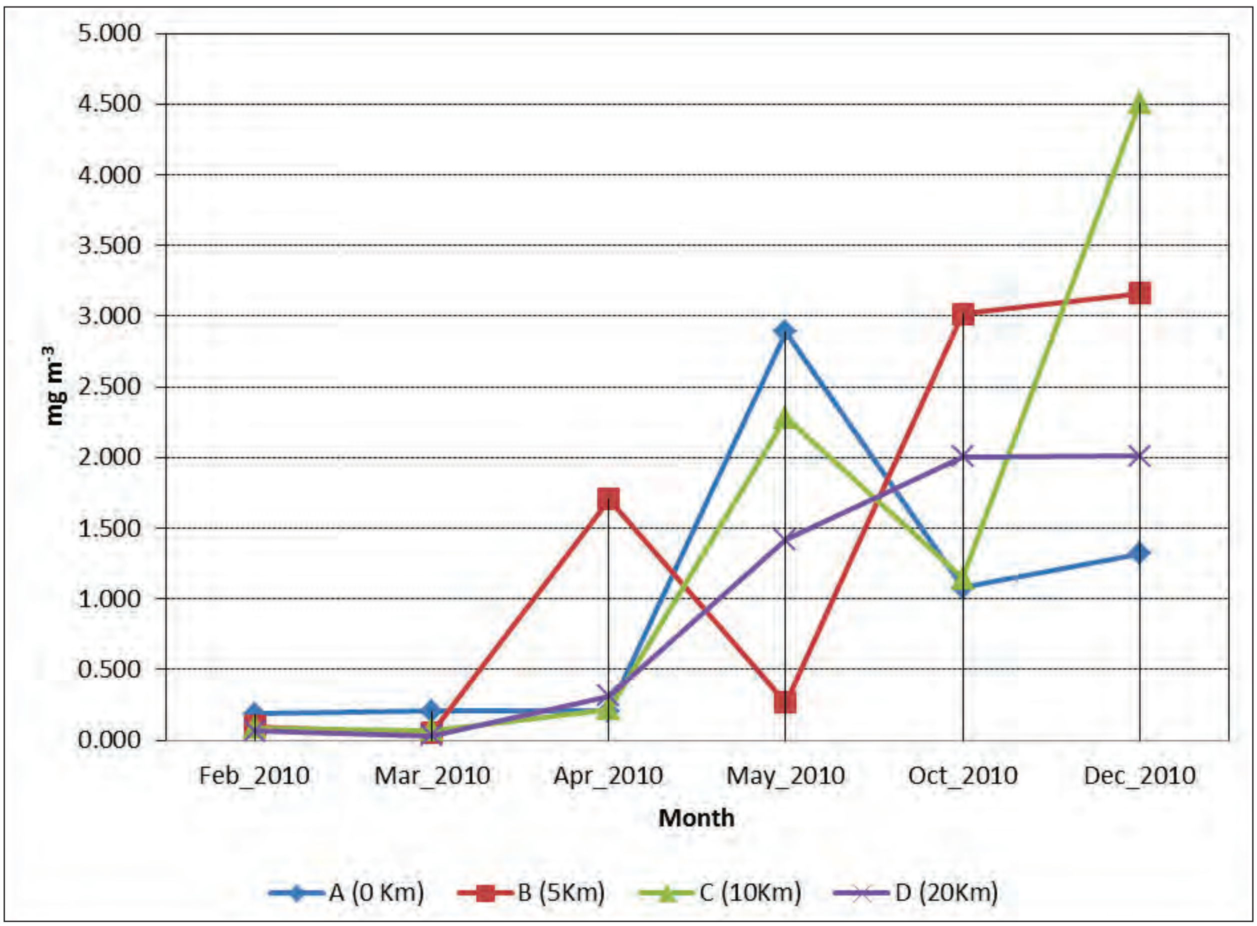


Fig. 8. Chlorophyll (mg m-3) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	1.10	1.10	1.23	1.20
Mar_2010	1.40	1.15	1.22	1.21
Apr_2010	1.40	2.15	4.10	5.85
May_2010	1.87	8.45	10.05	8.05
Oct_2010	1.16	4.85	9.25	10.35
Dec_2010	3.25	4.50	3.12	6.45

Table-7. Visibility (m) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

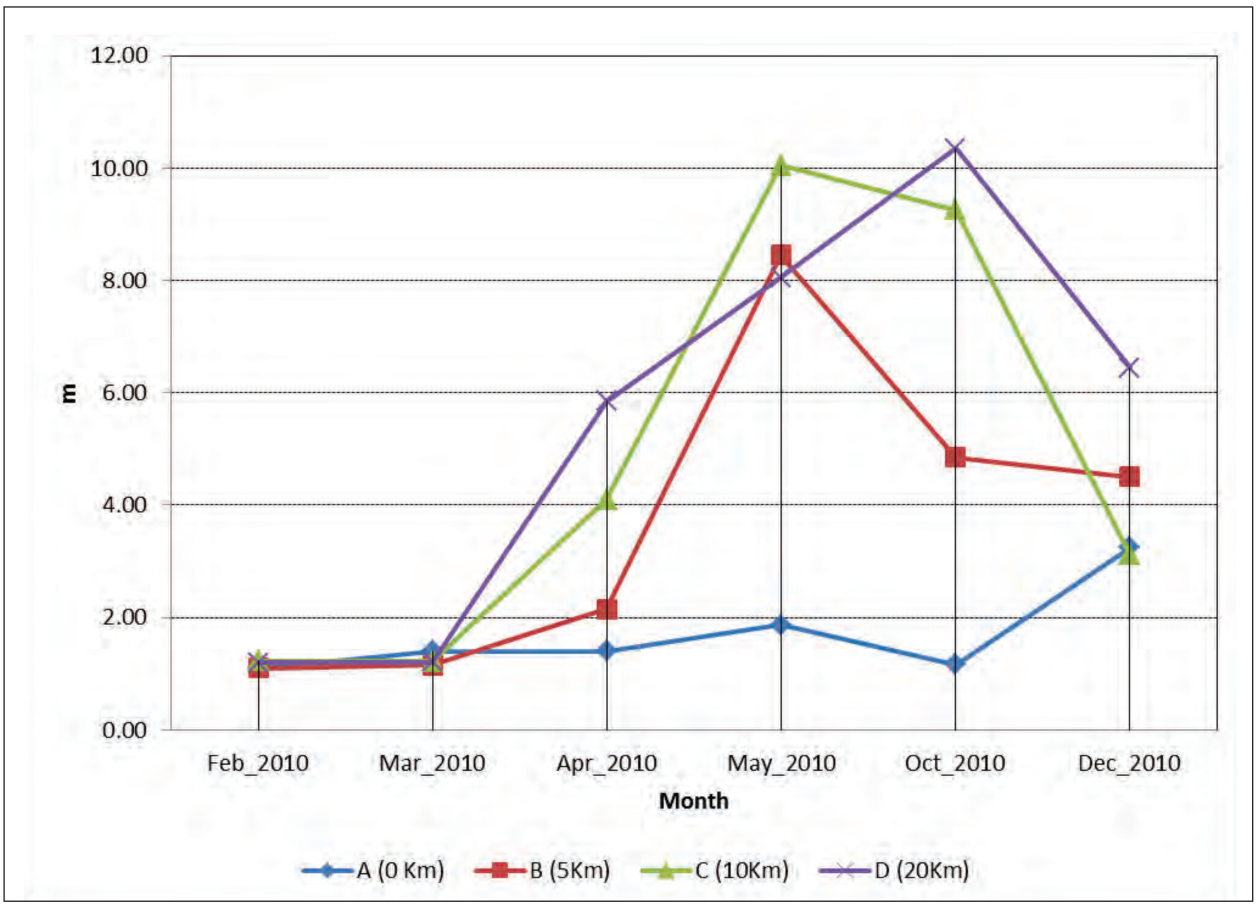


Fig. 9. Visibility (m) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

	A (0 Km)		B (5Km)		C (10Km)		D (20Km)	
	GPP	NPP	GPP	NPP	GPP	NPP	GPP	NPP
Feb_2010	0.080	0.060	0.17	0.07	0.01	0.02	0.06	0.05
Mar_2010	0.04	0.03	0.03	0.02	0.02	0.01	0.02	0.01
Apr_2010 error	0.040	0.030	0.09	0.08	0.05	0.04	0.03	0.02
May_2010 error	0.030	0.020	0.04	0.07	0.12	0.09	0.11	0.09
Oct_2010	0.270	0.010	0.08	0.03	0.09	0.03	0.08	0.03
Dec_2010	0.080	0.070	0.05	0.1	0.08	0.1	0.03	0.03

Table-8. Gross and Net Primary Productivity (mg C/L/Hr) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

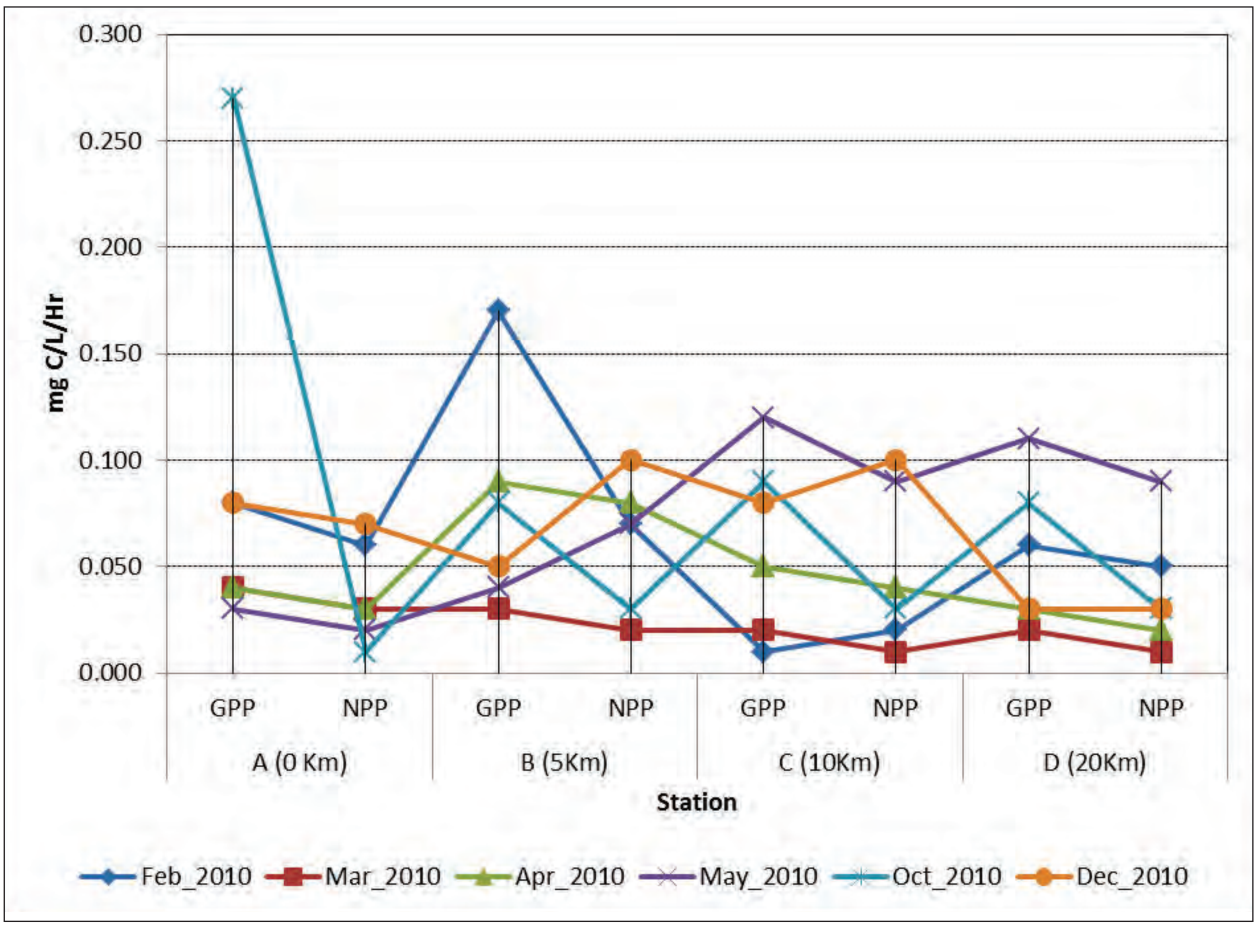


Fig. 10. Gross and Net Primary Productivity (mg C/L/Hr) flux in selected sites of Veraval during the Study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	0.189	0.098	0	0
Mar_2010	0.013	0.221	0.183	0.186
Apr_2010 error	0.013	0.105	0	0
May_2010 error	0.011	0.009	0	0.002
Oct_2010	0.235	0.102	0.057	0.11
Dec_2010	0.086	0.018	0.004	0.071

Table-9. Ammonia concentration flux in selected sites of Veraval during the Study period January-2010 to December-2010.

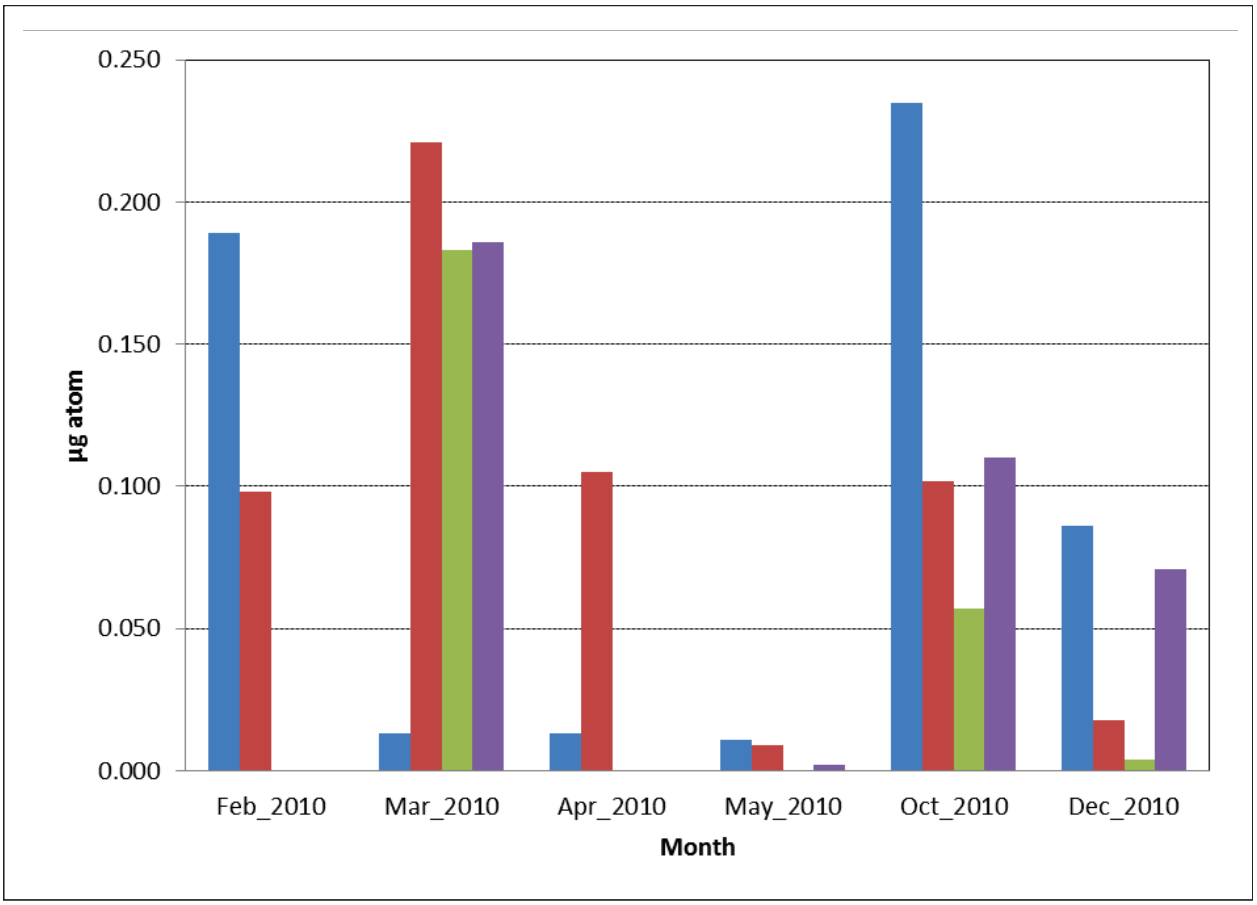


Fig. 11. Ammonia concentration flux in selected sites of Veraval during the Study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	0.071	0.056	0.088	0.005
Mar_2010	0.099	0.007	0.005	0
Apr_2010	0.099	0.047	0.001	0.039
May_2010	0.071	0.031	0.112	0.051
Oct_2010	0.136	0.057	0.054	0.059
Dec_2010	0.048	0.052	0.05	0.039

Table-10. Phosphate concentration flux in selected sites of Veraval during the study period January-2010 to December-2010.

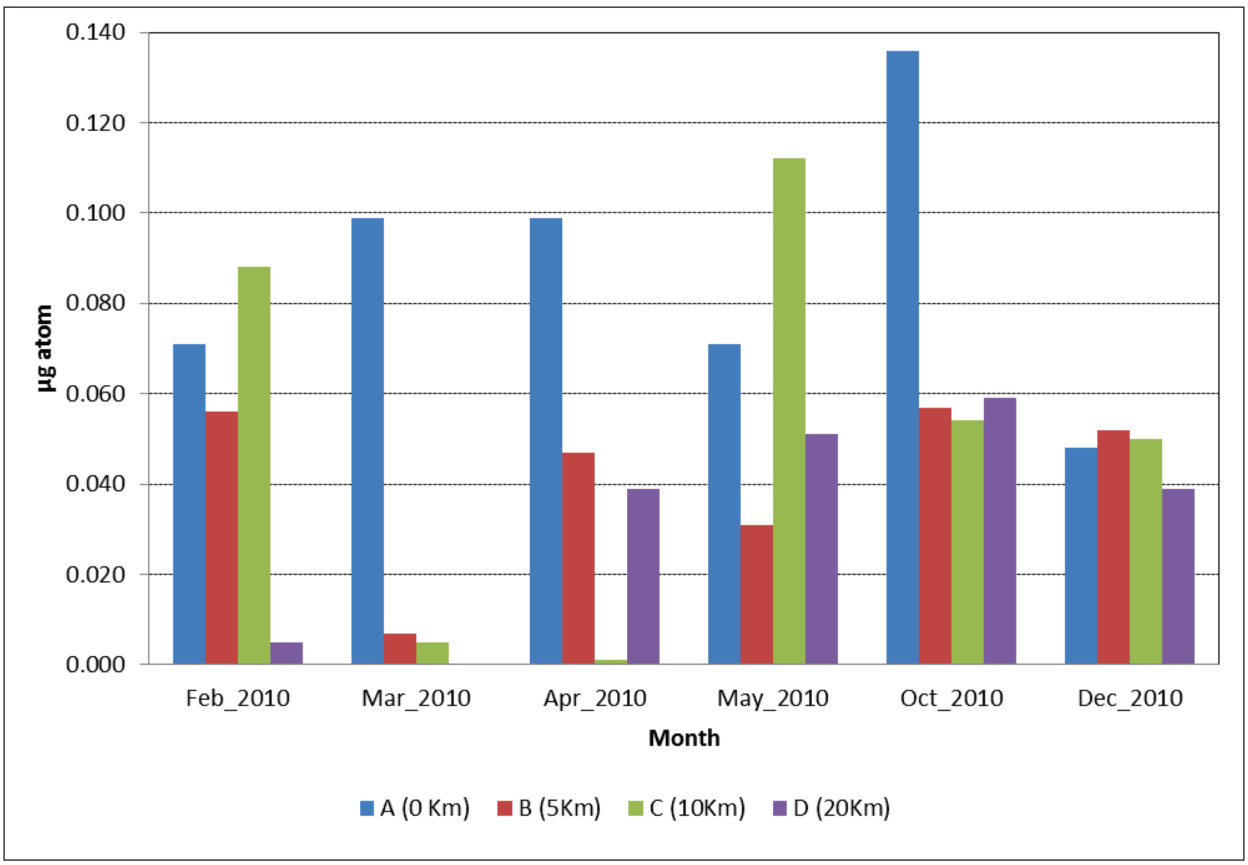


Fig. 12. Phosphate concentration flux in selected sites of Veraval during the study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	6.181	4.655	2.327	4.655
Mar_2010	5.189	4.112	3.123	5.021
Apr_2010	5.189	4.12	4.731	4.159
May_2010	4.230	4.165	3.118	3.126
Oct_2010	7.886	6.914	8.11	6.391
Dec_2010	5.681	5.793	3.438	2.728

Table-11. Nitrate concentration flux in selected sites of Veraval during the study period January-2010 to December-2010.

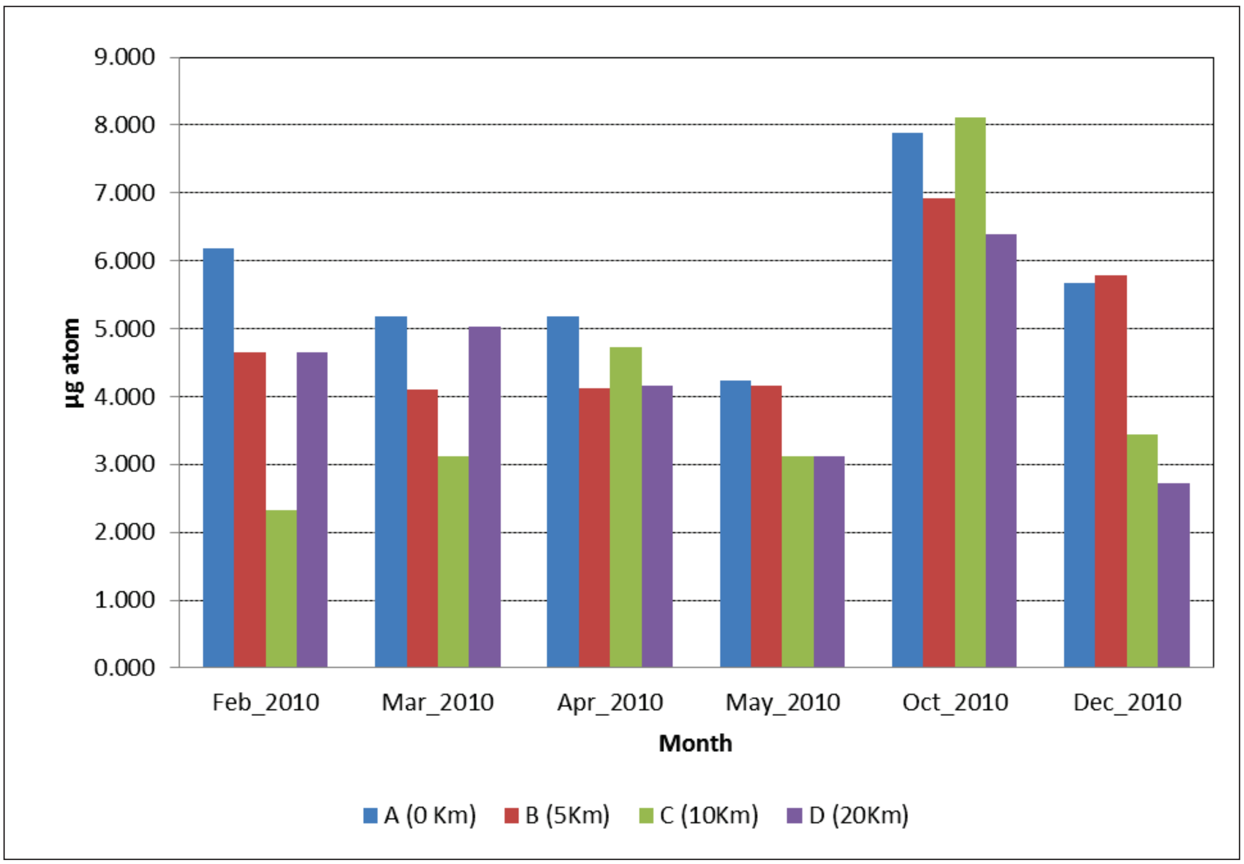


Fig. 13. Nitrate concentration flux in selected sites of Veraval during the study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	0.359	0.302	0.331	0.302
Mar_2010	0.735	0.184	0.183	0.189
Apr_2010	0.735	0.504	0.591	0.619
May_2010	0.639	0.622	0.461	0.342
Oct_2010	0.974	0.729	0.81	0.77
Dec_2010	0.729	0.892	0.729	0.157

Table-12. Silicate concentration flux in selected sites of Veraval during the study period January-2010 to December-2010.

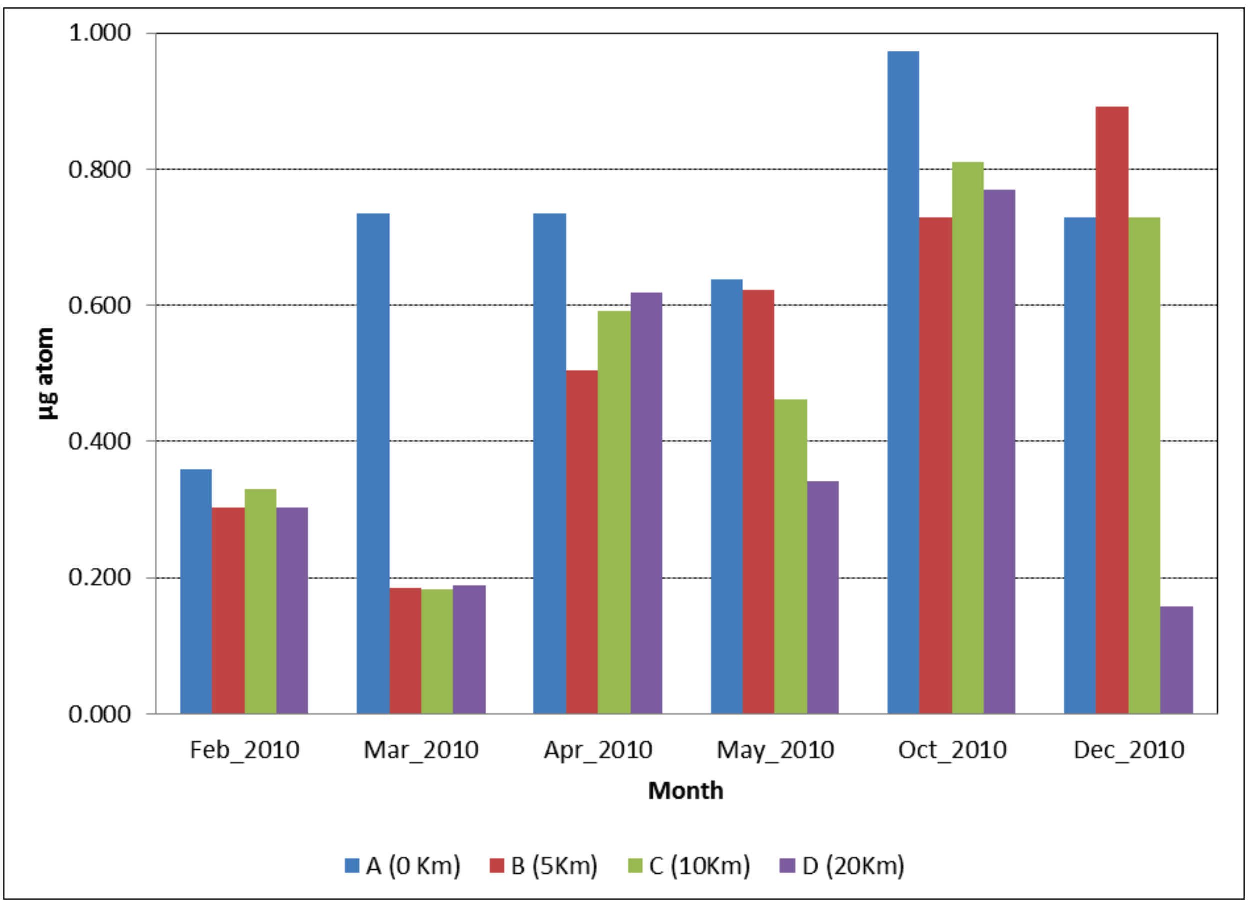


Fig. 14. Silicate concentration flux in selected sites of Veraval during the study period January-2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	30.9	31.4	30.6	31
Dec_2010	23.6	23.9	24.9	24.8

Table-13. Temperature (°C) flux in selected sites of Diu during the Study period October -2010 to December-2010.

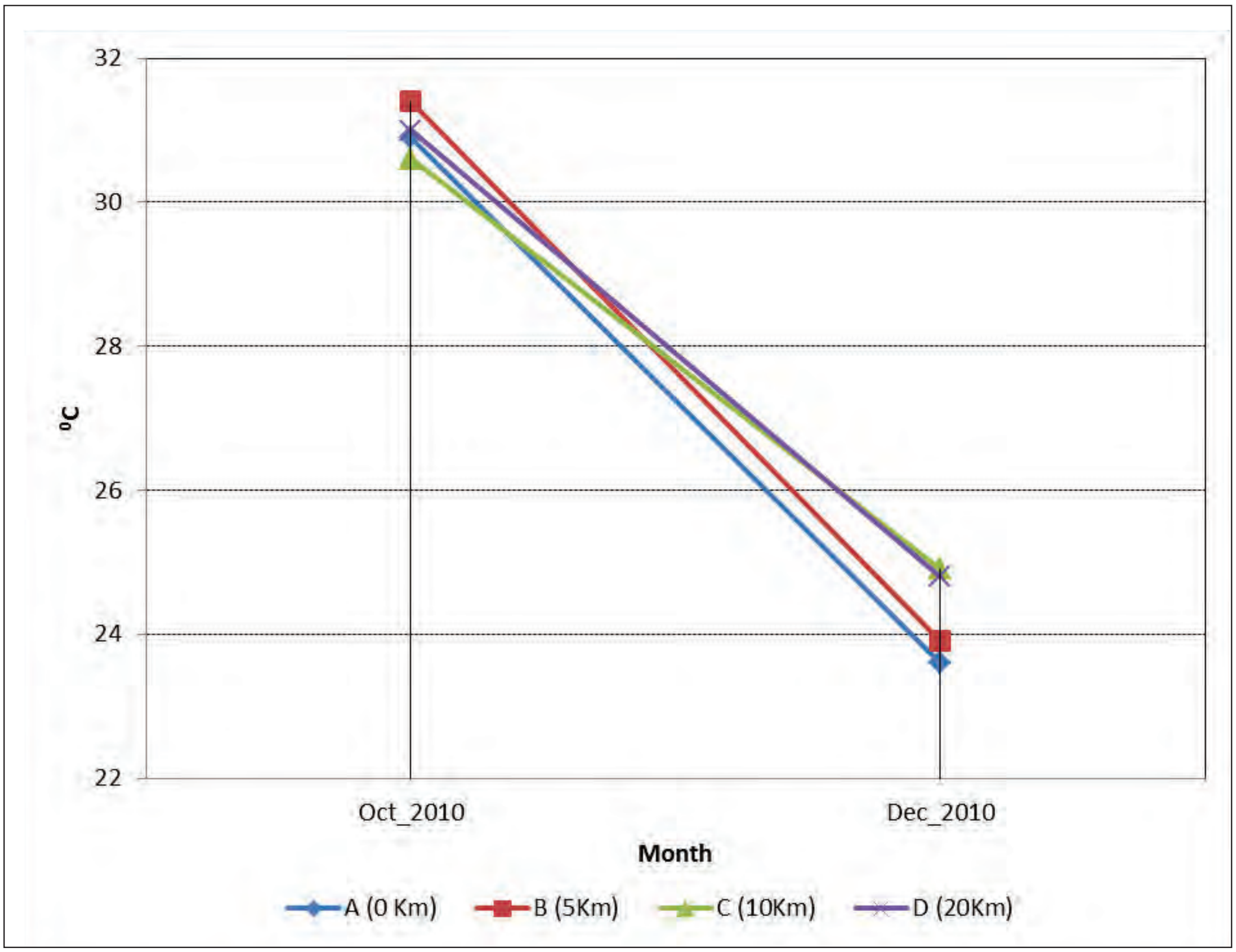


Fig. 15. Temperature (°C) flux in selected sites of Diu during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	8.2	8.2	8.4	8.4
Dec_2010	7.9	8.2	8.2	8.3

Table-14. pH flux in selected sites of Diu during the Study period October -2010 to December-2010.

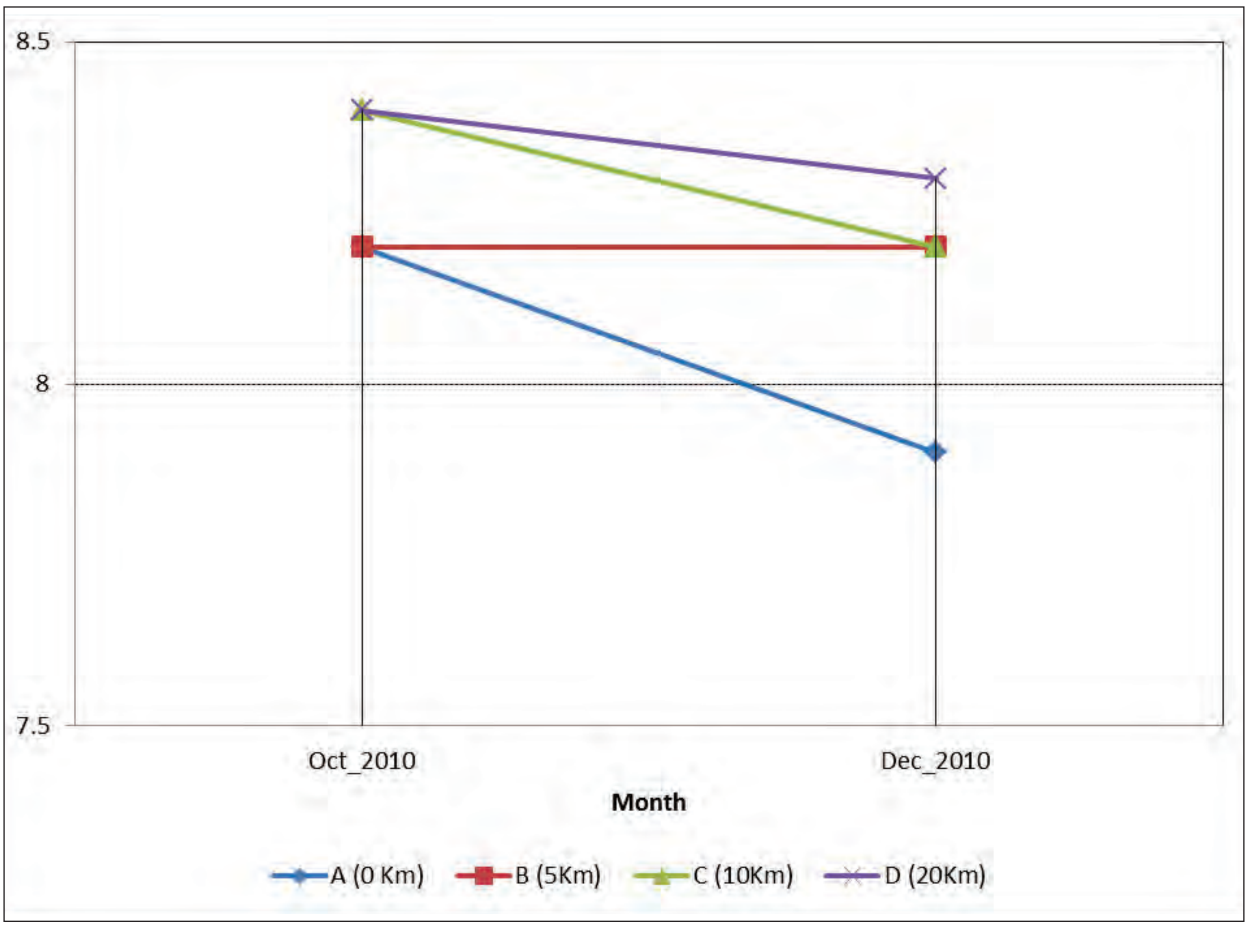


Fig. 16. pH flux in selected sites of Diu during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	32.2	34.1	33.4	35
Dec_2010	35.1	36.2	36.6	35.7

Table-15. Salinity (ppt) flux in selected sites of Diu during the Study period October -2010 to December-2010.

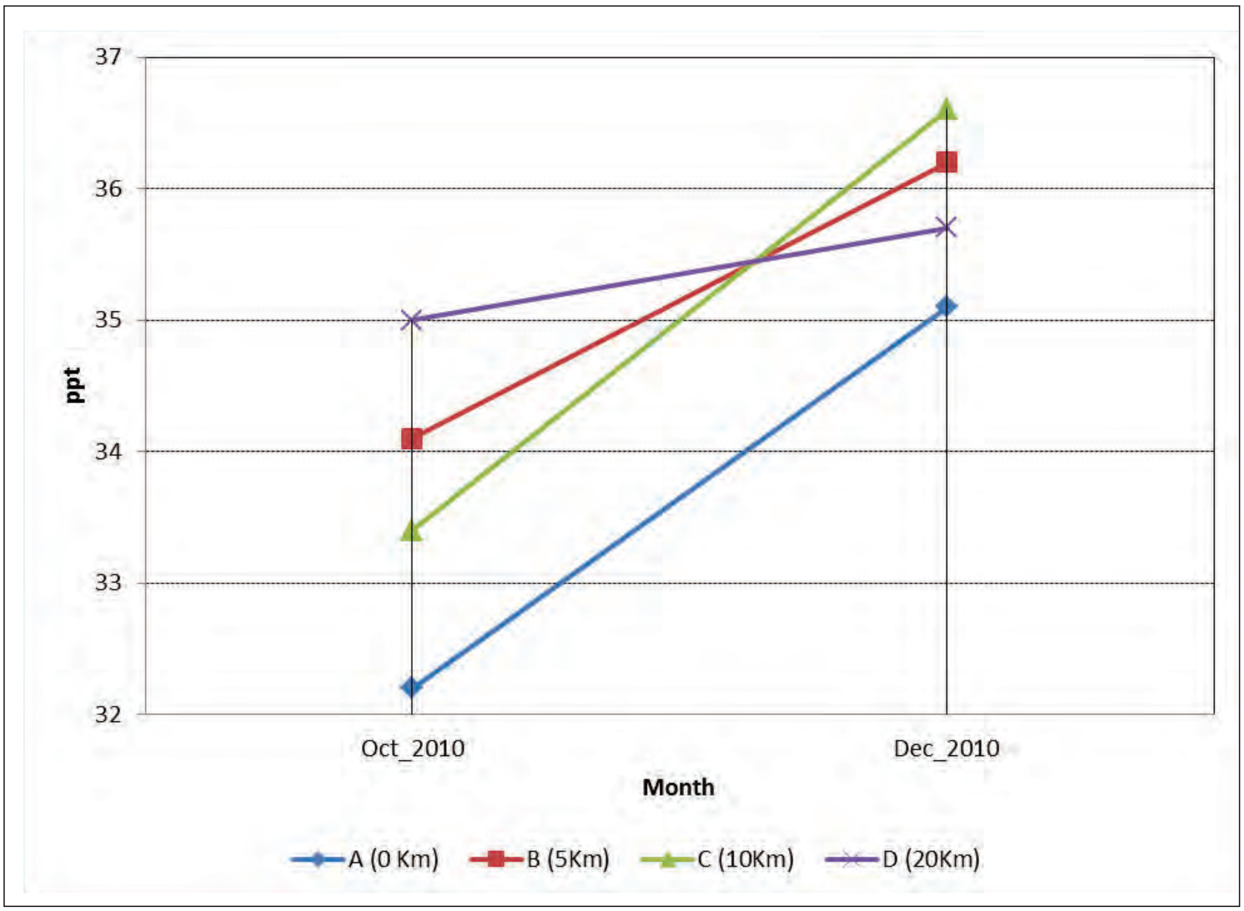


Fig. 17. Salinity (ppt) flux in selected sites of Diu during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	8.7	8.7	8.4	7.86
Dec_2010	5.2	5.2	5.48	5.31

Table-16. Dissolved Oxygen (ml/L) flux in selected sites of Diu during the Study period October -2010 to December-2010.

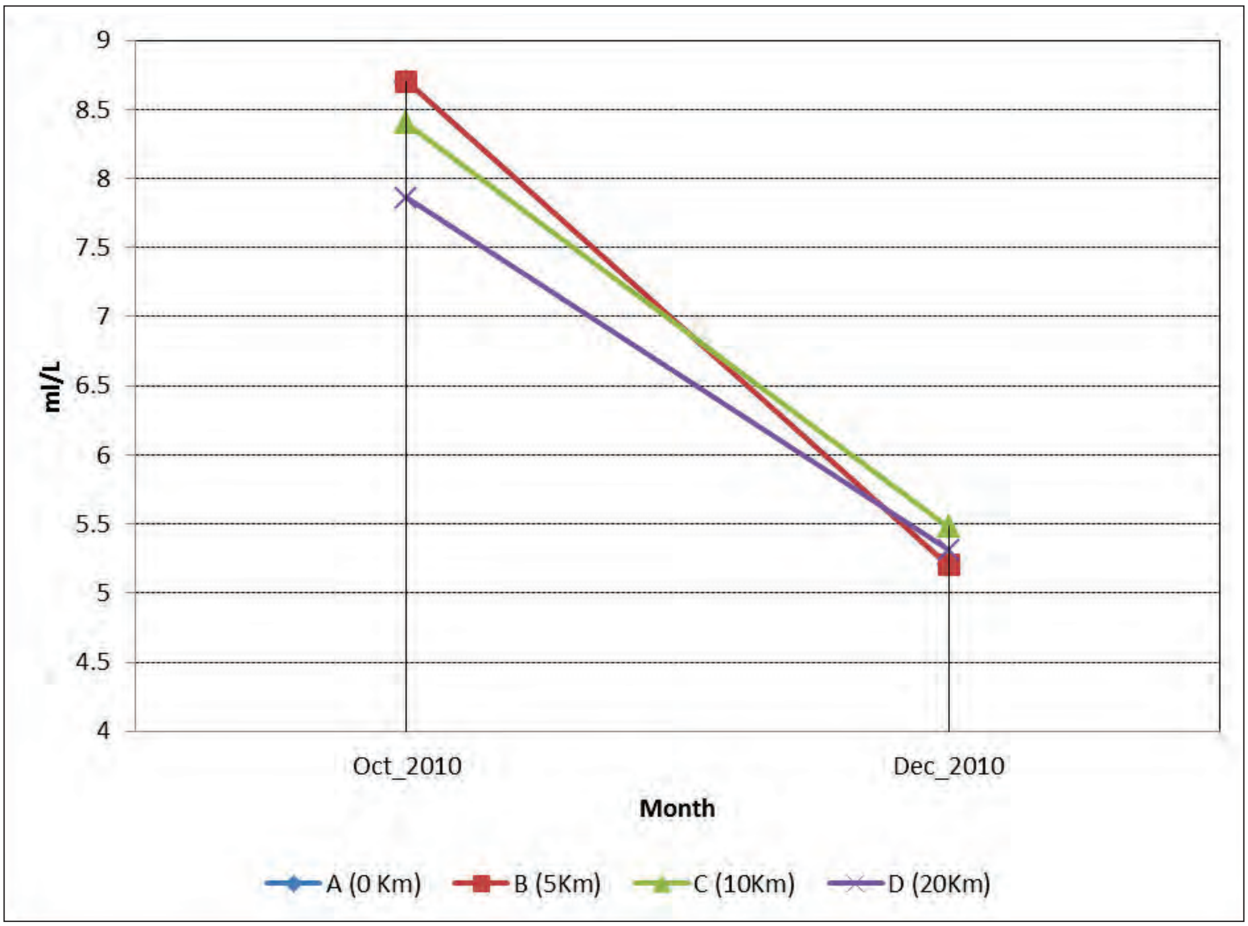


Fig. 18. Dissolved Oxygen (ml/L) flux in selected sites of Diu during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	1.5942	0.8864	0.8632	1.0154
Dec_2010	0.474	0.4016	0.4016	0.197

Table-17. Chlorophyll (mg m-3) flux in selected sites of Diu during the Study period October -2010 to December-2010.

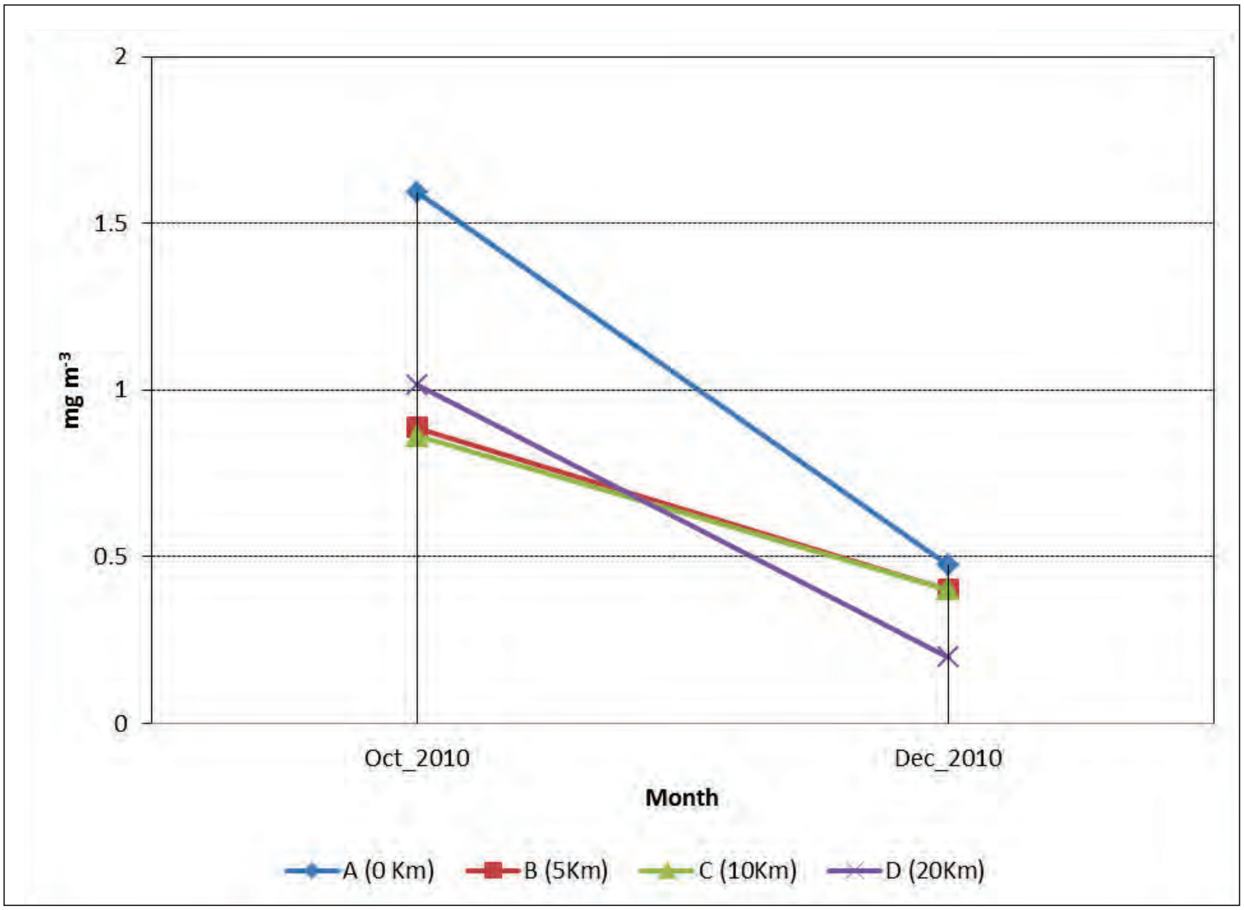


Fig. 19. Chlorophyll (mg m-3) flux in selected sites of Diu during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	2.97	3.15	3.8	3.33
Dec_2010	0.87	0.57	1.57	1.62

Table-18. Visibility (m) flux in selected sites of Diu during the Study period October -2010 to December-2010.

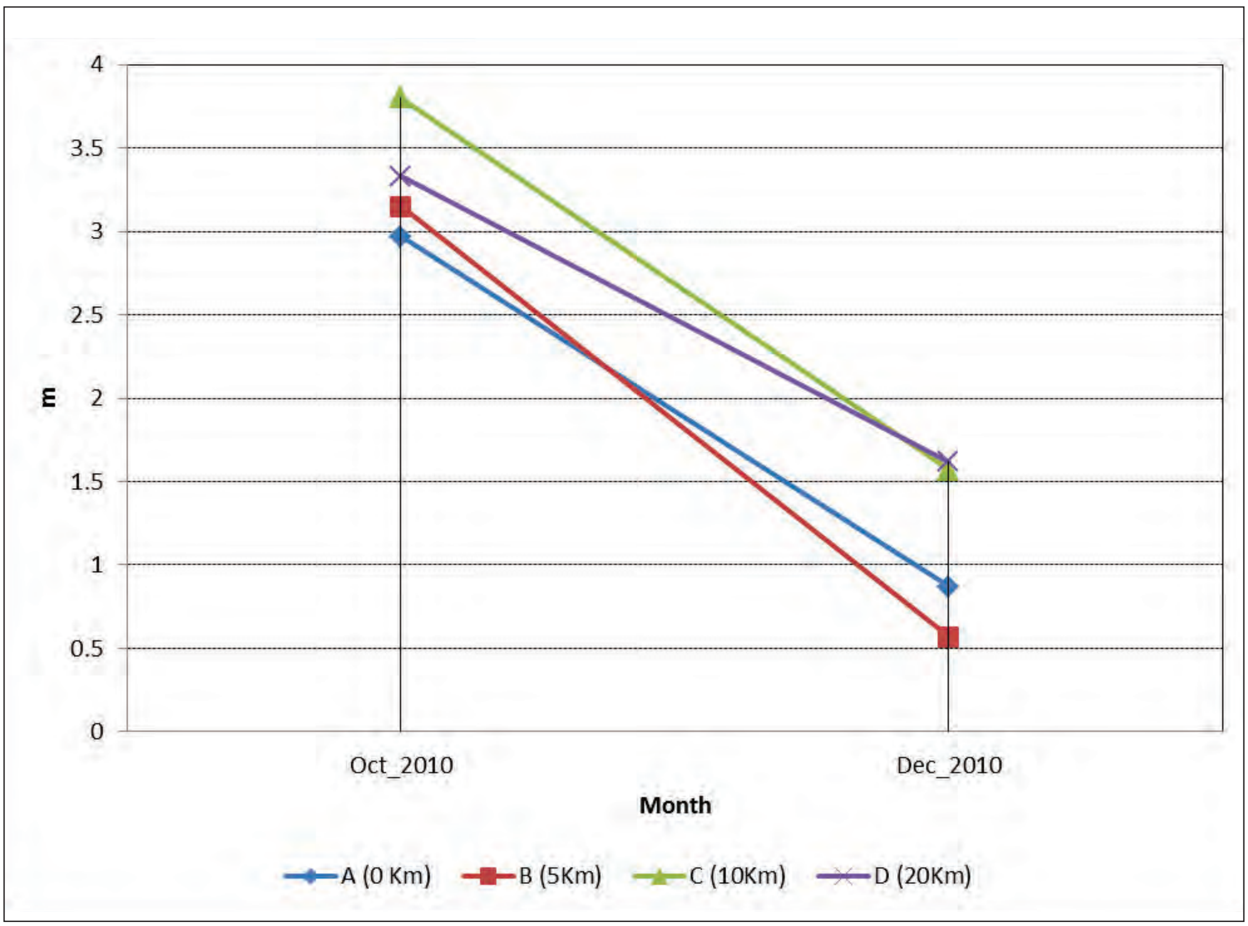


Fig. 20. Visibility (m) flux in selected sites of Diu during the Study period October -2010 to December-2010.

	A (0 Km)		B (5Km)		C (10Km)		D (20Km)	
	GPP	NPP	GPP	NPP	GPP	NPP	GPP	NPP
Oct_2010	0.02	0.02	0.08	0.11	0.01	0	0.01	0.05
Dec_2010	0.05	0.04	0.02	0.02	0.08	0.02	0.04	0.01

Table-19. Gross and Net Primary Productivity (mg C/L/Hr) flux in selected sites of Diu during the Study period October -2010 to December-2010.

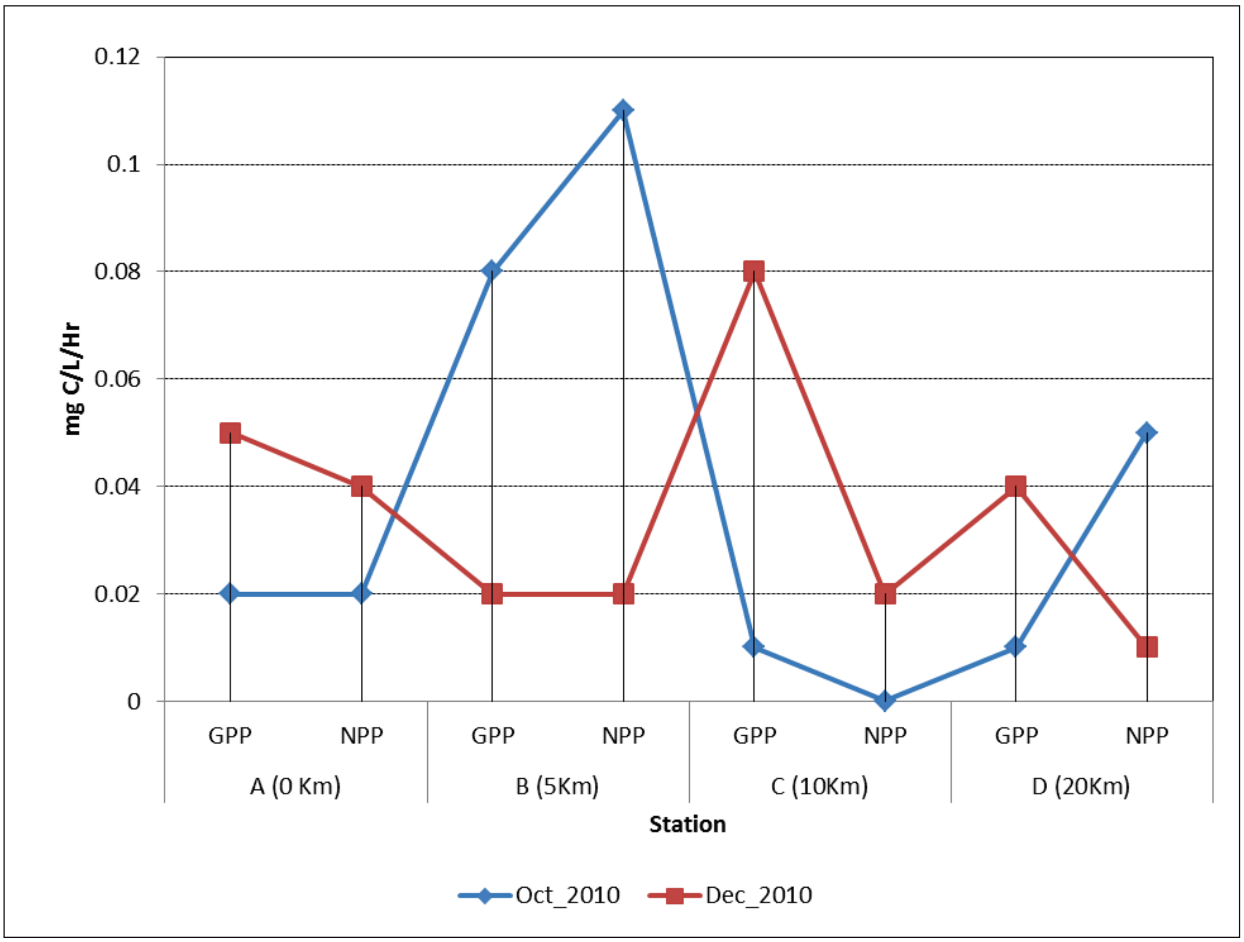


Fig. 21. Gross and Net Primary Productivity (mg C/L/Hr) flux in selected sites of Diu during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	0	0.158	0.089	0.052
Dec_2010	0	0	0.01	0.02

Table- 20. Ammonia concentration flux in selected sites of Diu during the Study period October -2010 to December-2010.

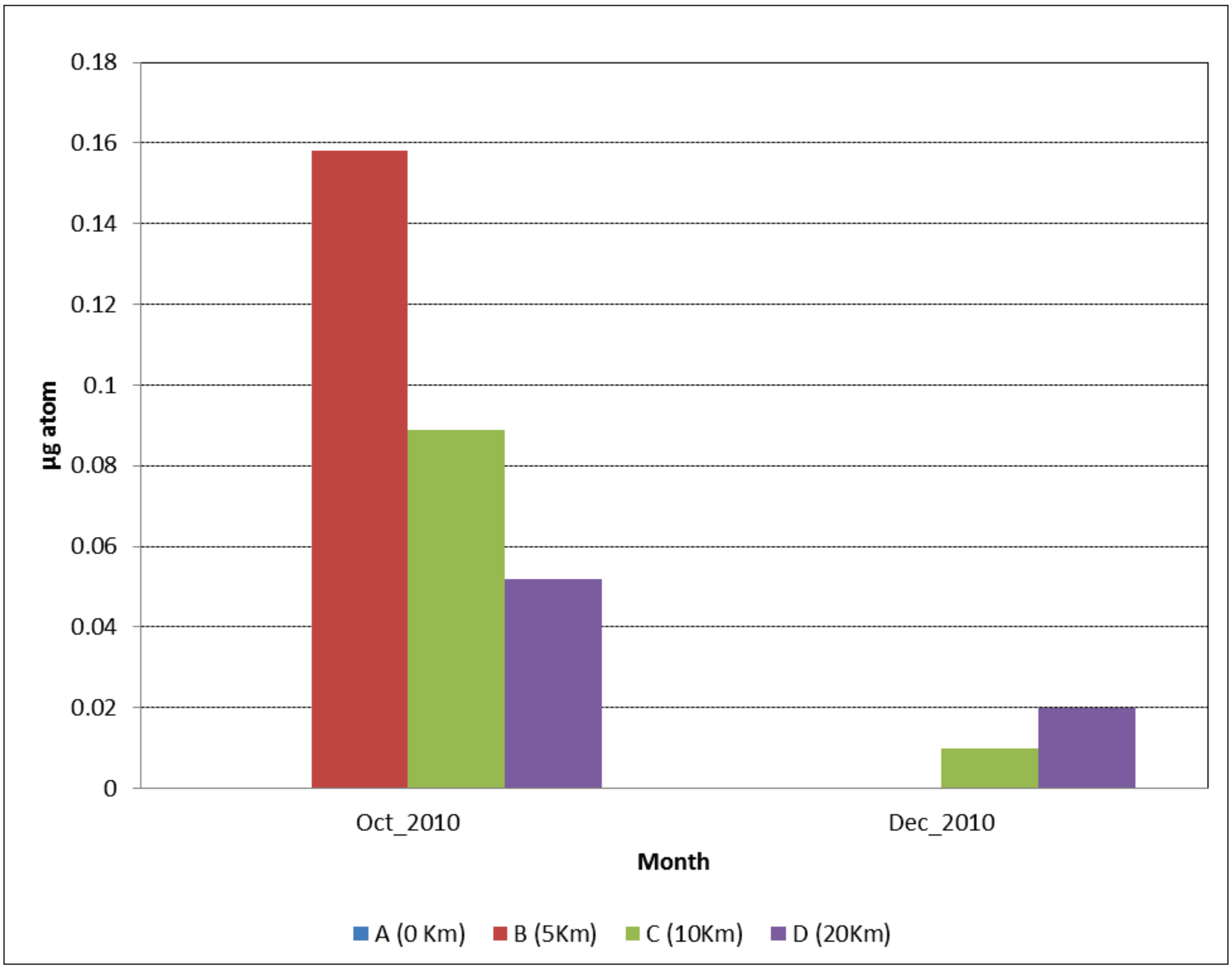


Fig. 22. Ammonia concentration flux in selected sites of Diu during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	0.048	0.081	0.068	0.054
Dec_2010	0.074	0.065	0.057	0.072

Table-21. Phosphate concentration flux in selected sites of Diu during the study period October -2010 to December-2010.

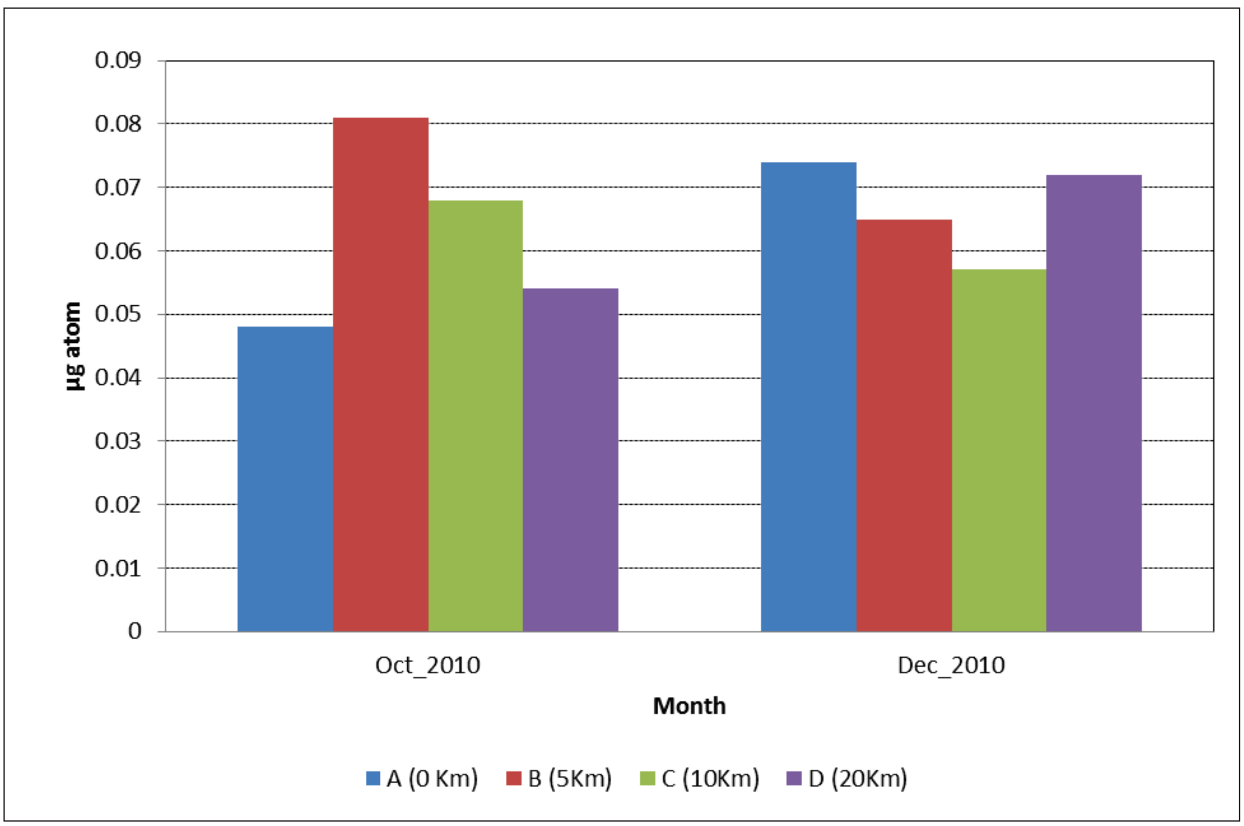


Fig. 23. Phosphate concentration flux in selected sites of Diu during the study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	4.373	4.448	4.448	3.663
Dec_2010	6.952	9.194	5.158	5.083

Table-22. Nitrate concentration flux in selected sites of Diu during the study period October -2010 to December-2010.

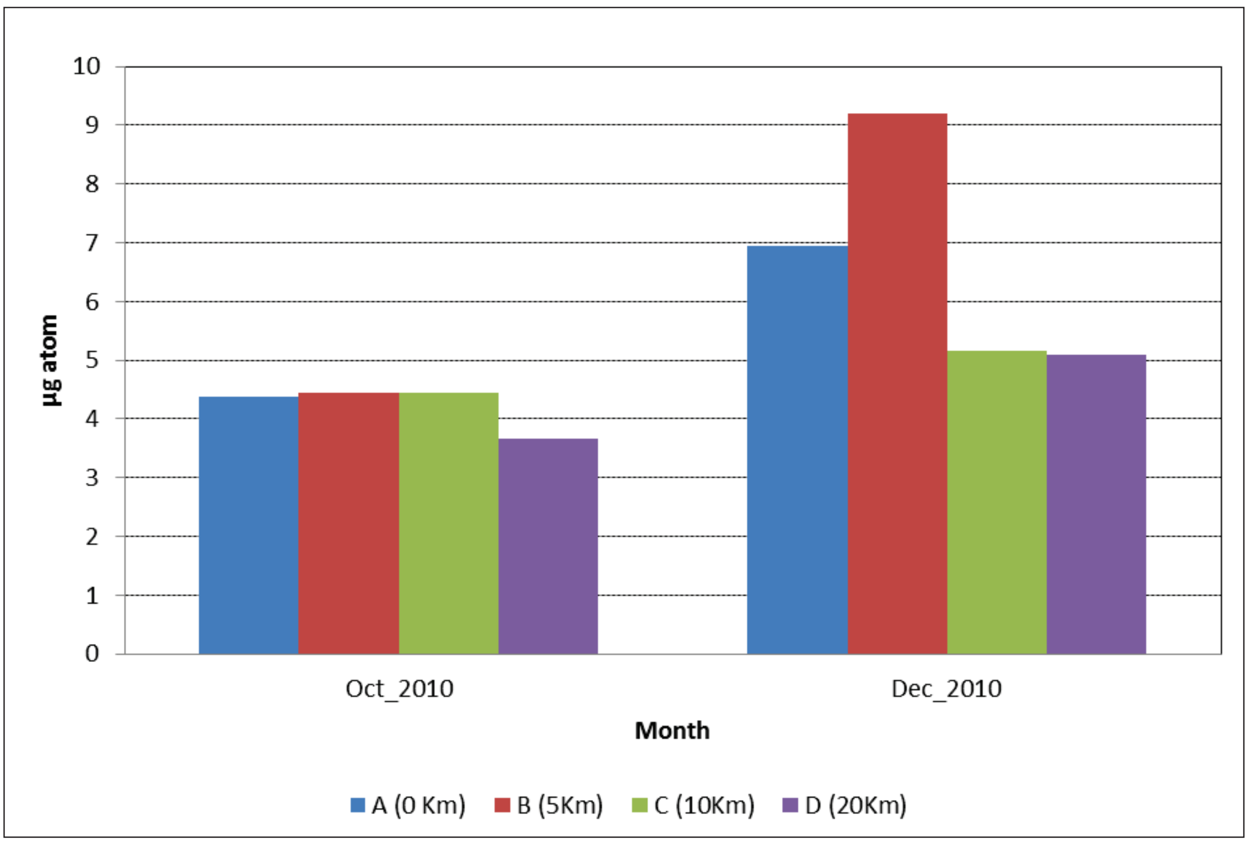


Fig. 24. Nitrate concentration flux in selected sites of Diu during the study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	0.566	0.443	0.157	0.402
Dec_2010	1.055	1.178	0.892	0.974

Table-23. Silicate concentration flux in selected sites of Diu during the study period October -2010 to December-2010.

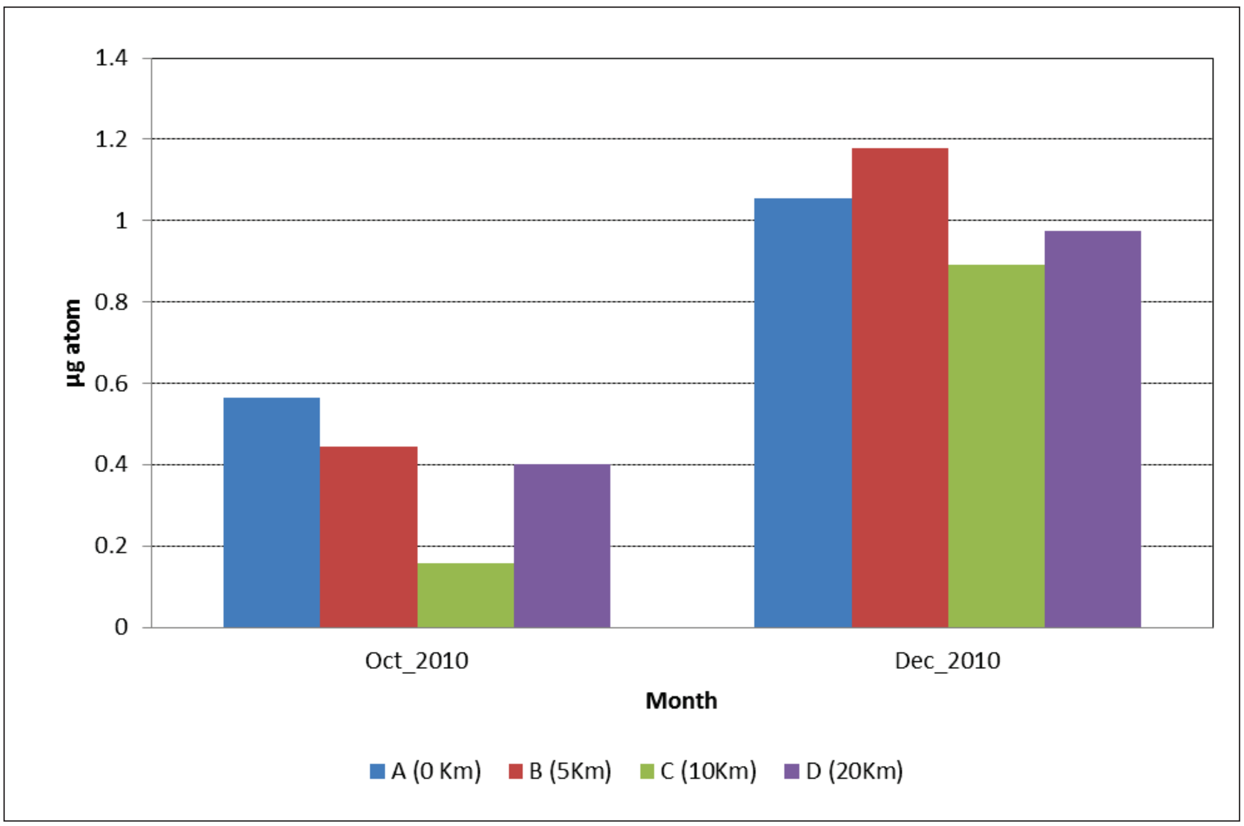


Fig. 25. Silicate concentration flux in selected sites of Diu during the study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	29.46	29.3	29.5	30.9
Dec_2010	24.4	24.6	24.9	25.7

Table-24. Temperature (°C) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

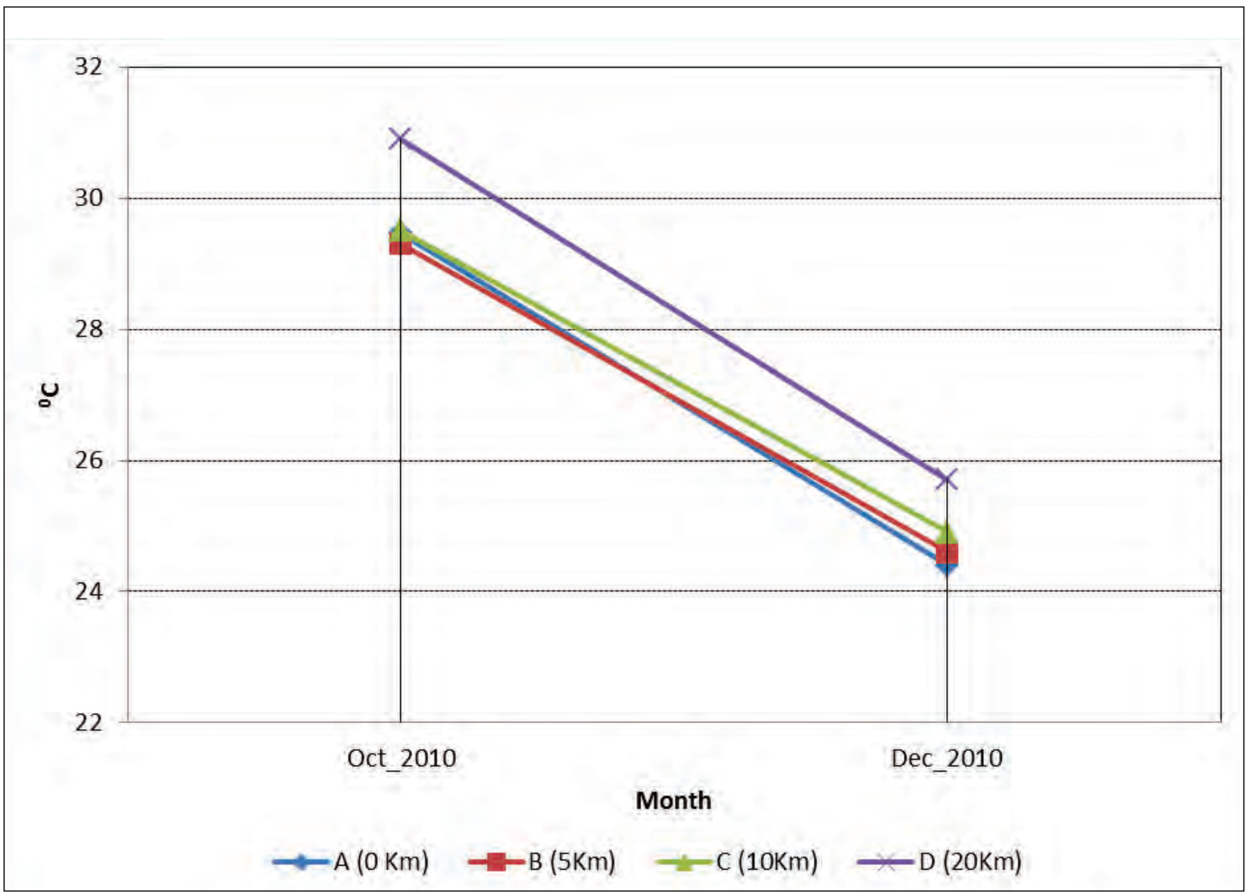


Fig. 26. Temperature (°C) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	7.4	7.9	7.8	7.3
Dec_2010	7.9	7.9	8	8.2

Table-25. pH flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

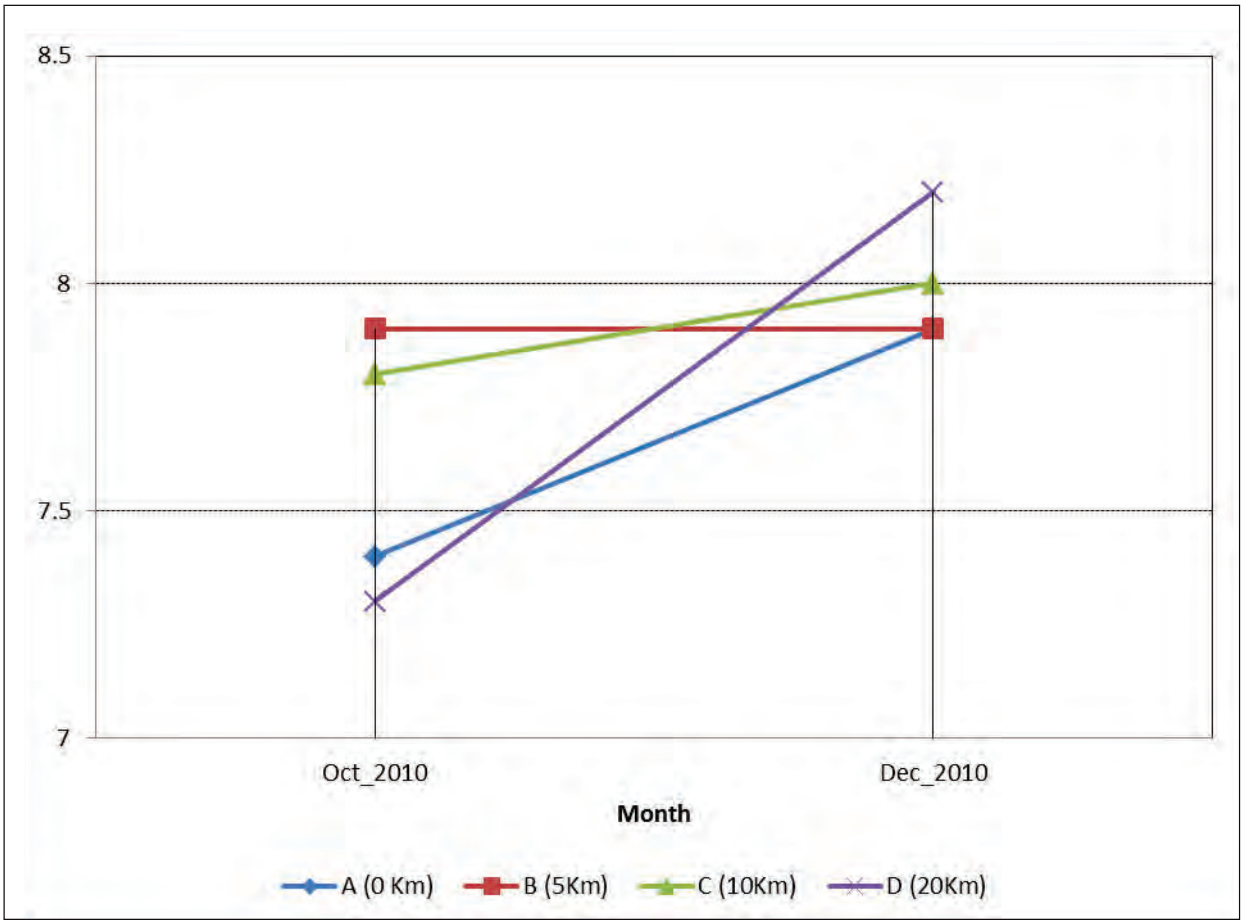


Fig. 27. pH flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	33.6	33.8	34.7	35.3
Dec_2010	34.4	34.3	35.1	35.3

Table-26. Salinity (ppt) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

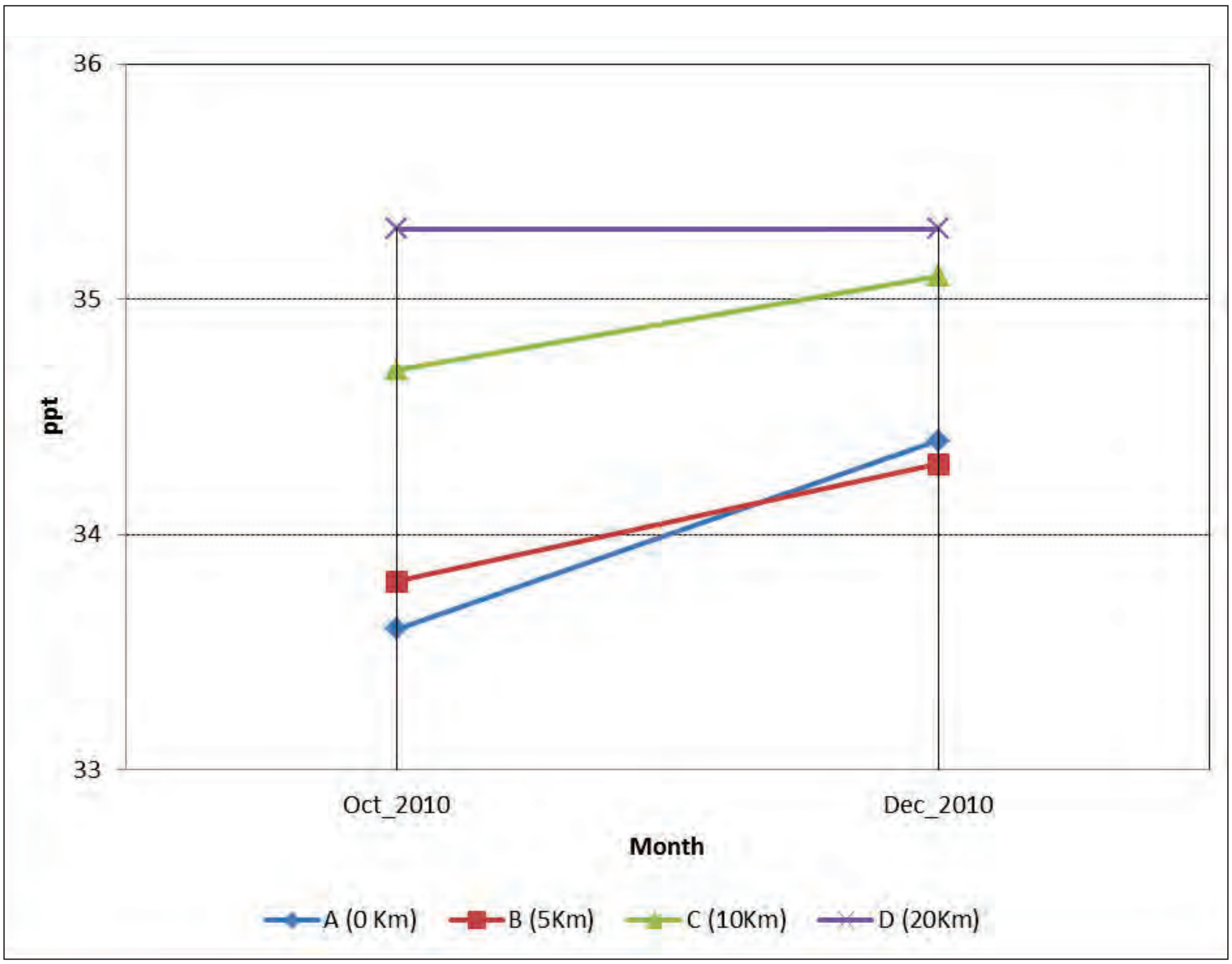


Fig. 28. Salinity (ppt) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	5.15	5.54	5.77	4.81
Dec_2010	5.31	5.15	4.97	4.75

Table-27. Dissolved Oxygen (ml/L) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

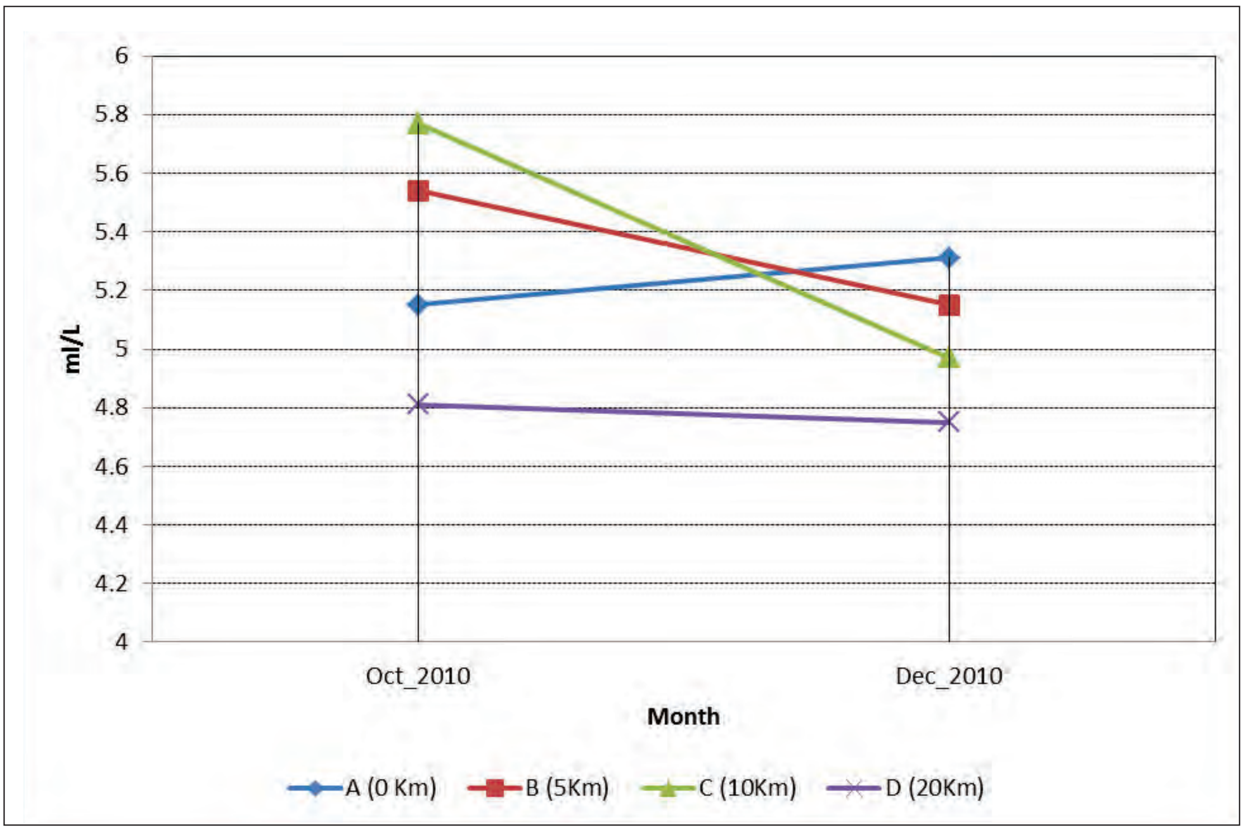


Fig. 29. Dissolved Oxygen (ml/L) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	1.9402	0.183	0.657	0.149
Dec_2010	1.7912	1.9774	1.051	0.943

Table-28. Chlorophyll (mg m-3) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

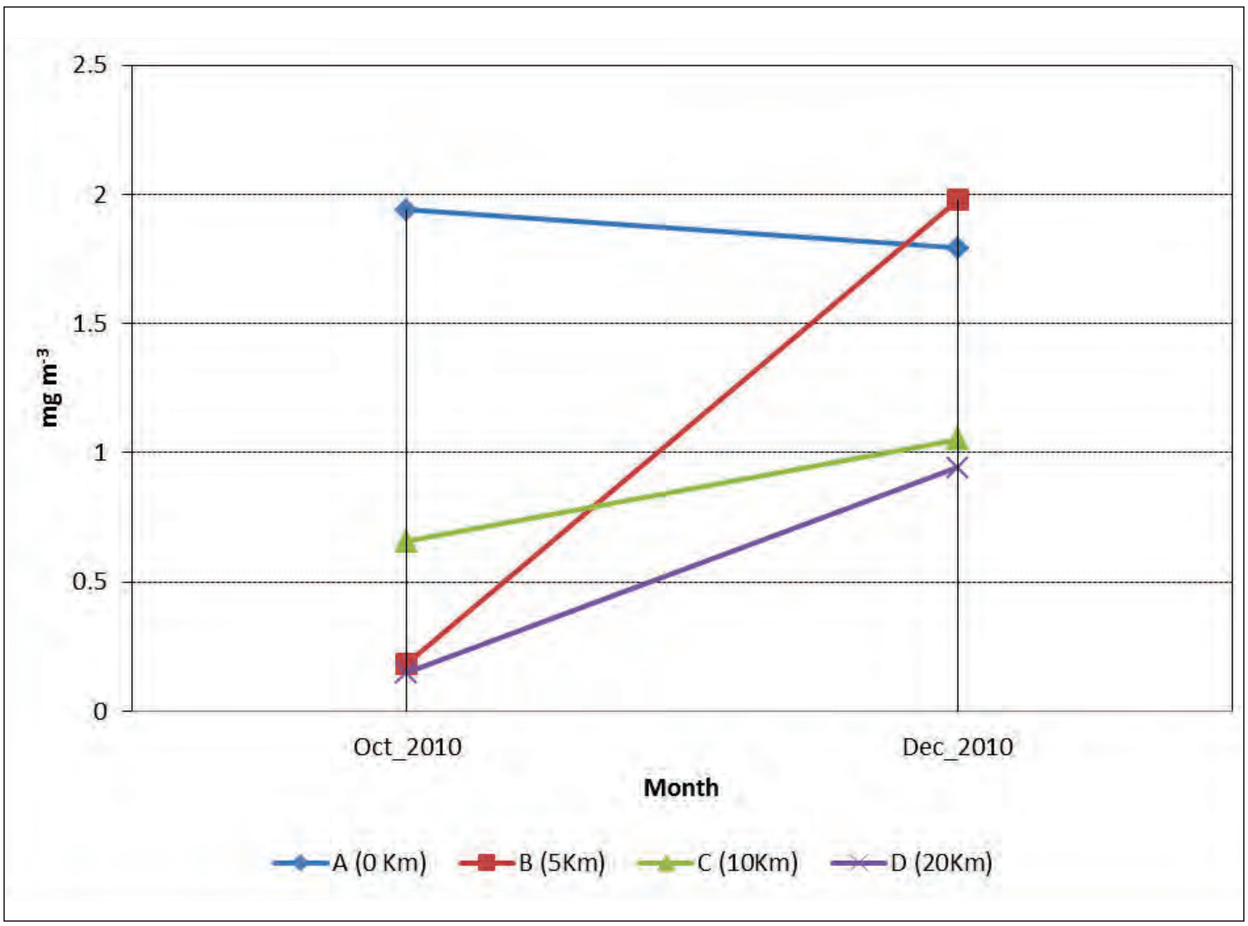


Fig. 30. Chlorophyll (mg m-3) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	5.25	7.25	7.25	10.3
Dec_2010	3.05	3.07	3.05	6.05

Table-29. Visibility (m) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

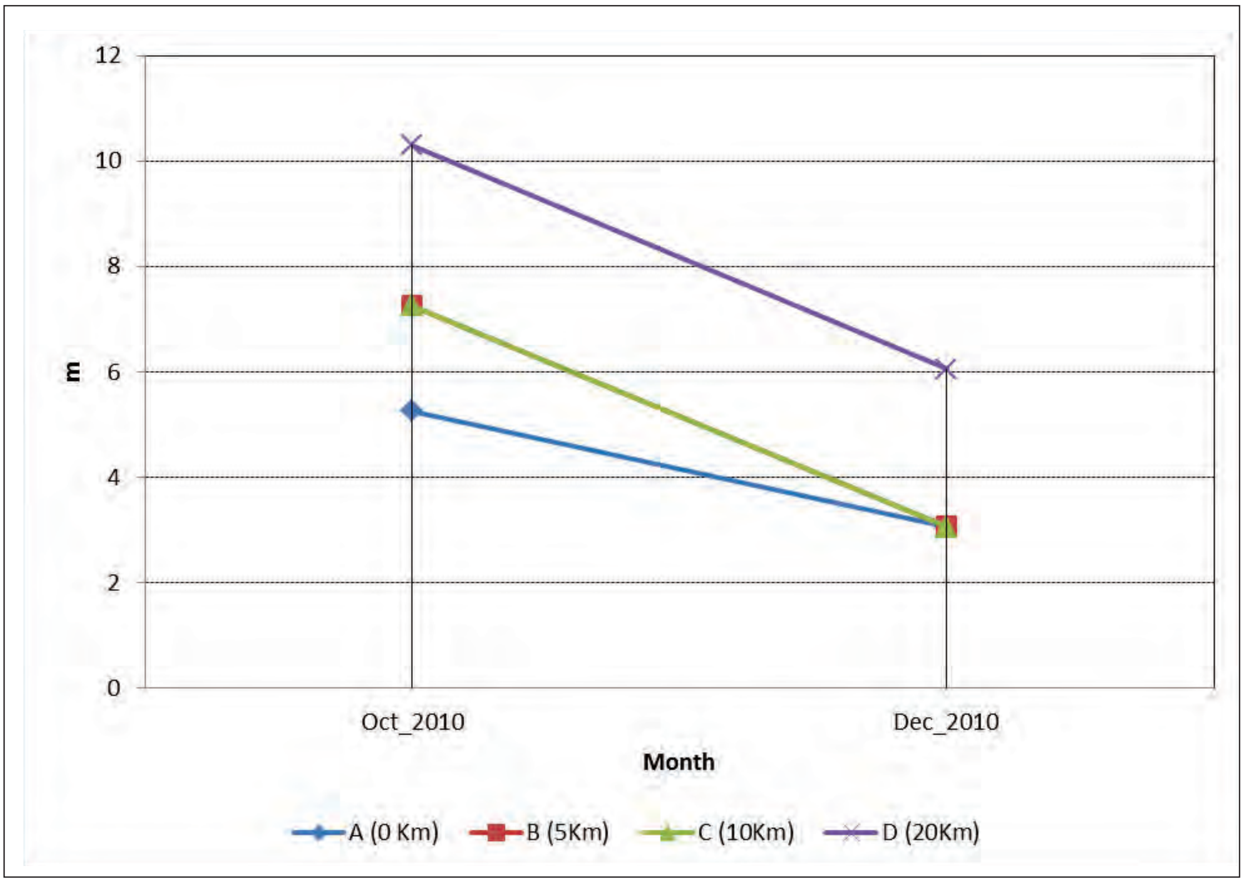


Fig. 31. Visibility (m) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

	A (0 Km)		B (5Km)		C (10Km)		D (20Km)	
	GPP	NPP	GPP	NPP	GPP	NPP	GPP	NPP
Oct_2010	0.12	0.06	0.06	0.02	0.11	0.04	0.11	0.09
Dec_2010	0.07	0.13	0.29	0.03	0.11	0.03	0.08	0.06

Table-30. Gross and Net Primary Productivity (mg C/L/Hr) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

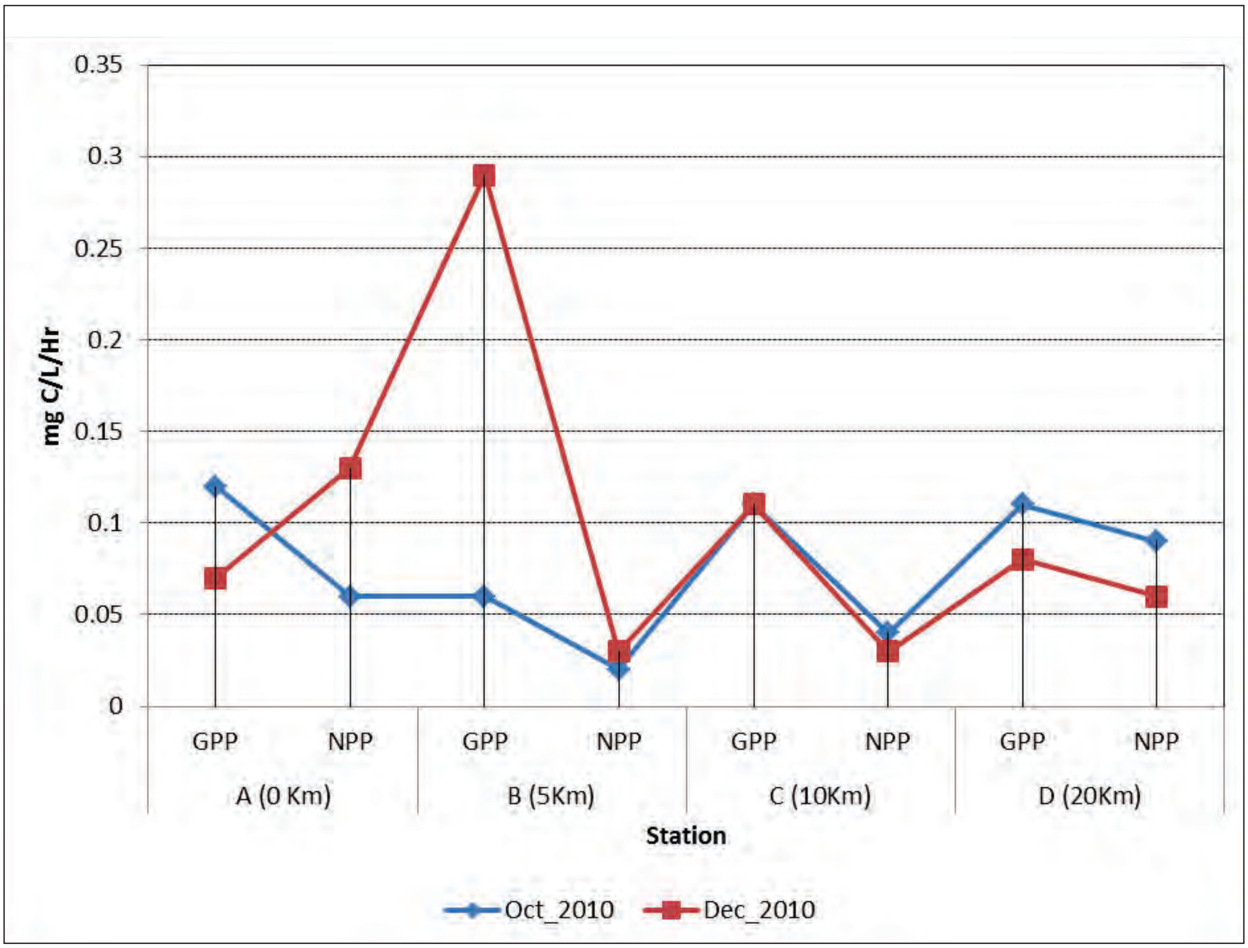


Fig. 32. Gross and Net Primary Productivity (mg C/L/Hr) flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	0.37	0.116	0.171	0.065
Dec_2010	0	0	0.015	0

Table-31. Ammonia concentration flux in selected sites of Mangrol during the Study period October - October -2010 to December-2010.

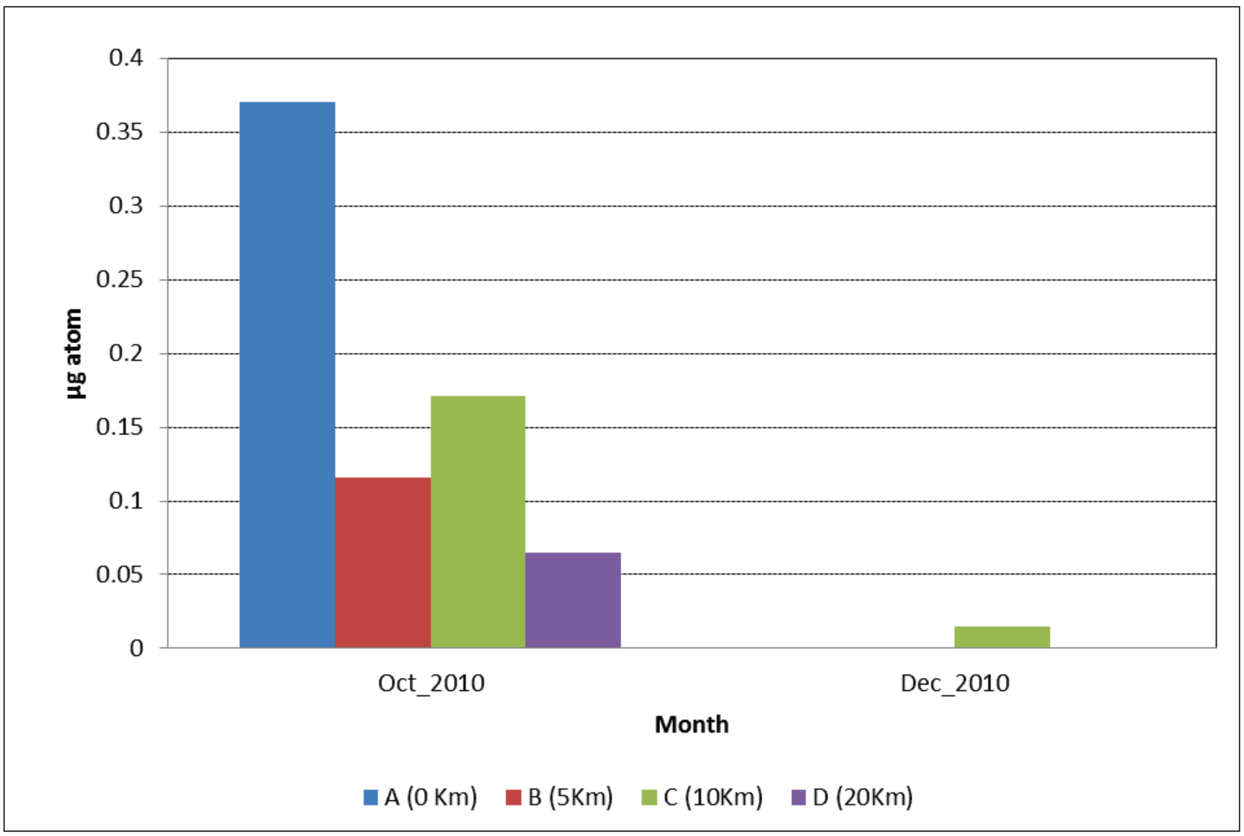


Fig. 33. Ammonia concentration flux in selected sites of Mangrol during the Study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	0.061	0.052	0.048	0.046
Dec_2010	0.052	0.043	0.054	0.032

Table-32. Phosphate concentration flux in selected sites of Mangrol during the study period October -2010 to December-2010.

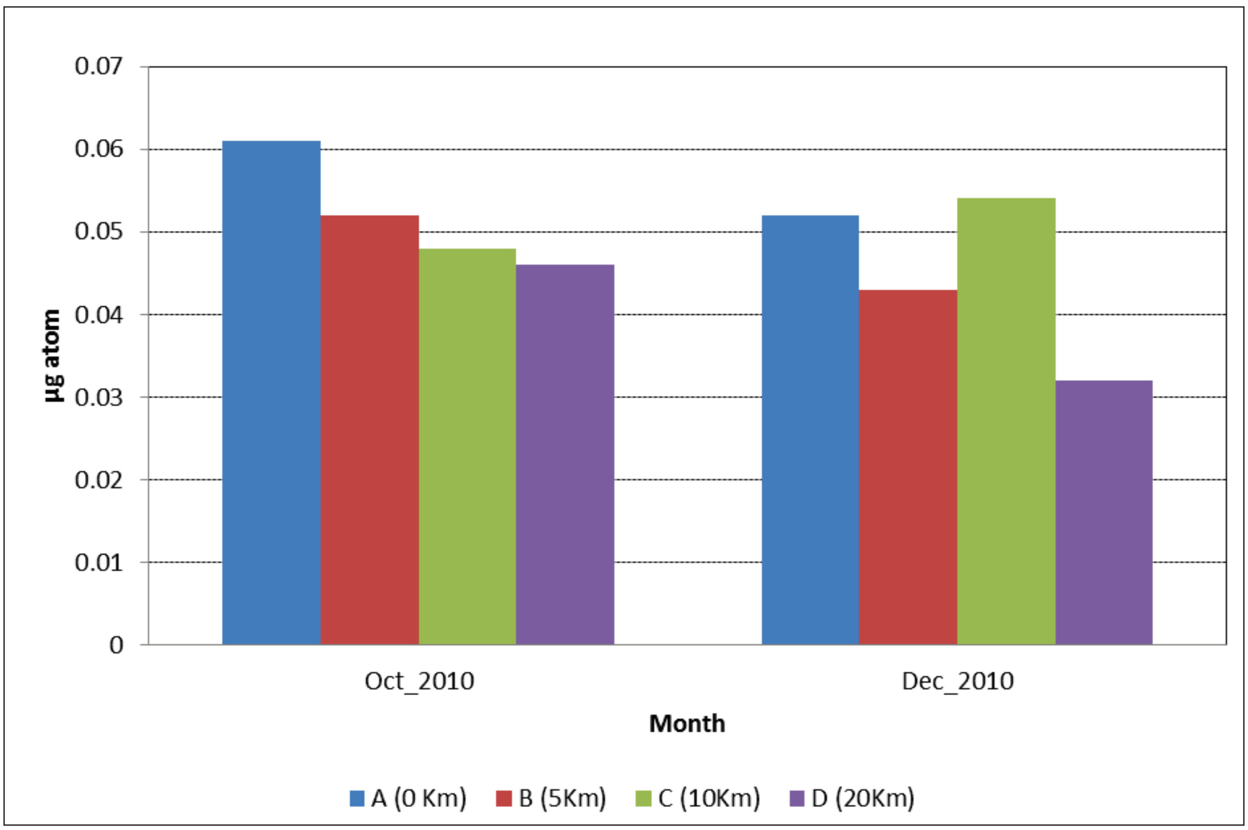


Fig. 34. Phosphate concentration flux in selected sites of Mangrol during the study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	6.129	3.85	4.485	5.345
Dec_2010	0	0	0.822	0.822

Table-33. Nitrate concentration flux in selected sites of Mangrol during the study period October -2010 to December-2010.

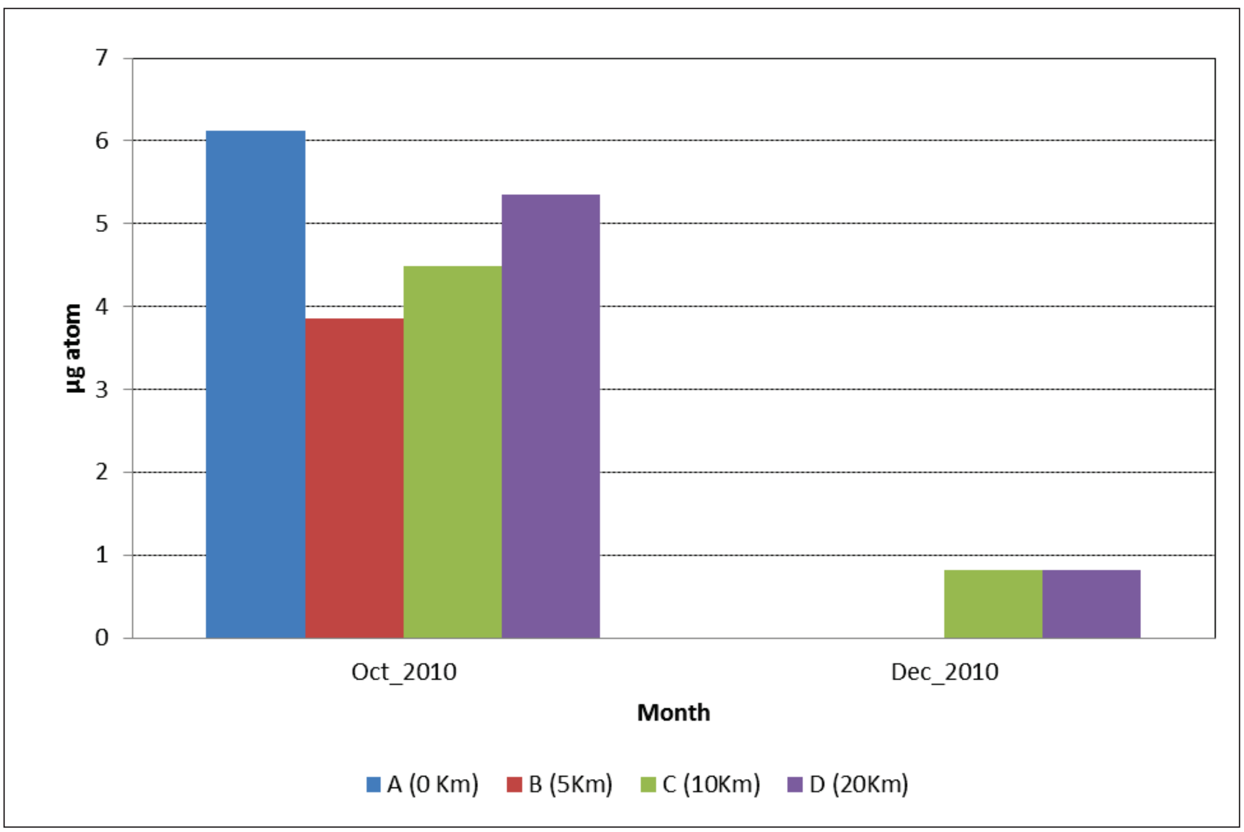


Fig. 35. Nitrate concentration flux in selected sites of Mangrol during the study period October -2010 to December-2010.

	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	0.647	0.647	0.321	0.296
Dec_2010	0.402	0.402	0.525	0.28

Table-34. Silicate concentration flux in selected sites of Mangrol during the study period October -2010 to December-2010.

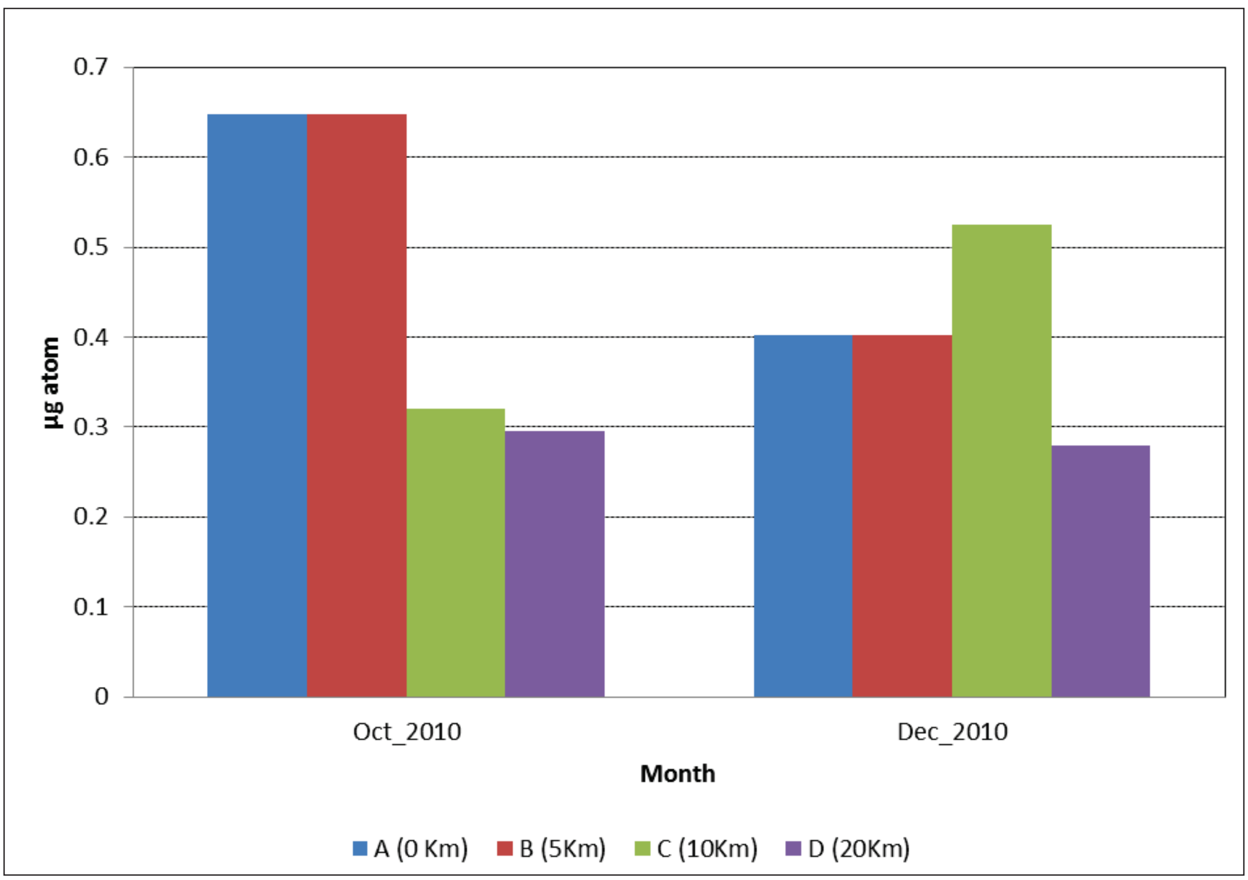


Fig. 36. Silicate concentration flux in selected sites of Mangrol during the study period October -2010 to December-2010.

Month	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Feb_2010	54300	53800	53700	43400
Mar_2010	44300	33800	23700	13400
Apr_2010	5300	38000	37000	30400
May_2010	33300	13800	9700	84400
Oct_2010	55300	33800	23700	12600
Dec_2010	36400	13800	3700	3400

Table-35. Abundance (in no of cells l-1) and pattern of monthly variations of phytoplankton in the selected sites of whale shark habituate at Veraval coast.

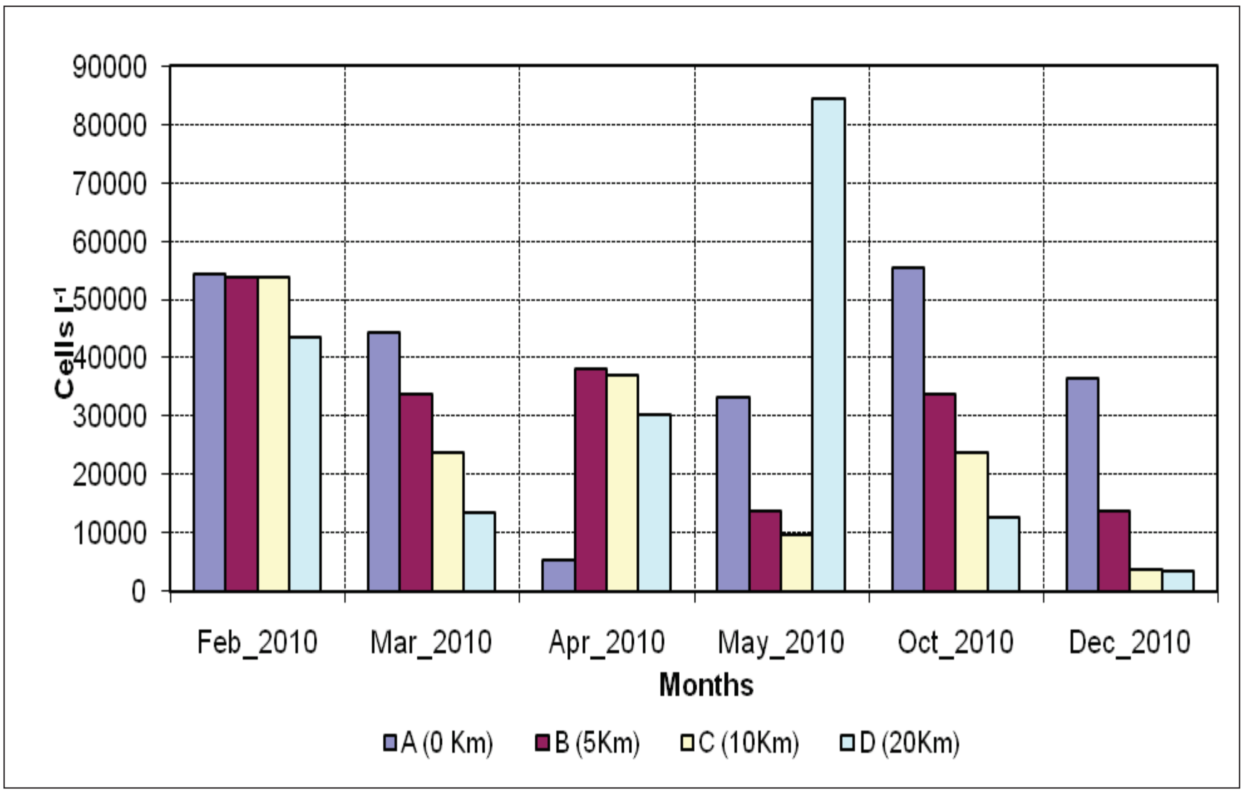


Fig. 37. Abundance (in no of cells l-1) and pattern of monthly variations of phytoplankton in the selected sites of whale shark habituate at Veraval coast.

Month	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	12000	5000	2500	2500
Dec_2010	9000	5000	1600	2300

Table-36. Abundance (in no of cells l-1) and pattern of monthly variations of phytoplankton in the selected sites of whale shark habituate at Diu coast.

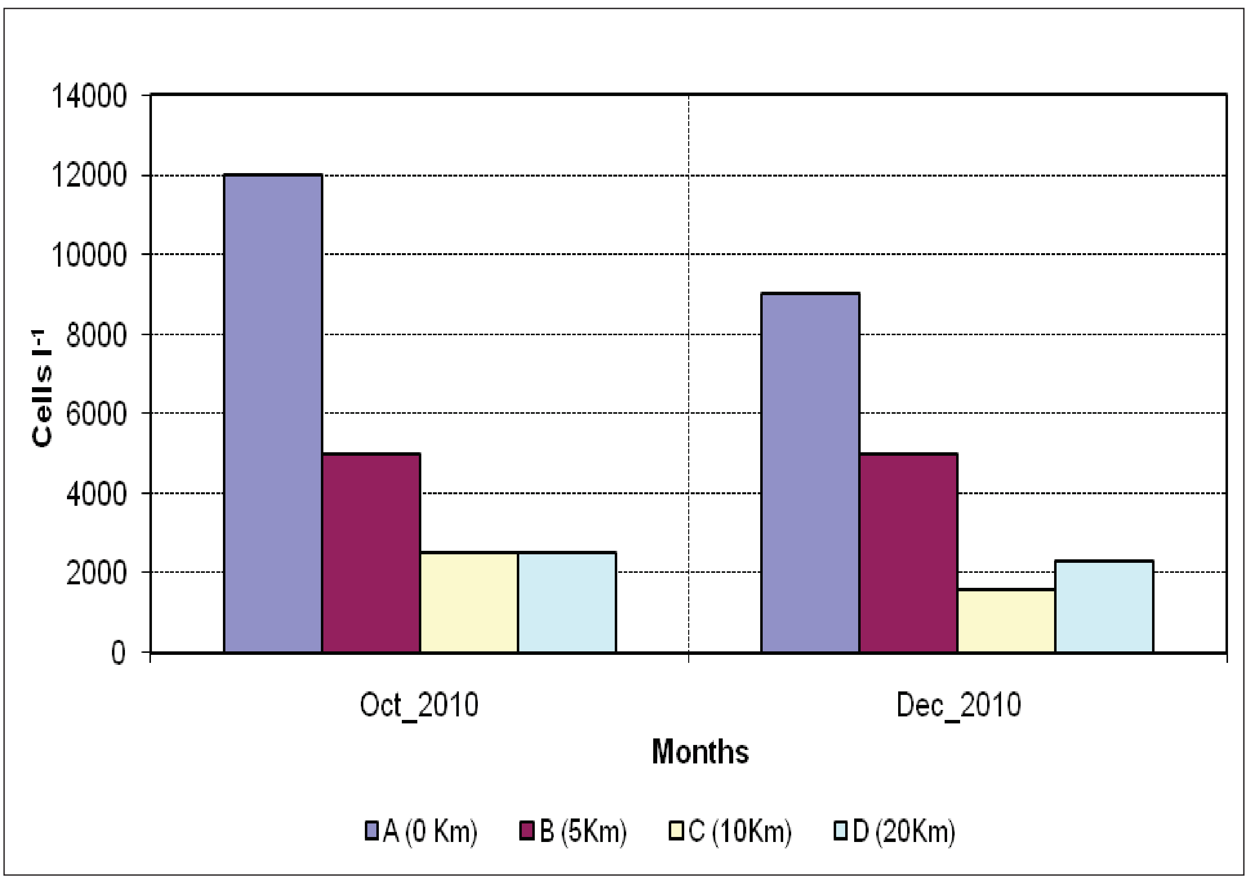


Fig. 38. Abundance (in no of cells l-1) and pattern of monthly variations of phytoplankton in the selected sites of whale shark habituate at Diu coast.

Month	A (0 Km)	B (5Km)	C (10Km)	D (20Km)
Oct_2010	26000	23000	10000	11000
Dec_2010	13000	6000	4500	2100

Table-37. Abundance (in no of cells l-1) and pattern of monthly variations of phytoplankton in the selected sites of whale shark habituate at Mangrol coast.

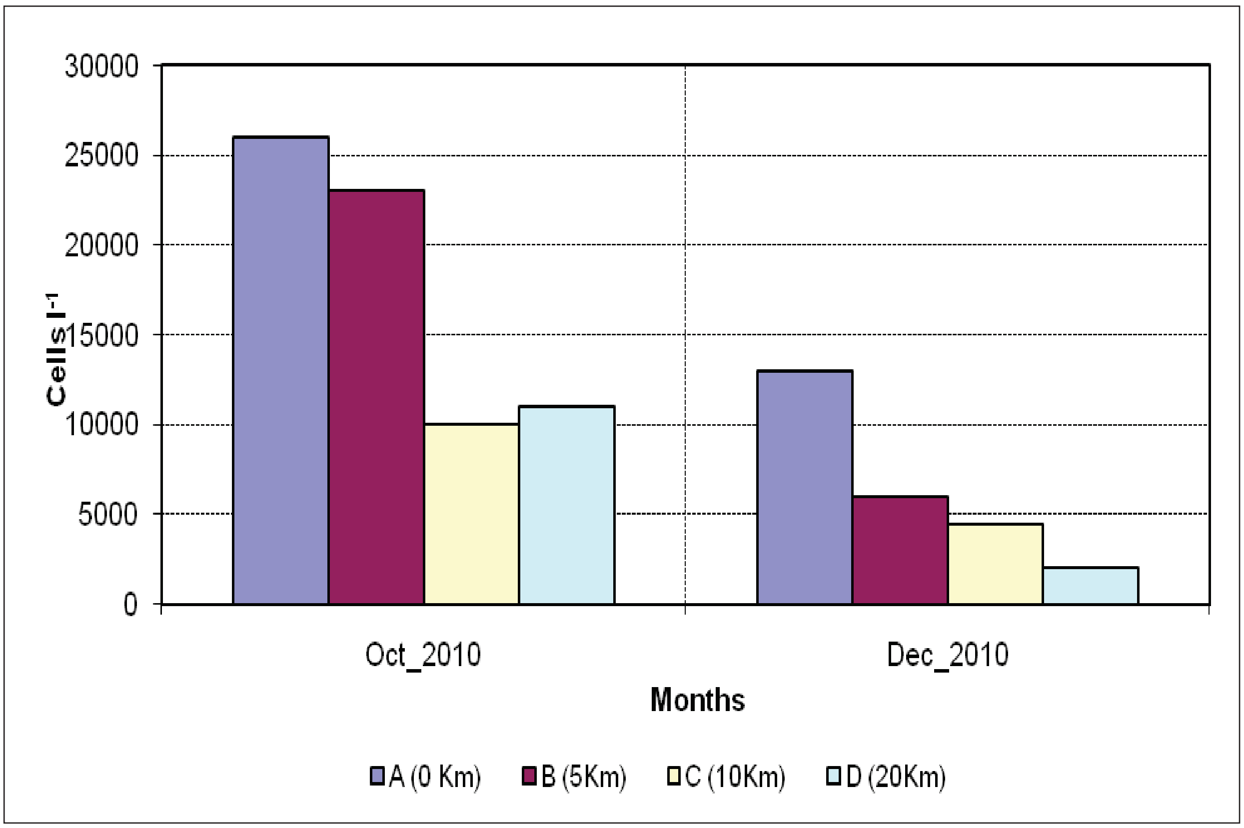


Fig. 39. Abundance (in no of cells l-1) and pattern of monthly variations of phytoplankton in the selected sites of whale shark habituate at Mangrol coast.

Table-38 (a) Diversity of Phytoplankton in the selected sites of whale shark habituate at Veraval, Diu and Mangrole.

Sl. No.	Name	Veraval (VRL)				Diu (DIU)				Mangrole (MGR)			
		A	B	C	D	A	B	C	D	A	B	C	D
	Diatoms- Centrales												
1.	Skeletonema costatum	+	+ +	+ +	-	-	+	+	-	-	-	-	-
2.	Thallassiophyxix palmeriana	-	+	-	+	-	-	+	+	+	+	-	-
3.	Thallassiosira subtilis	+ +	-	-	+	-	-	+	+	-	-	+	-
4.	Coscinodiscus excentricus	+ + +	+ +	+ +	+ +	+ +	+ +	+	+ +	+ +	+ +	+ +	+
5.	Planktoniella sol	-	+	+	-	-	-	-	-	+ +	+	-	-
6.	Rhizosolenia robusta	+	-	+ +	-	+	-	-	+	+ +	+	+	+
7.	Eucampia cornuta	-	+	-	-	-	+	-	-	-	-	+	+
8.	Biddulphia mobiliensis	+ +	+	+	-	+	-	-	-	+ +	+	-	-
9.	Ditylum brightwelli	-	-	-	-	-	-	+	+	+	+ +	+	-
10.	Biddulphia sinensis	+ +	+	+	-	-	-	-	-	+ + +	+ +	+	-
11.	Cerataulina bergonii	+	+ +	++	-	-	-	-	+ +	-	+	+	+
12.	Cyclotella sp.	+ + +	+	+	+	+ +	+	+	-	-	-	-	-
13.	Chaetoceros sp.	+ +	+ +	+ +		+	+	-	-	-	+	+ +	+ +
14.	LIthodesmium sp.	-	-	+	+	-	-	-	+	+ +	+	-	-
	Diatoms- Pennales												
1.	Grammatophora undulate	+ +	+	-	-	-	-	-	+	+ +	+	+	-
2.	Licmophora delicatula	-	-	+	+	-	-	-	+	+	-	-	+
3.	Fragilaria oceanic	+	+	-	-	-	-	-	+	-	+ +	+	-
4.	Rhaphoneis discoides	-	-	-	+ +	-	-	-	+ +	-	+	+ +	-
5.	Thallasiothrix frauenfeldii	+ +	+	+	+	+	+	+ +	+	+ +	+ +	+ +	+ +
6.	Asterionella japonica	-	-	-	+	-	-	+	+	-	+	+	-
7.	Mastogloia exilis	+	+	+	-	+	+ +	+	-	+	+	+ +	-

*Abundant = + + +; Average = + +; Less in Number = +; Absent = -

Table-38 (b) Diversity of Phytoplankton in the selected sites of whale shark habituate at Veraval, Diu and Mangrole.

Sl. No.	Name	Veraval (VRL)				Diu (DIU)				Mangrole (MGR)			
		A	B	C	D	A	B	C	D	A	B	C	D
8.	Cocconeis littoralis	-	-	+ +	+	-	-	+ +	+	-	-	-	-
9.	Gyrosigma balticum	-	+	+ +	+	-	+	+ +	+	+	+	+ +	-
10.	Bacillaria paradoxa	+	-	-	-	+	-	-	-	-	-	-	-
11.	Nitzschia closterium	+	+ +	+	+	+ +	+	-	+	+	+ +	+	+
12.	Nitzschia sp.	+ + +	+ +	+	+	-	+	+ +	+ +	+ +	+ +	+ +	+ + +
13.	Surirella fluminensis	-	-	+	+	-	-	-	+	-	+ +	-	-
14.	Campylodiscus iyengarii	-	-	-	+	-	-	-	+	-	-	+ +	+
15.	Navicula sp.	-	-	+	+	+	+ +	-	-	-	-	+	+ +
16.	Thalassionema nitzschioides	-	-	-	+	-	-	-	-	+ +	+ +	-	-
	Dinoflagellates												
1.	Ceratium sp.	+ +	+	+	+	-	-	+ +	+ +	+ +	+	+ +	+
2.	Cochlodinium citron	-	+	-	-	+ +	-	+	-	+	-	-	-
3.	Amphisolenia bifurcate	+	+	+ +	-	-	-	-	+	-	+	+	-
4.	Ceratium declinatum	-	-	+	-	-	-	+	-	-	-	-	+
5.	Dinophysis caudate	+	-	-	-	-	+	+ +	-	-	-	-	+
6.	Peridinium claudicans	-	-	-	+	-	-	+ +	+	-	-	+	+
7.	Podolampas bipes	-	-	-	-	-	-	-	-	-	-	-	-
8.	Pyrophacus horologium	-	-	-	-	-	-	-	-	-	-	-	-
9.	Diplopsalis sp.	-	-	-	-	-	-	-	-	-	-	-	-
10.	Ornithocercus magnificus	+ +	+ +	+	-	-	++	+	-	+ +	+ +	+ +	+ + +
11.	Prorocentrum sp.	-	-	-	-	-	-	-	-	-	+	+	-

Table- 38 (c) Diversity of Phytoplankton in the selected sites of whale shark habituate at Veraval, Diu and Mangrole.

Sl. No.	Name	Veraval (VRL)				Diu (DIU)				Mangrole (MGR)			
		A	B	C	D	A	B	C	D	A	B	C	D
	Silicoflagellates, Blue-Green algae & Nannoplankton												
1.	Blue green algae	+ + +	+	-	-	+ +	+	-	-	+ + +	+	-	-
2.	Spirulina sp.	-	-	-	-	-	-	-	-	-	-	-	-
3.	Pavlova sp.	-	-	-	-	-	-	-	-	-	-	-	-
4.	Dunaliena sp.	-	-	-	-	-	-	-	-	-	-	-	-
5.	Nanno Chloropsis	-	+	-	-	-	-	-	+	-	-	+	-
6.	Chlorella sp.	+	-	-	-	+	-	-	-	-	-	-	-
7.	Tetraselmis sp.	-	-	-	-	-	-	-	-	-	-	-	-

*Abundant = + + +; Average = + +; Less in Number = +; Absent = -

Group	Feb_2010	Mar_2010	Apr_2010	May_2010	Oct_2010	Dec_2010
Hydromedusae	0	0	30	0	0	0
Siphonophora	0	0	0	0	0	0
Chaetognatha	0	0	10	2	2	1
Copepod	1.2	1.3	0	3	24	12
Sergestidae	13	3	1.3	13	4	0
Invertebrate larvae	33	3	0.3	3	12	7
Thaliacea	2	0	0	0	0	0
Fish eggs	23	3	3	4	7	32
Fish larvae	1	2	1.7	7	2	50

Table-39. Group vise zooplankton population density in Station-A of whale shark habituate sites at Veraval.

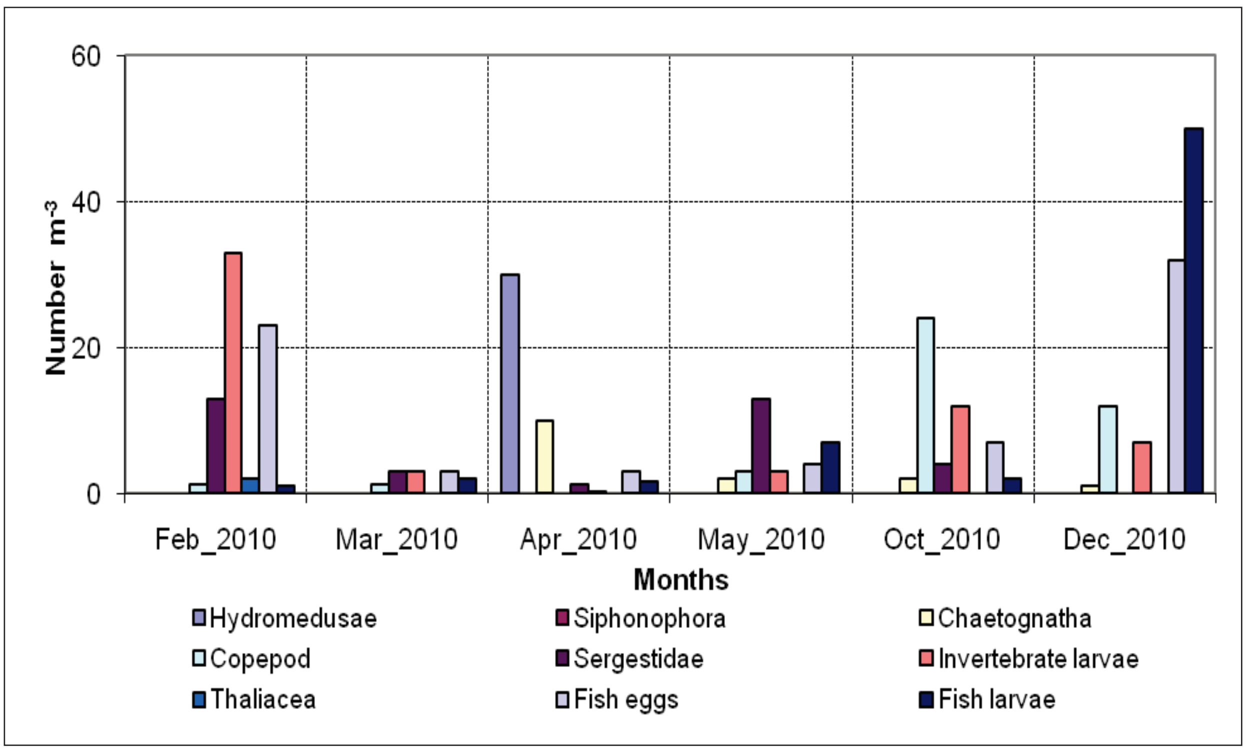


Fig. 40. Group vise zooplankton population density in Station-A of whale shark habituate sites at Veraval.

Group	Feb_2010	Mar_2010	Apr_2010	May_2010	Oct_2010	Dec_2010
Hydromedusae	12	2	21	0	5	0
Siphonophora	0	0	0	0	0	0
Chaetognatha	0	0	7.5	0	3	1
Copepod	11	123	2.2	1	27	25
Sergestidae	0	0	0.9	13	3	1
Invertebrate larvae	13	3	0	3	17	5
Thaliacea	0	0	0	0	0	0
Fish eggs	0	0	2.2	2	0	36
Fish larvae	25	5	2.5	7	0	12

Table-40. Group vise zooplankton population density in Station-B of whale shark habituate sites at Veraval.

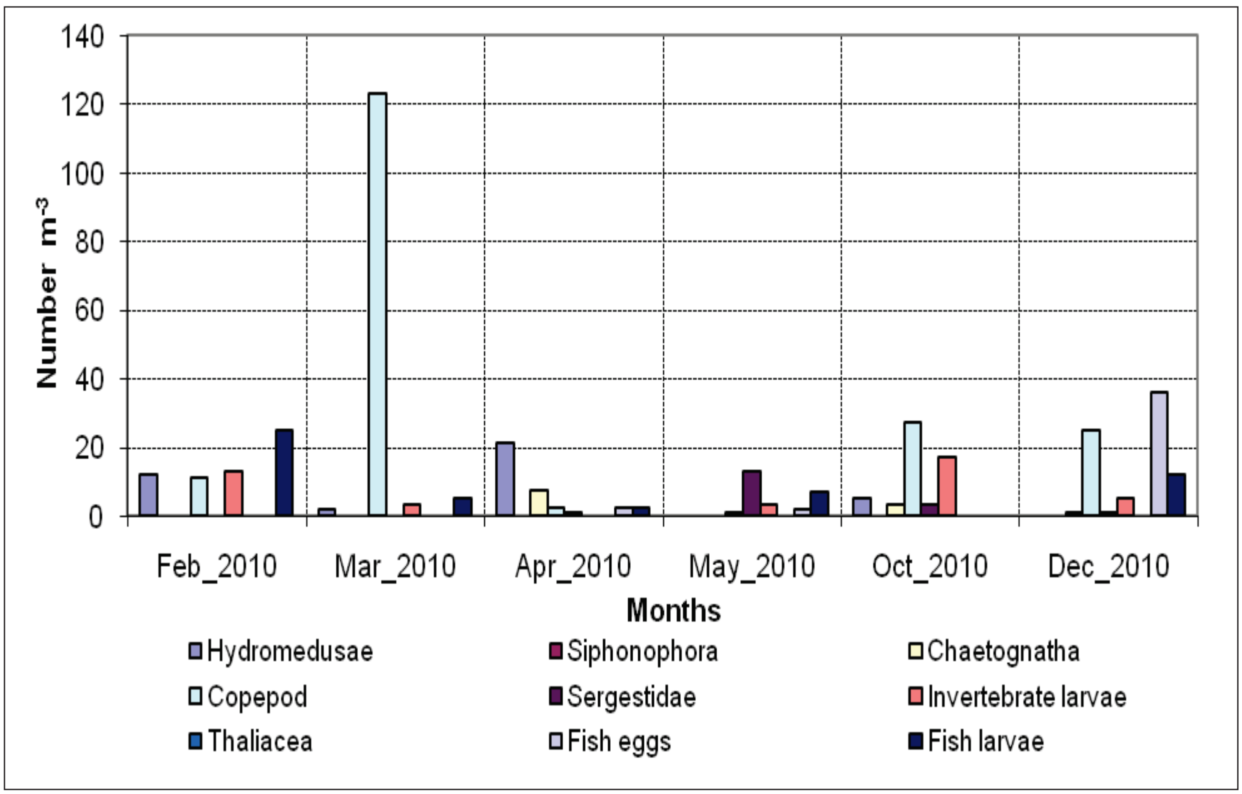


Fig. 41. Group vise zooplankton population density in Station-B of whale shark habituate sites at Veraval.

Group	Feb_2010	Mar_2010	Apr_2010	May_2010	Oct_2010	Dec_2010
Hydromedusae	11	1	27.5	0	3	2
Siphonophora	0	0	0	0	0	0
Chaetognatha	11	1	5.2	0	2	3
Copepod	14	156	2.5	14	17	22
Sergestidae	0	0	6	0	2	0
Invertebrate larvae	12	2	1.5	21	13	6
Thaliacea	0	0	0.7	0	0	0
Fish eggs	20	0	1.2	22	4.2	27
Fish larvae	22	2	0	32	1.3	4

Table-41. Group vise zooplankton population density in Station-C of whale shark habituate sites at Veraval.

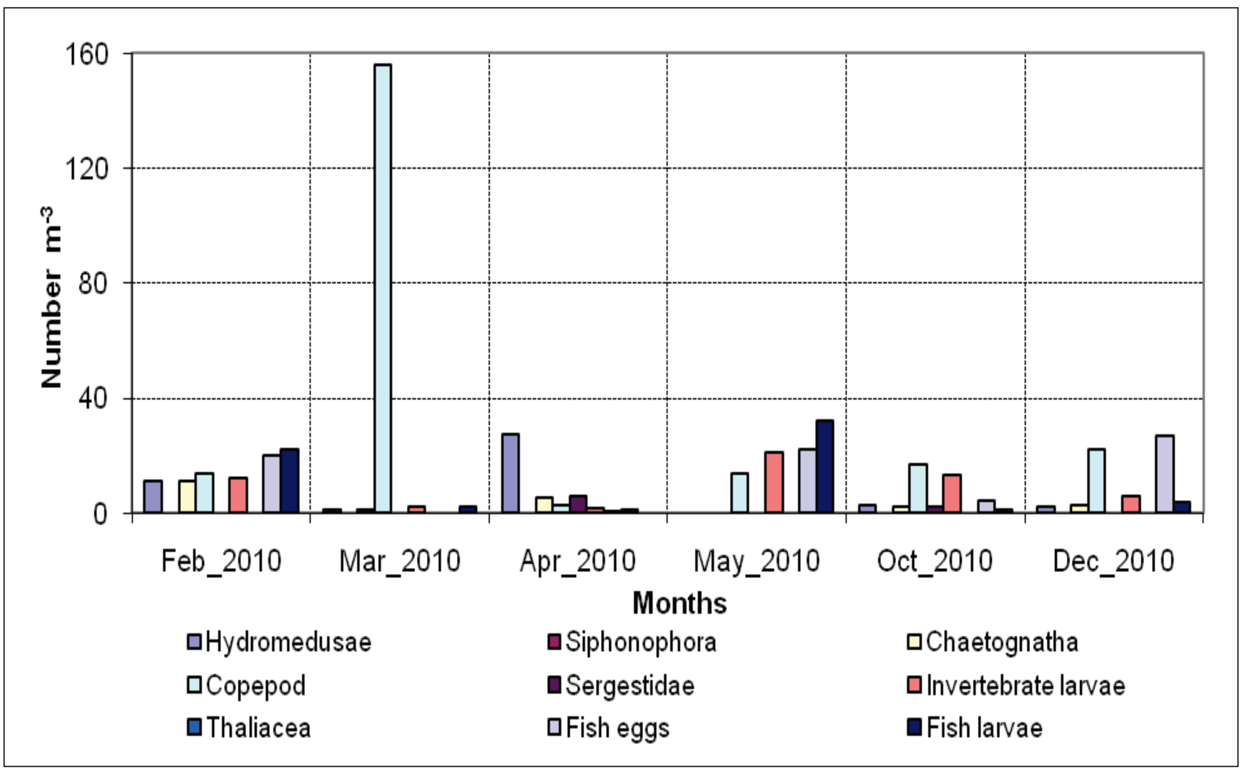


Fig. 42. Group vise zooplankton population density in Station-C of whale shark habituate sites at Veraval.

Group	Feb_2010	Mar_2010	Apr_2010	May_2010	Oct_2010	Dec_2010
Hydromedusae	0	0	21.3	0	8	0
Siphonophora	0	0	0	0	0	1
Chaetognatha	0	0	1	34	1	5
Copepod	42	133	3.1	19	15	23
Sergestidae	27	7	1.1	0	2	1
Invertebrate larvae	33	3	0.5	32	8	9
Thaliacea	0	0	0	0	2	2
Fish eggs	12	2	1	12	0	18
Fish larvae	13	3	0	18	0	7.9

Table-42. Group vise zooplankton population density in Station-D of whale shark habituate sites at Veraval.

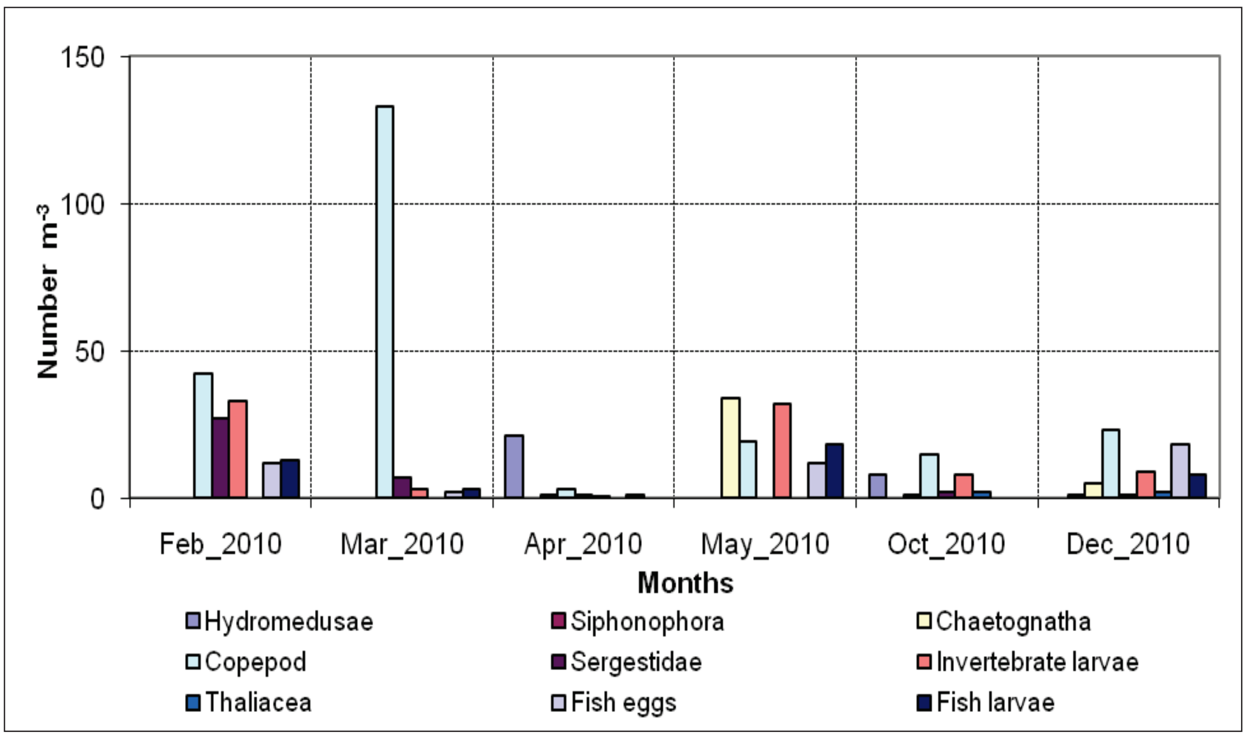


Fig. 43. Group vise zooplankton population density in Station-D of whale shark habituate sites at Veraval.

Group	Oct_2010	Dec_2010
Hydromedusae	0	1
Siphonophora	0	0
Chaetognatha	0	0
Copepod	25	26
Sergestidae	0	5
Invertebrate larvae	12	8
Thaliacea	0	0
Fish eggs	7	38
Fish larvae	1	0

Table-43. Group vise zooplankton population density in Station-A of whale shark habituate sites at Diu.

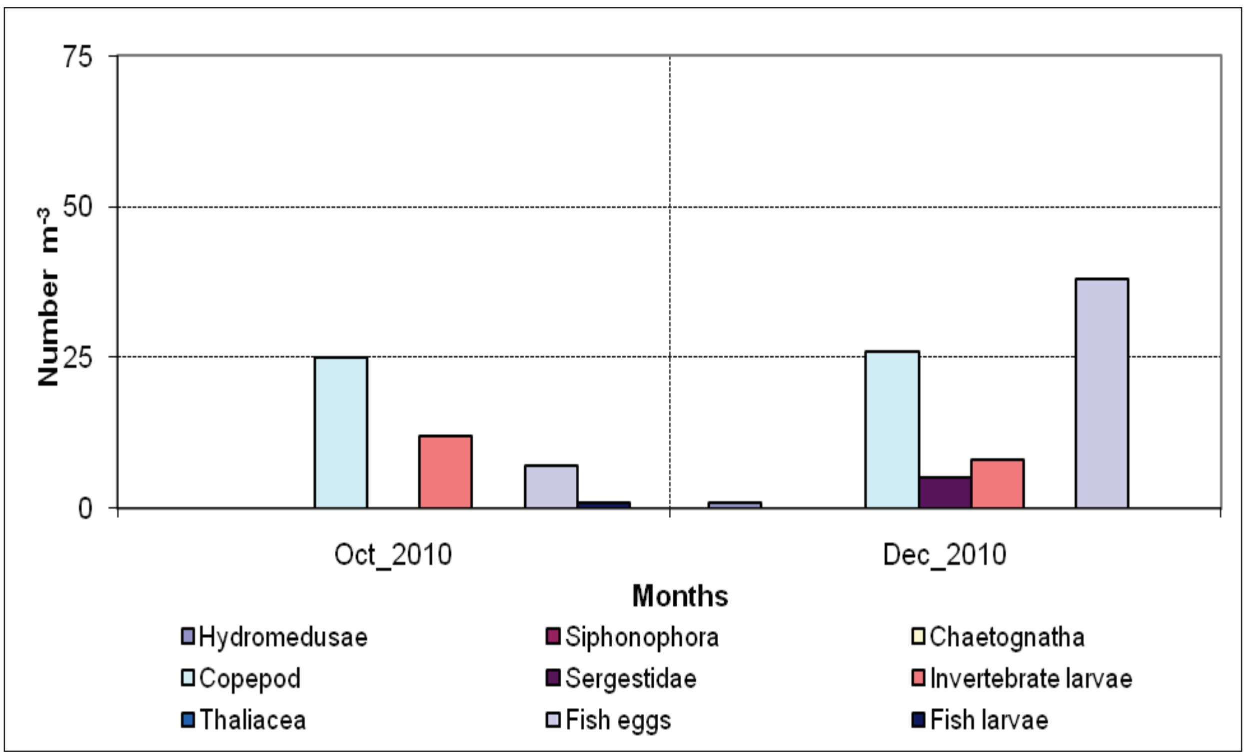


Fig. 44. Group vise zooplankton population density in Station-A of whale shark habituate sites at Diu.

Group	Oct_2010	Dec_2010
Hydromedusae	0	0
Siphonophora	0	0
Chaetognatha	0	2
Copepod	17	12
Sergestidae	0	0
Invertebrate larvae	11	5
Thaliacea	0	0
Fish eggs	8	43
Fish larvae	1	0

Table-44. Group vise zooplankton population density in Station-B of whale shark habituate sites at Diu.

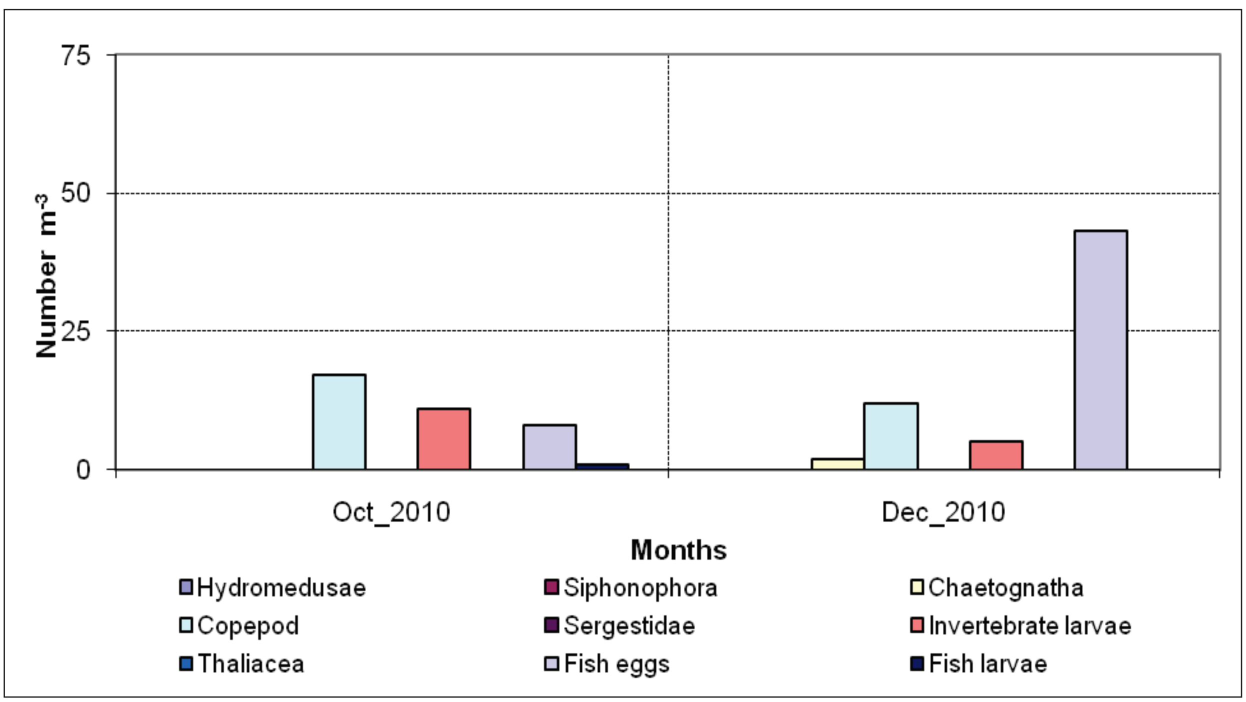


Fig. 45. Group vise zooplankton population density in Station-B of whale shark habituate sites at Diu.

Group	Oct_2010	Dec_2010
Hydromedusae	0	0
Siphonophora	0	0
Chaetognatha	1	0
Copepod	21	36
Sergestidae	0	2
Invertebrate larvae	13	9
Thaliacea	0	0
Fish eggs	4	55
Fish larvae	0	0

Table-45. Group vise zooplankton population density in Station-C of whale shark habituate sites at Diu.

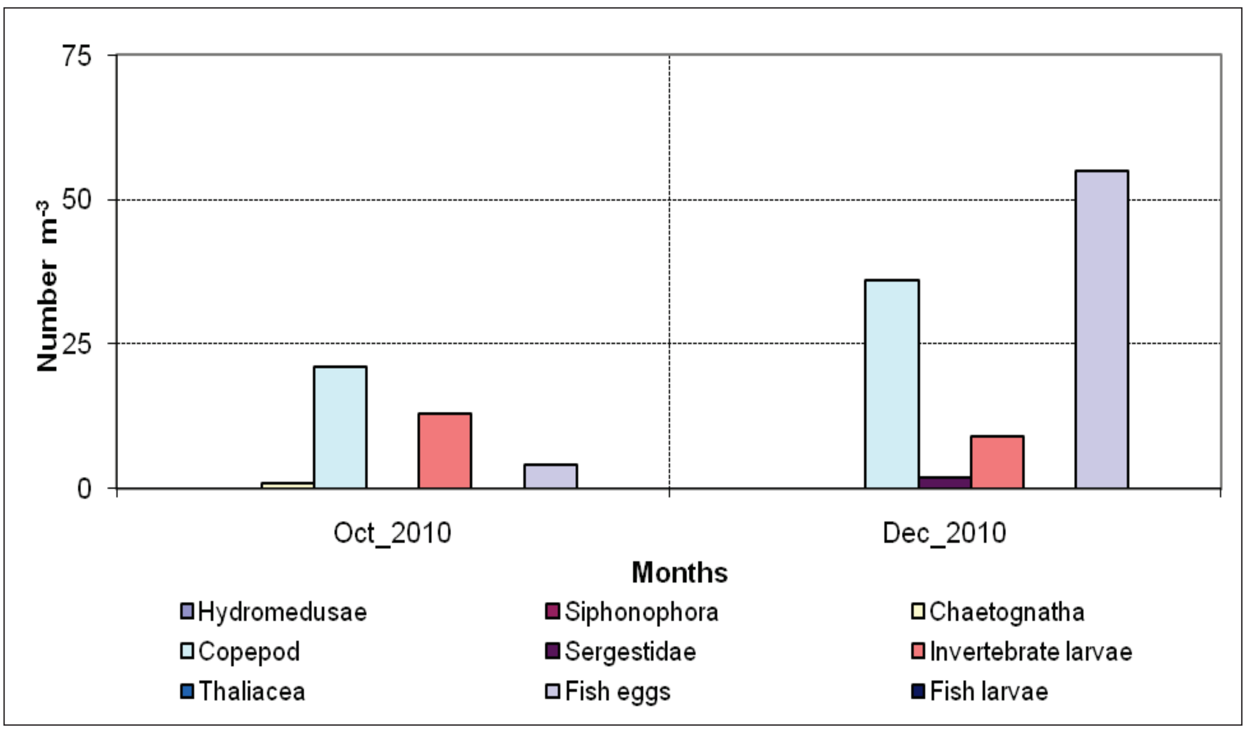


Fig. 46. Group vise zooplankton population density in Station-C of whale shark habituate sites at Diu.

Group	Oct_2010	Dec_2010
Hydromedusae	0	1
Siphonophora	0	0
Chaetognatha	0	3
Copepod	22	29
Sergestidae	0	2
Invertebrate larvae	14	0
Thaliacea	0	0
Fish eggs	13	68
Fish larvae	0	0

Table-46. Group vise zooplankton population density in Station-D of whale shark habituates sites at Diu.

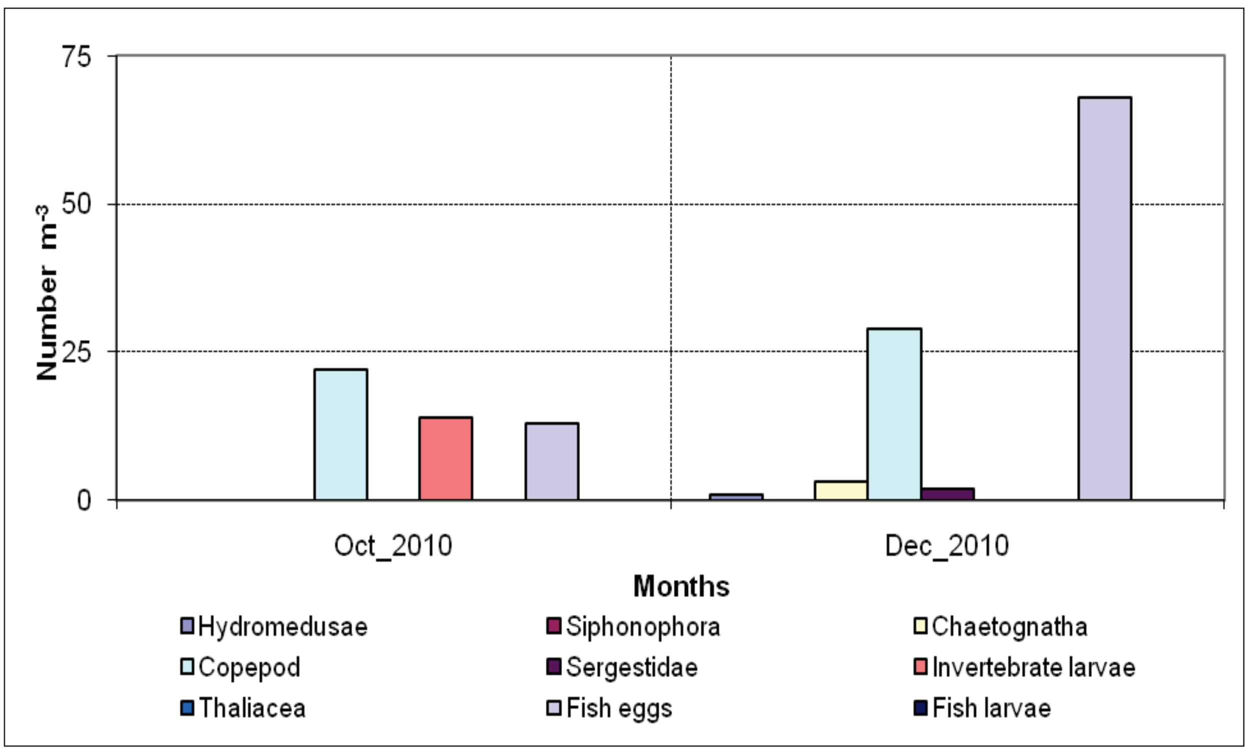


Fig. 47. Group vise zooplankton population density in Station-D of whale shark habituate sites at Diu.

Group	Oct_2010	Dec_2010
Hydromedusae	11	0
Siphonophora	0	0
Chaetognatha	2	2
Copepod	31	39
Sergestidae	0	1
Invertebrate larvae	6	3
Thaliacea	3	0
Fish eggs	0	52
Fish larvae	0	0

Table-47. Group vise zooplankton population density in Station-A of whale shark habituate sites at Mangrol.

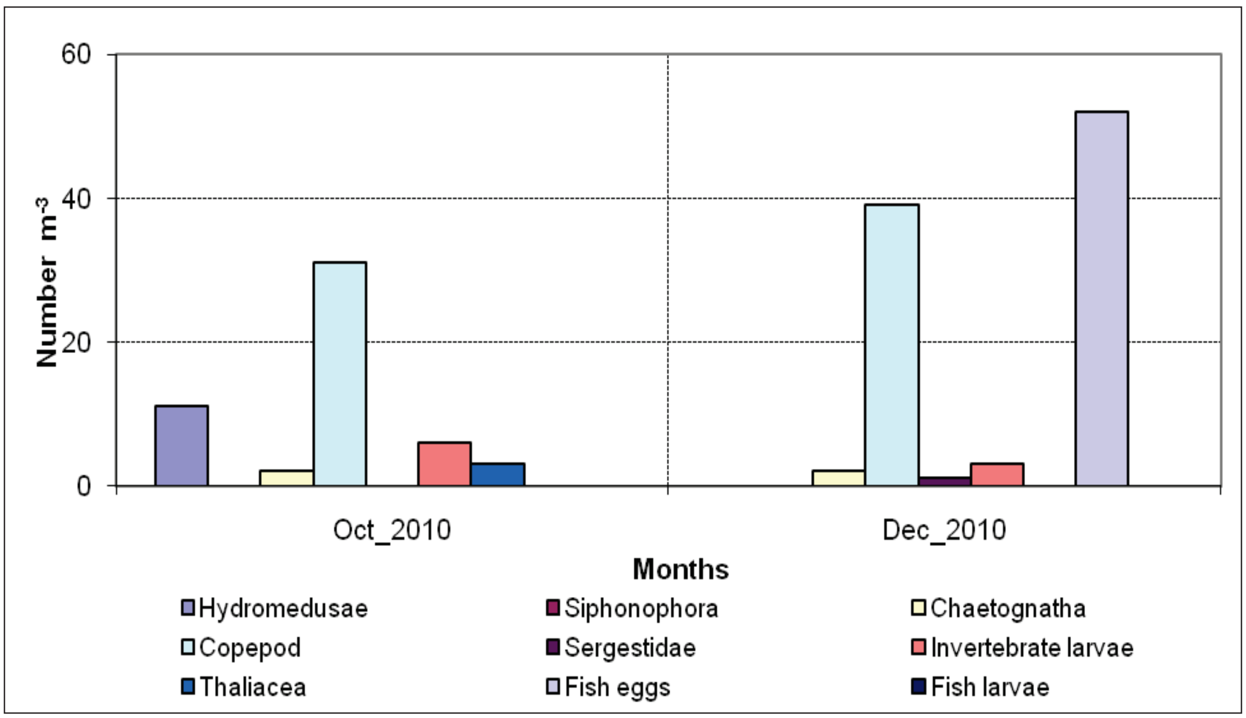


Fig. 48. Group vise zooplankton population density in Station-A of whale shark habituate sites at Mangrole.

Group	Oct_2010	Dec_2010
Hydromedusae	7	0
Siphonophora	0	0
Chaetognatha	2	0
Copepod	23	55
Sergestidae	7	0
Invertebrate larvae	8	14
Thaliacea	5	0
Fish eggs	16	21
Fish larvae	0	1

Table-48. Group vise zooplankton population density in Station-B of whale shark habituate sites at Mangrol.

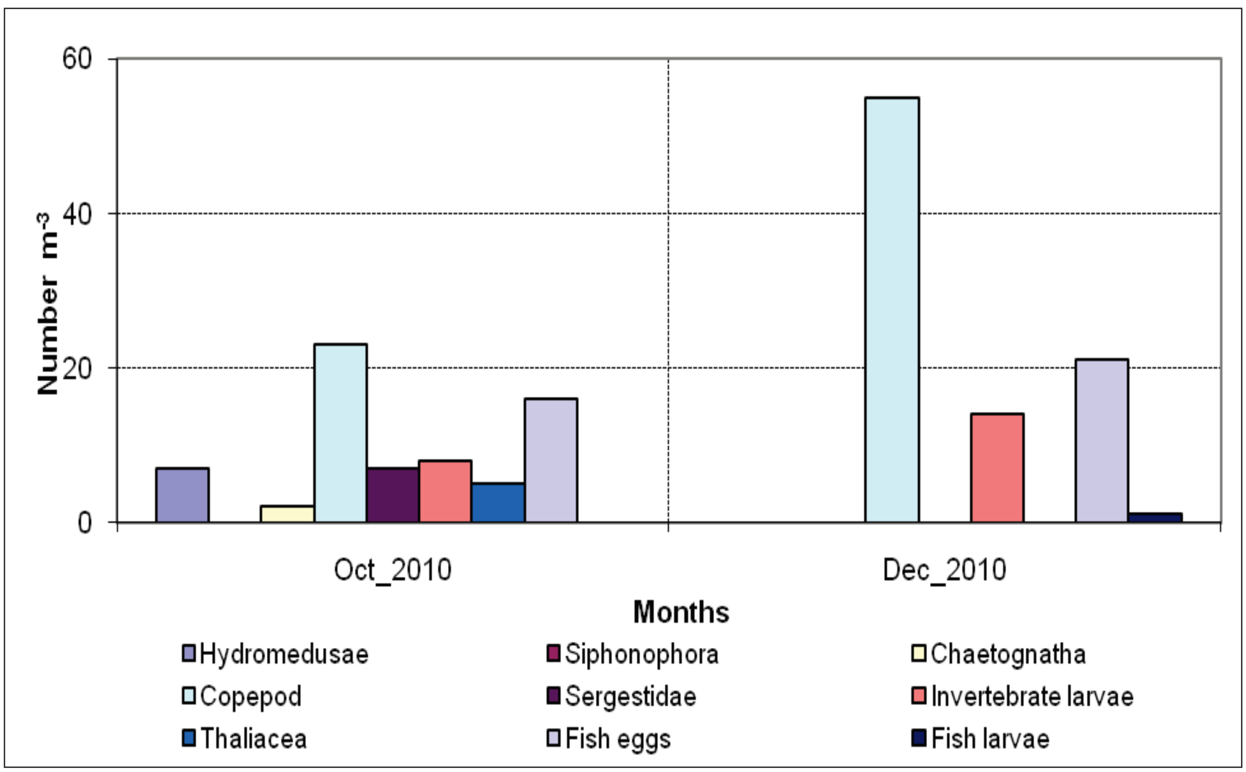


Fig. 49. Group vise zooplankton population density in Station-B of whale shark habituate sites at Mangrol.

Group	Oct_2010	Dec_2010
Hydromedusae	8	0
Siphonophora	0	0
Chaetognatha	0	2
Copepod	27	59
Sergestidae	3	1
Invertebrate larvae	9	13
Thaliacea	4	0
Fish eggs	15	52
Fish larvae	0	0

Table-49. Group vise zooplankton population density in Station-C of whale shark habituate sites at Mangrole.

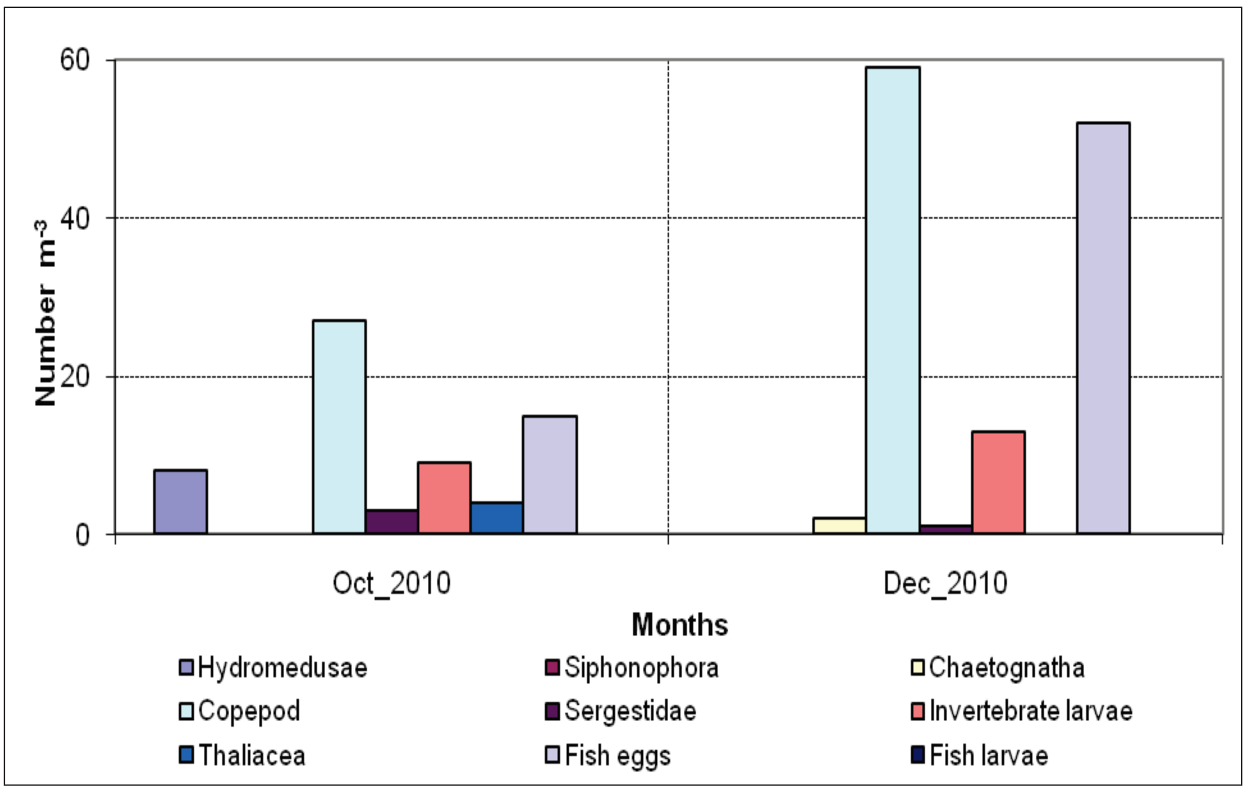


Fig. 50. Group vise zooplankton population density in Station-C of whale shark habituate sites at Mangrole.

Group	Oct_2010	Dec_2010
Hydromedusae	6	0
Siphonophora	0	0
Chaetognatha	2	2
Copepod	33	64
Sergestidae	0	0
Invertebrate larvae	11	15
Thaliacea	4	0
Fish eggs	0	24
Fish larvae	0	1

Table-50. Group vise zooplankton population density in Station-D of whale shark habituate sites at Mangrole.

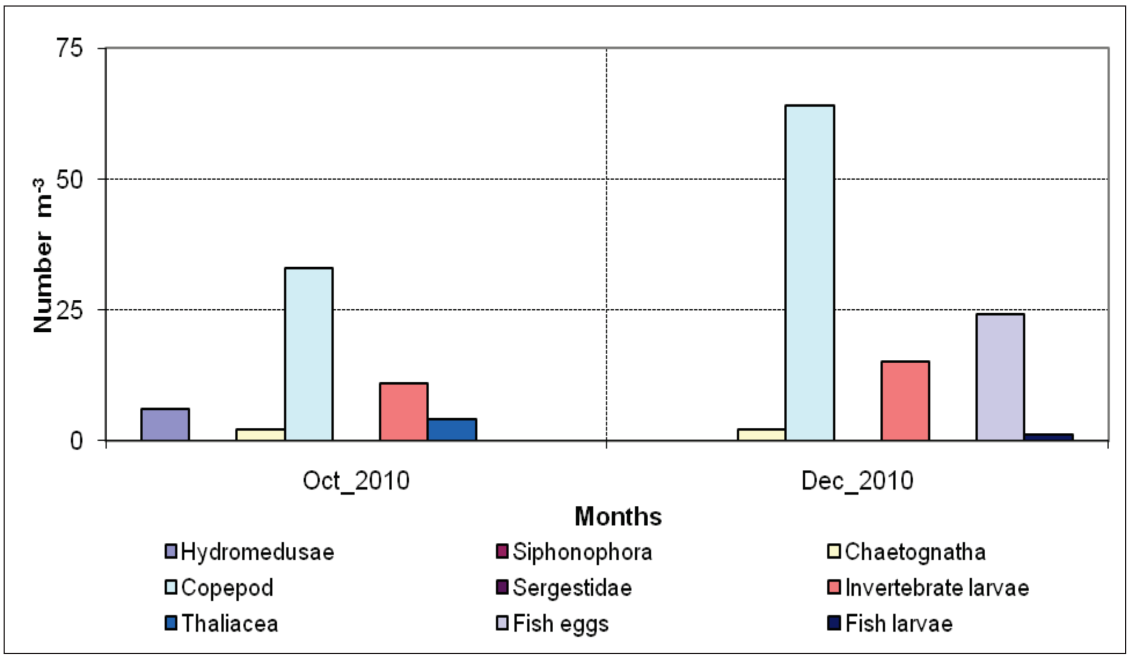


Fig. 51. Group vise zooplankton population density in Station-D of whale shark habituate sites at Mangrole.

Sl. No.	Date	Conducted by	Place	Sex	Length	GPS
1.	1/3/2010	FD	Veraval	M	23	N 20°50'408" E 70°18'134"
2.	1/4/2010	WTI	Sutrapada	M	23	N 20°47'294" E 70°27'713"
3.	1/4/2010	FD	Veraval	F	20	N 20°49'100" E 70°24'126"
4.	1/8/2010	WTI	Veraval	F	15	N 20°51'609" E 70°23'779"
5.	1/11/2010	FD	Veraval	F	18	N 20°48'100" E 70°24'094"
6.	1/12/2010	WTI	Veraval	M	15	N 20°52'754" E 70°14'550"
7.	1/12/2010	WTI	Veraval	M	20	N 20°57'183" E 70°17'807"
8.	1/13/2010	FD	Veraval	F	18	N 20°48'591" E 70°24'381"
9.	1/21/2010	FD	Veraval	F	19	N 20°50'255" E 70°18'302"
10.	1/24/2010	FD	Veraval	F	17	N 20°51'809" E 70°10'910"
11.	2/17/2010	WTI	Veraval (Adri)	M	21	N 20°52'799" E 70°15'383"

12.	3/21/2010	FD	Veraval	M	15	NA
13.	3/30/2010	FD	Veraval	F	18	N 20°41'418" E 70° 28'806"
14.	3/31/2010	FD	Veraval	F	22	NA
15.	04/04/10	FD	Veraval	F	20	N 20°41'101" E 70°28'406"
16.	4/5/2010	WTI	Veraval (Adri)	M	16	N 20°50'914" E 70°17'518"
17.	4/5/2010	FD (Jamvala)	Muldwarka	M	30	NA
18.	4/13/2010	FD (Jamvala)	Muldwarka (Madwad)	M	17	NA
19.	4/12/2010	WTI	Veraval (Near Jaleswar)	M	22	N 20°52'986" E 70°19'403"
20.	5/9/2010	FD	Veraval	F	21	N 20°50'090" E 70°18'113"
21.	5/10/2010	FD	Veraval	F	16	N 20°43'112" E 70°35'283"
22.	5/11/2010	WTI	Veraval (Near Jaleswar)	M	16	N 20°49'976" E 70°17'727"
23.	5/11/2010	WTI	Veraval (Near Jaleswar)	F	22	N 20°52'786" E 70°20'076"
24.	9/22/2010	FD	Veraval	F	20	NA
25.	9/25/2010	FD/WTI	Veraval	F	20	N 2052'320" E 7023'537"
26.	10/3/2010	FD	Dhamlej	F	22	N 2043181 E 7035541
27.	10/9/2010	FD	Veraval	F	19	N 2041418 E 7028806

Table-51 (a). Whale shark rescue data during the study period of January-2010 to December-2010.

Sl. No.	Date	Conducted by	Place	Sex	Length	GPS
28.	10/12/2010	FD	Sutrapada	M	15	N 2050089 E 7029036
29.	10/13/2010	FD	Veraval	F	20	N 205109 E 7026091
30.	10/14/2010	FD	Veraval	F	18	N 2051079 E 7026091
31.	10/20/2010	FD /WTI	Veraval	F	14	N 2054'286" E 7015'606"
32.	11/8/2010	FD	Dhamlej	F	25	NA
33.	11/14/2010	FD	Dhamlej	F	23	N 2050215 E 7017214
34.	11/28/2010	FD	Dhamlej	F	22	N 2052028 E 7018581
35.	11/29/2010	FD	Sutrapada	F	15	N 2049034 E 7027546
36.	11/29/2010	FD	Dhamlej	F	45	N 205109 E 7026091
37.	11/30/2010	FD	Sutrapada	F	15	N 2050106 E 7018196
38.	11/30/2010	FD	Sutrapada	F	25	N 2048050 E 7024021
39.	11/30/2010	FD	Sutrapada	M	35	N 2048089 E 7024012
40.	11/30/2010	FD/WTI	Sutrapada	M	23	N 2047'275" E 7027'865"
41.	12/2/2010	FD	Sutrapada	F	13	N2040297 E 7020715
42.	12/2/2010	FD /WTI	Veraval	M	17	N 2047235 E 7022539
43.	12/3/2010	FD/WTI	Sutrapada	M	15	N 2043'929" E 7031'642"
44.	12/4/2010	FD	Dhamlej	F	20	NA
45.	12/4/2010	FD	Dhamlej	M	22	N 2050396 E 70183446
46.	12/5/2010	FD/WTI	Sutrapada	F	14	N 2047'374" E 7025'882"
47.	12/5/2010	FD	Dhamlej	F	20	N 2055'210" E 7014'403"
48.	12/12/2010	FD/WTI	Veraval	M	16	N 2047'235" E 7020'271"
49.	12/13/2010	FD/WTI	Sutrapada	M	15	N 2044'801" E 7030'205"
50.	12/13/2010	FD/WTI	Sutrapda	M	25	N 2046'553" E 7027'844"
51.	12/13/2010	FD/WTI	Sutrapada	F	22	N 20 45'839" E 7030'106"
52.	12/13/2010	FD/WTI	Sutrapada	F	18	N 2044'524" E 7030'894"
53.	12/14/2010	FD/WTI	Sutrapda	NA	NA	N 2046'377" E 7029'637"
54.	12/15/2010	FD	Sutrapada	F	40	N2048'109" E 7024'204"
55.	12/16/2010	FD	Sutrapada	F	22	N 2048'080" E 7024'012"

Table-51 (b). Whale shark rescue data during the study period of January-2010 to December-2010.

APPENDIX III

Showing whale sharks rescued under self-documentation scheme (2012 - 2014).

S. no	Date	Whale Shark		Place	Direction from headland	Approximate distance from headland (nautical miles)
		Sex	Length (ft)			
1	02-10-2012	-	15	Veraval	Towards West	5
2	05-10-2012	-	36	Sutrapada	Towards South	6
3	10-10-2012	-	15	Sutrapada	-	-
4	14-10-2012	-	12	Sutrapada	Towards South	18
5	16-10-2012	-	15	Sutrapada	Towards South	12
6	20-10-2012	F	30	Dhamlej	Towards South	12
7	22-10-2012	M	20	Dhamlej	Towards South	15
8	22-10-2012	M	30	Dhamlej	Towards South	10
9	24-10-2012	F	18	Sutrapada	Towards South	6
10	27-10-2012	-	25	Dhamlej	Towards South	10
11	29-10-2012	M	28	Dhamlej	Towards South	7
12	31-10-2012	F	45	Sutrapada	Towards South	13
13	05-11-2012	-	17	Veraval	Towards South	3
14	07-11-2012	-	25	Dhamlej	Towards South	10
15	07-11-2012	M	25	Veraval	Towards West	4
16	08-11-2012	F	35	Sutrapada	Towards South	5
17	08-11-2012	F	25	Sutrapada	Towards South	7
18	09-11-2012	F	30	Sutrapada	Towards South	10
19	12-11-2012	-	20	Veraval	Towards South	3
20	12-11-2012	-	25	Veraval	Towards South	2
21	12-11-2012	F	30	Sutrapada	Towards South	16
22	13-11-2012	F	35	Sutrapada	Towards South	5
23	19-11-2012	M	18	Sutrapada	Towards South	1. 15
24	20-11-2012	F	25	Sutrapada	Towards South	11
25	20-11-2012	F	30	Sutrapada	Towards South	12
26	21-11-2012	-	15	Veraval	Towards South	4
27	21-11-2012	F	20	Sutrapada	Towards South	15
28	21-11-2012	-	33	Sutrapada	Towards South	11
29	22-11-2012	-	18	Sutrapada	Towards South	13

30	23-11-2012	-	20	Veraval	Towards South	21
31	30-11-2012	-	35	Sutrapada	Towards South	12
32	06-12-2012	F	30	Sutrapada	Towards South	16
33	06-12-2012	F	26	Sutrapada	Towards South	15
34	06-12-2012	-	25	Sutrapada	Towards South	15
35	07-12-2012	F	35	Sutrapada	Towards South	18
36	08-12-2012	-	25	Sutrapada	Towards South	18
37	12-12-2012	-	30	Sutrapada	Towards South	12
38	17-12-2012	F	20	Sutrapada	Towards South	16
39	19-12-2012	M	27	Dhamlej	Towards South	15
40	19-12-2012	F	30	Dhamlej	Towards South	13
41	20-12-2012	-	30	Dhamlej	Towards South	13
42	20-12-2012	-	35	Sutrapada	Towards South	23
43	20-12-2012	-	35	Sutrapada	Towards South	18
44	22-12-2012	M	30	Dhamlej	Towards South	14
45	24-12-2012	F	10	Sutrapada	Towards South	18
46	22-12-2012	F	30	Dhamlej	Towards South	10
47	25-12-2012	-	30	Sutrapada	Towards South	30
48	12-01-2013	-	30	Sutrapada	Towards South	12
49	06-03-2013	F	35	Sutrapada	Towards South	15
50	13-03-2013	F	25	Sutrapada	Towards South	25
51	14-03-2013	F	30	Sutrapada	Towards South	20
52	18-03-2013	-	24	Veraval	Towards West	8
53	25-03-2013	F	24	Dhamlej	Towards South	10
54	17-04-2013	-	25	Veraval	Towards West	3
55	06-05-2013	-	20	Sutrapada	-	-
56	07-05-2013	-	-	Veraval	-	-
57	03-09-2013	M	10	Sutrapada	Towards West	8
58	04-09-2013	M	20	Sutrapada	Towards North	8
59	12-09-2013	-	25	Veraval	Towards South	12
60	12-09-2013	-	22	Veraval	Towards North	8
61	13-09-2013	-	25	Veraval	Towards West	13
62	16-09-2013	-	33	Sutrapada	Towards West	10
63	11-10-2013	-	32	Veraval	Towards West	10
64	12-10-2013	F	30	Vadodra Jala	-	10
65	13-10-2013	F	-	Dhamlej	-	-
66	14-10-2013	-	18	Veraval	Towards North	5
67	16-10-2013	F	26	Sutrapada	Towards West	10

68	20-10-2013	-	15	Veraval	Towards West	12
69	06-11-2013	-	-	Veraval	Towards West	5
70	12-11-2013	-	25	Sutrapada	Towards South	12
71	16-11-2013	-	20	Veraval	Opp to Adheri	35
72	22-11-2013	-	22	Veraval	-	35
73	25-11-2013	M	30	Sutrapada	-	-
74	26-11-2013	M	36	Sutrapada	Towards West	30
75	27-11-2013	F	25	Sutrapada	Towards South	18
76	05-12-2013	-	24	Veraval	-	14
77	15-12-2013	F	28	Sutrapada	Towards South	30
78	16-12-2013	F	20	Sutrapada	Towards East	12
79	18-12-2013	-	30	sutrapada	Towards South	10
80	20-12-2013	F	22	sutrapada	Towards South	22
81	21-12-2013	F	37	Veraval-Chrowad	Towards South	5
82	21-12-2013	-	25	Sutrapada	Towards South	18
83	22-12-2013	-	25	Dhamlej	Towards South	30
84	22-12-2013	F	35	Dhamlej	Towards South	35
85	25-12-2013	F	25	Dhamlej	Towards South	25
86	25-12-2013	-	22	Dhamlej	Towards South	27
87	27-12-2013	F	18	Sutrapada	Towards South	4.7
88	30-12-2013	F	20	Dhamlej	Towards South	12
89	01-01-2014	F	30	Sutrapada	Towards West	23
90	03-01-2014	M	38	Sutrapada	Towards East	18
91	09-01-2014	-	40	Sutrapada	Towards East	13
92	03-02-2014	-	27	Sutrapada	Towards South	18
93	03-02-2014	-	32	Sutrapada	Towards South	10
94	27-02-2014	-	25	Dhamlej	Towards South	15
95	27-02-2014	-	15	Sutrapada	Towards South	20
96	01-03-2014	-	18	Dhamlej	Towards East	12
97	10-03-2014	-	30	Sutrapada	Towards East	15
98	10-03-2014	-	20	Sutrapada	Towards South	25
99	11-03-2014	M	25	Sutrapada	Towards South	12
100	15-03-2014	-	30	Sutrapada	Towards West	25
101	27-03-2014	-	20	Sutrapada	Towards South	20
102	13-04-2014	F	32	Veraval	Towards West	22
103	14-04-2014	F	30	Dhamlej	Towards South	25
104	18-04-2014	-	20	Sutrapada	Towards South	10
105	18-04-2014	-	25	Sutrapada	Towards South	15

106	13-05-2014	M	28	Sutrapada	Towards North	24
107	13-05-2014	-	20	Sutrapada	Towards North	18
108	27-05-2014	-	34	Sutrapada	Towards West	10
109	27-05-2014	M	30	Dhamlej	Towards West	10
110	29-05-2014	-	25	Sutrapada	Towards West	15
111	05-06-2014	-	25	Dhamlej	Towards West	15

APPENDIX IV

DNA sequence of whale shark in Gujarat water

Rty 2 CR - mtDNA control region sequence information generated from sample Rty-2 (1397 bp)

TTGGCTCCCAAAGCCAAGATTCTTCCCAAACTGCCCCCTGAGGCATCATGCAAATT-
GCATGGTTTTATGTACGTCAGTATGACATATTAATGATTCAGCCCACATTCCTTA-
ATATACCACATATGACTTACTTTTCTATATCAACTCTAATATACTTTCCACAGGTATATA-
CATACTATGTTTAATACTCATTAATTTACTTGCCACTATATTATTACATTATATGAT-
TAATCCACATTTCTATAACATATTAGACTTTCCTCAACTAGATATTATTTTCGTAAT-
TAATGTACGTCAGTATGACATATTAATGATTCGGCCCACATTCCTTAATATACCA-
CATATGACTTACTTTTCTATATCAACTCTAATATACTTTCCACAGGTATATACATAC-
TATGCTTAATACTCATTAATTTACTTGCCACTATATTATTACATTATATGATTAATC-
CACATTTCTATAACATATTAGACTTTCCTCAACTAGATATTATTTTCGTAATTATTAT-
GCAGGTTTGTAAAAACCTGCATTAATCCATTTAAGTACTAATATTACTGCTATAT-
CATCTATAATTGATTTAAACTGACATTTGATTACTGCTTAAATTCATTTGGTTCTTA-
ATCGTATCAATCATGAATTCACTCTAGTTCCCTTATATTGACATACAGTTCTTAATC-
GTATCAATCATGAATTTACTCTAGTTCCCTTATATTGACATACAGTTCTTAATCGTCT-
CAGAATTTATTTTCCTCCCAGATTTTTTAGTTTCGGCTTGAAGCTCCGACACCT-
GCCCCGGGAAGGCTGAAACCAGGAACAATAAATATTAAGTTAGAACTTTCCACTCGA-
CATCTGCCGTCAATAATCCTCACTACTGCTCATTCGTGGGAAATAGATTGTCAAGTT-
TACCATAACTGAAAGAGATAATAATAATGGAACCATTAAATGACAACAGTATTGAT-
TAATCCAACAATAATTGAAGAGATACATACAAGATTAATCAACAACTTAGGAGATA-
AATATTATTTATGAATGTAAAAAACATACCATTATTTAGCACATTCTTGCTTAGTCG-
GACATACAAGTATTATATATATACCCCCCTCCTTCACAAAAAAAAAAACGACAAAATA-
AAAAAAAATTTTTCCGTAAAAACCCCCCCTCCCCCCTAAATATACAAGGACACCTC-
GAAAAACCCCAAAAACGAGGGCCGTGCGTATATTTATTCTAAAACCATGCATA-
ATTTTTCACTATACATTGTTACACAATATGATGCTAGTGTAGCTTAATTTAAAGTATAG-
CACTGAAAATGCTAAGATGAAAAATAATATTTTTCCGCAAGCATGAAAGGTTTG-
GTCCTAGCCTTAGTGTTAATTGTAACCAAAATTATACATGC

Rty 3CR - mtDNA control region sequence information generated from sample Rty-3 (1404 bp)

TTGGCTCCCAAAGCCAAGATTCTTCCCAAACTGCCCCCTGAGGCATCATGCAAATT-
GCATGGTTTTATGTACGTCAGTATGACATATTAATGATTCAGCCCACATTCCTTA-
ATATACCACATATGACTTACTTTTCTATATCAACTCTAATATACTTTCCACAGGTATATA-
CATACTATGTTTAATACTCATTAATTTACTTGCCACTATATTATTACATTATATGATTA-
ATCCACATTTCTATAACATATTAGACTTTCCTCAACTAGATATTATTTTCGTAATTAG-
TATGACATATTAATGATTCAGCCCACATTCCTTAATATACCACATATGACTTACTTTTC-
TATATCAACTCTAATATACTTTCCATAGGTATATACATACTATGTTTAATACTCATTAATT-
TACTTGCCACTATATTATTACATTATATGATTAATCCACATTATATGATCTTCCACATTTC-
TATAACATATTAGACTTTCCTCAACTAGATATTATTTTCGTAATTATTATGCAGGTTTGTA-
AAATCCTGCATTAATCCATTTAAGTACTAATATTACTGCTATATCATCTATAATTGATTTA-
AACTGACATTTGATTACTGCTTAAATTCATTTGGTTCTTAATCGTATCAATCATGAATT-
TACTCTAGTTCCCTTATATTGACATACAGTTCTTAATCGTATCAATCATGAATTTACTC-
TAGTTCCCTTATATTGACATACAGTTCTTAATCGTCTCAGAATTTATTTTCCTCCCA-
GATTTTTTAGTTTCGGCTTGAAGCTCCGACACCTGCCCCGGGAAGGCTGAAACCAG-
GAACAATAAATATTAAGTTAGAACTTTCCACTCGACATCTGCCGTCAATAATCCT-
CACTACTGCTCATTCGTGGGAAATAGATTGTCAAGTTTACCATAACTGAAAGA-
GATAATAATAATGGAACCATTAAATGACAACAGTATTGATTAATCCAACAATAATT-
GAAGAGATACATACAAGATTAATCAACAACTTAGGAGATAAATATTATTTATGAAT-
GTAAAAAACATACCATTATTTAGCACATTCTTGCTTAGTCGGACATACAAGTATTG-
TATATATACCCCCCTCCTTCACAAAAAAAAAACGACAAAATAAAAAAAAATTTTTCC-
GTAAAAACCCCCCCTCCCCCCTAAATATACAAGGACACCTCGAAAAACCCCAAAAAC-
GAGGGCCGTGCGTATATTTATTCTAAAACCATGCATAATTTTTCACTATGCATTGTTA-
CACAATATGATGCTAGTGTAGCTTAATTTAAAGTATAGCACTGAAAATGCTAAGAT-
GAAAAATAATATTTTTCCGCAAGCATGAAAGGTTTGGTCCTAGCCTTGGTGTTAATTG-
TAACCAAAATTATACATGC

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CONSERVATION ACTION SERIES

The Whale shark (*Rhincodon typus*), the largest fish in the world, was hunted indiscriminately in the waters of the Arabian sea of the coast of Gujarat. Following an illuminating film by filmmaker Mike Pandey, the whale shark was brought under the schedule 1 of CITES, affording it legal protection from international trade. The first phase of WTI's campaign to save the whale shark, turned a quarry into an icon of conservation and pride in Gujarat within a short span of two years with the species now being called 'Vhali' or a friend instead of the barrel, the technique the fishermen used to kill it.

The multi-pronged campaign raised questions on the ecological requirements of this species, a project that WTI continued with the support of Tata Chemicals Limited and Gujarat Forest Department. This report deals with the habitat requirements of the species, tracking whale sharks through satellite tags, preliminary genetics and population studies and the activities undertaken with regard to its awareness. Involving the fishing community in rescues through self-documentation was a significant achievement and this unique scheme of the Gujarat Forest Department motivated rescues, reducing pre-release stress on the whale shark thereby substantially improving its chances of survival post release.

This co-management of community and government resulted in the Junagadh Forest Division of the Gujarat Forest Department being awarded the Indian Bio-diversity Awards, 2014, given by the United Nations Development Program (UNDP) and the Ministry of Environment and Forests and Climate Change, Govt. of India for its work in saving the area's natural heritage - the whale shark.

Wildlife Trust of India
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