STUDY OF SINGLE-DAY AND MULTI-DAY TRAWL FISHERY OF GUJARAT COAST

Thesis submitted in partial fulfillment
of the requirements
for the degree of

Ph.D. (Fisheries Resource Management)

By

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Dedicated to

My Family, friends
and
Guide

Date: 29th August, 2019

CERTIFICATE

Certified that the thesis entitled "**STUDY OF SINGLE-DAY AND MULTI-DAY TRAWL FISHERY OF GUJARAT COAST**" is a record of independent bonafide research work carried out by **Mr. Rajesh Kumar Pradhan (FRM-PA3-09)** during the period of study from September, 2013 to August, 2019 under our supervision and guidance for the degree of **Doctor of Philosophy (Fisheries Resource Management)** and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

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I hereby declare that the thesis entitled **“STUDY OF SINGLE-DAY AND MULTI-DAY TRAWL FISHERY OF GUJARAT COAST”** is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associate ship, fellowship or any other similar title.

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सारांश

वर्ष 2018 में गुजरात राज्य,7.80 लाख टन केमछली अवतरण के साथभारतके 9 तटीय राज्यों मेंपहले स्थान पर रहा, जो कि कुल समुद्री मछली अवतरण में 22.4% का योगदान देता है। गुजरात में एक-दिवसीयऔर बहु-दिवसीय ट्रॉलर मात्स्यिकीके महत्वपूर्ण पहलुओं पर वर्ष 2016 से 2018 के दौरान जांच की गई।वर्तमान अध्ययन के लिए गुजरात में सौराष्ट्र तट का चयन इसके राज्य कीमात्स्यिकी में महत्वपूर्णयोगदान के कारण किया गया। 3 जिलों में नमूनों के चयन एवं सर्वेक्षणहेतु गिर-सोमनाथ में वेरावल (20.9054010N, 70.3752170E), जूनागढ़ में माँगरोल (21.1077870N, 70.1000190E) और पोरबंदर जिले में पोरबंदर (21.6408130N, 69.5961520E) मछली अवतरण केन्द्रों का चयन किया गया। पकड़ संघटना और मात्स्यिकी विशेषताओं के आंकलन से पता चलता है कि दोनों प्रकार के ट्रॉलरों ने गुजरात से मछली पकड़ने के अलग-अलग स्थान साझा किए हैं और बहु-दिवसीयट्रॉलरों का यह प्रचालन भारतके पश्चिमी तट पर उत्तरी छोर से विस्तारित होकर कर्नाटक के मंगलौर तट तक दक्षिण में 200 मीटर की गहराई तक था । बहु-दिवसीय ट्रॉलरों से प्रति दिन सबसे अधिक अनुमानित पकड़ मानसून के बाद (368 किग्रा/दिन), सर्दियों (359 किग्रा/दिन) और मानसून पूर्व (325 किग्रा/दिन) के दौरान पाया गया । एक दिवसीयट्रॉलरोंसे मत्स्य प्रजातियों की संघटना के समूह विश्लेषण मे सर्दियों और मानसून बाद के समय के बीच मे अधिकतम समानता (80%) का पता चला, जबकि बहु दिन इकाई के मामले में, यह सर्दियों एवं पूर्व मानसून(96%) औरपूर्व एवं पश्च-मानसून (86%) के बीचकुछ इसी तरह की समानता थी । मत्स्य-पकड़के चरण में एक दिवसीय ट्रॉलरों (0.68 किग्राCO_2e/किग्रामछली) की तुलना में बहु-दिवसीय ट्रॉलरों (0.79 किग्राCO_2e/किग्रा मछली) के मामले में उच्च कार्बन फुटप्रिंट पाया गया और मत्स्य-पकड़ के बाद के चरण में (0.82 किग्राCO_2e/किग्रामछली)उच्च कार्बन फुटप्रिंट पाया गया । एक दिवसीय ट्रॉलरों (1.73 किग्रा CO_2e/किग्रा मछली) की तुलना में बहु-दिवसीय ट्रॉलरों (2.08 किग्रा CO_2e/ किग्रा मछली) का समग्र कार्बन फुटप्रिंट प्रति किग्रा मछली के उत्पादन के लिए तुलनात्मक रूप से अधिक था। पूँजीगत उत्पादकता (प्रचालन अनुपात) सूचकों से पता चलता है कि एक दिवसीय और बहु-दिवसीय ट्रॉलर दोनों ही समान रूप से कुशल हैं जिनका मूल्य क्रमशः 0.467 और 0.497 है। एक दिन के लिए इनपुट-आउटपुट अनुपात 0.369 होने का अनुमान पाया गया जो कि बहु-दिवसीय ट्रॉल के लिए अनुमानित मूल्य 0.368 के लगभग समान था।डीजल हेतु प्रति प्रचालक पकड़ के संदर्भ में, यह एक दिवसीय और बहु-दिवसीय ट्रॉलर के लिए क्रमश 4.80 और 2.95 किग्रा मछली के रूप में गणना की गई ।हालांकि, एक दिवसीय और बहु-दिवसीय ट्रॉलरों के लिए राजस्व के मामले में संगत मूल्य क्रमशः 220.00 रुपये और 224.20 रुपये था । वर्तमान अध्ययन में टीपीसी और टीएमए के साथ-साथ टीपीसी और टीवीबीएन के बीच एक मजबूत संबंध पाया गया। मछली के लिए 7 लॉगcfu/ग्रामके टीपीसी को सुरक्षित और स्वीकार्य मानदंड के रूप में ध्यान में रखते हुए, टीएमए और टीवीबीएन के लिए स्वीकार्य सीमा क्रमशः 13.5 और 34.0 मिलीग्राम N/100 ग्राम है और बर्फ में 15 दिनों की भंडारण अवधि को मानव उपभोग के लिए स्वीकार्य माना जा सकता है।

ABSTRACT

Among the nine maritime states, Gujarat remained in the first position with landings of 7.80 lakh tonnes contributing 22.4% to the total marine fish landings along the coast of mainland of India for the year 2018. Investigations were carried out on important aspects of single-day and multiday trawl fisheries of Gujarat during 2016-2018. Saurashtra coast of Gujarat was selected for the study due to its importance in trawl fisheries of the state and Veraval (20.905401°N, 70.375217°E) in Gir-Somnath, Mangrol (21.107787°N, 70.100019°E) in Junagarh and Porbandar (21.640813°N, 69.596152°E) in Porbandar district were selected for regular sampling. Assessment of catch composition and fishing characteristics revealed that both types of trawlers shared different fishing grounds of Gujarat. The operational area of multiday trawlers extended from northern most part on the west coast of India to Mangalore coast of Karnataka in the south up to 200 m depth. Single-day trawlers operate in a limited depth zone up to 40 m of the sea. Seasonal variation in CPUE revealed that highest CPUE (per day in kg) from multi-day trawlers was during post-monsoon (368 kg/day) followed by winter (359 kg/day) and pre-monsoon (325 kg/day) while single-day unit recorded highest CPUE in pre-monsoon followed by winter and post-monsoon. Significant variation in the monthly species composition was observed for both single [P=0.001] and multi-day trawler [P=0.001]. The cluster analysis of species composition of single-day trawler revealed maximum resemblance (80%) between winter and post-monsoon whereas in the case of multiday unit, resemblance (96%) between winter and pre-monsoon and 86 % between pre and post-monsoon was somewhat similar.Higher carbon footprint was estimated in the case of multiday trawler (0.79 kgCO_2e/kg fish) compared to single-day trawler (0.68 CO_2e/kg fish) in the harvest phase. Estimated carbon footprint in the post-harvest phase was 0.82 kgCO_2e/kg of fish. The overall carbon footprint of multiday trawler (2.08 kgCO_2e) was comparatively higher than that of single-day trawler (1.73 kgCO_2e) for production of every kg of fish. The capital productivity (operating ratio) indicators revealed that both single-day and multiday trawlers are equally efficient having values 0.467 and 0.497 respectively. The input-output ratio of single-day was estimated to 0.369 which was almost similar to the value estimated for multiday trawl (0.368). In terms of catch per liter of diesel; it was calculated as 4.80 and 2.95 kg of fish for single-day and multiday trawler respectively. However, the corresponding values were Rs 220.00 & Rs. 224.20 in terms of revenue for single-day and multiday unit respectively. Assessment of fish quality of selected commercially important fishes of the state revealed a strong correlation between Total Plate Count (TPC) and TMA as well as TPC and TVBN. The acceptable limit for Trimethylamine (TMA) and Total Volatile Base Nitrogen (TVB-N) is 13.5 and 34.0 mg N/100g respectively. The shelf life of selected fishes stored in ice as determined by the overall acceptability sensory scores, chemical quality and microbiological data is 15 days.

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Introduction

1. INTRODUCTION

Fishing has grown in to an industry with global relevance providing livelihood to 39.4 million fishers involved in capture fishery and contributing towards 16.7% of globally consumed animal protein (SOFIA, 2014). The capture fishery sector is dominated by marine fishery, accounting for 87.2% of the total capture production of 90.9 million tons. Most of the research inputs related to capture-based fisheries aim primarily at judicial exploitation by sustainably harvesting the natural resources. They also provide nutritional security through affordable cheaper source of protein to burgeoning population of our country, in addition to providing employment to rural masses. Taking into consideration the resource-starved fish processing industry and the growing demand for seafood in the domestic sector, it is imperative to augment research effort in capture fisheries to increase and sustain the production. This necessitates constant monitoring of the status and health of the fishing practices followed, profitability of systems, fish produced and the fishery environment. In the history of marine fisheries, trawling is one of the most efficient technological interventions that has happened the world over. Trawling has contributed to increased marine fish production and has led to its widespread adoption by many countries. In India, trawlers have contributed major part of the total marine fish production (Srinath, 2003). Total marine fish landings of India for the year 2018 was estimated at 3.49 million tons showing a decline of about 3.47 lakh tons (9%) compared to 3.83 million tons in 2017. Among the nine maritime states, Gujarat remained in the first position with landings of 7.80 lakh tons (FRAD, CMFRI, 2019). Out of the total marine fish landings from Gujarat coast, largest share (54.3%) came from trawlers in terms both quantity and revenue with maximum CPUE compared to other gears (CMFRI, 2015).

The ever-increasing international demand for shrimps and cephalopods further induces acute competition, higher investment and continuous demand for up gradation of trawlers. During late seventies and early eighties, a conspicuous change in the trawlers took place. Some shrimp trawlers were exclusively operated during night hours. These boats, popularly known as night-boats subsequently extended their operations during day as fish trawl. Further, trawlers started undertaking multi-day fishing. By the mid-eighties, most of the bigger boats switched over to this type of stay-over fishing to bring quality fishes. This method of fishing resulted in substantial increase in returns mainly by saving the fuel cost. These 'night boats' have continuously expanded their trawling grounds and ventured into deeper areas. In recent years, the multi-day trawl fishery has expanded considerably and now it exists as a separate fishery. The species composition differs centre-wise with the seasonality in a year (Hassan & Sathiadhas, 2009).

The Arabian Sea bestows Gujarat its extensive coastline of 1600 km which is approximately 23% of the country's mainland coastline. In addition, the state is blessed with excellent trawling zones in its continental area and one of the most important and largest fishing harbors on the west coast of India. The two major sectors within the marine fishery sector of Gujarat are multi-day and single-day trawl which together contribute nearly 60% of total marine fish landings of the state. Total of 28400 numbers of craft operated from the Gujarat coast and mechanized sector shares nearly 64% followed by motorized sector of 29% and rest of 7% contributed by artisanal non-motorized crafts. In case of mechanized sector, more than 60% are trawlers and nearly 20% are Gillnetters and rest dol-netters. Out of total 11582 trawlers in Gujarat, Gir-somnath district harbors highest number of trawlers compared to coastal districts (71%) followed by Porbandar with 21%.

Fishery being the environmental driven sector depends totally on the abiotic and biotic factors, for its production and sustenance, hence studying the interrelation between both of them is essential for sustainable management, environment protection, and long-term returns. Sustainable fisheries management calls for a broader perspective on the environmental impacts inclusive of both the direct and indirect effects (mainly the emissions to the atmosphere and seawater) of fishery. Studies pertaining to the impacts of fishing on ecological processes like productivity, trophic chain and flow of biomass etc. have been already well documented (Pauly, 1979; Pauly and Christensen, 1995). The environmental impacts of different fishing methods like destruction of coral reefs by blast fishing (Goñi, 1998), bycatch and discards by using unscientific gears (Alverson *et al.,* 1994), ghost fishing of different organisms by voluntary dumping or loss of fishing gears (Goñi, 1998) etc. had also been covered by various researchers. However, there is dearth of studies pertaining to the greenhouse gas (GHG) emission or carbon footprint, of fishery derived products. In the wake of global warming, the importance of Life Cycle Analysis (LCA) for environmental policy and industry has escalated. Researchers are working on forecasting energy fluxes in relation to different economic growth and regulatory scenarios. LCA can clear the deficit of the economic system in estimating the total cost (including the environmental cost) of a product (Pelletier and Tyedmers, 2011). LCA provides valuable information on the energy consumption in different fisheries (Tyedmers, 2001 and Thrane, 2004). ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment (LCA) (ISO, 2006). Type III Environmental product declaration of seafood products require LCA according to the ISO14040-series (ISO 14025, 2006) and third-party verification of the same.

Study on LCA in fishery and aquaculture was started much later than the food production industry. The life cycle assessment studies on frozen block of cod fillets and oil consumption during fishery phase from Baltic sea and Iceland have been reported by Ziegler *et al.* (2003). Silvenius and Grönroos (2003) estimated lifecycle assessment for typical rainbow trout production system in Finland along with other rainbow trout production methods. Various Finnish Fish food product (FFPs) and various Danish FFPs were assessed by Silvenius and Grönroos (2004) and Thrane (2006) respectively. The environmental impacts of canned tuna products were estimated by Hospido *et al.* (2006). The potential and limitation of LCA in setting ecolabelling criteria for shrimps in developing countries has been estimated by Munkung *et al.* (2006). The environmental impacts of Norwegian cod fishing and salmon farming was reported by Ellingsen and Aanondsen (2006), the results were compared with chicken farming, and it was reported that the fishing phase and feeding phase for chicken and salmon farming accounted for all environmental impacts. LCA of the different gears used in Swedish fishery indicated that trawling contributed maximum to the emissions per kilogram of landed fish (Ziegler, 2007). The cumulative energy use, biotic resource-use, green-house gas emission and eutrophying emission associated with farmed salmon in Norway was assessed by Pelletier *et al.* (2009) using LCA as a tool. The LCA studies for southern pink shrimp products for artisanal fishery and trawl fishery from Senegal was compared by Ziegler *et al.* (2008). It was reported that fishing was the major activity contributing towards the environmental impacts for the products originating from trawling, while fishing was important from biological point of view in artisanal fishery. Vazquez-Rowe *et al.* (2010) suggested a synergistic model of LCA with data envelopment analysis (DEA) which can facilitate both the environmental impacts and economic issues like operational fishery. A comparative LCA study of coastal purse seining and bottom trawling fleets involved in Atlantic horse mackerel fishery and associated activities indicated that purse seining offered lower environmental burdens for all the impact categories (Vazquez-Rowe *et al.,* 2010). LCA is demonstrated to be an important instrument for defining sustainable sea food production in a study on species-specific Swedish nephrops trawl fisheries (Horborg *et al.,* 2012). A review of the LCA framework studies for the environmental assessment of fisheries emphasizes the importance of energy efficiency of fishing vessels, among the key deciding factors of impacts of fishery operations (Avadi and Freon, 2013).

The ever-increasing international demand for shrimps and cephalopods further induces acute competition, higher investment and continuous demand for up gradation of trawlers. Gujarat having highest number of trawlers and the trawl industry is one of the highly overcapitalized fishing sectors in India. The occurrence of intensive processing and export industry in the Saurashtra coast plays vital role in stepping up the capital flow to fishery of the region. The technical specifications, capital investment, catch composition and revenue for single and multi-day day units differ drastically (Hassan & Sathiadhas, 2009). Knowledge on economic performance of both the single-day and multi-day trawlers is quite fundamental to identify with the fishery in long term.

Fish are recognized as being highly perishable, having a relatively short shelf life, which is defined as the length of time from the day of catch that fresh fish can be in the marketplace unspoiled (Regenstein and Regenstein, 1991). Consequently, proper handling and preservation of fish is needed to increase its shelf life and quality and also retain its nutritional characteristics. Quality is defined as the aesthetic appearance and freshness or degree of spoilage which the fish has undergone (FAO, 1995). Immediately after fish is caught, it loses its natural resistance to attack by microorganisms and also undergoes both physical and chemical changes that in turn lead to changes in appearance, taste, smell and texture (Amos *et al.,* 2007).

However, not all fish landed reach factories, about 10-30% is regarded as “rejects” both at landing sites and in fish processing factories. However, rejected fish always finds its way to local or regional markets, and is often processed locally by frying, smoking or salting and drying to minimize further spoilage during distribution. EU regulation (EC No. 852/2004) demands imported foods from exporting countries to be of at least the same hygienic standards as food produced within the EU. With the increase in voyage time, the quality of fish varies as a result of several factors like storage facility, knowledge, microbial and physiological phenomena with critical environmental parameters. Storage time and storage conditions have also great impact on the quality of fish and fish products, and the storage stability of fish depends on the composition of the fish (Ashie *et al.,* 1996).

Quality products can never be produced from defective raw materials (Amos *et al.,* 2007). Hence it affects the acceptability of raw material and the value, which leads to a loss of economy to operator providing the raw material. Therefore, knowledge of optimum voyage period to keep the raw material in an ideal quality with their available storage system is highly essential, and it should fetch the highest price and also be able to produce quality products.

This study on single-day and multi-day trawlers from Gujarat waters was conducted with the following objectives:

1. To study the catch composition and characteristics of trawl fishery
2. To estimate the carbon footprint by trawlers
3. To evaluate the economic performance of selected trawl fishing systems
4. To assess the fish quality of selected commercially important species

Review of Literature

2. REVIEW OF LITERATURE

2.1. Catch composition and characteristics of single-day and multi-day trawl fishery

Exploratory trawling off Goa by the Government of India fishing vessels was conducted during November-December 1967 and March-April 1968. The fish catch data; area and depth-wise distribution of the fishes were presented. The result of the study showed that the major catch comprised of small sciaenids, catfishes and elasmobranch which formed 80% of the total catch. Other groups in the catch comprised *Lactarius*, *Nemipterus*, pomfrets, prawns, *Sphyraena*, cephalopods soles, ghol and other miscellaneous fishes (Rao and Dorairaj, 1968)

Pillai and Bhat (1981) studied the abundance of zooplankton and trawl catch during the post-monsoon months along the northwest coast of India. The trawl catch per hour ranged from 80.2 kg/hr to 366.7 kg/hr. The major trawl catch consisted of small sciaenids (38.6% to 69.4%), catfish (55.9% to 73.9%), elasmobranchs (20.9% to 42.5%), *Nemipterus japonicus* (11.2% to 25.2%), *Upeneus* spp., *Trichiurus* spp., *Polynemus* spp., cephalopods, pomfrets, *Pomadasys hasta*, penaeid prawns, lobsters, and *Rastrelliger kanagurta*. Species landed in smaller quantities consisted of *Pellona, Chirocentrus, Saurida tumbil, Lutjanus, Sphyraena, Pseudosciaena, Caranx, Lactarius, Platecephalus, Cybium, Cynoglossus* and *Psettodes*.

The catch of trawlers at NFW during 1987-88 comprised of prawn, lobster, cephalopods, elasmobranchs, croakers, ribbonfish, eels, catfish, lizard fish, Bombay duck, perches, pomfret, clupeiods and miscellaneous catch (Sehara *et al.,* 1991).

The major species composition in the annual catch of the mechanized trawler operated off Kerala coast was given by Hassan and Sathiadhas (2009).Deep-sea prawn dominated the catch at Neendakara with a contribution of 64% followed by cuttlefish (11%). In Munambam, the catch mostly consisted of less priced threadfin breams (31%) followed by high priced cuttlefish (24%) along with ribbon fishes (12%) and prawns (5%). Ribbon fishes (60%) followed by cuttlefish (17%) formed the major catch at Cochin fisheries harbour.

Studies pertaining to the impacts of fishing on ecological processes like productivity, trophic chain and flow of biomass etc. have been already well documented (Pauly, 1979; Pauly and Christensen, 1995). The environmental impacts of different fishing methods like destruction of coral reefs by blast fishing (Goñi, 1998), bycatch and discards by using unscientific gears (Alverson *et al.,* 1994), ghost fishing of different organisms by voluntary dumping or loss of fishing gears (Goñi, 1998) etc. had also been covered by various researchers.

The Indian squids were reported to form large congregations in inshore waters during the spawning season during which they were caught by purse seiners in Hong Kong using lights (Roper *et al.,* 1984).

Along Maharashtra coast, maximum landings of cephalopods were in post-monsoon and pre-monsoon during 1984-88. Trawl net mostly contributed to cephalopod landing (Alagaraja, 1992).

The occurrence of such sizeable quantities of large sized mature squids during September-October of 1990 and 1991 indicates that the squids might have congregated for spawning in the eastern Arabian Sea off southern Karnataka (Mohamed, 1993).

Fish populations show spatial and temporal repartition of life stages (Harden-Jones, 1968). The shift in habitat of each developmental stage *i.e.,* areas of juvenile development, sub-adult and adult grounds, indicates that species change their ground during the life cycle. In some species, these areas can be geographically separated (Koubbi *et al.,* 2006). How the spatial distribution of fish during their different stages of development can be superimposed on oceanographic features. For some species, spawning grounds, nurseries and adults are geographically separated as a function of the water currents was also described.

Geographical Information System (GIS) is a potential and powerful tool in fisheries management and ecosystem studies. It is possible to analyze and map the distribution of species with GIS (Valavanis *et al.,* 2002; 2004). Spatial reallocation of fishing pressure can be a method for attaining sustainability and also for avoiding conflicts in the sea (Douvere, 2008). The studies on spatio-temporal distribution of marine fishes using GIS in the Indian context is limited to the works of Selvaraj *et al.* (2007) and Dineshbabu *et al.* (2012).

Involvement of local fishermen in spatial data collection process for GIS analysis proved to be a very handy and useful input for developing management tools (Hutching and Ferguson, 2000; Maurstad, 2000).

The team led by Graham *et al.* (2002) could succeed in preparing "Atlas on ground fish spawning in Bay of Fundy" with participatory research program involving commercial fishermen. Involving fishermen in the marine spatial planning proved to be very efficient method in decision making on fishing area sharing and resource sharing in multi-species, multi-gear scenarios (St. Martin and Hall Arber, 2008).

Azeez *et al.* (2016) have studied the distribution of ribbon fishes and juveniles of this species in all the three seasons, had reported the trend and abundance along Saurashtra coast, which remained steadily high, especially along the south Saurashtra coast (below 20˚48′ N) at a depth above 30 m in summer and during post-monsoon and in winter, the abundance was observed above 50 m. Southern Saurashtra coast is close to the mouth area of Gulf of Khambhat, a high-productive zone influenced by the large amount of nutrients brought in by many perennial and seasonal rivers and high tidal range. This is a detritus rich zone that provides a preferred feeding habitat for *Acetes* sp. (Deshmukh, 2002), leading to their higher levels of abundance, which is the most favorite item of most of the fishes.

The abundance of sub-adults of ribbon fishes along Saurashtra coast continued to increase towards both northern and southern side. It was highest (19-23 kg h-1) in the offshore (>50 m depth) off Devbhoomi Dwarka, inshore (30-50 m depth) off Porbandar and south to Gir-Somnath districts. The comparison of spatio-temporal distribution of juveniles and sub-adults revealed that the sub-adults were more common along the northern region of Saurashtra coast *i.e.,* off Devbhoomi

Dwarka District (Azeez *et al.,* 2016). Higher abundance of adults was observed further south off Gir-Somnath District (below 19˚44′N) except during post-monsoon. In post-monsoon, the higher abundance was observed in deeper waters (100-200 m depth) off Porbandar district. The study indicates that the contribution of juveniles and adults in the total catch of *T. lepturus* was at moderate level with the catch rate of adults dominating in the deeper waters (>50 m depth) during winter. The findings of this study confirm that juvenile grounds are in the waters along the south Saurashtra coast and hence there is a need to divert the fishing pressure to the waters off south Saurashtra and north Saurashtra coasts where subadults and adults are abundant, in order to realize better recruitment to the fishery.

According to the study by Azeez *et al.* (2016) ribbon fishes migrated to deeper waters for breeding and therefore the abundance of adults was relatively high in deeper waters, especially during winter. Such studies are beneficial to both resource managers and fishers to understand the spatio-temporal distribution with respect to its life stages.

The result from the long-term spatial analysis of catch and effort from the trawlers operated from Mangalore brings out very important points which call for attention of policy makers for marine fishery policy development in future. Ever since the advancement of mechanization was adopted in the fishery sector, the fishery extended beyond territorial waters (Dineshbabu *et al.,* 2013). This extension of fishing ground demands inclusion of spatial dimension in the fishery data analysis to come out with present sea-truth information. Since India does not have a compulsory log book keeping system, spatial studies of marine fisheries have been difficult tasks, but the study revealed prevalence of a system of maintaining organized log data among many of the progressive trawler operators, which are being used as the record of area of high catch and low catch with species information. This data base is generally kept confidential with limited access to group members. Such organized log sheet maintenance opens up a very promising future for involvement of fishermen in deriving fishery management policies (Dineshbabu *et al.,* 2017).

The depth of trawler operation off Mangalore coast extended up to 200m and lat. long of 10°16.678′N to 17°25.373′N and 72° 47.901′E to 75° 53.939′E and there was a definite pattern of fishing operational route followed in different months and this route was repeated in the following years also (Yogesh *et al.,* 2019).

Dineshbabu *et al.* (2011) studied the fishing ground off Mangalore which revealed that the depth of operation was between 5 and 167 m and the most intensive trawling operations were observed in fishing grounds at 30 m depth off Mangalore to Panaji, followed by fishing grounds at 100 m depth off Malpe to Karwar. Fishing grounds at 30 m depth off Ratnagiri was found to be fished with moderate intensity. Most of the fishing operations were concentrated within the 150 m depth zone and extension was mainly parallel to shore, towards south or north.

Behera *et.al.* (2016) estimated mean catch rates of total bycatch differed significantly between seasons with higher catch rates for biomass and number in post fishing ban period from Vishakhapatnam waters. Seven teleost and four invertebrate species had mean catch rates higher during post fishing ban period, while one each had higher catch rate during pre-fishing ban period.

Study by Bhendekar *et al.* (2018) revealed the spatial variability and abundance pattern of Indian squid off Maharashtra coast. The annual latitudinal variability in trawl fisheries for Indian squid revealed three different fishing patterns. After fishing ban during June-July, fishers target Indian squid in 17°N to 16°N latitudinal ranges in August with fishing fleet concentrating in 20-40 m depth range catching on an average 55 (±36) kg of Indian squid per hour. In September, fishing fleet moved further down from 16°N to 15°N in 40-60 m depth with average catch of 43 (±23) kg/hr. As season advanced, the trawl fishing fleet for Indian squid became more scattered moving towards north in the latitudinal range of 17°N to 20°N with reduced catch per hour. Annual bathymetric distribution of squid fishing fleet showed that most of the efforts were concentrated in 30 to 50 m depth. The study also revealed targeted fishing grounds for Indian squid in different months. The monthly landing of Indian squid in trawl net during 2017-18 showed peak landing during August, September and October in Maharashtra. The annual latitudinal variability in trawl fisheries for Indian squid revealed three different fishing patterns viz. August (17°N to 16°N latitude), September (16°N to 15°N latitude) and scattered fishing positions during rest of the months.

Aswathy *et al.* (2018) discussed the technological changes and its impact on sustainability of trawl operations in Kerala during 1997 to 2015 using total factor productivity analysis. The study showed there was increase in engine horsepower from 90 to 550 and total factor productivity analysis indicated that technological change has resulted in economic unsustainability in the production system.

Study on catch composition of trawl landings along Maharashtra coast by Devi *et al.* (2019) revealed that, the difference in catches of the single-day and multi-day trawlers was mostly due to the difference in depth of operation, distance from the shore, speed of trawling and fishing ground. Analysis of catch composition revealed significant landing of *L. duvauceli* by multiday trawlers of Mumbai coast, a trend observed in the recent past. The study highlighted the changing trends of trawl fisheries along Mumbai coast of Maharashtra in terms of catch, catch composition, intensity of fishing, voyage duration and fishing capacity. The increase in number of fishing days in a trip is a clear indication of high intensity and high fishing pressure. Exhaustive studies to include the directions of fishing, depth of operation, fishing ground etc. are needed to elucidate the reason for change in composition of resources.

Trawling has contributed to increased marine fish production and has led to its widespread adoption by many countries. In India, trawlers have contributed major part of the total marine fish production (Srinath, 2003).

Trawl nets due to their low selectivity and high efficiency are often implicated with generation of large quantities of bycatch (Kennelly, 1995; Hill & Wassenberg, 2000; Ye *et al.,* 2000; Gamito & Cabral, 2003; Heales *et al.,* 2007; Boopendranath *et al.* 2008). It is debated that introduction of highly selective gears may undermine the very objectives of sustainable fishing or stock sustenance (Cushing, 1984; Zhou, 2008).

Though trawl nets are very efficient for the capture of shrimps, the targeted catch formed only 25-30% and the rest of the catch is either discarded or brought to the shore which forms the input for the fish meal industry (Boopendranath *et al.,* 2008; Dineshbabu *et al.,* 2013).

Edwin *et al.* (2013) have given a detailed account of the history and changes in the trawling sector over the years. Renju *et al.* (2014) have described the structural changes in the marine mechanized trawling sector of India.

Fishing has grown in to an industry with global relevance providing livelihood to 39.4 million fishers involved in capture fishery and contributing towards 16.7% of globally consumed animal protein (SOFIA, 2014). Out of the total marine fish landings of 7.12 lakh tons from Gujarat coast, trawlers share the largest (54.27%) in terms of both quantity and revenue with maximum CPUE compared to other gears (CMFRI, 2015).

Total marine fish landings of India for the year 2018 was estimated at 3.49 million tons showing a decline of about 3.47 lakh tons (9%) compared to 3.83 million tons in 2017. Among the nine maritime states, Gujarat remained in the first position with landings of 7.80 lakh tons. Sector wise landings in Gujarat showed that mechanized sector landed 89%, motorised 10% and non-motorized 1%. Compared to landings in 2017, major losers among the resources were ribbon fishes, bulls eye and non-penaeids and Indian mackerel, threadfin breams and anchovies were the gainers (FRAD, CMFRI, 2019).

2.2. Estimation of Carbon footprint of single-day and multi-day trawlers

Energy intensity in North Atlantic fisheries ranged from 230 to 2,700 l/ton with mean of 510 l/ton (Eyjolfsdottir *et al.,* 2002). Tyedmers (2004) reported that fuel use in fisheries ranged from 20 to 3,400 l/ton of fish landed.

Hospido and Tyedmers (2005) reported an average fuel consumption of 0.44 l/kg for nine Spanish vessels targeting skipjack and yellow fin tuna. The resulting partial footprint was 1.15–5.27 kgCO_2/kg of landed tuna. The carbon footprint of tuna caught using long line gear, large-pump boats and small-pump boats was 6.64-8.86, 2.11-4.70 and 3.26-4.35 kgCO_2/kg landed tuna respectively.

Fishing stage has the largest impact potential for the investigated impact categories as shown by the flatfish LCA (Thrane, 2006). This is mainly due to relatively high fuel consumption and significant emissions of biocides from antifouling agents (contributing to ecological toxicity). But large reductions in fuel intensity (fuel consumption per kg caught fish) can be obtained by changing the type of fishing gear – particularly in flatfish fisheries. The consumption and retail stages represent significant impact potentials as well, while processing is insignificant. LCA screenings of other fish species showed the same picture, but there were cases (herring, mackerel and mussels) where the fishing stage was less important, while the opposite was the case for processing, mainly due to energy intensive packaging materials.

Ziegler and Valentinsson (2008) reported the prevalence of major differences between the fishing methods with regard to environmental impact: creeling was found to be more efficient than conventional trawling in all traditional impact categories and in the two additional fishery-related categories involving seafloor impact and discarding. Since the quality of the creel-caught nephrops was higher, the difference was probably even higher than indicated

Boopendranath *et al.,* (2008) estimated the annual fuel consumption by the mechanized and motorized fishing fleet of India to be 1220 million litres which formed 1% of the total fossil fuel consumption in India in 2000 (122 billion litres). The amount of CO_2 released was estimated to be 3.17 million tons. The intensity of CO_2 emission was 1.13 t of CO_2 per ton of live-weight of marine fish landed. The emission of CO_2 was highest for large scale mechanized bottom trawling (3.52 kgCO_2/kg fish) followed by motorized mini-trawling, small-scale mechanized bottom trawling, large scale mechanized aimed mid water trawling, small scale mechanized gillnetting-cum-lining, motorized ring seining and mechanized purse seining.

It has been estimated that fossil-fuel burning by global fisheries is 42.4 mt, representing 1.2-3.5% of global oil consumption, releasing approximately 134 mt of CO_2 into the atmosphere at an average of 1.7 t of CO_2/t of live weight landed product (World Bank and FAO, 2009).

Environmental burdens regarding horse mackerel landing are associated mainly with activities related to diesel production, transport and consumption of the fishing vessels. Furthermore, cooling agent leakage from the cooling chambers was identified as a major impact regarding ozone layer depletion and global warming potentials. Horse mackerel captured by purse seiners presented reduced environmental burdens for all impact categories with respect to horse mackerel landings by bottom trawlers. The environmental reduction ranged from 49 to 89%, depending on the impact category analyzed (Vázquez-Rowe *et al.,* 2010).

The carbon footprint for the exploitation of various species such as Atlantic horse mackerel, Atlantic mackerel, Hake, Blue whiting and other species has been reported as 1.44, 0.88, 6.46, 1.54, 2.26 kg CO_2 equivalent for the production of every kg of fish respectively by the coastal trawling activity along the Glacian water of North-west Spain (Iribarren *et al.,* 2011)

Increasing greenhouse gaseous concentration in the atmosphere perturbs the environment to cause grievous global warming and associated consequences. Following the rule that only measurable is manageable; mensuration of greenhouse gas intensities of different products, bodies, and processes going on worldwide, is expressed as their carbon footprints (Pandey *et al.*, 2011). Overfished stocks at lower densities and smaller individual body sizes require vessels to exert more effort, catch greater numbers of individual fish, and travel to more distant or deeper grounds or fish over a wider area, all of which would increase fuel use per ton of landings.

Vivekanandan *et al.* (2013) reported energy intensity of the harvest phase as 393.3 l/ton for marine fish caught in India. In Indian marine fisheries, the enhanced fishing effort and efficiency in the last five decades has resulted in substantial increase in diesel consumption, equivalent to CO_2 emission of 0.30 million tons (mt) in the year 1961 to 3.60 mt in 2010. For every ton of fish caught, the CO_2 emission had increased from 0.50 to 1.02 t during the period. The trawlers emitted more CO2 (1.43 t CO_2/t of fish) than the gillnetters, bag netters, seiners, liners and dol netters (0.56–1.07 t CO_2/t of fish).

According to Vivekanandan *et al.* (2013), for every ton of fish caught, CO_2 emission increased from 0.5 to 1.02 ton during 1961–2000. However, they considered only the harvest phase and the pre-harvest and post-harvest phases were ignored. They reported that mechanized craft emitted 1.18 tons CO_2/ton of fish caught and the motorized boats emitted 0.59 tons CO_2/ton of fish caught.

The fuel and electricity consumption and C and CO_2 emissions were high for mechanized landings and low for motorized landings. They calculated the average fuel and electricity consumption as 0.48 l/kg and 0.255 kWh/kg of marine fish at all life cycle phases at Visakhapatnam (Ghosh *et al.*, 2014).

Ghosh *et al.* (2014) reported that 0.382 kgC and 1.404 kgCO_2 was emitted per kilogram of marine fish over all its life cycle stages at Visakhapatnam. The highest emission was in the harvest phase, wherein 0.345 kg C and 1.267 kg CO_2 was emitted per kilogram of marine fish landed. Harvest phase contributed 90.2% to the total emissions. The emissions at the pre-harvest and post-harvest phases were trivial to the tune of 0.002 kg C and 0.006 kg CO_2 and 0.036 kg C and 0.131 kg CO_2 respectively. During post-harvest phase, icing and processing contributed more in the range of 0.009 kg C and 0.032 kg CO_2 and 0.022 kg C and 0.081 kg CO_2 respectively. Pre-harvest phase consisted of vessel construction and maintenance and provision of fishing gear; harvest phase included harvest from mechanized and motorized craft and post-harvest phase involved fish transportation and fish processing**.**

Fuel inputs to fisheries vary by several orders of magnitude, with small pelagic fisheries ranking among the world's most efficient forms of animal protein production and crustaceans ranking among the least efficient. Trends in Europe and Australia since the beginning of the 21st century reported improvement in fuel-use efficiency, although this has been countered by a more rapid increase in oil prices. The mean FUI (Fuel use intensity) of all fisheries fuel-use records since 1990 is 706 liters and the median FUI of all records since 1990 is 639 liters. Fuel-use intensity varies considerably between fisheries, on the scale of at least three orders of magnitude, but several patterns are clear when comparing fisheries on the basis of target species class and primary gear type Parker *et al.* (2015).

Compared to other sources of animal protein, products derived from marine fisheries and destined for human consumption produce relatively low GHG emissions. Over half of fishery-derived products for consumption were estimated to produce fewer GHGs than the low end of emission ranges for pork, beef and lamb and fisheries had a carbon footprint similar to the range reported for poultry production, Parker *et al.* (2018).

Parker *et al.* (2018) reported that fisheries consumed 40 billion litres of fuel in 2011 and generated a total of 179 million tons of CO_2-equivalent GHGs (4% of global food production). Emissions from the global fishing industry grew by 28% between 1990 and 2011, with little coinciding increase in production (average emissions per ton landed grew by 21%).

2.3. Economic performance of single-day and multi-day trawlers

Venkata Raju *et al.,* (2017) assessed the economic viability of the non-motorized (NM) fishing craft of outboard motor (M-OBM) and inboard motor (M-IBM) fishing crafts at Andhra Pradesh for a period of two years (2003 and 2004). Among the motorized crafts, the returns form M-OBM crafts was fairly good since there was flexibility of fishing in the near-shore as well as distant-water compared to M-IBM crafts.

Devaraj and Smita (1988) analyzed the average annual catch, effort and catch per unit effort for a mechanized trawler unit in Kerala from 1971 to 1982 and reported the economically optimum level of fishing effort.The yield from trawl fishery was estimated at 91,323 tons, comprising 44,931 tons of shrimps and 46 392 tons of finfish. The other surplus vessels may be engaged by targeting other fisheries resources.

Watanabe and Okubo (1989) estimated that direct fuel energy inputs to fishing typically accounted for a major share of 75–90% of total energy inputs of the sector.

Panikkar *et al*. (1993) revealed maximum fuel efficiency for purse seiners among the mechanized fishing craft and boat seine with country craft fitted with 7 HP outboard engines among different motorized craft-gear combinations. Though the fuel expenditure per trip was maximum for purse seine, it was minimum with regard to production of one kg of fish. Among motorized craft, the oil expenditure per trip was minimum for gill net operation but it was higher than that of boat seine operation per kg of fish.

Sehara (1998) evaluated the economic efficiency of a trawl unit. During 1994-95 an average trawl unit had an investment of Rs. 9.7 lakhs which resulted in an annual fixed cost of Rs. 3.6 lakhs. For 200 days of trawl operation in a fishing season, operational cost was Rs. 5.61 lakhs. Fish landings of 79.4 tons (Rs. 10.31 lakhs) gave an operational surplus of Rs. 4.7 lakhs and a net profit of Rs. 1.09 lakhs. Rate of return to capital, net annual profit and other efficiency ratios were in favors of trawlers during 1994-95.

Sehara *et al*. (2000) studied the economic evaluation of different types of fishing methods along the Indian coast and found that the introduction of more and more trawlers in search of shrimps led to decline in catch rates in the in-shore waters. A medium trawler, having acquisition cost of about Rs. 7.7 lakhs in 1991, earned a profit of about Rs. 1.79 lakhs whereas a small trawler with an initial investment of Rs. 3.9 lakhs earned a profit of Rs. 77,000 during 1991. The payback period was about 3 years and the rate of return to capital, 34-38%.

Tietze (2001) assessed the financial statement of the rate of return from the fishing sector of India. The study came out with positive economic/financial results for fishing vessels of India which indicated that all fishing vessels except trawlers and gillnetters targeting demersal fisheries resources showed excellent results.

Aswathy and Sathiadhas (2006) analyzed the characteristics of ring seine fishery during ban period.Nearly 10 % of the trawl workers were employed in the ring seine units. Growth and instability in landings in the pre and post ban periods were analyzed.The marine fish landings were in a stabilized state with a positive growth rate of 0.108 % and a lower instability index of 11.4 in the post ban period.

Najmudeen and Sathiadhas (2007) studied the economic efficiency of trawlers along the Kerala coast by assessing the input-output relationship of trawlers operated along three major landing centres of the Kerala coast using the model Cobb-Douglas production function. The study suggested the optimum level of operation and to increase the fishing days from the existing level.

Hassan and Sathiadhas (2009) appraised trawl fishery of Kerala. Increasing international demand for shrimps and cuttlefishes further induced acute competition, higher investment and continuous up gradation of trawlers. Although the multi-day trawlers are economically efficient, the wastes and discards generated from these units are the main cause which affects the long-term sustainability of the resources.

Study by Narayanakumar *et al.* (2009) showed that the multi-day fishing (MDF) of 6-10 days duration earned higher returns than the other two methods in the east coast, while the MDF of 2-5 days duration performed better than the other two in the west coast of India. It was calculated that the average operating cost per trip of single day trawling in India during 2001-05 was Rs. 5,907/- per trip with a gross revenue of Rs. 11,589/- per trip, operating cost of multi-day fishing of 2-5 days duration Rs. 31,500/- per trip with a gross revenue of Rs. 52,737/- and the multi-day fishing of 6-10 days duration worked out to Rs. 56,376/- with a gross revenue of Rs. 97,542/- respectively.

Shyam *et al*. (2010) provided an insight into the trade-off between monsoon trawl ban and the livelihood of trawl labourers in Maharashtra and the result showed that the fishing ban created problems in employment, poverty and income distribution of fishermen during ban period.Unrest among mechanized and traditional sector of fishing was reported. Authors emphasized on the alternative source of livelihood for the trawl labourers during the monsoon ban period. In addition, policy guideline or intervention from the government, directing the trawl owners to enhance the closed season relief amount from the existing Rs. 1500 to 3000 per month was suggested.

Aswathy *et al*. (2011) studied the socioeconomics of fishing ban along Kerala coast, and opined that in the long run, the reduction in catch rates led to reduction in fishing effort levels. The paper analyzed the viability of various mechanized fishing units in the Kerala state using different economic and financial indicators. The economic performance also plays a crucial role in the investment decisions at micro level.The trend of decreasing profits of trawlers over the years has been reported.

Narayanakumar (2012) analyzed the economic efficiency of trawlers of major landing centers throughout the Indian coast. The capital productivity ratios for both single-day and multi-day trawl operations for Veraval coast were 0.58 and 0.57 respectively. Fuel cost accounted for 50–54% of operating cost of mechanized boats, and 36–44% of operating cost of motorized boats (CMFRI, 2012).

2.4. Assessment of fish quality of selected commercially important species from single-day and multi-day trawlers

Botta *et al.* (1987) studied the effect of catching method and season on sensory quality of raw Atlantic Cod (*Gadus morhua*). Catching method significantly affected the clolour and final overall grade, whereas season did not affect any sensory variables. Both the method of catching and time of season affected the pH of the meat.

Marrakchi *et al.* (1990) assessed the sensory, chemical and microbiological of Moroccan sardines (*Sardina pilchardus)* stored in ice for a period of 18 days. Sensory analysis indicated shelf life of 8 days, and that TMA-N and TVB-N could be considered good indicators of freshness. The pH value of sardine stored in ice was 5.8 at day 0 and 6.36 at day 9, indicated that pH was not a good indicator of spoilage for this species. The TPC count was above the limit of 10^6cfu/g of flesh at the 12th day.

Benjakul *et al.* (1997) revealed that the myosin heavy chain (MHC) was degraded by 45% within 8 days, but no noticeable difference was observed in actins. Results indicated that autolysis may be the main cause for the physicochemical changes in Pacific whiting muscle proteins during iced storage.

Simeonidou *et al.* (1997) assessed the quality of seven Mediterranean fish species, bogue (*Boops boops*), chub mackerel (*Scomber japonicascollias*), horse mackerel (*Trachurus trachurus*), Atlantic mackerel (*Scomber scombrus*), Mediterranean hake (*Merluccius mediterraneus*), sardine (*Sardine mediterraneus*), striped mullet (*Mullus barbatus*) during ice storage for a week and suggested that the fish taste, TBA and FA records may be useful for monitoring quality changes of all fish species examined.

Vishwanath *et al.* (1998) found that the pH value for fresh fish and smoked fish was 7.25 and 6.90 respectively. The Total plate count (TPC) and fungi (TFC) were 10^6-10^7 cfu/g and 10^2 cfu/g respectively forfresh fish meat of mud eel (*Monopterues albus*).

Gokodlu *et al.* (1998) investigated on the physical, chemical and sensory analysis of sardines (*Sardina pilchardus*) which was stored at 4°C, and found the colour and texture value decreased while pH, TMA-N, TVB-N increased. Sensory results indicated the acceptability up to 6th day.

Kyrana and Lougovois (2002) experimented on the sensory, chemical, and microbiological assessment of farm-raised European sea bass (*Dicentrachus labrax*) stored in melting ice for a period of 22 days from the day of harvest. TMA, TVB-N, and pH showed practically no change during the first half of the edible storage life of the meat.

Microbiological, chemical and sensory changes of whole and filleted Mediterranean aqua-cultured sea bass (*Dicentrarchus labrax*) stored in ice was studied by Taliadourou *et al.* (2003). Result showed that the TMA values of un-gutted muscle increased very slowly, whereas higher value was obtained for filleted sample. Sensory assessment of raw fish using EC freshness scale assigned a grade score of E up to 5th day and grade C (unfit) declared after 13th day for whole un-gutted specimen. Also, the overall acceptability limit by sensory score and microbiological information was 8-9 days and 12-13 days for filleted and un-gutted fish respectively.

The post-mortem changes in quality of ice-stored flounder (*Paralichthys patagonicus)* conducted by Massa *et al.* (2005) for the period of 12th day revealed the muscle pH fluctuated between 6.6 and 7.0. Microbiologically the flesh was acceptable up to 7th day and beyond that the TPC count exceeded 10^7cfu/g. The sensory score determined by the Quality Index Method linearly increased (r^2 =0.96) against time. The overall acceptance of the fish flesh was 7 days.

Ozogul *et al.* (2005) assessed the freshness of European eel (*Anguilla anguilla*) which was stored in ice and without ice by the sensory, chemical and microbiological methods. The limit for the acceptability of fish in ice was 12-14 days. Values of pH for storage in ice were statistically insignificant ($P>0.05$).

Guillerm-Regost *et al.* (2006) developed the quality index method for farmed Atlantic halibut with the instrumental, chemical, sensory, and bacteriological analysis of meat which was stored for 26 days in ice, by providing two types of diet with difference only in the lipid content in the feed. The texture, liquid-holding capacity and colour were significantly affected during storage period, but it did not change significantly from 8^{th} day of storage to the end of experiment on 26^{th} day.

Ozogul *et al.* (2006) reported12-15 days as the acceptability limit of turbot (*Scophthalmus maximus*) assessed by the sensory method. TVB-N could not be a good indicator for the test of freshness for the species due the fluctuation in the concentration. The TMA value also increased from 9.36 mg/kg at 1^{st} day to 38.9 mg/kg at 19^{th} day. The pH value decreased on 8^{th} and 12^{th} day and then increased till last day of experiment at 19^{th} day for turbot stored in ice. The shelf life for the turbot was approximately 13-14 days considering10^6 microorganisms/g being the TPC limit.

Rodríguez *et al.* (2006) studied the effect of application of slurry ice (preservation method) on the microbial, chemical and sensory quality of the shelf life of farmed turbot (*Psetta maxima*). Results obtained in sensory analysis were well correlated with the chemical and microbial changes. They also suggested use of slurry ice during storage and distribution of farmed turbot.

The quality of Mediterranean horse mackerel (*Trachurus mediterraneus*) and blue jack mackerel (*Trachurus picturatus*) during storage in ice was assessed by Tzikas *et al.* (2007). The reported shelf life for Mediterranean horse mackerel and blue jack mackerel was 10^{th} and 7^{th} day respectively as per the sensory analysis. The pH values of both species increased gradually with time and the bacterial load was low (<6 log cfu/g) before 10^{th} day.

Rodriguez-Casado *et al.* (2007) followed the DRIFT spectroscopy method to analyze the structural changes in sardine (*Sardina pilchardus*) muscle during iced storage and this method mostly focused on the changes in lipids and proteins.

Erkan and Özden (2008) assessed the quality of whole un-gutted and gutted sardine (*Sardina pilchardus)* stored in ice. At day 9, the TVB-N value was 15.03-29.23 mg/100 g and 2.36-4.16 mg/100 g for whole un-gutted and gutted sardine respectively. The psychrophilic bacterial count for both the categories was not different.

Hernández *et al.* (2009) analyzed the sensory, physical and microbiological changes in aquaculture meager (*Argyrosomus regius*) fillets during the ice storage at 4°C for 18 days. The analytic test carried out at 0, 4, 7, 11, 14, and 18 days of storage time. All the sensory analysis showed significant variation and well correlated with time. The TBA, sensory, and microbiological analyses showed very strong correlation over time and was considered as the suitable parameter for indication of freshness of the meager.

Ozogul *et al.* (2011) studied the biochemical, sensory and microbiological quality indices of Common sole (*Solea soles*) from the Mediterranean Sea during the ice storage, and reported that the quality of meat decreased from 16^{th} day and not acceptable on 20^{th} day. All the parameters revealed that the shelf life of common sole was approximately 16-18 days. The TVB-N value fluctuated with the storage time, at the beginning the TVB-N value was 13.44 mg/100 g flesh and then reduced to 9.73 mg/100 g on day 6, then at the end of the experiment on 20^{th} day, the value reached to 34.03 mg/100 g. The initial pH value was 6.65 and then increased to 6^{th} day, then decreased on 10^{th} day, then again, the pH value increased continuously till the end of the storage period. The TPC value was 4 log cfu/g (day 0) for gutted common sole and 8.3 log cfu/g (day 24).

Alparslan *et al. (*2012) determined the sensory and quality changes of treated sea bass (*Dicentrachus labrax*) during the storage in refrigerated condition. The samples were sampled on days 0, 2, 4, 6, 8, 10 and 12. The observed shelf life of sea bass was 16 days in iced condition. There was increase in pH value due to the higher nitrogen content with the storage time. The TVB-N value at the beginning for fresh fish was 18.87±1.62 mg/100 g and at the end of 12^{th} day of storage period, the content increased to 28.09±1.30 for scaly-whole fish. The study further revealed that all the samples were considered for consumption up to 12^{th} day based on the pH, TBA and TMA-N, but the TVB-N values exceeded the consuming limit after 8th day of storage.

Castillo-Yanez *et al.* (2014) reported the postmortem biochemical changes and evaluation of freshness in the meat quality of Tilapia (*Oreochromis niloticus*) in ice-stored condition with the load of bacteria count exceeding 7 log cfu/g at 15^{th} day. The analysis of parameters was conducted up to 18^{th} day. The texture and water-holding capacity was not affected. The TVB-N value significantly increased from 24.2±1.34 mg/100 g to 38.37±2.94 mg/100 g at 0^{th} and 18^{th} day storage time respectively. Based on the pH and TVB-N, the shelf life indicated to be 12^{th} day. Overall results indicated that the fish meat is acceptable for at least 15^{th} day of storage.

Binsi *et al.* (2015) carried out investigation on the microbiological and shelf life characteristics of eviscerated and vacuumed-packed fresh water catfish (*Ompok pabda*) during chilled storage. The shelf life of chilled gutted pabda catfish was 14-16 and 18-20 days for air packed and vacuum-packed samples respectively. Initial reduction of count during chilled storage which then increased gradually and reached to 10^7 cfu/g on the 20^{th} day of storage. For sensory evaluation, the panelist rejected the quality of meat covered with polyethylene and vacuum packed meat at 20th day 26^{th} day respectively.

Mokrani *et al.* (2018) compared the shelf life of European sea bass (*Dicentrachus labrax*) during ice storage condition at two different terrestrial ponds by using heated water from power plants and floating cages in the open sea. The acceptance limit in sensory analysis was 13^{th} day and 15th day for fish cultured in the heated water and floating cages in sea respectively. He suggested that the fish rearing conditions were important for storage and management in processing.

Material and Methods

3. MATERIAL AND METHODS

3.1. Sampling Protocol

The Saurashtra coast of Gujarat was selected for the study due to its importance in trawl fisheries of the state as well as the country. The 3 major sampling sites fixed for data collection according to their magnitude in trawling belonged to 3 districts i.e. Veraval (20.905401^{0}N, 70.375217^{0}E) in Gir-Somnath, Mangrol (21.107787^{0}N, 70.100019^{0}E) in Junagarh and Porbandar (21.640813^{0}N, 69.596152^{0}E) in Porbandar district (**Fig.3.1.1**). The trawlers of these districts venture out for fishing both north and south of Gujarat and adjacent states up to >200m depth zone in the Arabian Sea.

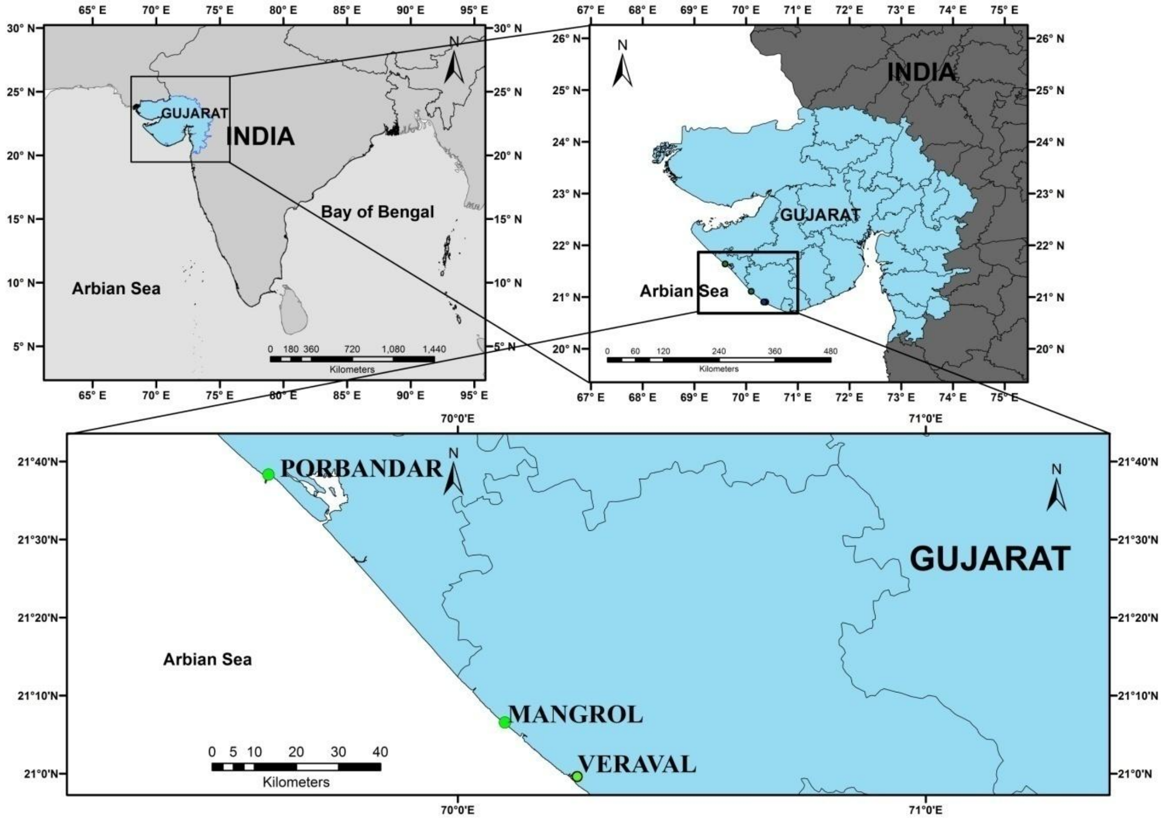


Fig. 3.1.1. Map illustrating sampling locations for data collection

The study was carried out during September 2016 to August 2018. Uniform fishing ban of 61 days is observed during the period 1st June to 31st July along the west coast every year. Thus, data for the months of June and July was not collected for both the observed years.

Gujarat was the highest contributor to marine capture fisheries (20.5%) of the country in 2017 and shared a commendable proportion in export. Trawlers were the major contributors to the mechanised sector in terms of both catch and revenue. Data was collected covering major aspects of trawl fishery i.e. catch, structural behaviour, economic performance, carbon footprint and catch quality of commercially important fishes. Gir-Somnath district contributed highest followed by Porbandar and rest followed with a marginal contribution.

3.2. Catch composition and characteristics of trawl fishery

Trawlers are classified into two categories i.e. single-day and multi-day trawler according to their duration of fishing trips. Single-day trawler starts voyage early in the morning and returns to the harbour on the same day with 2 to 3 hauls of operation. Voyage of multi-day trawlers ranges between 7-20 days duration. Shore-based catch assessment was done for both single-day and multi-day trawlers from January 2017 to December 2017. Sampling was done fortnightly. Questionnaire prepared in vernacular language was used together information including catch details of each haul for the entire voyage duration. The number of boats landed and number of landing days were observed and recorded through actual observation and enquiry. For the estimation of total monthly catch, the catch of each observed unit was raised to total of day's catch and eventually raised to monthly catch. GPS points were recorded with the help of skipper of surveyed boat for each haul to analyse spatial and temporal distribution of different fish species along the fishing grounds for every voyage. Trawlers were selected randomly for assessing the composition of catch landed at veraval, mangrol and porbandar. The catch was segregated into species-level at the landing centre and if not, the samples were brought to the laboratory for further identification. Bycatch samples from the same vessel were brought to laboratory for further identification and to assess the species composition. Information on discards during each voyage was obtained from crew members working onboard through a questionnaire provided to them.

The landings have been classified following the terms and definitions (Costa *et al.,* 2008). The 'total catch' is the quantity of all species brought onboard;

‘landed catch’ is part of the total catch that has economic value (i.e. the quantity of commercial fish for edible use and low-value species for non-edible purpose); ‘total bycatch’ is the portion of the total catch, which may be retained if it has some commercial value (LVB) or discarded at sea if it is not used for any purpose (Discards).

Measures of diversity (species richness, S’, Shannon-Wiener diversity index, H’) were compared between samples of both types of trawlers and between different seasons and species using ANOVA. Multivariate, non-metric, multi-dimensional scaling (MDS) was used to identify whether area or season affected the composition of the trawl based on their Bray-Curtis similarity using PRIMER v6 (Clarke & Warwick, 2001).

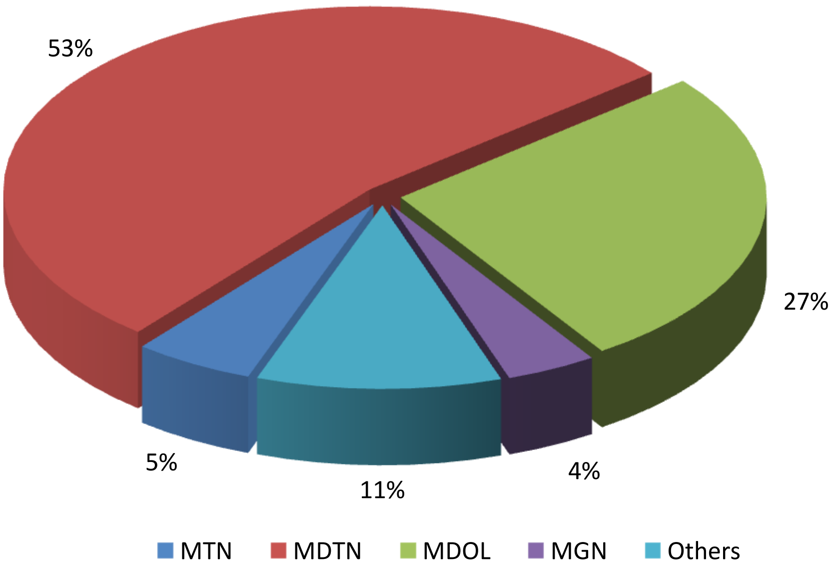
Trawlers cover a wide area of fishing than any other gears operated in the coast based on seasonality and availability of fishes. To assess the trawling ground in accordance with the targeted species and time of harvest, mapping of trawling ground is highly essential. Most of the multi-day trawlers are provided with GPS while very few single-day trawlers have GPS. Data regarding date, time, speed of trawler and GPS location of each point of shooting and hauling of net along with the total catch (kg), low-value bycatch (kg) and discards (kg) for each trip was collected from multi-day trawlers. In case of single-day trawl data regarding date, time, speed and direction of movement from the landing centre was recorded to identify the location of fishing ground. The recorded data was interpreted with ARCGIS 10.1 version to demarcate the fishing ground and spatial and temporal variation in catches of both the trawling systems. The data collected was grouped into three pre-determined seasons: post-monsoon (August-November), winter (December to February) and pre-monsoon (March to May).

3.3. Estimation of Carbon footprint by trawlers

Life cycle assessment (LCA) study was conducted in three different steps: (1) definition of the goal and scope of study (2) life cycle inventorization and (3) life cycle impact assessment

3.3.1 Definition of the goal and scope of study

It is mandatory for any LCA study to define the goal of study which is nothing but the reason for which such a study is conducted. The present study was conducted for preliminary estimation of the carbon footprint of trawl fishery sector thriving in Gujarat waters. The trawlers were selected for the study due to their immense contribution (58%) to the fisheries of Gujarat **(Fig.3.3.1.1)**. The study was envisaged to create awareness among the stakeholders (fishermen, fishery managers, seafood exporters, researchers *etc*.) about the probable environmental impact of trawl fisheries activity. The assumptions and limitations of the study are important factors for defining the scope of LCA study. It was assumed that different fishing methods produce different carbon footprint depending on the efficiency of harvesting method, and therefore, LCA analysis was conducted for two dominant categories of fish harvesting methods prevalent in the region, i.e. mechanized single-day and multi-day trawling. The functional units and the system boundary were also defined for the study. The functional unit used to assess the global warming potential of fisheries related activities in the present study was carbon dioxide equivalent per kg of fish i.e., $CO_2e\ kg^{-1}$ harvested from different fishing methods. Although LCA study should cover the inputs from cradle to grave, in the present study the carbon footprint during the consumption of the produce was not included in the assessment. The fugitive emission i.e. emission of greenhouse gas produced from the coolant during the production of ice for preservation during post harvesting phase as well as during the frozen preparation of the produce in the processing plant was beyond the scope of the present study. Similarly, the carbon footprint from the discarded fish catch was ignored due to the operational difficulties in arriving at the actual quantity discarded as well as numerical parameters to convert them to the quantifiable environmental impact. The other input parameters such as the metallic assembly components, machinery for propulsion, chemical utilization inside and outside the fishing vessels, ice and processing plant equipment, utilization of freshwater during various harvesting phases, waste disposal along with domestic transportation of the process inputs and outputs between places were also not included in this study due to difficulties in collecting reliable data.



*MTN=Mechanized Trawl net, MDTN= Multi-day trawl net, MDOL= Mechanized Dol Net, MGN= Mechanized Gill Net

Fig. 3.3.1.1. Gear-wise average contribution to the total fish landing of Gujarat from 2006-17

3.3.2. Life cycle inventorization

One of the fundamental requirements of any LCA study is to collect required input and output data of the activities/processes involved in the fishery. The whole capture fisheries activities were grouped into four production phases which are summarized as follows (**Fig.3.3.2.1**):

1. Pre-harvest phase is mainly contributed by the preparation of input materials such as craft and gear required for the onboard fishing activity.
2. Harvest phase is mainly contributed by the burning of fossil fuel (diesel) for fishing activities envisaged for catching fish.
3. Post-harvest phase is mainly contributed from the preservation of output (catch) by the use of ice as an onboard preservative as well as for frozen processing of the catch by the processing plants.
4. Transportation phase was identified as an integral variable phase involved in each phase of the above-mentioned production phases.

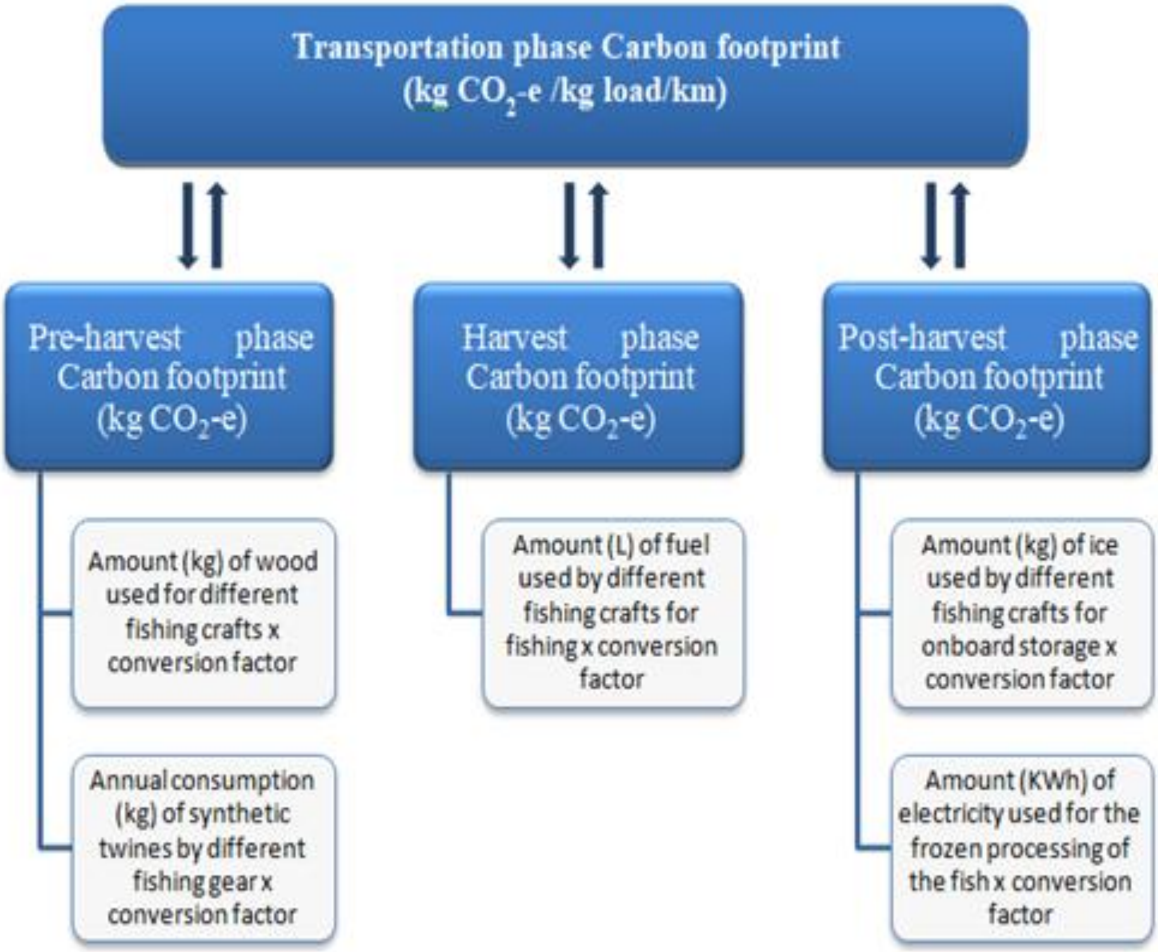


Fig.3.3.2.1. Schematic illustration of phases of capture fisheries activities used for building the inventory of data for estimation of carbon footprint

The data inventory was prepared by on-site monitoring and through the questionnaires as well as interviews with different stakeholders. A total of 150 observation days from single-day trawler and 150 observation days from multi-day units were sampled to collect data on fish catch, fuel and ice consumption for fish harvesting phase during the study period of 12 months from September 2016 to August 2017. Data for 2 months i.e. June and July could not be collected on account of the state-imposed monsoon fishing ban. Data on the amount of materials required for the construction of fishing craft and gear were gathered from the manufacturers of boats (n=20) and nets (n=20) at Veraval and Mangrol boat building yards. The fish catch potential (catch per unit hour, CPUH) of craft and gear used in the analysis was the annual averages of the last twelve-year catch data acquired from Fisheries Resource Assessment Division of Central Marine Fisheries Research Institute, Kochi (collected through the stratified multi-stage random sampling technique). The information about the quantity of ice and fuel used by fishing craft for onboard storage was obtained from the boat manager and crew of the boats and the ice consumption was validated with the ice manufacturer and supplier (n=25). The information on power consumption for the postharvest storage and processing was obtained from the Ice plants (n=5) and processing plants (n=10) situated in Veraval and Mangrol. Similarly, the operators from different categories of transportation vehicles (n= 20) were interviewed to collect data on transportation phase.

3.3.3. Life Cycle Impact Assessment

The process inputs involved in different phases of capture fisheries activity produce certain amount of greenhouse gases (GHGs) and thus contribute to the global warming. The greenhouse effect is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases (GHGs), resulting in an elevation of the average surface temperature. Global warming potential (GWP) of all the GHGs are not equal, rather it depends on radiative force and the average time for which that gas molecule stays in the atmosphere. Therefore, GWP of GHGs was calculated as a relative measure of warming effect they can produce in comparison to functionally equivalent amount or concentration of carbon dioxide. Therefore, unit of GWP is expressed as carbon dioxide equivalent (CO_2-e). In this step, the system input data such as craft and gear construction materials and fuel used for fishing, ice used for onboard storage were converted to environmental indicator i.e. 'CO_2 equivalent' using standard conversion factors adopted from DEFRA (2012), Benoit and Bruna (2017), Abbott (2008) and Parajuli (2014) and given in **Table 3.3.3.1**. To determine the environmental impact, the indicator was divided by the system output i.e. total fish catch (kg) and was expressed as 'kg CO_2 equivalent per kg^{-1} fish' produced.

Table 3.3.3.1 Standard conversion factors used for the estimation of environmental indicator i.e. CO_2 equivalent for different input parameters

Materials	GWP (kg CO_2-e/kg material)	Reference
Wood (kg)	1.2	Abbott (2008)
Polyamide	7.95	Benoit and Bruna (2017)
High density polyethylene-HDPE (kg)	2.79	DEFRA (2012)
Poly-propylene-PP (kg)	3.25	DEFRA (2012)
Diesel (L)	3.24	DEFRA (2012)
Electricity (KWh)	1.42	DEFRA (2012)
ABS (Acrylonitrile Butadiene Styrene)	3.94	Parajuli (2014)
Cast Iron	1.5	Benoit and Bruna (2017)
Brass	3.7	Benoit and Bruna (2017)
Steel	5.0	Benoit and Bruna (2017)
Fiber Reinforced Plastic (FRP)	7.7	Benoit and Bruna (2017)
Polyester paint	2.1	Benoit and Bruna (2017)

3.4. Economic performance of selected trawl fishing systems

Random sampling method was used to select the sample fishing units for collection of data on operating costs and returns from single-day and multi-day mechanized trawlers. Cost and earning data were collected monthly from the selected trawlers based on a pre-scheduled questionnaire. The fishing craft were classified as single-day and multi-day trawlers and economic performance was estimated separately for each category.

The various components of costs were classified into operational costs and fixed costs. The operating costs included all those costs, which were incurred only when the vessels were under operation and the fixed costs were those incurred even if there was no operation. The gross revenue is the total income obtained after selling the catch.

Variables included items such as initial investment, operating costs and return per trip of different mechanized fishing units in Gujarat. The collected data was used to work out the operating cost per trip, gross revenue per trip, net operating income, capital and labour productivities. Month-wise estimates of revenue and operating cost per unit were derived by averaging the values obtained from different units. The month-wise estimates were pooled together to get the quarterly and yearly estimates. The annual values were represented by averaging the values for 2016-17 and 2017-18.

The cost and earning data wereutilized for the calculation of the economic indicators such as net profit, rate of return on investment etc. (Aswathy *et al.,* 2017). Economic performance of different types of fishing units was assessed using indicators like net operating income, capital productivity and labour productivity (Hassan and Sathiadhas, 2009; Narayanakumar (2012)). Kunjir *et al.* (2007) had used capital turnover ratio as one of the economic indicators. The present study estimated the economic indicators like net profit, net operating income, Input-output ratio, labour productivity, fuel efficiency, gross value added, GVA to GR (%) etc.

Capital investment

It is the cost incurred on buying fixed assets like hull, engine, winch and other fittings, gear and accessories, GPS, compass, echo sounder/other devices.

Fixed cost

Fixed cost includes the interest on initial investment, its depreciation and insurance. Depreciation in the case of mechanized fishing units comprised of hull, engine, gear and other accessories. Fixed cost includes the following:

i. Depreciation on fixed assets: calculated @ 10% per annum.

ii. Interest on fixed capital: It was calculated @ 7% per annum on fixed capital.

iii. Expenses on repair and maintenance of fixed assets: estimated based on the information collected from sample units.

Variable cost or Operational cost

Operating cost or variable cost includes the following:

1) Fuel 2) Crew wages including Skipper 3) Food 4) Transportation 5) Water 6) Starter oil and 7) Ice.

Gross revenue

Gross revenue was worked out by multiplying the quantity of fish catch (species/group-wise) with respective prices.

Gross revenue = $\Sigma Q_i \times P_i$

[Where, Q_i = Quantity of group/species (Kg) P_i = Selling price of group/species (Rs/kg)]

Total cost

It is the sum of total fixed cost and total variable cost that is estimated as:

TC (Total cost) = TFC + TVC

[where, TFC = Total fixed cost, TVC = Total operating cost]

Net income/ Net profit

The returns left after deducting all the expenditure such as fixed cost and variable cost from gross Revenue.

Net income = GR - TC

[Where, GR= Gross revenue, TC = Total cost]

Capital productivity or operating ratio

Capital productivity can be defined as the proportion of gross revenue that would cover the operating expenses.

$$\text{Capital productivity or Operating ratio} = \frac{\text{Operating costs}}{\text{Gross revenue}}$$

Labour productivity

Labour productivity is the average quantity of product generated per labour. It can be expressed as:

Labour productivity (kg/crew/trip) = Average catch (kg) / Average crew size

Fuel efficiency

Fuel efficiency (Kg/lit) = Average catch in kg/ Average fuel consumption

Fuel efficiency (Rs./lit) = Average catch value in rupees/ Average fuel consumption

Input–output ratio

Input-output ratio = Input costs / Gross revenue

Gross value added

Gross value added (GVA) = Net profit + Crew wages

GVA to GR (%)

(Gross Value added in rupees/ Gross revenue in rupees) x 100

3.5. Quality of selected commercially important fish species

In case of multi-day trawlers, fishes mixed with ice are kept in fish hold, whereas they are caught and marketed fresh by using minimum amount of ice by single- day trawlers.The value of fishes harvested by multi-day and single-day trawlers depends on the type of species, consumer demand and flesh quality and delicacy.

3.5.1. Raw material

Samples of fishes and shell fishes were collected from the single-day trawl landings on the day of its capture and brought to the laboratory. Selected species from different groups were washed and kept in ice to carry out further analysis on 5^{th}, 10^{th}, 15^{th} and 20^{th} day of post-storage biochemical, microbial and sensory changes. Same day catches from single-day trawl were used for 0^{th} day observation.

3.5.2. Chemicals and glassware

All chemicals used were of analytical grade and obtained from Sigma Aldrich, Merck, Hi-Media and Qualigens. The glass wares manufactured by Borosil were used for the study.

3.5.3. Instruments used

Weighing balance for measuring tissue sample, chemical and medias, mortar and pestle for homogeniser, Digital pH meter (Eutech tutor pH/˚C meter , Autoclave (Mediquip) for sterilising the glass wares, media and broth, Laminar air flow (Don Whitley Scientific Equipment Pvt. Ltd.) for microbiology work, Bacteriological incubator (Sunbim India) used for incubation.

3.5.4. pH measurement

10 g of meat was homogenised with 50 ml of distilled water in the mortar and pestle for 10 minutes and pH value of fish homogenate was measured by digital pH meter (Eutech tutor pH/ºC meter, Eutech Instruments, Singapore) standardized earlier by buffers at pH 4.8 and 9.2.

3.5.5. Determination of total volatile base nitrogen (TVB-N)

The total volatile base nitrogen (TVB-N) was determined based on an adaptation of the current official European steam-distillation method (EU-EC, 2008). 10 g of flesh was weighed and blended with 20 ml of 7.5% TCA in a mortar. Then the blend was filtered through Whatman no.1 filter paper to obtain a clear extract. The extraction process was repeated twice or thrice to make up the volume to 100 ml (TCA extract). Then the 25 ml of extract was pipetted into the distillation tube and 6 ml of 10% NaOH was added to it. The distillation was carried out, and at the end, the distillate was collected in a flask containing 15 ml of 4% boric acid and a few drops of Tashiro’s indicator. The steam distillation procedure was continued until

100 ml of distillate had been collected. The obtained basic solution was titrated against 0.025N to the endpoint indicated by a green to pink color change. TVB-N is calculated using the formula:

$$\text{TVB-N (mg N/100 g)} = \frac{\text{Tv x N x 14 x V1 x 100}}{\text{V2 x W}}$$

Where,

Tv= Titre value

N= Normality of acid used for titration

V1= Total volume of TCA extract

V2= Volume of TCA extract taken for distillation

W= Weight of the sample

3.5.6. Determination of trimethylamine (TMA)

The trimethylamine (TMA) was determined based on an adaptation of the current official European steam-distillation method (EU-EC, 2008). 10g of flesh was weighed and blended with 20 ml of 7.5% TCA in a mortar. Then the blend was filtered through Whatman no.1 filter paper to obtain a clear extract. The extraction process was repeated twice or thrice to make up the volume to 100 ml (TCA extract). Then the 25 ml of extract was pipetted into the distillation tube and 6ml of 10% NaOH was added along with 20 ml of 35% formaldehyde. The distillation was carried out, and at the end, the distillate was collected in a flask containing 15ml of 4% boric acid and a few drops of Tashiro's indicator. The steam distillation procedure was continued until 100ml of distillate had been collected. The obtained basic solution was titrated against 0.025N H_2SO_4 to the endpoint indicated by a green to pink color change.

TMA is calculated using the formula:

$$\text{TMA (mg N/ 100g)} = \frac{\text{Tv x N x 14 x V1 x 100}}{\text{V2 x W}}$$

Where,

Tv = Titre value

N = Normality of acid used for titration, V1= Total volume of TCA extract

V2= Volume of TCA extract taken for distillation, W= Weight of the sample

3.5.7. Total plate count (TPC)

TPC enumerates viable cells or microorganism in food sample that can form visible colonies under incubation conditions. The entire samples were labeled and immediately transferred to microbiological laboratory in insulated box at a temperature below 4˚C. Serial dilution was performed for all the samples and total plate count (Nutrient agar medium) measured according to US Food and Drug Administration, (Bacteriological analytical manual, 1998) and 0.1 ml of inoculum from different dilutions of samples was plated onto pre-set media plates in duplicate and spread using a sterile glass rod. The plates were incubated at 37˚C for 24 hrs after which colony forming units (CFUs) were counted.

3.5.8. Sensory evaluation

The sensory evaluation for overall acceptability of the selected fish sample was done by trained panel members which included staff and students from Post- harvest Technology department, ICAR-CIFE (n=10) and ICAR-CMFRI using 9-point hedonic scales with 1 being the lowest and 9 being the highest score and 5 was taken as the border of acceptability. The attributes were appearance, colour, odour, texture and overall acceptability.

Analysis of variance (ANOVA) was carried out and the significant difference among the treatments were determined by Tukeys HSD. The level of significance was set up at $p \leq 0.05$. All the above experiments were carried out in triplicates and the results were expressed as a Mean ± Standard deviation.

Results

4. RESULTS

4.1. Catch composition and characteristics of trawl fishery

4.1.1. Characteristics of fishing activities

Gujarat is bestowed with 1600 km long coast line adjacent to Arabian Sea and spread over 12 districts. According to the Marine Fisheries Census report 2010 by ICAR-CMFRI and DAHD&F (2010), in all, 62, 231 fishermen families' reside in 247 fishing villages of the state depending upon fishing and fishery allied activities. The state has 121 fish landing centres with the highest number in Kutch and Valsad districts but the major fishing harbors are located in Junagarh and Porbandar districts. Among 28,400 fishing crafts operated in the state 11,582 are trawlers. Highest number of trawlers operate from Junagarh district (8215) followed by Porbandar district (2426) and together they comprised 92% of the total trawlers of the state.

The trawl fishery industry of the state is mostly concentrated at three major landing centres i.e. Veraval, Mangrol and Porbandar. The single-day and multi-day trawlers are the two major categories of trawlers operating from these centres. All these centres are equipped with berthing facilities, ice, drinking water, fuel, auction halls and docking yards.

4.1.1.1. Specifications of fishing craft

Single-day trawlers operating in Gujarat usually have an overall length of 12-14 m and 1.8-3.0 m width whereas multi-day trawlers have an overall length of 14-18.2 m and 2.4-4.5 m width. Wood is used as the primary material for construction of both types of boats and are fitted with 88-99 hp engine and 100-400 hp engine in single-day and multi-day trawler respectively. The fish hold capacity of trawlers depends upon the size of boat and duration of trips. Multi-day trawlers have wide range of fish hold capacity and voyage duration extends up to 21 days per trip. The particulars and specification of both types of trawlers are depicted in **Table. 4.1.1.1**

Table 4.1.1.1 Particulars and specification of trawlers operated from Gujarat.

Particulars	Single-day Trawlers	Multi-day Trawlers
Overall length (m)	12.0-14.0	14-18.2
Width (m)	1.8-3.0	2.4-4.5
Materials used	wood	Wood
Engine power (hp)	88 -99	100-400
Number of engine cylinders	6	8
Fish hold capacity (kg)	1000-4000	4000-12000
Crew size (numbers)	5	7
Endurance	Single day	Up to 21 days
Navigational and other equipment	Magnetic compass, GPS, Mobile, Wireless	Echo-sounder, SONAR, Magnetic Compass, VHF, GPS, Mobile

4.1.1.2. Specifications of fishing gear

Trawlers operating from Gujarat mostly target 3 major groups of resources i.e. ribbon fishes, shrimps and cephalopods. Based on these three primary target groups, fishing gear were designed and operated as per abundance of the resources. A single-day trawler generally carries 5-10 nets (2-4 shrimp nets& 3-6 ribbonfish nets) during a fishing trip. However, the cephalopod net is also used seasonally depending on the resource abundance. The multi-day trawler carries 10-22 nets (2-4 shrimp nets, 5-8 ribbonfish nets & 5-10 cephalopod nets) during a trip. The cod end mesh size for shrimp trawl ranges from 10-20mm where as for ribbonfish trawl, it is 20-30 mm and for cephalopod, it goes up to 40 mm. Two types of netting materials are used in all the nets i.e. net made up of PA (Polyamide) & PP (Polypropylene) and HDPE (High density polyethylene) & PP for construction. For maintaining the horizontal opening of the net, two types of otter boards are used i.e. flat rectangular & V shaped. Vertical opening is attained by means of sinkers at the footrope and floats at the head rope as per the requirement and depth of operation. Tickler chains are used in shrimp trawl for increasing the catching efficiency of the net. The details of the gear are given in **Table 4.1.1.2**

Table 4.1.1.2. Specification and particulars of fishing gears used for trawling in Gujarat

Description	Single-day Trawler		Multi-day Trawler		
	Shrimp net	**Ribbonfish net**	**Shrimp net**	**Ribbonfish net**	**Cephalopod net**
No of nets carried	2-4	3-6	2-4	5-8	5-10
Length of Head rope (m)	18-30	18-25	18-25	25-30	25-30
Mesh size (mm)	10-20	20-25	10-20	20-30	20-40
Netting material	PA & PP	PA, PP & HDPE	PA & PP	PA &PP	PP, PA & HDPE
Warp material	10mm wire rope	10mm wire rope	10-12 mm wire rope	10-12 mm wire rope	10-12 mm wire rope
Sinker material	Cast Iron Chain	Cast Iron Chain	Cast Iron Chain	Cast Iron Chain	Cast Iron Chain
Float material	ABS	ABS	ABS	ABS	ABS
Otter board	Flat rectangular		Flat rectangular & V shaped		

HDPE: high density polyethylene, PA: polyamide, PP: Polypropylene, ABS: acrylonitrile butadiene styrene

Plate 4.1.1.1 (a) Trawlers at Veraval Fishing Harbour during monsoon fishing ban

Plate 4.1.1.1 (b) Multi-day trawler under construction at Veraval, Gujarat

4.1.1.3. Extent of fishing operations

The analysis of data collected from selected sampling locations, to assess the spatial distribution of trawl catch, revealed that the fishing grounds of multi-day trawlers extend from 30 m to 200 m depth depending on the resource availability and nature of species targeted. They extend from the border of north-western territorial waters up to the coast of Mangalore (**Fig. 4.1.1.3. (a)**). The maximum spread of fishing grounds from the coastline was observed off Gulf of Khambhat and adjacent to Mumbai waters. The single-day trawlers mainly operated in the near-shore waters up to a depth of 40 m (**Fig. 4.1.1.3. (b)**). A single-day trawler takes 2 to 3 hauls (total 6-8 hours) in a trip/ day but a multi-day trawler usually takes 3 hauls (total 9 hours) per day.

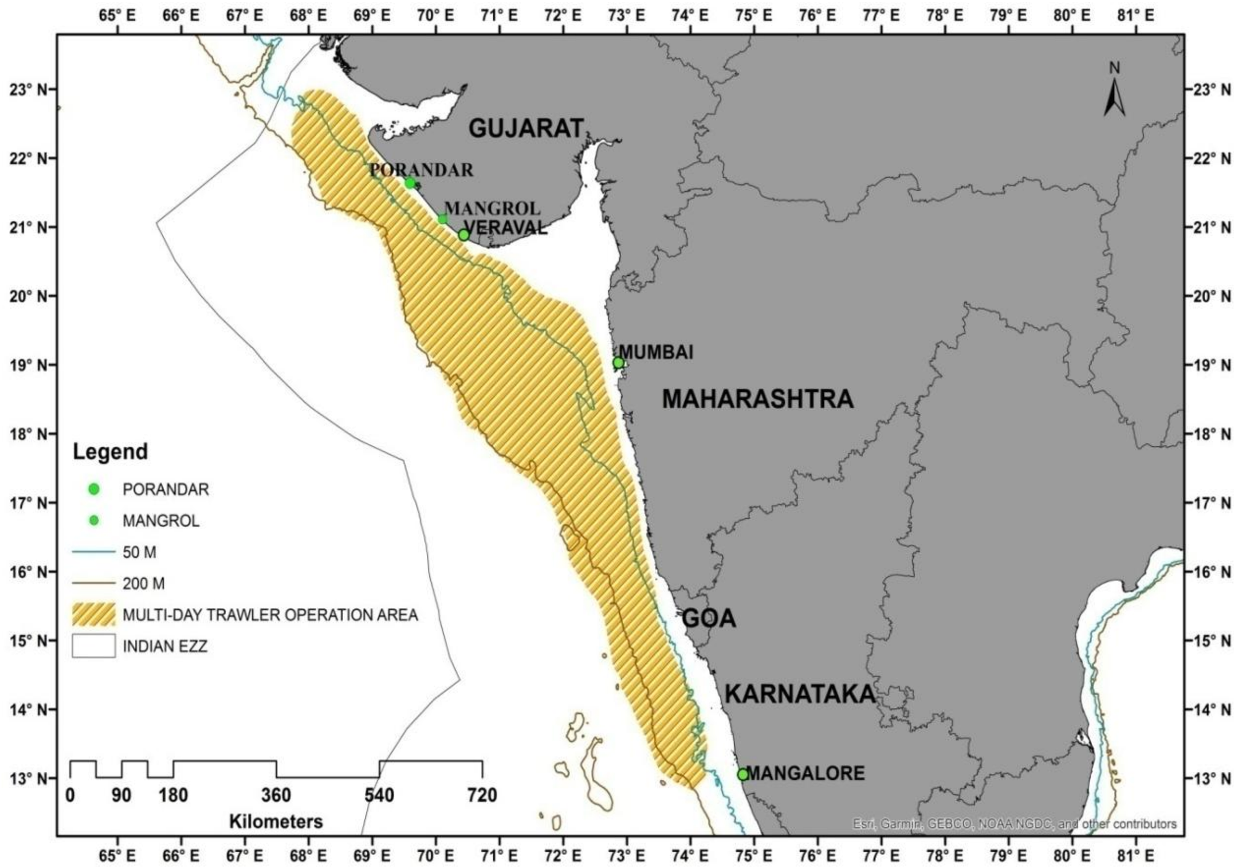


Fig. 4.1.1.3. (a) Fishing areas of multi-day trawlers operating off Gujarat coast

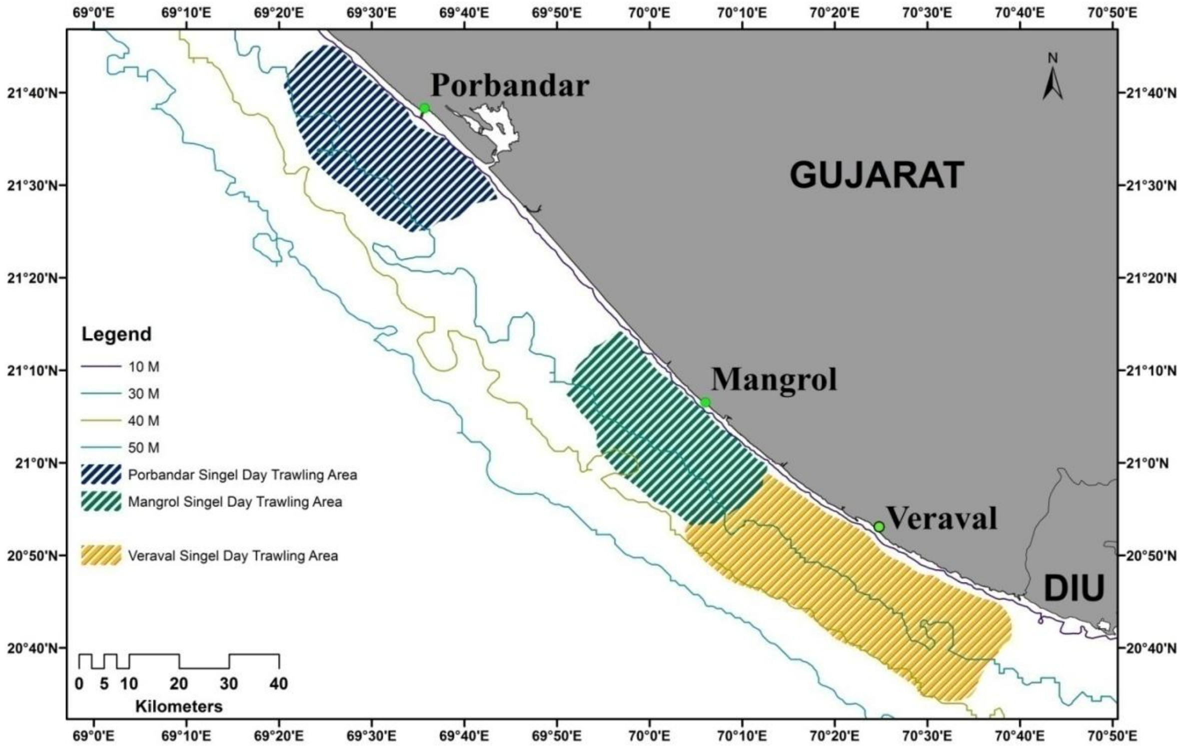


Fig. 4.1.1.3. (b) Fishing areas of single-day trawlers operating off Gujarat coast

4.1.2. Trawl fishery resources of Gujarat coast

Month wise catch of selected trawl resources of multi-day and single-day trawl are given in Fig. 4.1.2 (a) and Fig. 4.1.2 (b) respectively.

4.1.2.1. List of commercially important species recorded in trawl catch off Gujarat coast

The single-day trawler generally lands the entire catch (except the dangerous and venomous organisms, protected species, and species or organisms having no value at all) at the landing centre. Sorting of the catch is done in a multi-day trawler according to their value and market demand and fish are preserved in ice and stored in the fish-hold. The commercially important species recorded from both types of trawls are listed in **Table 4.1.2.1**

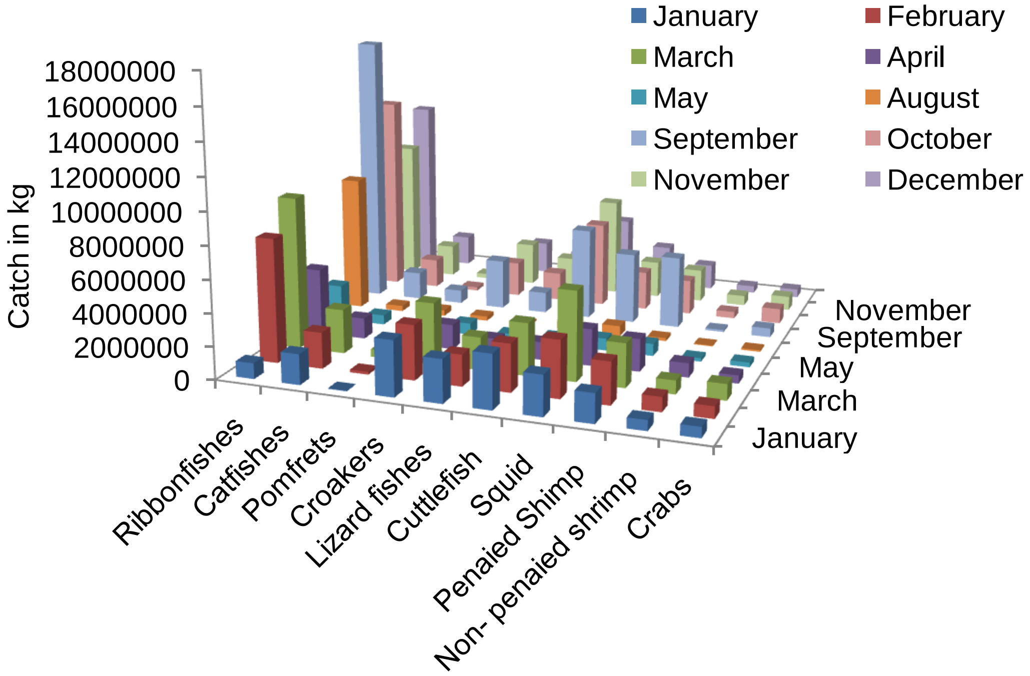


Fig. 4.1.2 (a) Month-wise catch of selected multi-day trawl resources of Gujarat in 2017

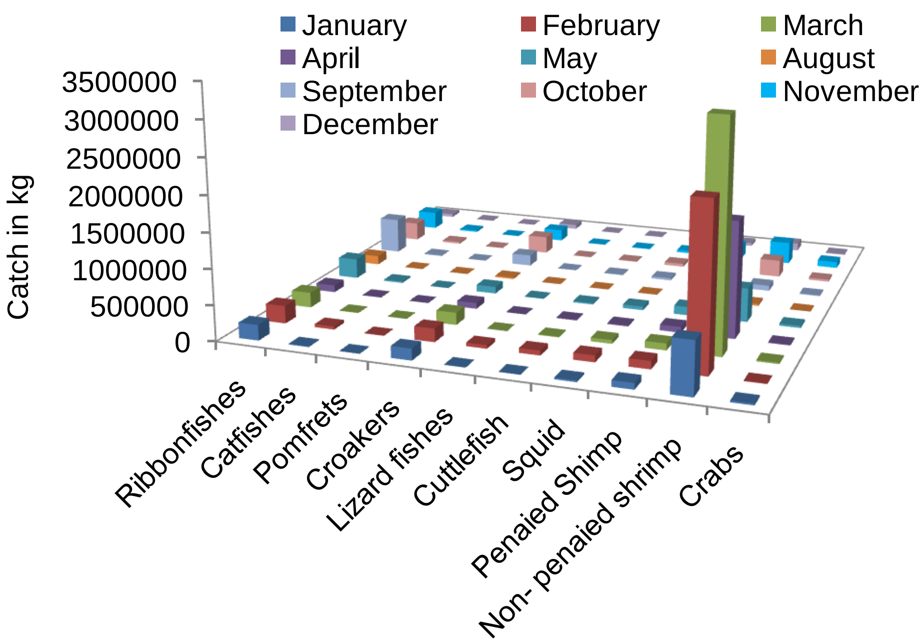


Fig. 4.1.2 (b) Month-wise catch of selected single-day trawl resources of Gujarat in 2017

Table 4.1.2.1 List of commercially important species recorded in both types of trawl catch off Gujarat coast

Order	Family	Scientific name	Common name
Perciformes	Trichiuridae	*Trichiurus lepturus* (Linnaeus, 1758)	Large-head hairtail
		Lepturacanthus savala (Cuvier, 1829)	Savalai hairtail
		Eupleurogrammus muticus (Gray, 1831)	Small-head hairtail
	Stromateidae	*Pampus argenteus* (Euphrasen, 1788)	Silver pomfret
		Pampus chinensis (Euphrasen, 1788)	Chinese silver pomfret
	Carangidae	*Parastromateus niger* (Bloch, 1795)	Black pomfret
	Priacanthidae	*Priacanthus hamrur* (Forsskål, 1775)	Moon-tail bulls eye
	Nemipteridae	*Nemipterus japonicus* (Bloch, 1791)	Japanese threadfin bream
		Nemipterus mesoprion (Bleeker, 1853)	Mauve-lip threadfin bream
		Nemipterus randalli Russell, 1986	Randall's threadfin bream
	Sciaenidae	*Otolithoides biauritus* (Cantor, 1849)	Bronze croaker
		Protonibea diacanthus (Lacepède, 1802)	Black-spotted croaker
		Nibea maculata (Bloch & Schneider, 1801)	Blotched croaker

		Otolithes ruber (Bloch & Schneider, 1801)	Tiger-tooth croaker
		Otolithes cuvieri Trewavas,1974	Lesser tiger-tooth croaker
		Johnius carutta Bloch, 1793	Karut croaker
		Johnius spp.	Croaker
	Lutjanidae	*Lutjanus johnii* (Bloch, 1792)	John's snapper
		Lutjanus sp.	Snapper
Siluriformes	Ariidae	*Nemapteryx caelata* (Valenciennes, 1840)	Engraved catfish
		Arius arius (Hamilton, 1822)	Threadfin sea catfish
		Arius maculatus (Thunberg, 1792)	Spotted catfish
		Netuma bilineata (Valenciennes, 1840)	Bronze catfish
		Netuma thalassina (Rüppell, 1837)	Giant catfish
		Osteogeneiosus militaris (Linnaeus, 1758)	Soldier catfish
		Plicofollis dussumieri (Valenciennes, 1840)	Black-tip sea catfish
Carcharhiniformes	Carcharhinidae	*Scoliodon laticaudus* Müller& Henle, 1838	Spade-nose shark
		Carcharhinus leucas (Müller & Henle, 1839)	Bull shark
	Sphyrnidae	*Sphyrna* sp.	Hammer-head
	Triakidae	*Mustelus mosis* Hemprich& Ehrenberg, 1899	Arabian smooth-hound
Squaliformes	Centrophoridae	*Centrophorus moluccensis* Bleeker, 1860	Small-fin gulper shark

Myliobatiformes	Dasyatidae	*Himantura sp.*	Stingrays
		Dasyatis sp.	Stingrays
	Mylobatidae	*Mobula* sp.	Eagle and manta rays
Sepioidea	Sepiidae	*Sepia pharaonis* Ehrenberg, 1831	Pharaoh cuttlefish
		Sepia aculeata Van Hasselt, 1835	Needle cuttlefish
		Sepia elliptica Hoyle, 1885	Oval-bone cuttlefish
		Sepia omani Adam & Rees, 1966	Oman cuttlefish
		Sepia kobiensis Hoyle, 1885	Kobi cuttlefish
		Sepiella inermis (Van Hasselt, 1835)	Spineless cuttlefish
Myopsida	Loliginidae	*Uroteuthis (Photololigo) duvaucelii* (D'Orbigny, 1835)	Indian squid
		Uroteuthis (Photololigo) singhalensis (Ortmann, 1891)	Long-barrel squid
Decapoda	Portunidae	*Portunus pelagicus* (Linnaeus, 1758)	Blue swimming crab
		Portunus sanguinolentus (Herbst, 1783)	Three-spot swimming crab
		Charybdis feriatus (Linnaeus, 1758)	Crucifix crab
	Plaemonidae	*Nematopalaemon tenuipes* (Henderson, 1893)	Spider prawn
	Hippolytidae	*Exhippolysmata ensirostris* (Kemp, 1914)	Hunter shrimp

	Solenoceridae	*Solenocera crassicornis* (Milne-Edwards, 1837)	Udangmerah
	Penaeidae	*Metapenaeus affinis* (Milne-Edwards, 1837)	Jinga shrimp
		Parapenaeopsis stylifera (Milne- Edwards, 1837)	Kiddi shrimp
		Parapenaeopsis sculptilis (Heller, 1862)	Rainbow shrimp
		Metapenaeus monoceros (Fabricius, 1798)	Speckled shrimp
		Penaeus semisulcatus de Haan, 1844	Green tiger prawn
		Metapenaeus kutchensis George, George & Rao, 1963	Ginger shrimp
		Fenneropenaeus merguiensis De Man, 1888	Banana shrimp
		Metapenaeus brevicornis (Milne-Edwards, 1837)	Yellow shrimp
		Penaeus monodon Fabricius, 1798	Giant tiger prawn
		Penaeus penicillatus Alcock, 1905	Redtail prawn
		Parapenaeopsis hardwickii (Miers, 1878)	Spear shrimp
		Fenneropenaeus indicus Milne Edwards, 1837	Indian white shrimp
		Penaeus japonicus (Bate, 1888)	Kuruma shrimp

Landings of Ribbon Fishes at Veraval

Landings of Black pomfret at Veraval

Landings of Crabs at Veraval

Landings of Cephalopods at Veraval

Landings of Silver Pomfret at Veraval

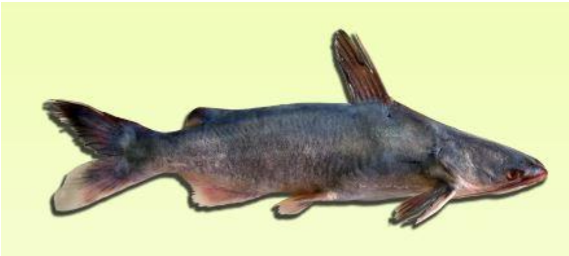
Landings of Bulls eye at Veraval

Plate 4.1.2.1 (a) Landings of selected commercial fish groups in Veraval, Gujarat

Scoliodon laticaudus

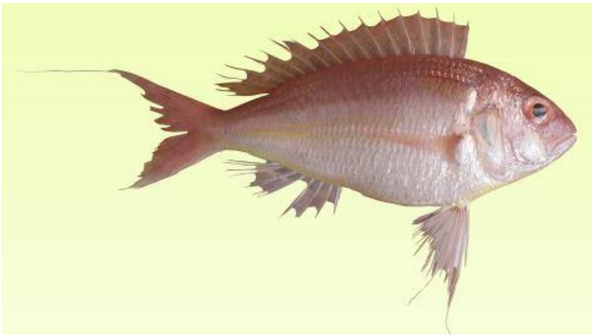
Tenualosa ilisha

Trichiurus lepturus



Osteogeneiosus militaris

Priacanthus hamrur



N. japonicus

Plate 4.1.2.1 (b) Selected Fin fish species landed in Trawls of Veraval, Gujarat

Portunus pelagicus

Portunus sanguinolentus

Charybdis feriata

Charybdis lucifera

Plate 4.1.2.1 (c) Selected Crab species landed in Trawls of Veraval, Gujarat

Fenneropenaeus indicus

Penaeus monodon

Parapenaeopsis stylifera

Fenneropenaeus merguiensis

Solenocera crassicornis

Metapenaeus affinis

Plate 4.1.2.1 (d) Selected Shrimp species landed in Trawls of Veraval, Gujarat

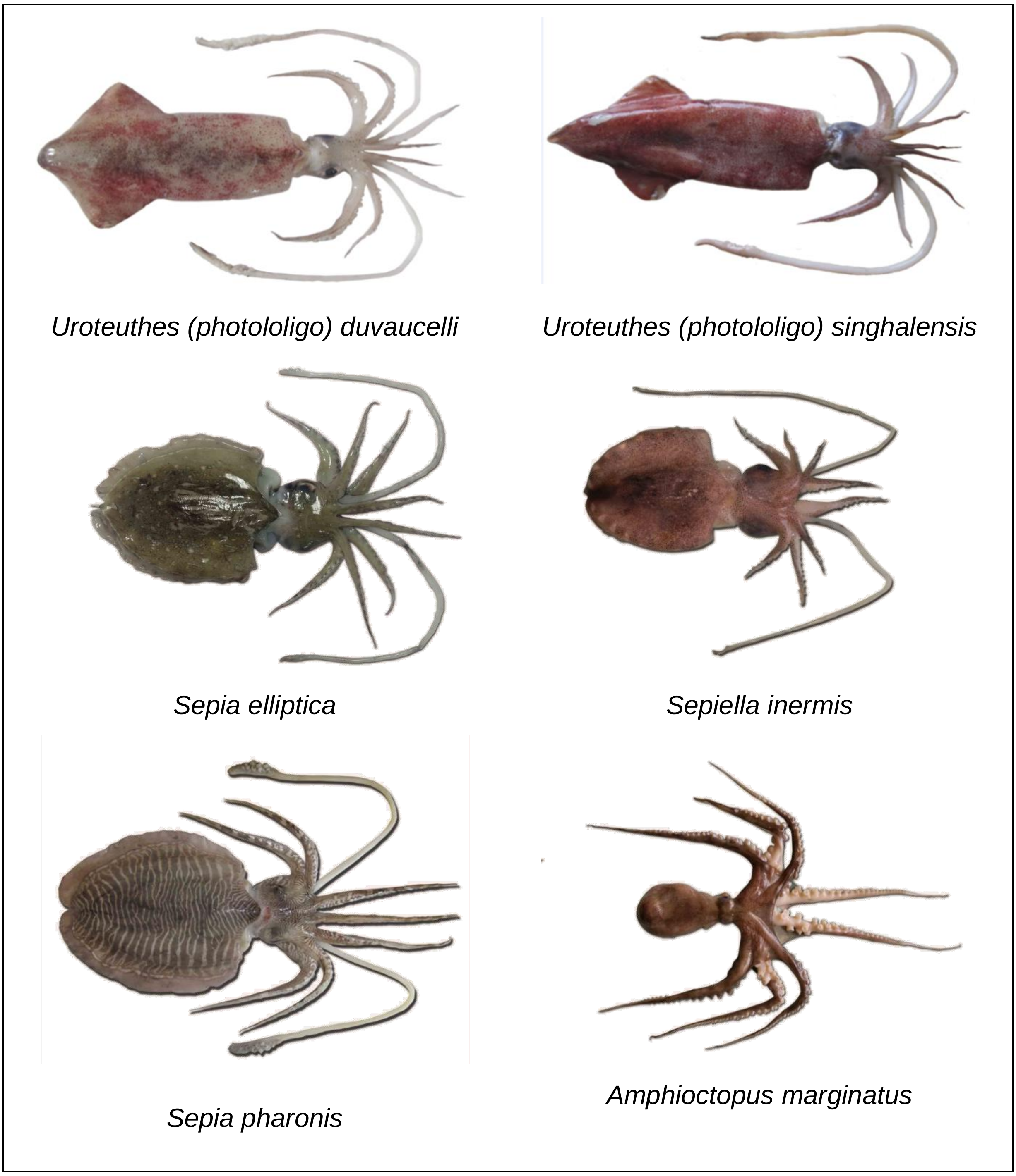


Plate 4.1.2.1 (e) Selected Cephalopod species landed in Trawls of Veraval, Gujarat

4.1.2.2. Low-value bycatch (LVB) recorded in trawl catch off Gujarat coast

The low-value bycatch occurred from both single-day and multi-day trawlers. These resources mostly comprise of small size fishes, juveniles of valued fishes, non-preferred fishes, fishes with low freshness quality etc. which do not fetch good price and mostly used for drying and fish meal preparation. Occasionally, the fresh LVB are sold in the local markets for local consumption at a marginal price. Multi-day trawlers hardly pay attention towards this portion of the catch.

The annual Overall catch from both single-day and multi-day trawlers were analyzed and showed in **Fig. 4.1.2.2 (a & b)**. It was found that discards forms 9% in multi-day trawl catch and 5% in single-day trawl catch. In case of multi-day trawl low value bycatch (LVB) shared 23% of overall catch whereas it was only 9% in case of single-day trawl. The list of species recorded under the LVB is given in **Table 4.1.2.2**.

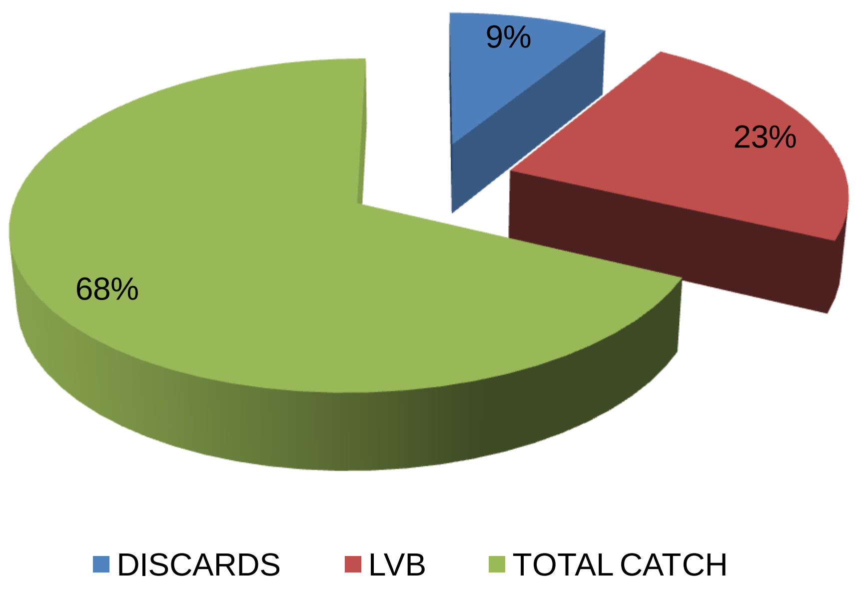


Fig. 4.1.2.2 (a) Annual percentage contribution of total catch, low-value bycatch and discards to overall catch of multi-day Trawler

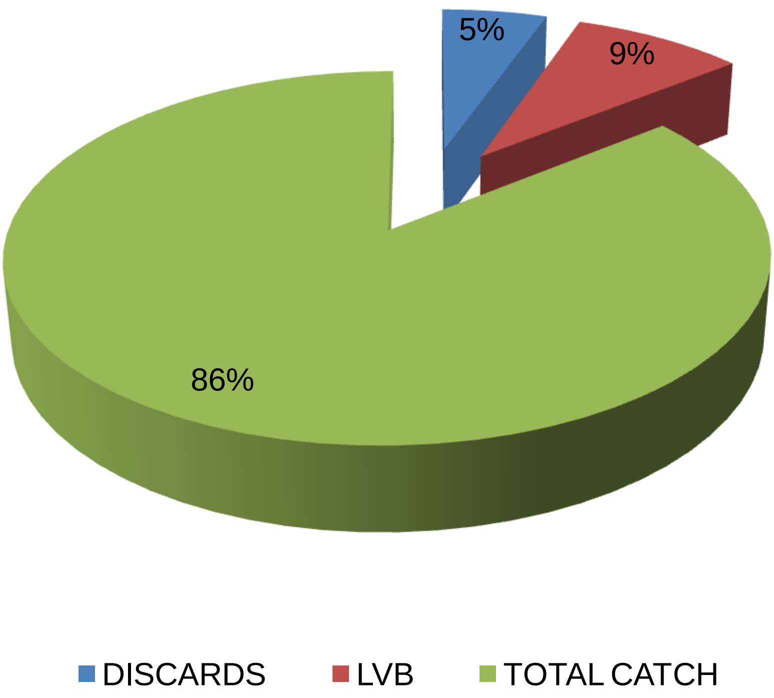


Fig. 4.1.2.2 (b) Annual percentage contribution of total catch, low-value bycatch and discards to overall catch of single-day trawler

Plate 4.1.2.2 (a) Low-value bycatch landed from multi-day trawlers of Veraval, Gujarat

Table 4.1.2.2 List of LVB species recorded in trawl catch off Gujarat coast

Order	Family	Scientific name	Common name
Aulopiformes	Synodontidae	*Saurida tumbil* (Bloch, 1795)	Greater lizard fish
		Saurida undosquamis (Richardson, 1848)	Brush-tooth lizard fish
		Harpadon nehereus (Hamilton, 1822)	Bombay-duck
Perciformes	Mullidae	*Upeneus* sp.	Goatfish
	Gobiidae	*Trypauchen vagina* (Bloch & Schneider, 1801)	Gobies
	Echeneidae	*Remora remora* (Linnaeus, 1758)	Shark sucker
	Ariommatidae	*Ariomma indicum* (Day, 1871)	Indian drift-fish
	Apogonidae	*Apogon* sp.	Cardinal fishes
		Halapogon sp.	
	Scatophagidae	*Scatophagus argus* (Linnaeus, 1766)	Spotted scat
	Carangidae	*Alepes kleinii* (Bloch, 1793)	Razor scad
		Alepesd jedaba (Forsskål, 1775)	Shrimp scad
		Decapterus russelli (Rüppell, 1830)	Indian scad
		Selar crumenophthalmus (Bloch, 1793)	Big eye scad
		Uraspis helvola (Forster, 1801)	White-tongue jack
		Uraspis uraspis (Günther, 1860)	White -mouth jack
		Seriolina nigrofasciata (Rüppell, 1829)	Black-banded trevally
		Selar boops (Cuvier, 1833)	Ox eye scad
Clupeiformes	Engraulidae	*Thryssa mystax* (Bloch & Schneider, 1801)	Moustached thryssa

		Thryssa dussumieri (Valenciennes, 1848)	Dussumier's thryssa
		Thryssa malabarica (Bloch, 1795)	Malabar thryssa
		Thryssa setirostris (Broussonet, 1782)	Long jaw thryssa
		Coilia dussumieri Valenciennes, 1848	Golden Anchovy
Tetraodontiformes	Tetraodontidae	*Arothron* sp. *Tetradon* sp.	Puffer fishes
	Monacanthidae	*Aluterus monoceros* (Linnaeus, 1758)	Unicorn leather jacket
Stomatopoda	Squillidae	*Oratosquilla* sp.	Mantis shrimp
Decapoda	Sergestidae	*Acetes indicus* Milne-Edwards, 1830	Jawla paste shrimp
	Poutunidae	*Portunus* sp.	crab
		Charybdis sp.	crab
Pleuronectiformes	Cynoglossidae	*Cynoglossus arel* (Bloch & Schneider, 1801)	Large-scale tongue sole
		Cynoglossus macrostomus Norman, 1928	Malabar tongue sole
		Cynoglossus sp.	Tongue sole
Scorpaeniformes	Platycephalidae	*Platycephalus* sp.	Sand flat heads

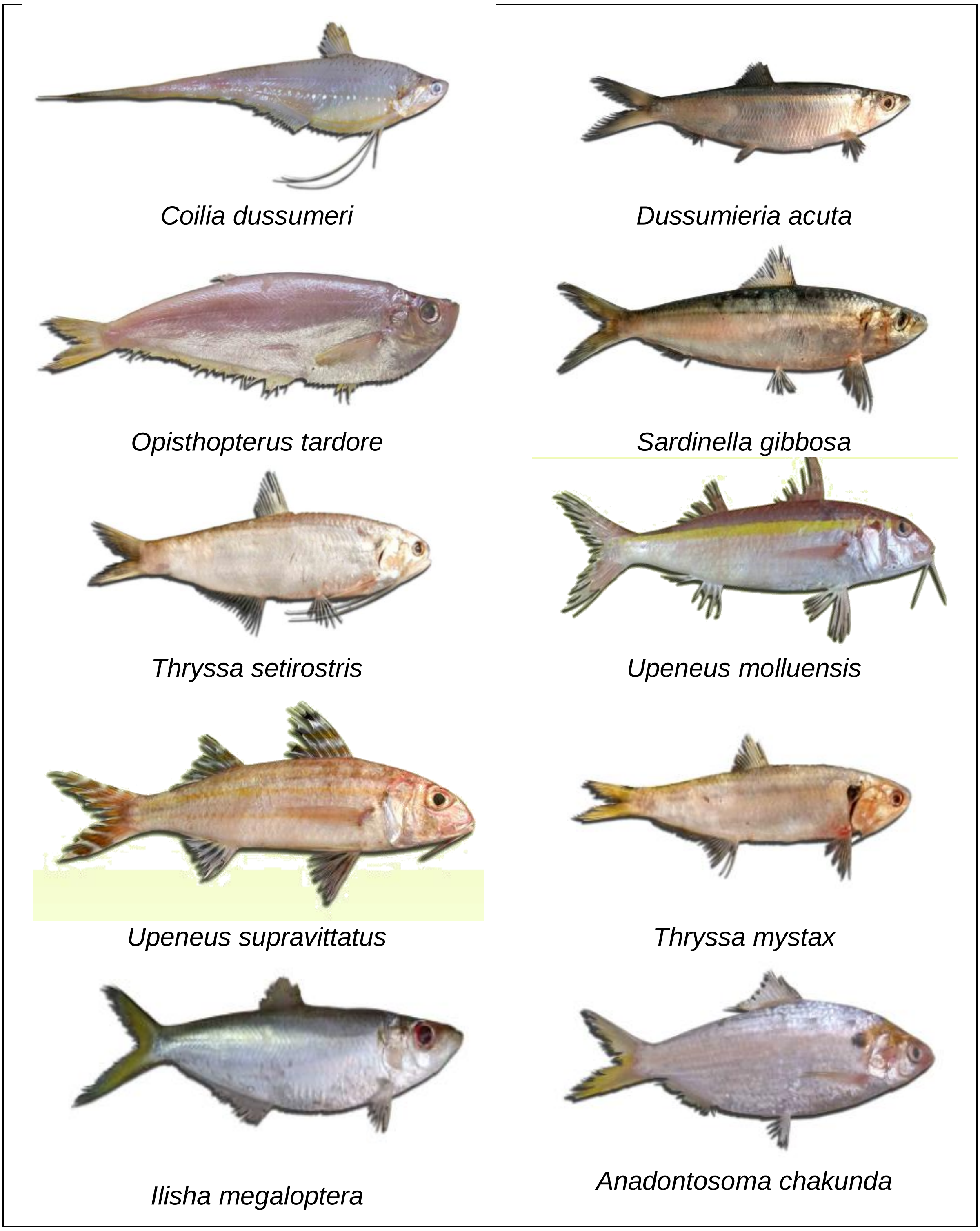


Plate 4.1.2.2 (b) Selected Low-value species landed in trawls of Veraval, Gujarat

4.1.3. Spatio-temporal distribution of catch, low-value bycatch and discards from mechanized trawls of Gujarat

The total catch of multi-day trawlers varied from 118 to 365 kg per day with maximum abundance of resources exploited from the waters off Maharashtra, Goa and Mangalore between depth ranges of 50 to 200 m. Medium to high abundance of resources was recorded from the waters off Veraval and Porbandar and Okha up to 50m depth. The least abundant areas were recorded between 50 to 200 m off Gujarat coast and this could be the reason for which the multi-day trawls of Gujarat venture far towards south for trawling. The discard and bycatch ranged from lowest 15 and 14 kg per day to highest 69 and 200 kg per day respectively. The discard and low-value bycatch were also observed to follow similar pattern of abundance with highest values from the waters off Maharashtra, Goa and Mangalore between depth ranges of 50 m to 200 m while areas between 50 to 200 m along Gujarat coast recorded least abundance. The spatial distribution of catch, bycatch and discard of multi-day trawlers were depicted in **Fig. 4.1.3 (a)**

The total catch of single-day trawlers varied from 134 to 1084 kg per day with maximum abundance of resources between 30 and 40 m depth off Veraval coast. Some dispersed areas between 20 to 30 m and 30 to 40 m showed the lowest abundance of resources targeted by the single-day trawlers. The discard and bycatch ranged from lowest 13 and 20 kg per day to highest 81 and 121 kg per day respectively. The discard and bycatch also showed similar scattered pattern of abundance with lowest from 30m depth zone off Veraval. As the single-day trawler undertook voyage only for a day, the swept area is limited to a nominal distance around the fishing harbor. The spatial distribution of catch, bycatch and discard of single-day trawlers were depicted in **Fig. 4.1.3 (b)**

Highest CPUE (catch in kg per day) was observed during post-monsoon followed by winter and lowest during pre-monsoon season in multi-day trawl fishery. The CPUE was higher in offshore waters (100 to 200 m depth) during pre and post-monsoon while it was higher in comparatively shallower waters (up to 50 m depth) during winter. The abundance of resource was found to be less in the northern portion (along Gujarat coast) of north-west coast during post-monsoon which gradually shifted towards north through the winter and became abundant during pre-monsoon season. The southern portion of north-west coast (along Maharashtra coast) remained highly abundant during winter followed by post-monsoon but became less abundant during pre-monsoon season. The seasonal distribution of catch of multi-day trawlers were depicted in **Fig. 4.1.3 (c)**

Unlike total catch, higher abundance of bycatch (kg per day) was observed during winter season followed by post-monsoon in multi-day trawl fishery. However, the CPUE was lowest during pre-monsoon season. The CPUE was higher in offshore waters (100 to 200 m depth) during pre and post monsoon seasons while it was higher in comparatively shallower waters (up to 50 m depth) during winter.

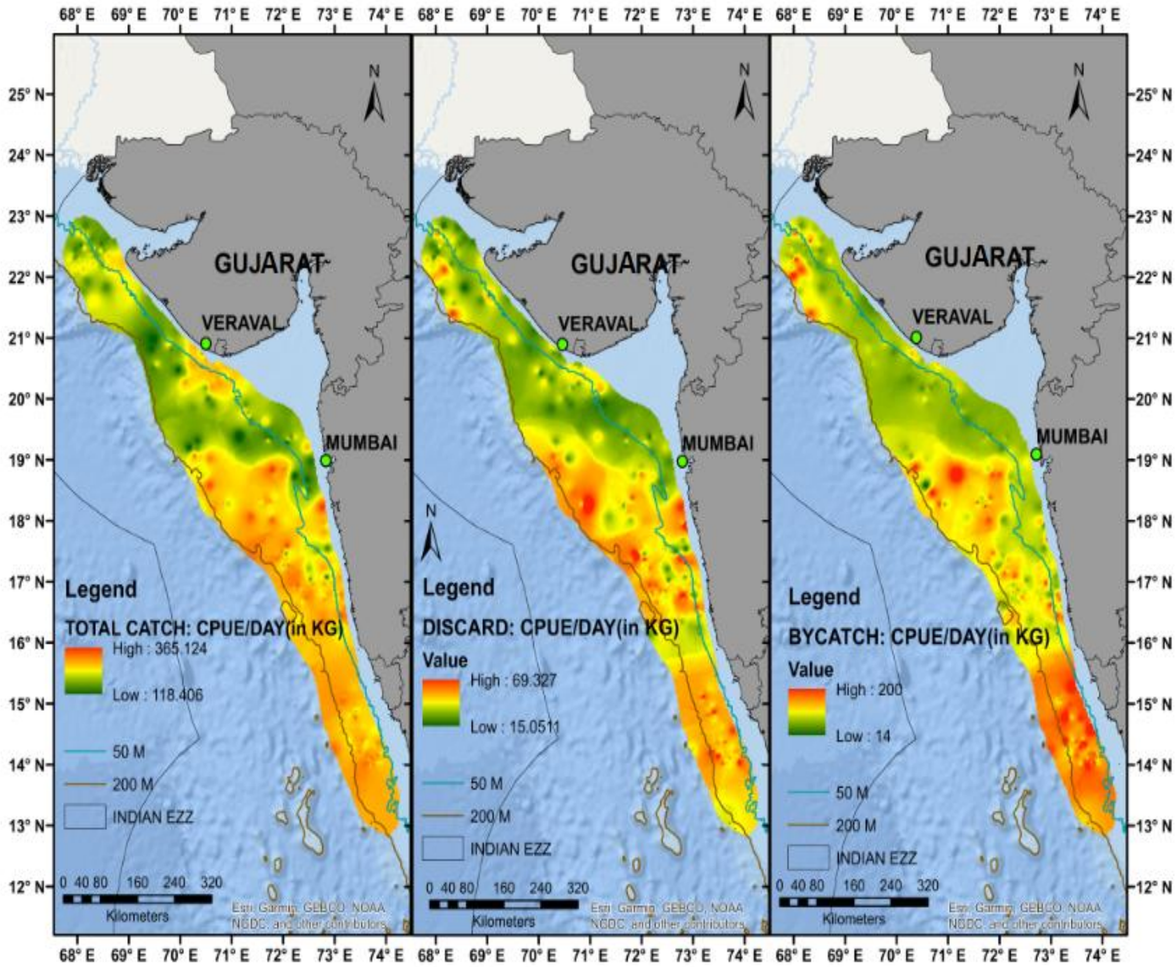


Fig. 4.1.3 (a) Spatial distribution of catch, LVB and discard of multi-day trawlers

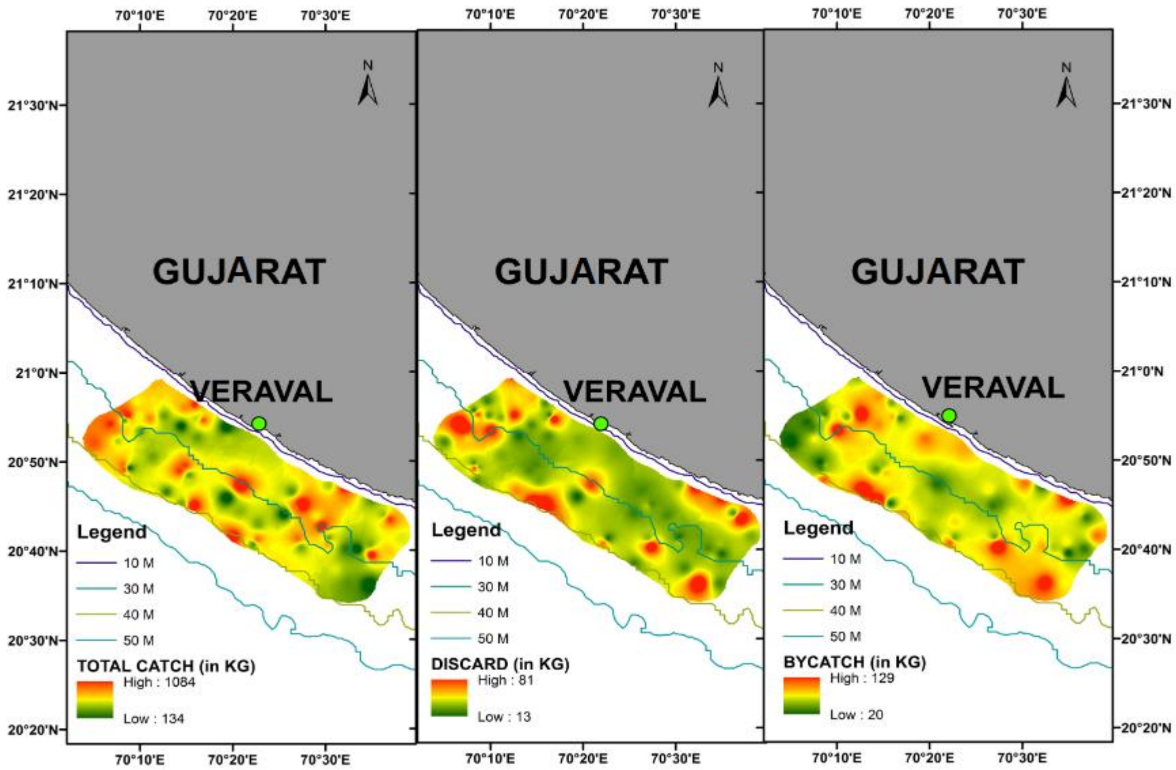


Fig. 4.1.3 (b) Spatial distribution of catch, LVB and discard of single-day trawlers

The abundance of bycatch was found to be less in the northern portion (along Gujarat coast) of north-west coast during winter which gradually shifted towards north through pre-monsoon and became abundant during post-monsoon season. The southern portion of north-west coast (along Maharashtra coast) recorded higher bycatch during pre-monsoon followed by post-monsoon but became less abundant during winter. This clearly indicates spatio-temporal changes in catch composition along north-west coast of India. Very high landings of bycatch was also recorded along Karnataka coast during winter which reduced during pre-monsoon but increased again during post monsoon. The seasonal distribution of bycatch of multi-day trawlers were depicted in **Fig. 4.1.3 (d)**

Analysis of discard from multi-day trawlers revealed that the quantity varied depending on the season and fishing ground. Highest concentration of discards was observed in the northern most trawling grounds off Gujarat during post-monsoon but reduced with the onset of winter and then again increased with the start of pre-monsoon period. CPUE of discards was relatively lesser in both pre and post-monsoon period but higher in winter along the southern part of the grounds off Maharashtra, Goa and Karnataka. The distribution of highest CPUE of discards mostly shifted from the coast towards offshore areas during pre-monsoon. However, it remained concentrated near the coast off Mumbai and Gujarat. This clearly implies that the target resources of multi-day trawl fishery are available off Maharashtra in post-monsoon which gradually shift towards off Gujarat in winter and then again shift southwards in pre-monsoon season. The seasonal distribution of discards of multi-day trawlers were depicted in **Fig. 4.1.3 (e)**

Highest CPUE was observed during pre-monsoon followed by winter and lowest during post-monsoon in single-day trawl fishery. The CPUE was higher in inshore waters (up to 30 m depth) during winter while it was higher in scattered fishing grounds both in shallower as well as relatively deeper waters (30 to 40 m depth) during pre and post monsoon. The abundance of resource was found to be more in the north-western (along Mangrol coast) and south-eastern regions (along Mul Dwarka coast) off Veraval during winter with a long and relatively lesser abundant region along Veraval coast separating the two regions. However, the CPUE from this low-abundance region along Veraval coast increased during pre-monsoon and gradually decreased during post-monsoon becoming less abundant in winter. The seasonal distribution of CPUE of single-day trawlers were depicted in **Fig.4.1.3 (f)**

Unlike total catch, higher abundance of bycatch was observed during winter followed by post-monsoon in single-day trawl fishery. The bycatch was lowest during pre-monsoon season. The CPUE was higher in deeper inshore waters (30 to 40 m depth) during winter and pre-monsoon while it was higher in comparatively shallower waters (up to 20 m depth) during post-monsoon. This could be due to the higher availability of newly recruited juveniles during post-monsoon in inshore waters. The seasonal distribution of bycatch of single-day trawlers were depicted in **Fig.4.1.3 (g)**

The discards from the single-day trawlers showed differential distribution with respect to the season and fishing ground. Discard was highest in pre-monsoon followed by winter and lowest in post-monsoon. The seasonal distribution of discards of single-day trawlers were depicted in **Fig.4.1.3 (h)**

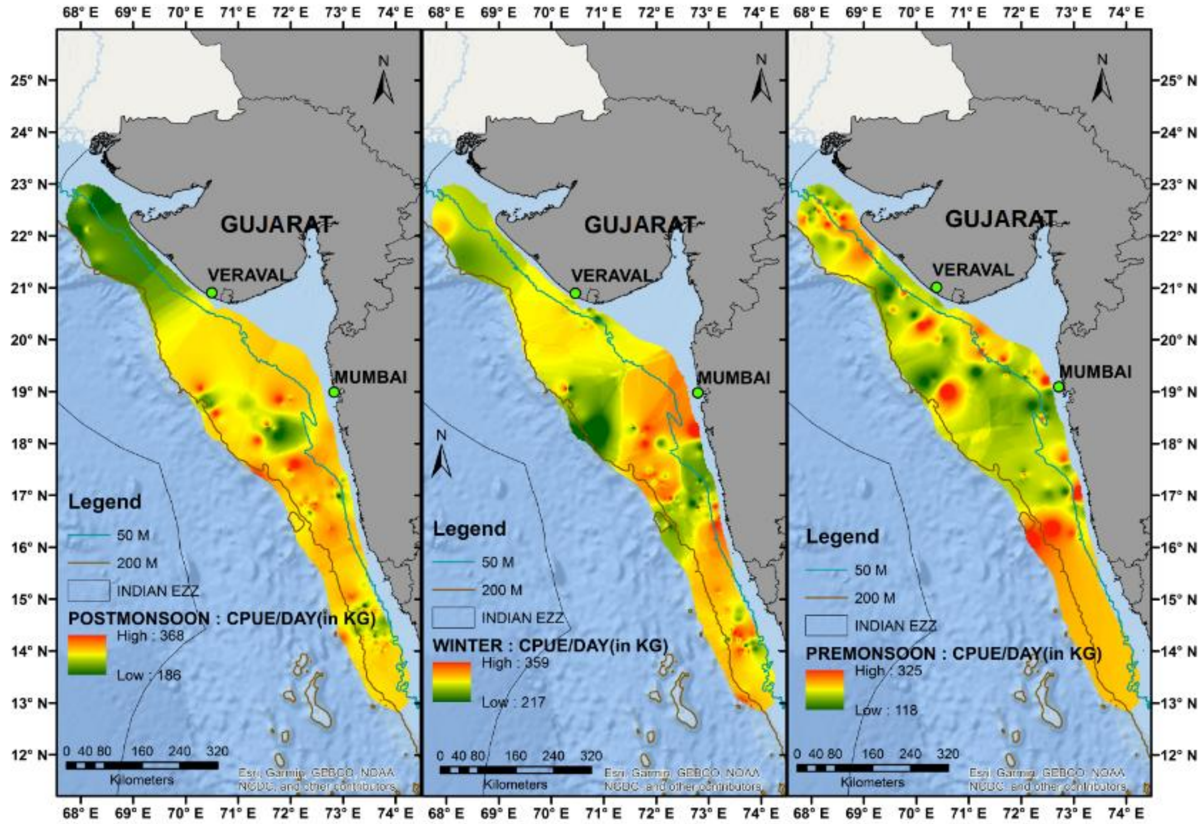


Fig. 4.1.3 (c) Seasonal variation of CPUE in multi-day trawlers

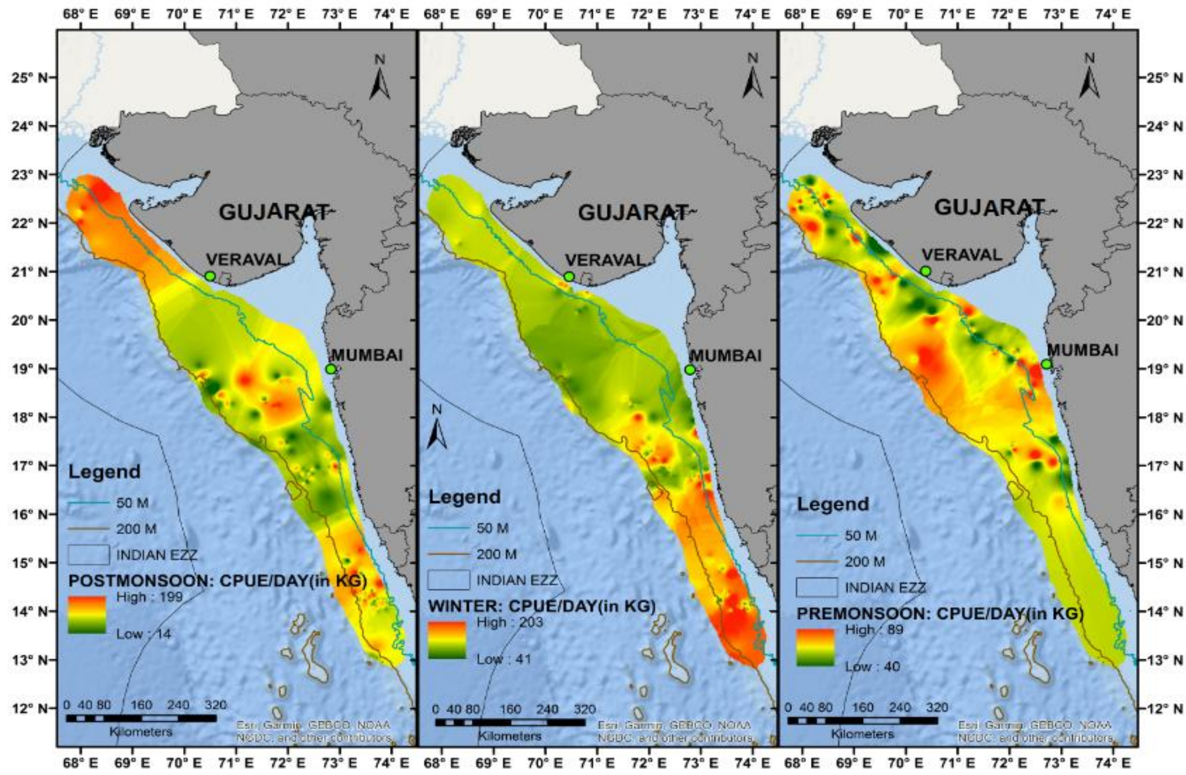


Fig. 4.1.3 (d) Seasonal variation of Low-value bycatch in multi-day trawlers

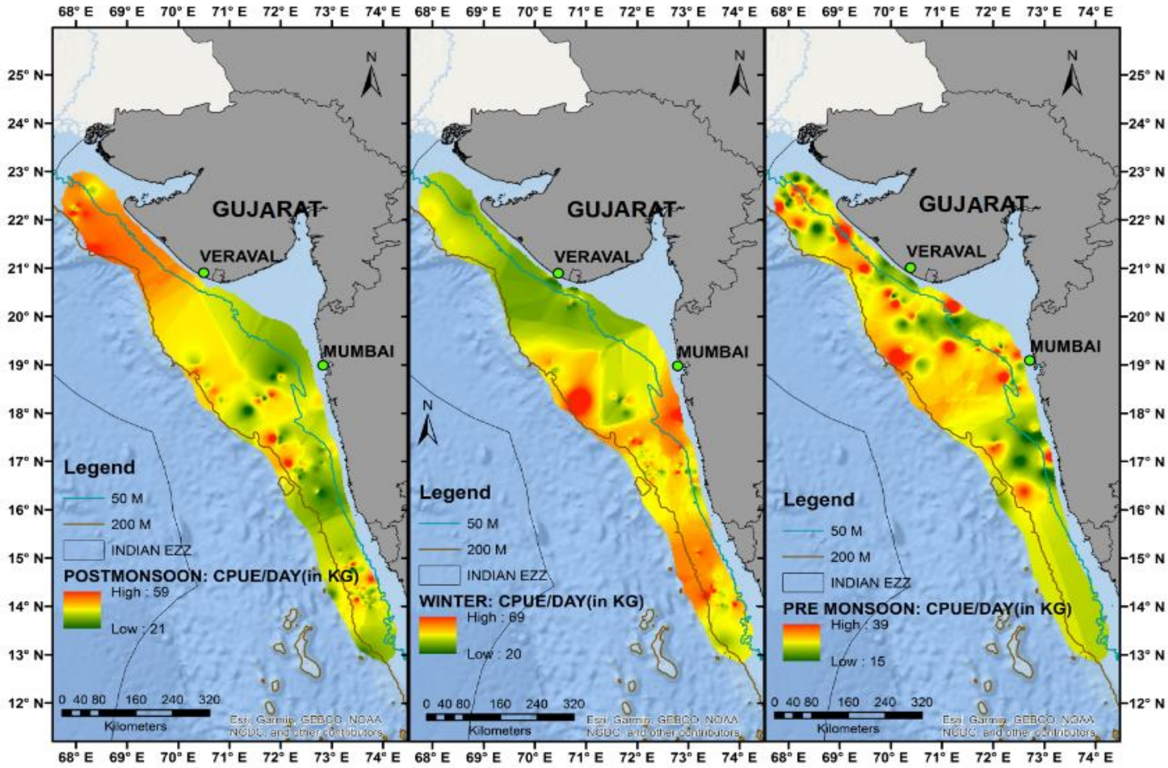


Fig. 4.1.3 (e) Seasonal variation of discard in multi-day trawlers

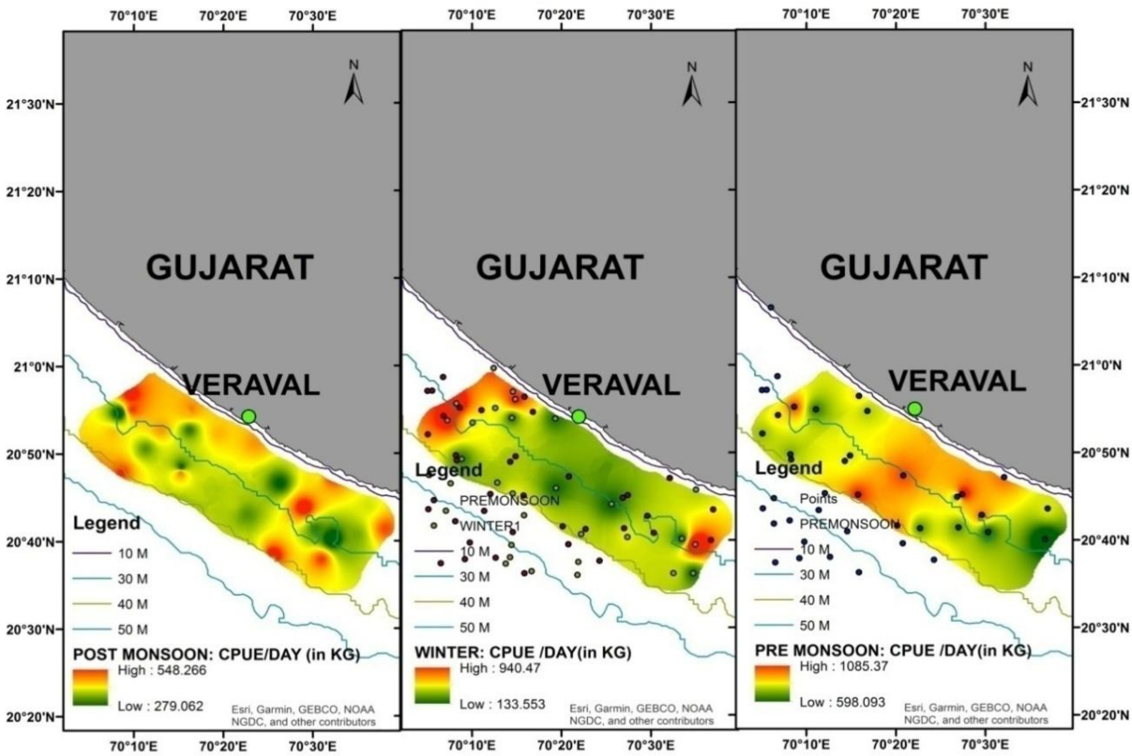


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Fig. 4.1.3 (f) Seasonal variation of CPUE in single-day trawlers

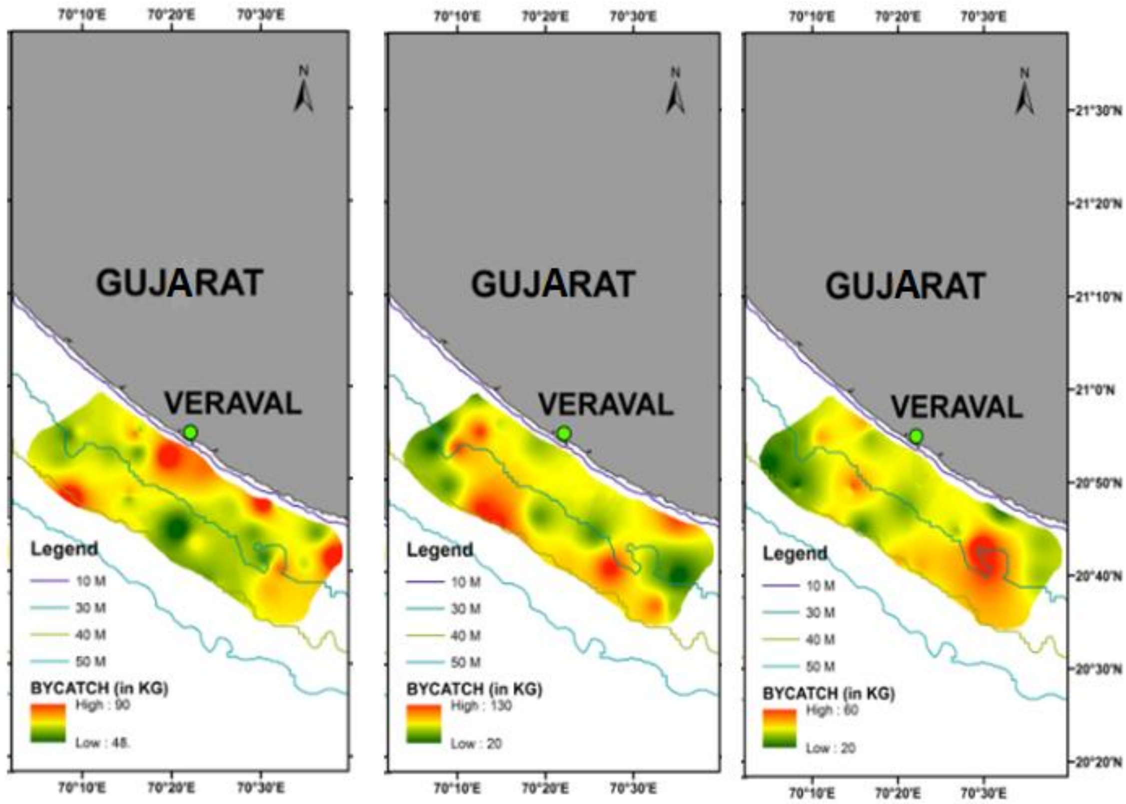

Fig. 4.1.3 (g) Seasonal variation of low-value bycatch in single-day trawlers

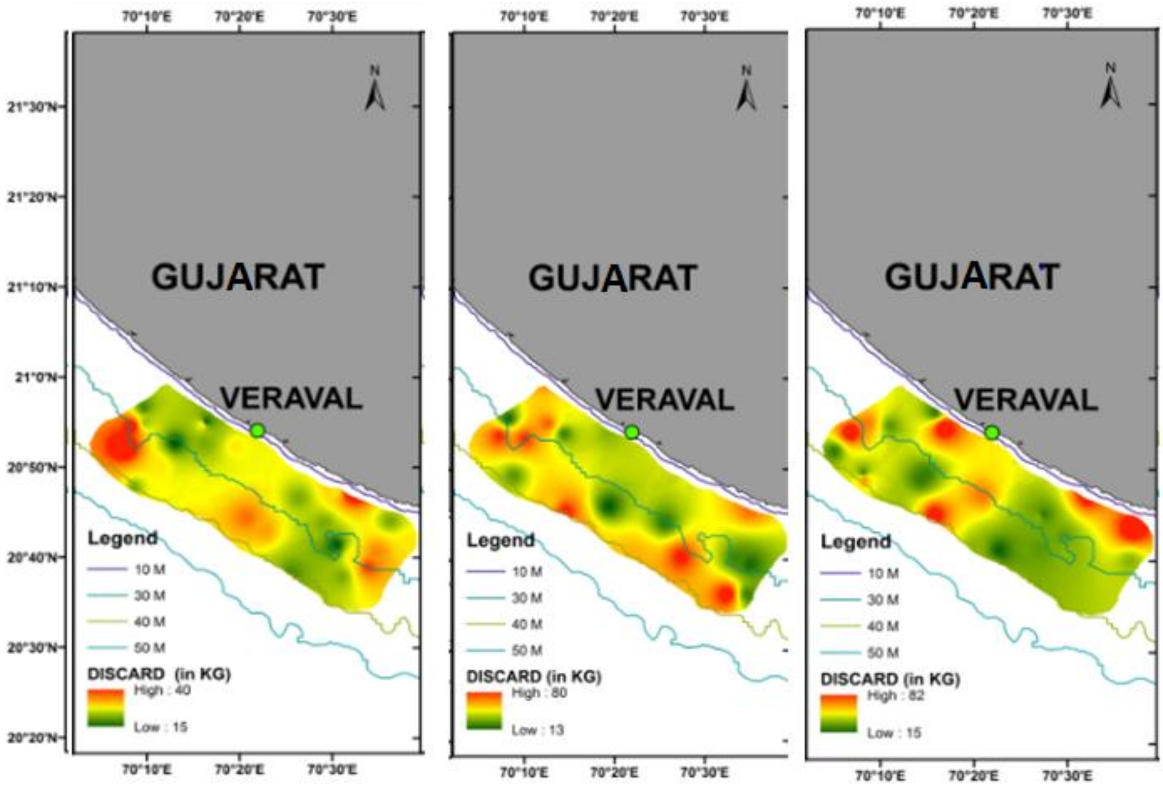

Fig. 4.1.3 (h) Seasonal variation of discard in single-day trawlers

4.1.4. Spatio-temporal distribution of selected trawl resources of Gujarat

The level of abundance varies seasonally according the resources and the details of abundance are given in **Table 4.1.4.1**.

Table 4.1.4.1 Seasonal abundance of selected resources in multi-day and single-day trawlers operated from Gujarat

Name of Resources	**Level of abundance**					
	Multi-day Trawler			**Single-day trawler**		
	Post-monsoon	**winter**	**Pre-monsoon**	**Post-monsoon**	**winter**	**Pre-monsoon**
Ribbonfish	More abundant	Abundant	Less abundant	More abundant	Abundant	Less abundant
Sciaenids	Abundant	More abundant	Less abundant	More abundant	Abundant	Less abundant
Squids	Abundant	More abundant	Less abundant	Less abundant	Abundant	Less abundant
Cuttlefish	More abundant	More abundant	Less abundant	Less abundant	Abundant	Abundant
Shrimps	Abundant	Abundant	More abundant	More abundant	Less abundant	Abundant
Acetes	More abundant	Less abundant	More abundant	Abundant	More abundant	More abundant
Clupeids	Less abundant	Abundant	Less abundant	More abundant	Abundant	Less abundant

4.1.4.1. Ribbon fishes

Ribbon fishes represent one of the most important pelagic fishery resources of Gujarat contributing 113903.81 t that accounted for 14.48% of total and 40.4% of pelagic fish landings of Gujarat. Mechanized multi-day trawlers contributed 78.7% towards ribbonfish landings of the state during 2017. The seasonal distribution of ribbon fishes for multi-day and single-day trawlers are shown in **Fig. 4.1.4.1(a)** and **Fig. 4.1.4.1(b)** respectively. In post-monsoon season, ribbon fishes showed abundance in the deeper region at 100 to 200 m depth off Gulf of Khambhat and in Maharashtra. It was highly abundant in 50- 200 m depth off Veraval during winter and it was recorded off Dwarka and Gulf of Khambhat region in multi-day trawling grounds during pre-monsoon.

In single-day trawl, abundance of ribbonfish was observed up to 40 m depth north Veraval coast and similar pattern continued till the end of winter but in pre- monsoon it shifted to shallower waters between 20 to 30 m depth in south Veraval coast.

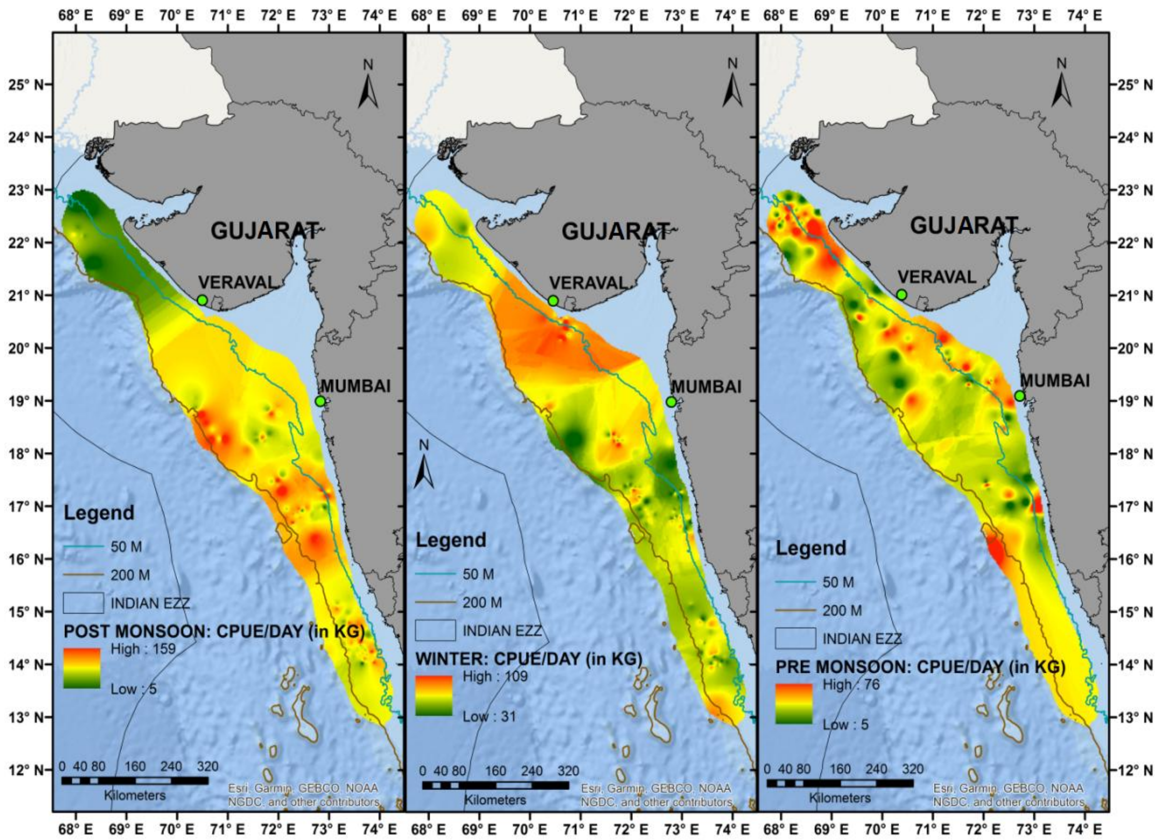

Fig. 4.1.4.1(a) Seasonal variation in CPUE of Ribbon fishes in multi-day trawlers

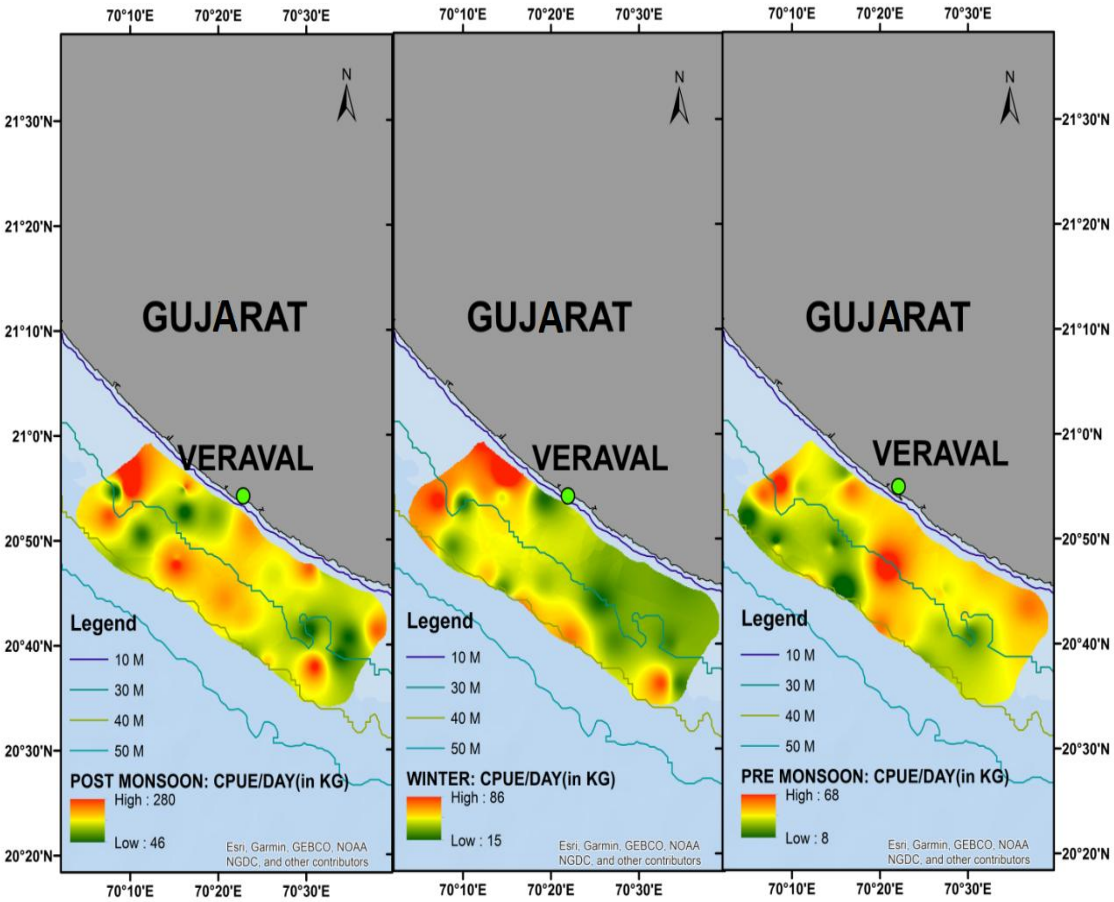

Fig. 4.1.4.1(b) Seasonal variation in CPUE of Ribbon fishes in single-day trawlers

4.1.4.2. Sciaenid

Sciaenid constitutes one of the important demersal fishery resources of Gujarat contributing about 19.67% to the total demersal marine fish landings of the state. (CMFRI, 2017). It was predominantly exploited in winter followed by post-monsoon and pre-monsoon. In multi-day trawl, sciaenids were abundantly exploited from southern Maharashtra and Goa coast during winter. The abundance gradually shifted towards north of Maharashtra and south of Goa coast showing increased abundance along Mangalore coast during post-monsoon. During post-monsoon, the resource also showed some abundance near Gulf of Kutch at a depth range of 50-200 m. However, the abundance of the resource increased significantly during pre-monsoon along Gujarat coast showing dispersed abundant regions along Saurashtra coast and Gulf of Khambhat. The resource was mostly found to be abundant between 50 to 200 m depth except for pre-monsoon months when the abundance was also found in shallower grounds (**Fig. 4.1.4.2. (a)**).

In single-day trawls, the resource was predominantly exploited during post-monsoon followed by winter and pre-monsoon. The resource was abundantly exploited from north-western region off Veraval coast during winter which gradually shifted towards the south-eastern region off Veraval coast during pre-monsoon becoming more abundant off Veraval during post-monsoon (**Fig. 4.1.4.2 (b)**).The resource was mainly found to be abundant in the shallower waters (up to 20 m depth) during winter and pre-monsoon which shifted to comparatively deeper waters (30-40 m depth) during post-monsoon.

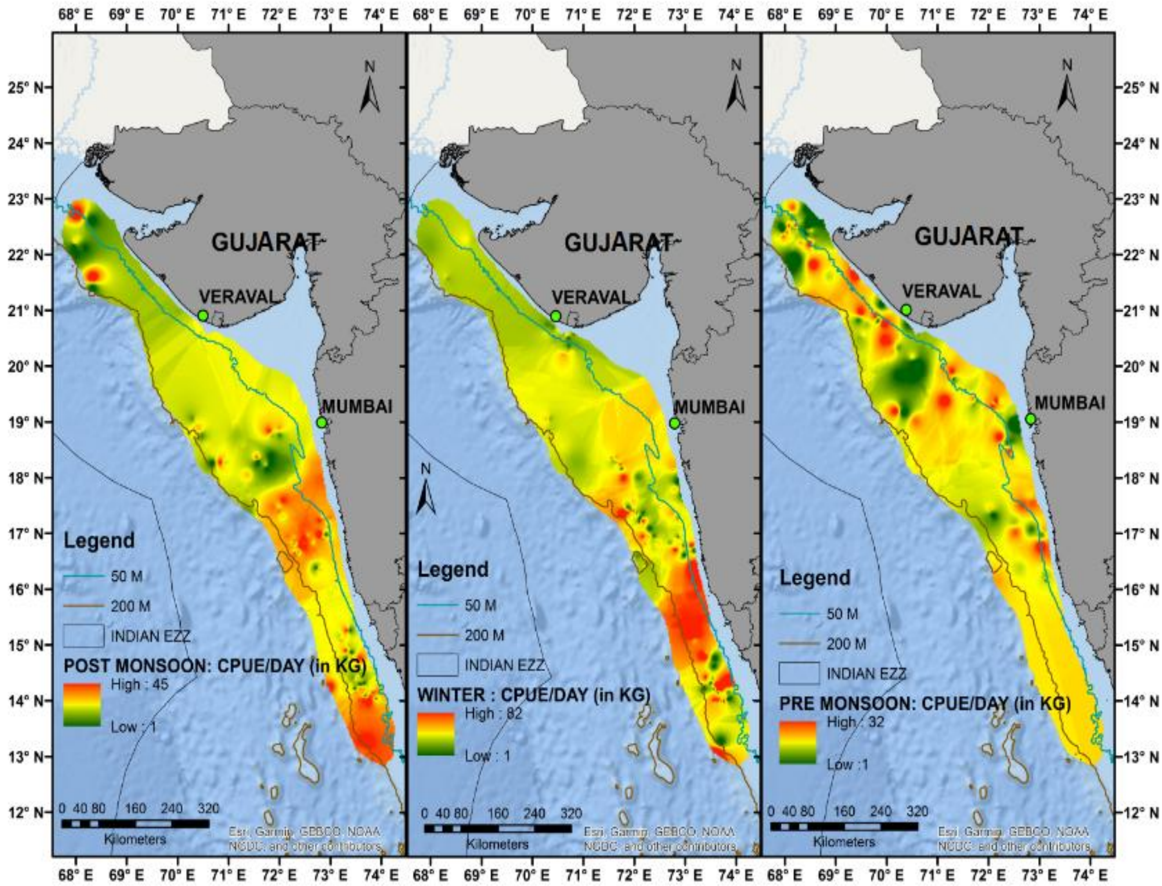

Fig. 4.1.4.2. (a) Seasonal variation in CPUE of Sciaenids in multi-day trawlers

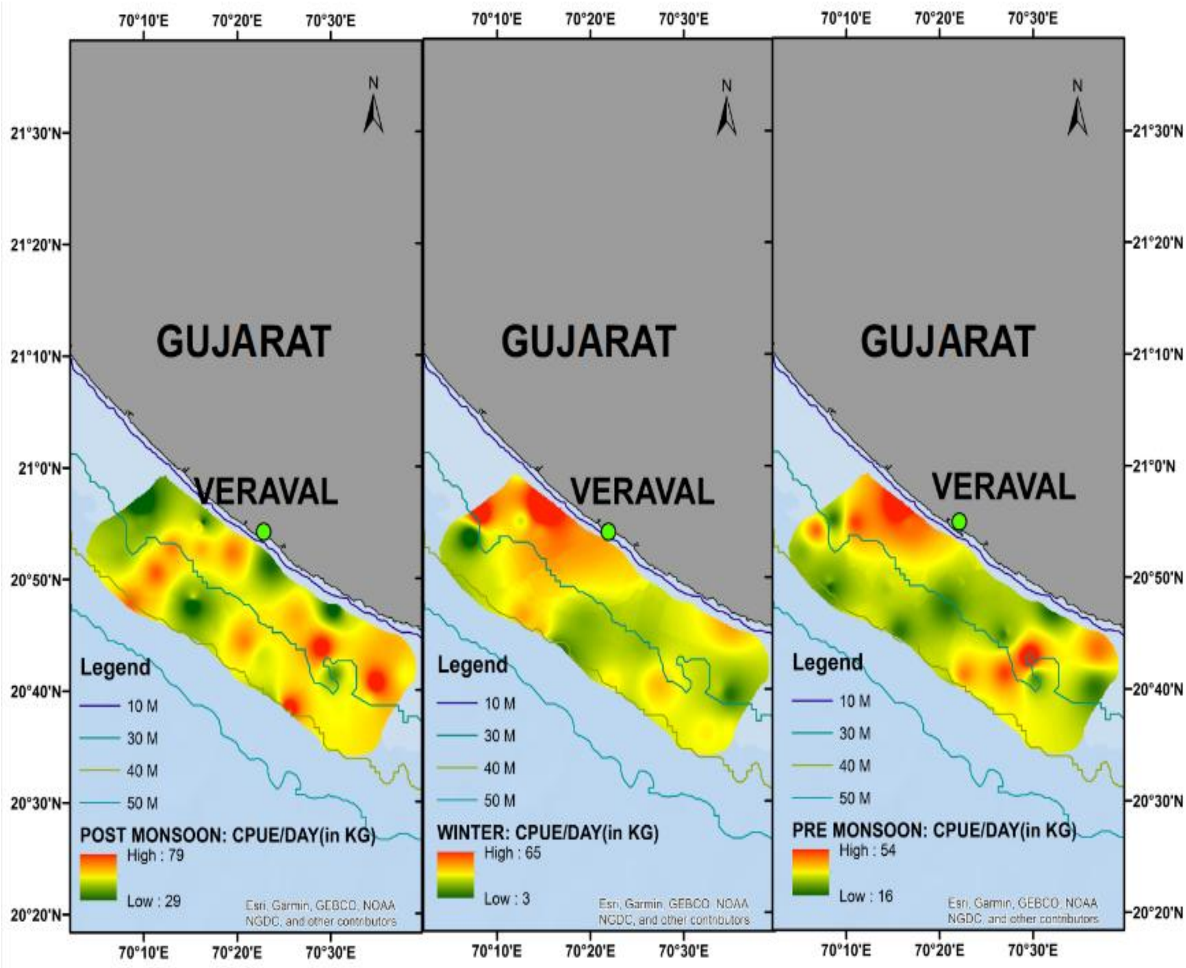

Fig. 4.1.4.2 (b) Seasonal variation in CPUE of Sciaenids in single-day trawlers

4.1.4.3. Squids

Squids constitute one of the important cephalopod fishery resources of Gujarat contributing about 45.4% to the total molluscan landings of the state. Squid resource showed highest dominance in winter followed by post-monsoon. The pre-monsoon period showed least abundance with scattered distribution **(Fig. 4.1.4.3 (a))**. The resource was abundantly exploited from southern Maharashtra and Goa coast during winter. The abundance shifted off Gulf of Khambhat and northern most regions off Gulf of Kutch and scanty distribution along the near shore waters off Mumbai and offshore waters of southern Maharashtra coast at depth range 150 to 200 m. However, abundance of these resources condensed from northern part of Veraval coast up to northern most part of Kutch at 200 m depth zone. It clearly revealed higher availability of squid in multi-day trawl catch in winter and post-monsoon and drastic reduction in pre-monsoon.

In single-day trawls, the resource was predominantly exploited during winter but the abundance of the same decreased and showed a similar CPUE in both pre and post-monsoon period (**Fig. 4.1.4.3 (b)**). The resource was abundantly exploited from north-western region off Veraval coast during winter which gradually shifted towards the southern region off Veraval coast during pre-monsoon. Inshore waters off Veraval (20 to 30 m depth) showed highest degree of abundance during winter and pre-monsoon period but in post-monsoon it concentrated off Veraval.

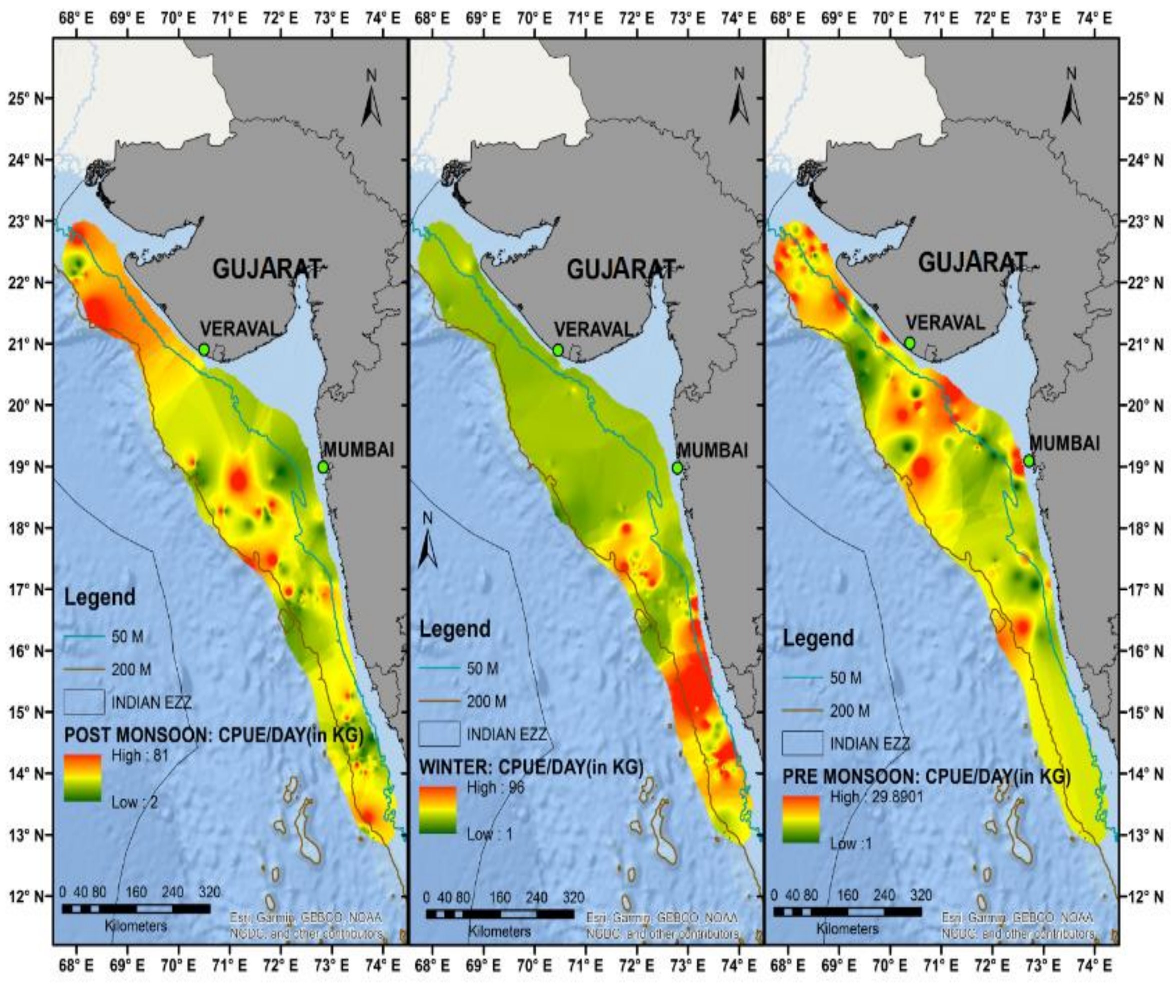

Fig. 4.1.4.3 (a) Seasonal variation in CPUE of Squids in multi-day trawlers

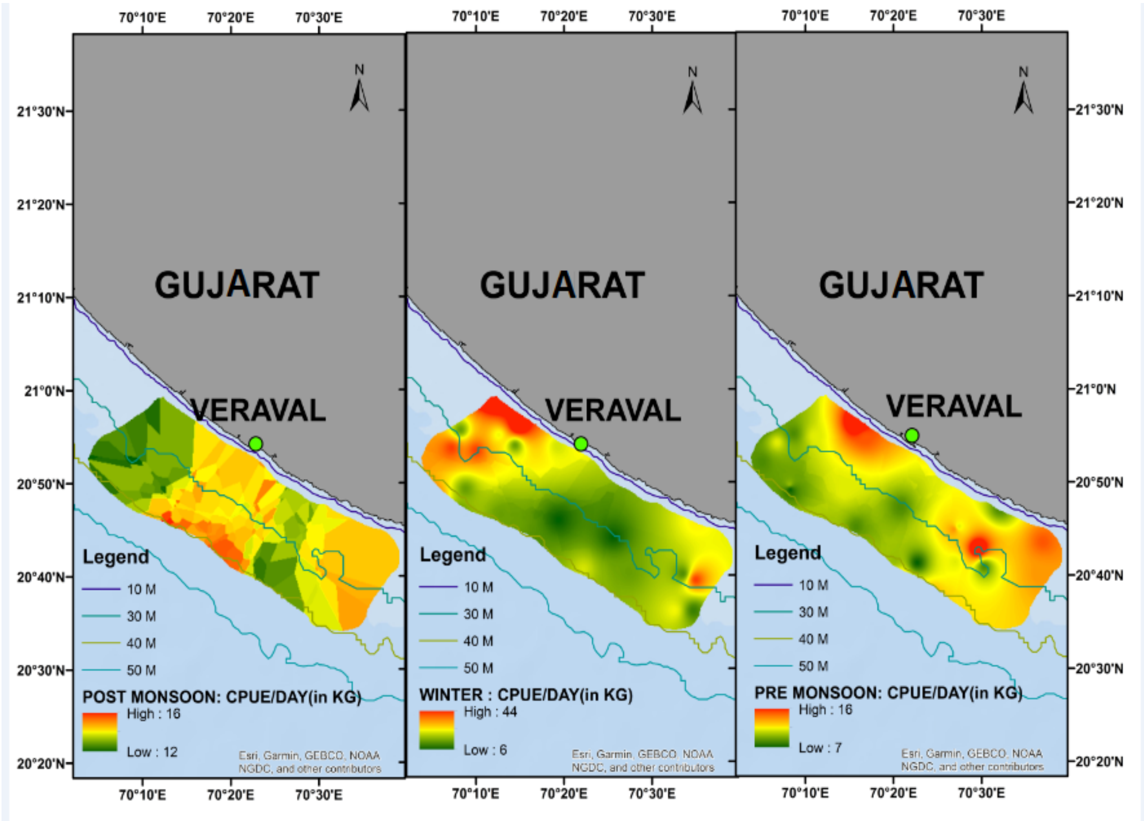

Fig. 4.1.4.3 (b) Seasonal variation in CPUE of squids in single-day trawlers

4.1.4.4. Cuttlefishes

Cuttlefishes are the major cephalopod fishery resources of Gujarat contributing about 53.8% to the total molluscan landings of the state. Unlike the squids, cuttlefish resources were mainly exploited with higher CPUE immediately after monsoon trawl ban which lasted up to the end of winter but decreased gradually towards the pre-monsoon period. The targeted fishery for these resources was recorded along Saurashtra coast at 200 m depth during the post-monsoon period. However, targeted fishery was recorded along Goa and off Mumbai in winter at 50 to 200 m depth zone. At the onset of pre-monsoon, the resource was also caught at 50 m depth zone all around the grounds of the multi-day trawlers (**Fig. 4.1.4.4 (a)**).

In single-day trawls, the resource was mostly exploited during winter followed by pre-monsoon and post-monsoon with minimal difference in the CPUE (**Fig. 4.1.4.4 (b)**). The resource was abundantly exploited throughout off Veraval coast during post-monsoon in inshore waters at 30 m depth which gradually shifted and intensified towards the northern region off Veraval coast during winter. In the pre-monsoon, these resources were targeted as per their abundance closer to the coast and restricted up to 30 m depth off Veraval.

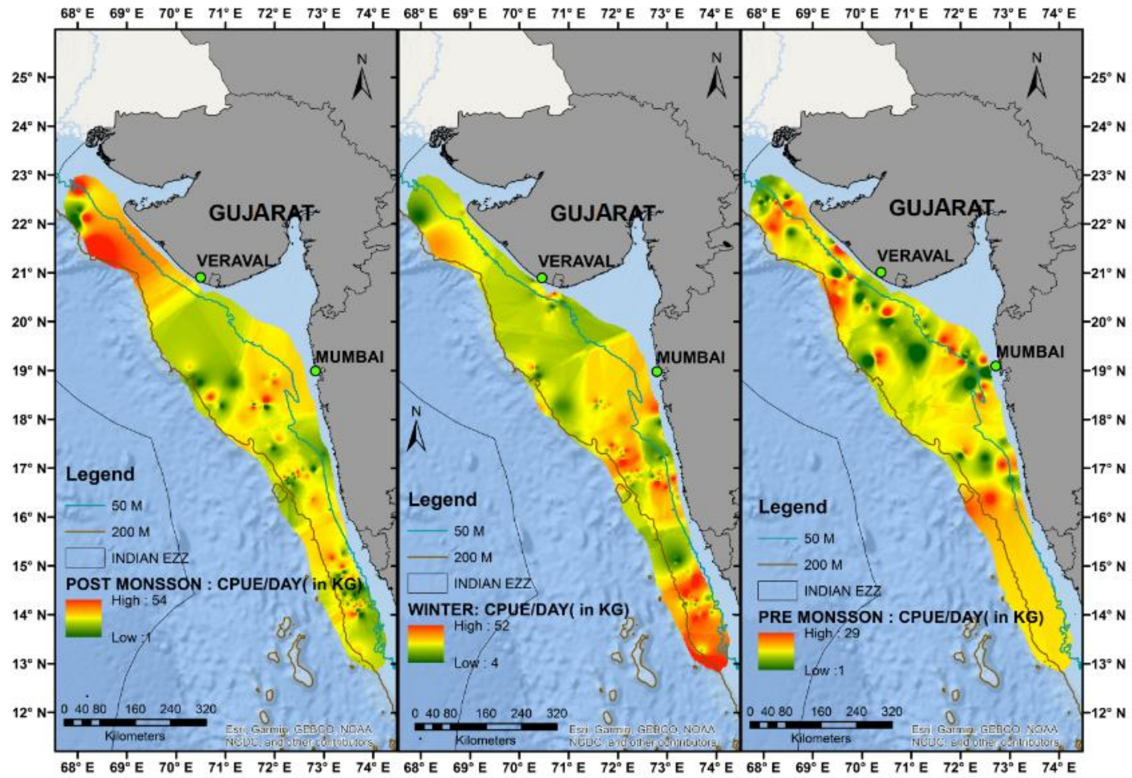

Fig. 4.1.4.4 (a) Seasonal variation in CPUE of Cuttlefish in multi-day trawlers

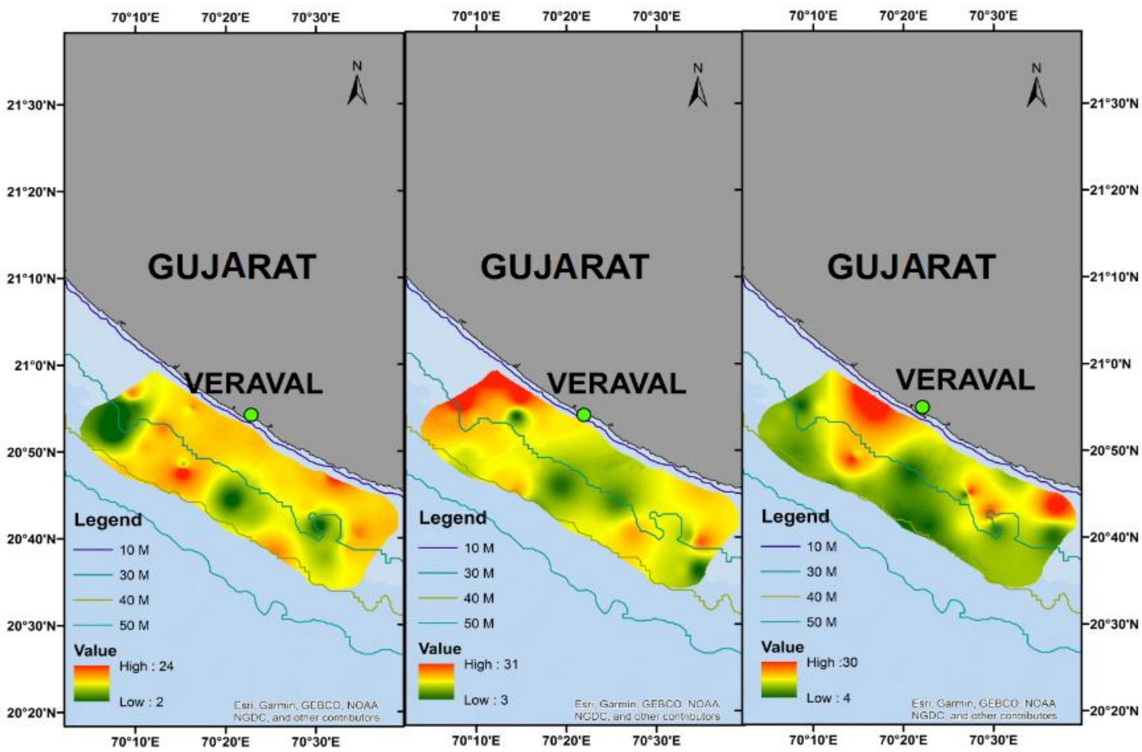

Fig. 4.1.4.4 (b) Seasonal variation in CPUE of cuttlefish in single-day trawlers

4.1.4.5. Shrimps

Crustacean resources contributed 1.97 lakh t accounting for 26% of total fish landings of Gujarat during 2017. Non-penaeid shrimps were the major component with a contribution of 75.4% to the total crustacean landings followed by penaeid shrimps (17.9%).The resource was largely exploited in pre-monsoon followed by post-monsoon and winter (**Fig. 4.1.4.5. (a)**). It was abundantly exploited off Gulf of Khambhat and towards southern Maharashtra during the post-monsoon in the depth range 40 to 200 m. The abundance gradually shifted towards north of Maharashtra and northern Saurashtra coast during winter. The distribution of shrimp resources in pre-monsoon mostly occurred in shallower waters off Maharashtra and scanty distribution in Gujarat waters.

Single-day trawlers recorded the highest CPUE in post-monsoon followed by pre-monsoon and winter. The resource was abundantly exploited from southern region off Veraval coast during post-monsoon in shallower depth zone which gradually shifted towards the deeper zone during winter becoming less abundant in this region during post-monsoon. The resource was mainly found to be abundant in shallower waters (30 m depth) off Veraval coast during pre-monsoon (**Fig. 4.1.4.5 (b)**).

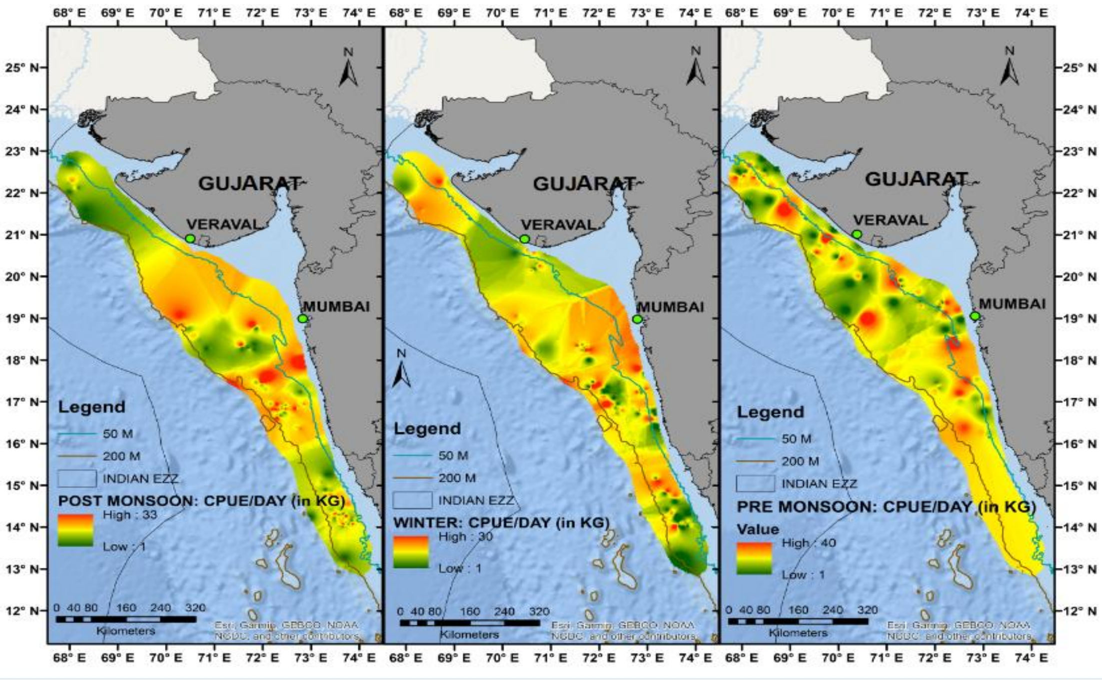

Fig. 4.1.4.5 (a) Seasonal variation in CPUE of Shrimps in multi-day trawlers

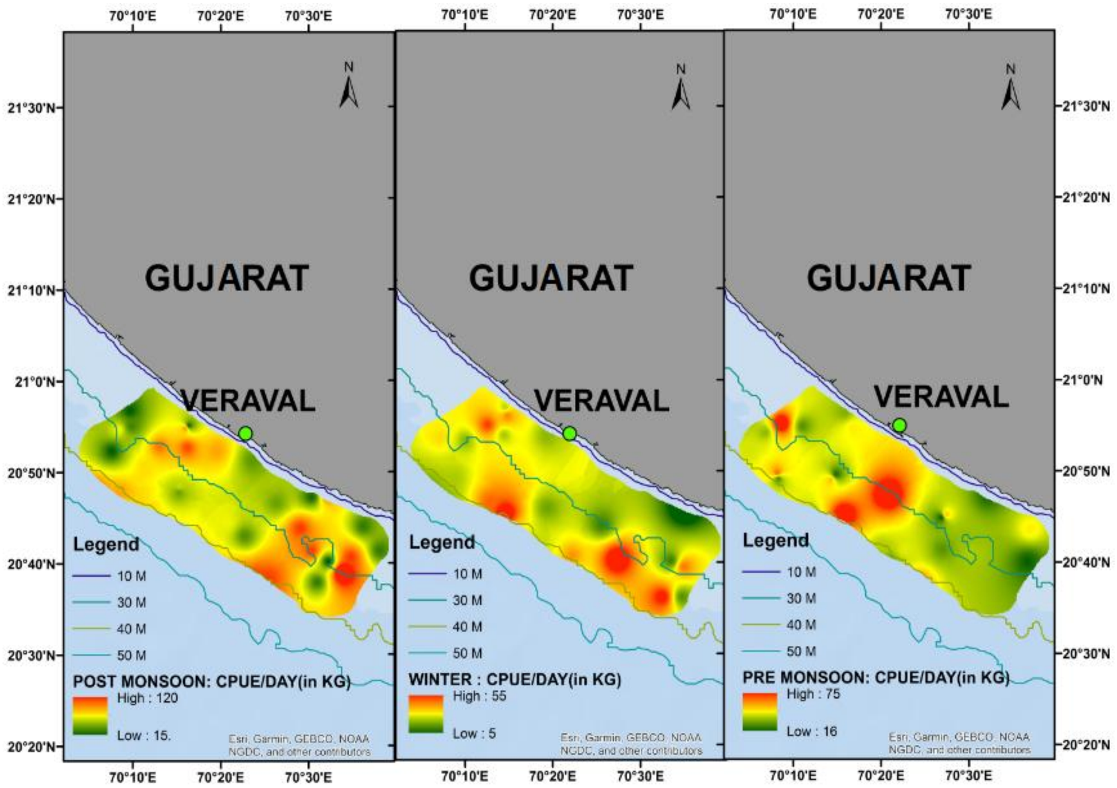

Fig. 4.1.4.5 (b) Seasonal variation in CPUE of Shrimps in single-day trawlers

4.1.4.6. *Acetes* sp.

This resource is basically targeted in pre-monsoon followed by post-monsoon and winter by multi-day trawlers. These resources are rarely targeted by multi-day trawlers due to their small size and lower value. In post-monsoon period, the *Acetes* species were predominantly found off Gulf of Khambhat and southern part of Maharashtra coast which gradually shifted off Mumbai to northern Gujarat coast in winter. Elevated degree of abundance of the same was seen off Okha and off Diu coast in deeper zone during pre-monsoon (**Fig. 4.1.4.6. (a)**).

Heavy landings of *Acetes* sp. were recorded by single-day trawlers in pre-monsoon followed by winter and very minimal landings during post-monsoon. Due to decrease in targeted catch in near shore waters, the single-day trawlers exploited huge quantity of these resources after post-monsoon with modification in the fishing system. The resource was exploited from near shore waters of both northern and southern part off Veraval coast (**Fig. 4.1.4.6. (b)**)

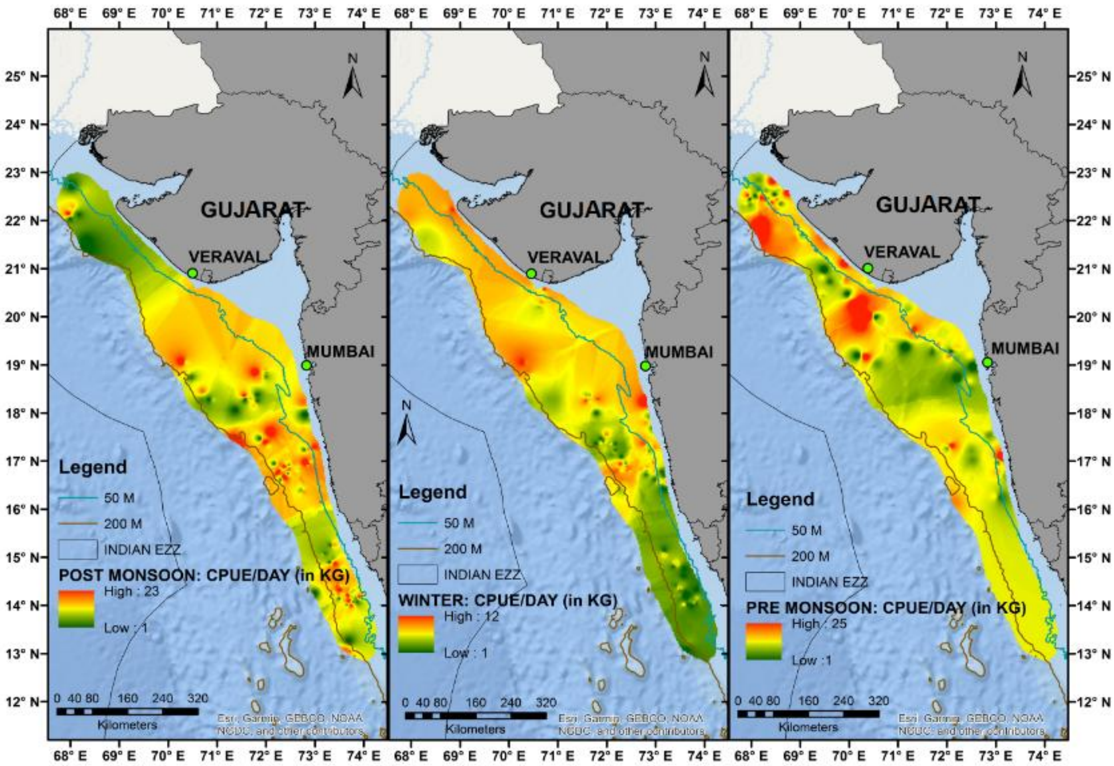

Fig. 4.1.4.6 (a) Seasonal variation in CPUE of *Acetes* sp. in multi-day trawlers

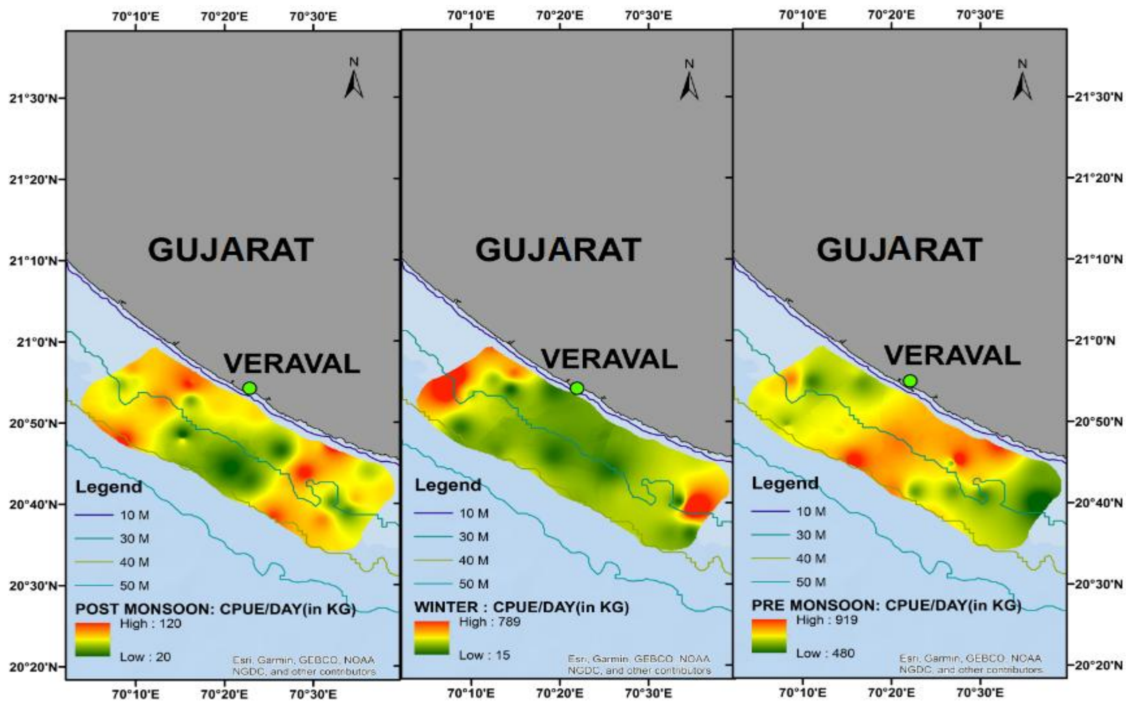

Fig. 4.1.4.6 (b) Seasonal variation in CPUE of *Acetes* sp. in single-day trawlers

4.1.4.7. Bull’s eye

Bull’s eye constitutes one of the important demersal fishery resources of Gujarat contributing about 15.7% to the demersal marine fish landings of the state. Bull’s eye mostly comprised of the *Priacanthus* sp. mostly targeted by the multi-day trawlers beyond 50m depth zone. Highest abundance of this resource was observed in winter followed by post-monsoon and pre-monsoon. In both winter and post-monsoon period, the abundance of the resource was recorded off Goa and Mangalore and Mumbai (**Fig. 4.1.4.7**).

4.1.4.8. Cat fishes

Highest abundance of cat fishes was observed during post-monsoon followed by both winter and pre-monsoon (**Fig. 4.1.4.8**). However, in post-monsoon the abundance was restricted to off Mumbai coast in shallower waters and off southern Maharashtra in deeper regions. During winter, these resources were predominantly exploited off Gujarat to Mumbai coast but in pre-monsoon, it was distributed mostly in offshore waters throughout the trawling grounds of multi-day trawlers.

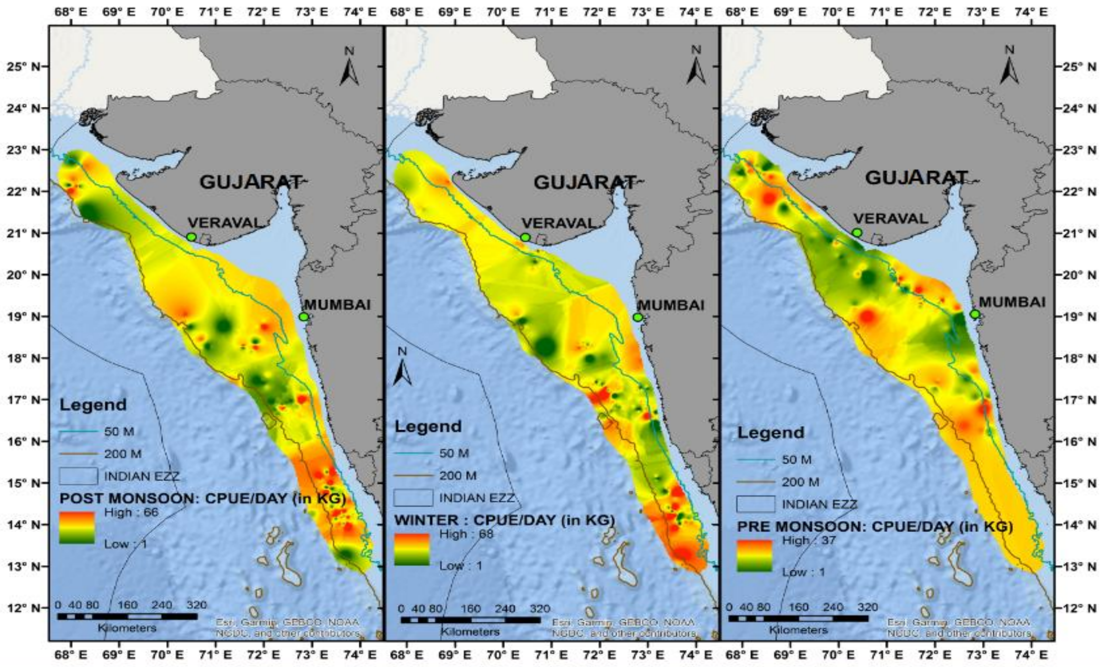

Fig. 4.1.4.7 Seasonal variation in CPUE of Bulls eye in multi-day trawlers

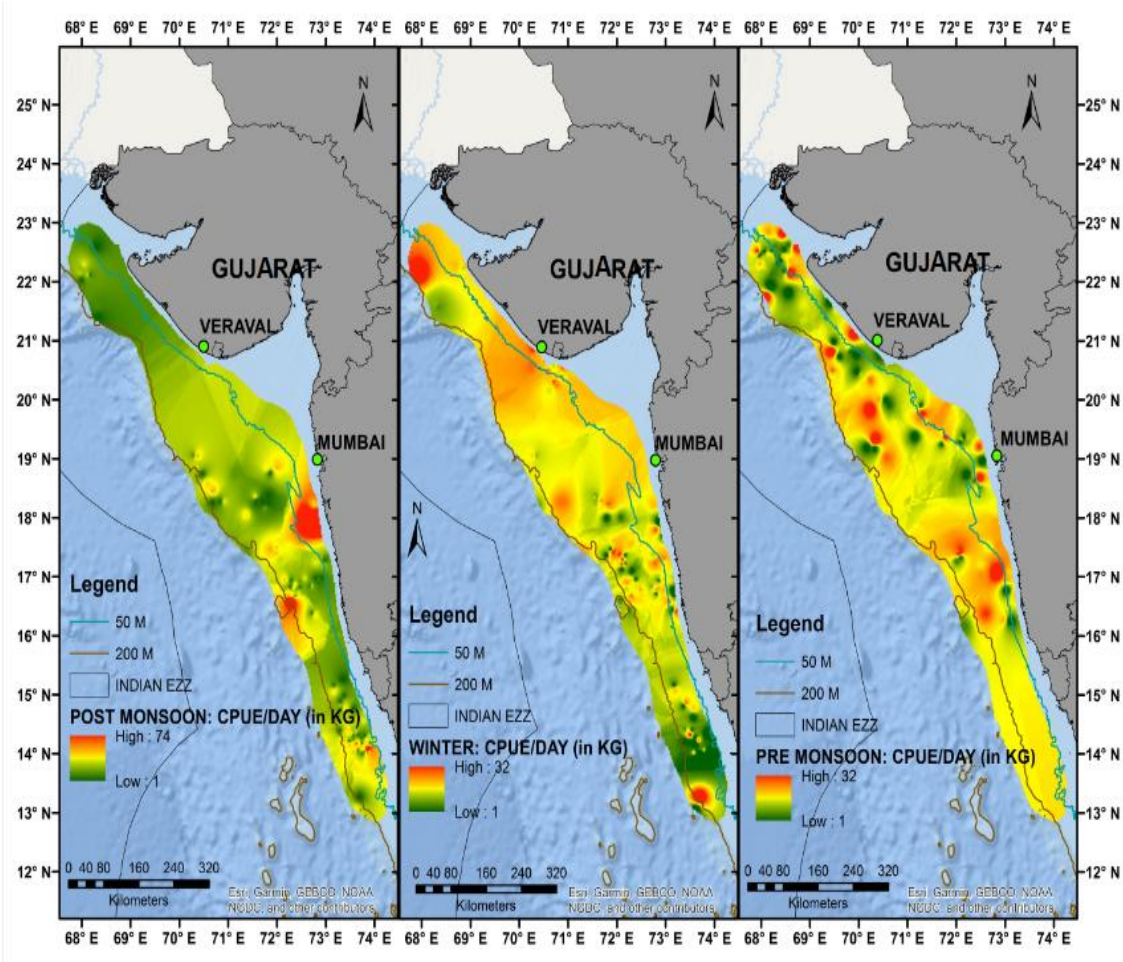

Fig. 4.1.4.8 Seasonal variation in CPUE of cat fishes in multi-day trawlers

4.1.4.9. Clupeids

In multi-day trawl fishery, clupeids showed almost the same abundance level round the year. The exploitation of these resources peaked in near shore waters off Gulf of Khambhat and Maharashtra coast in post-monsoon but gradually shifted towards Gujarat coast during winter and became sporadic in pre-monsoon period (**Fig. 4.1.4.9. (a)**). But in case of single-day trawl, highest abundance occurred immediately after monsoon ban in shallower depth at northern side of Veraval coast while the resources were exploited from 40m depth zone in winter off Veraval and continued in pre-monsoon (**Fig. 4.1.4.9. (b)**).

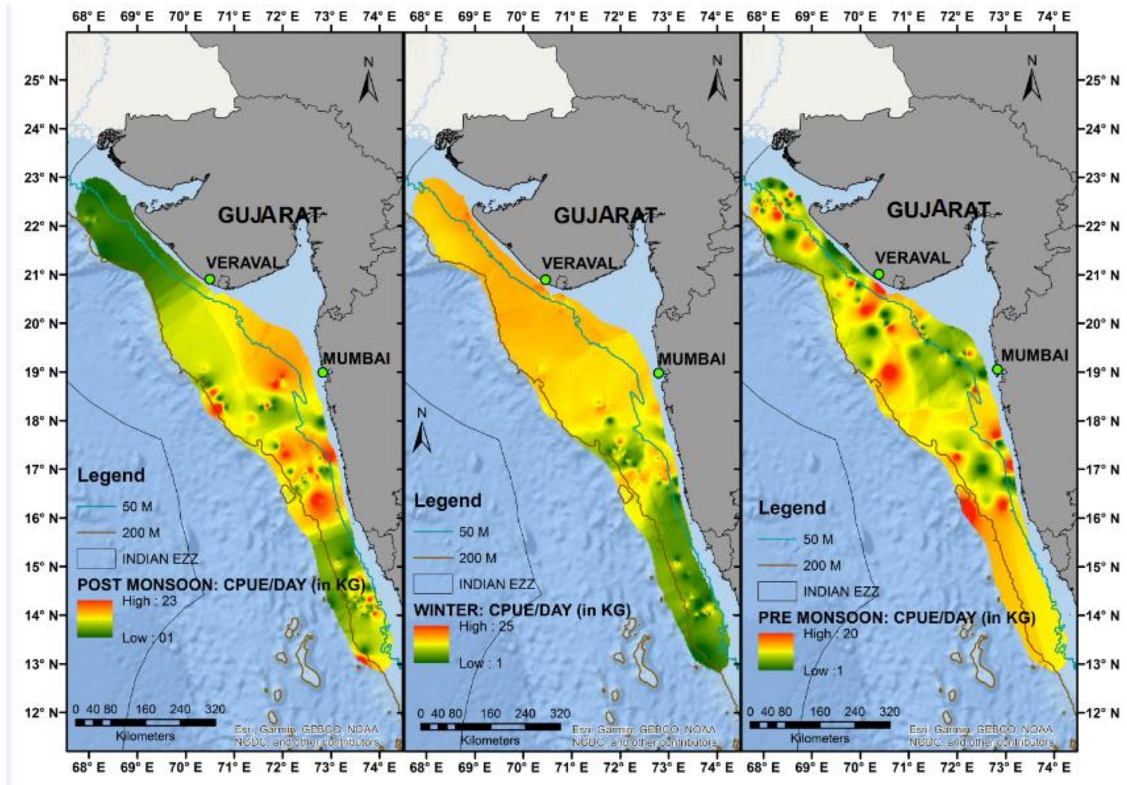

Fig. 4.1.4.9. (a) Seasonal variation in CPUE of Clupeids in multi-day trawlers

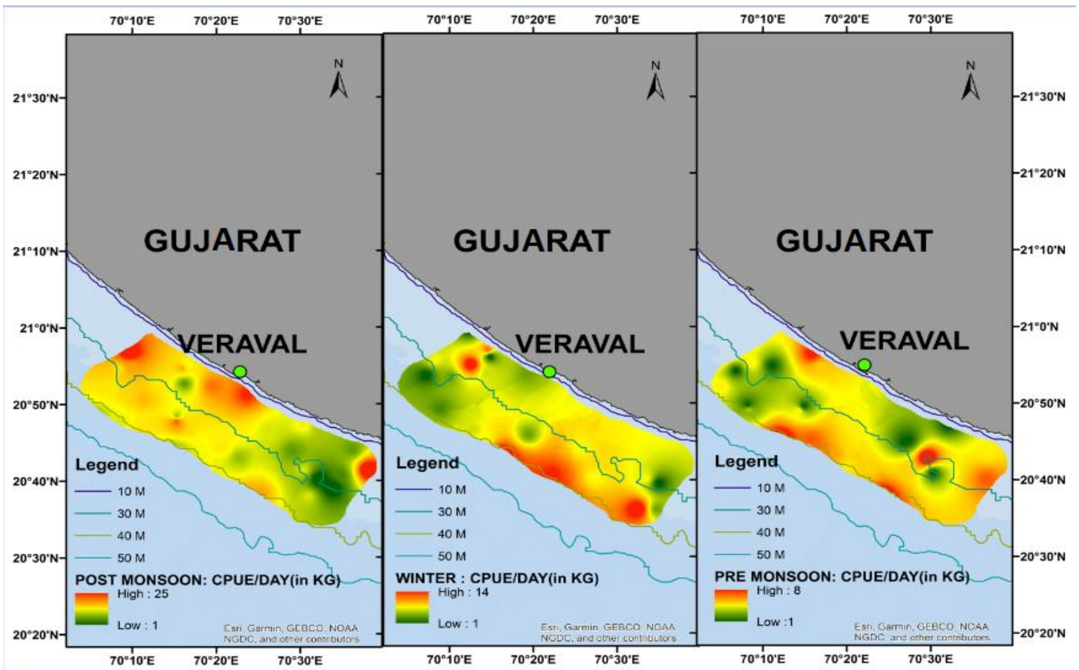

Fig. 4.1.4.9 (b) Seasonal variation in CPUE of clupeids in single-day trawlers

4.1.4.10. Crabs

In single-day trawls, crabs were predominantly abundant in near shore waters at depth less than 30 m off Veraval in winter but in pre-monsoon, mostly occurred in 40 m depth zone (**Fig. 4.1.4.10**).

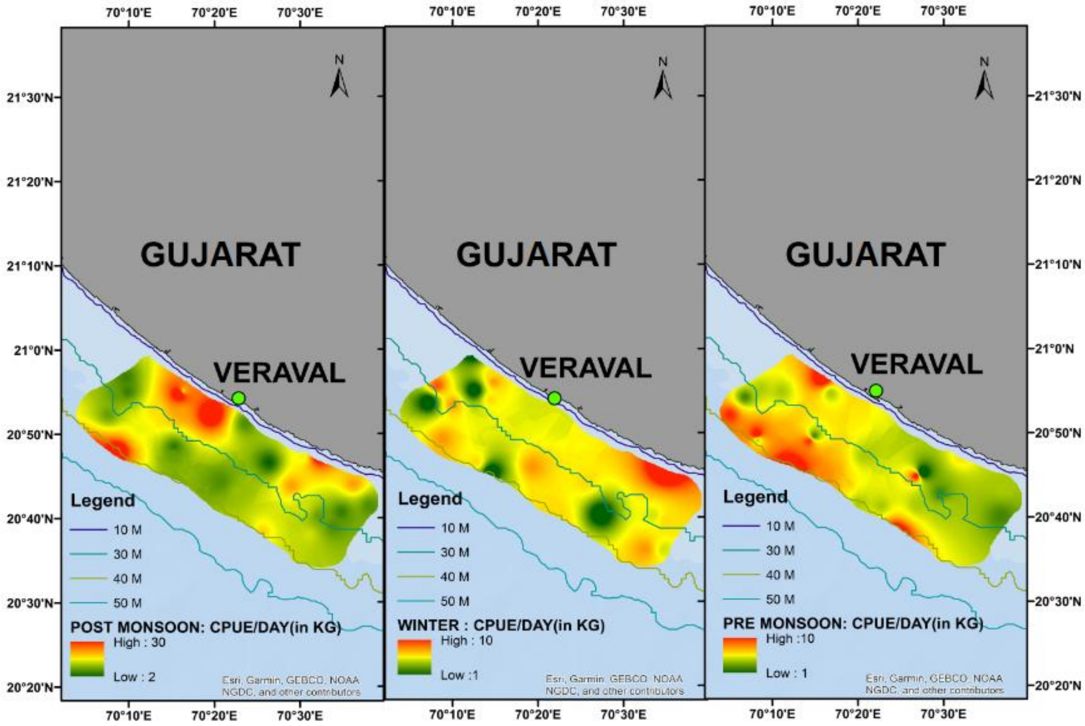

Fig. 4.1.4.10 Seasonal variation in CPUE of crabs in single-day trawlers

4.1.4.11. Threadfin breams

In case of threadfin breams resources, abundance was recorded off Maharashtra coast round the year and lowest catch on the northern Gujarat coast. (**Fig. 4.1.4.11**)

4.1.4.12. Lizard fishes

Lizard fishes are basically species of *Saurida* genera mostly abundant during the post-monsoon in single-day trawl at shallower depth off Veraval. However, these resources were caught beyond 30 m depth zone in pre-monsoon off Veraval coast. These are low valued species targeted for the surumi and fish meal industry (**Fig. 4.1.4.12**).

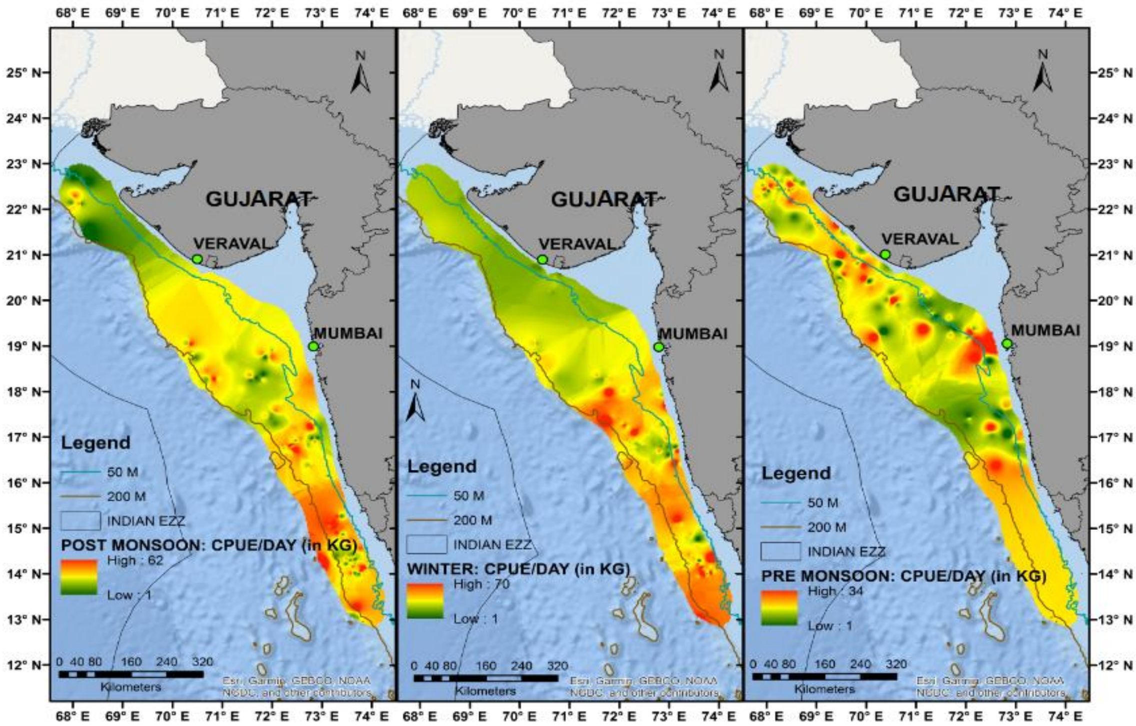

Fig. 4.1.4.11 Seasonal variation in CPUE of Threadfins in multi-day trawlers

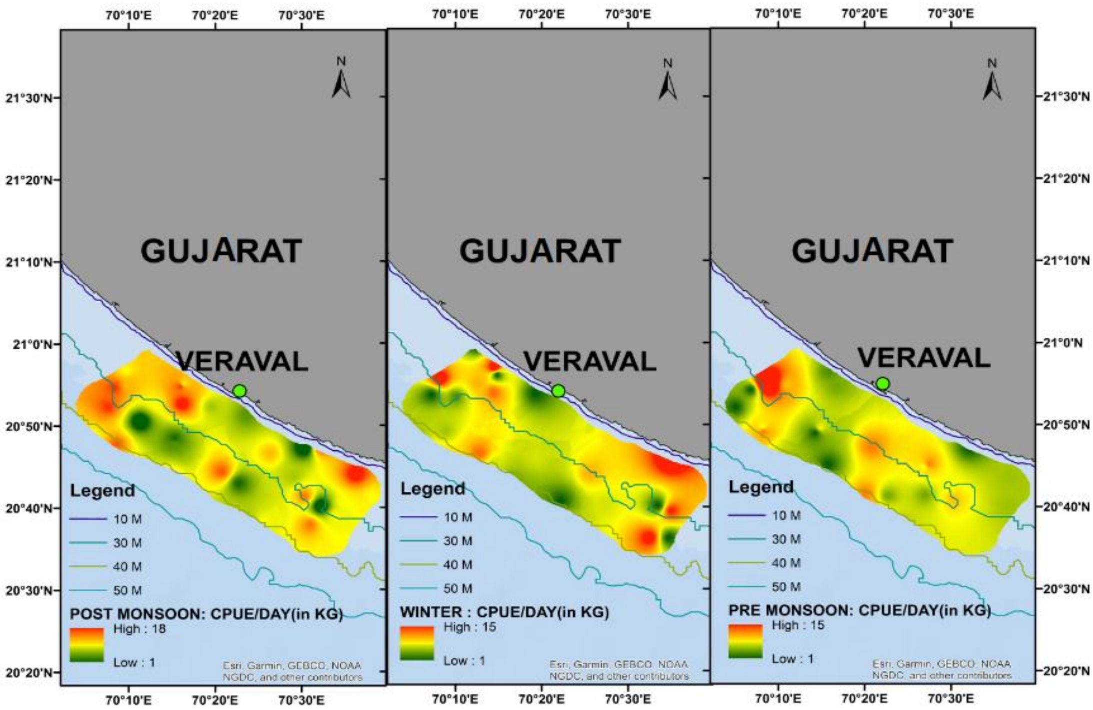

Fig. 4.1.4.12 Seasonal variation in CPUE of Lizard fishes in single-day trawlers

4.1.5. Diversity and variation in trawl catch composition

The numerical abundance of various species caught by single-day and multi-day trawl was processed to derive the biodiversity indices of the catch along Gujarat coast. Biodiversity indices are presented in **Table 4.1.5.1**. The Margalef species richness index (d) for the catch of single-day trawl was found to be similar to that of multi-day trawlers which indicates that the variation in species number of catch between single-day and multi-day trawlers was negligible. However, the Pielou's Evenness index (J') for the catch of single-day trawl was found to be lower than that of multi-day trawlers. Simpson index and Shannon-Wiener index which give consideration for both species richness and relative abundance were found to be lower for single-day trawls compared to that of multi-day trawls.

4.1.5.1. Monthly variation in species composition

Significant variation in the monthly species composition was observed both for single [P=0.001] and multi-day trawl [P=0.001]. The global R values (black vertical line) for single-day [ANOSIM Global R=0.776] and multi-day trawl [ANOSIM Global R=0.343] were found to be different from the samples permuted global R value (Blue histogram) (**Fig. 4.1.5.1 (a & b)**) which clearly indicates dissimilarities in species composition across the months. The degree of dissimilarity depends on the ANOSIM global R value which ranges from 0 to 1 and therefore, it is less in multi-day trawls compared to the single day trawls. This could be due to the targeted exploitation, excessive sorting and selective retention of high valued items throughout the year by multi-day trawls.

The pair-wise monthly similarity in species composition for single-day and multi-day trawls is illustrated in **Table 4.1.5.1**. The variation appears to be significant and strong most of the months except for March and April; October and November where no significant variation in species composition was observed for single-day trawls. On the contrary, the variation though appears to be significant but not strong for most of the months except April and October; April and November; October and November; October and December; November and December, where no significant variation in species composition was observed for multi-day trawls.

Table 4.1.5.1 Biodiversity indices derived from the species composition of single-day and multi-day trawl catch

Months /Indices	Margalef species Richness index (d)	Pielou's Evenness index (J')	Shannon-Wiener index (H')	Simpson index (1-Lambda')
Single-day trawler				
January	2.37	0.67	1.99	0.76
February	2.30	0.43	1.31	0.51
March	2.11	0.29	0.86	0.32
April	2.23	0.29	0.89	0.33
August	2.37	0.65	1.99	0.75
September	2.57	0.65	1.99	0.77
October	2.44	0.75	2.28	0.86
November	2.35	0.74	2.25	0.85
December	2.76	0.79	2.39	0.87
Average	2.39	0.58	1.77	0.67
Multi-day Trawler				
January	2.40	0.90	2.73	0.92
February	2.39	0.85	2.59	0.89
March	2.38	0.91	2.76	0.92
April	2.54	0.90	2.75	0.92
August	2.37	0.75	2.28	0.80
September	2.30	0.84	2.55	0.88
October	2.47	0.82	2.51	0.89
November	2.42	0.84	2.50	0.89
December	2.35	0.77	2.33	0.87
Average	2.40	0.84	2.55	0.89

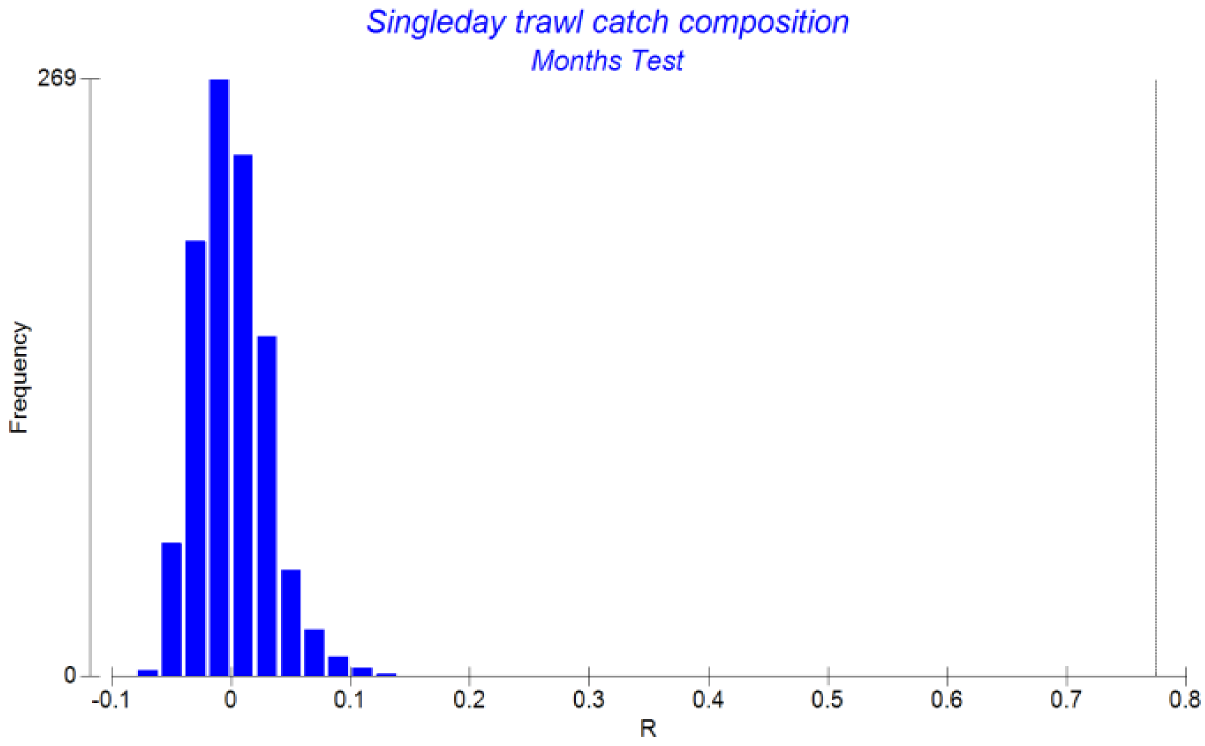

Fig.4.1.5.1 (a) Month-wise similarity in the catch composition of single-day trawlers [ANOSIM Global R=0.776, P=0.001]

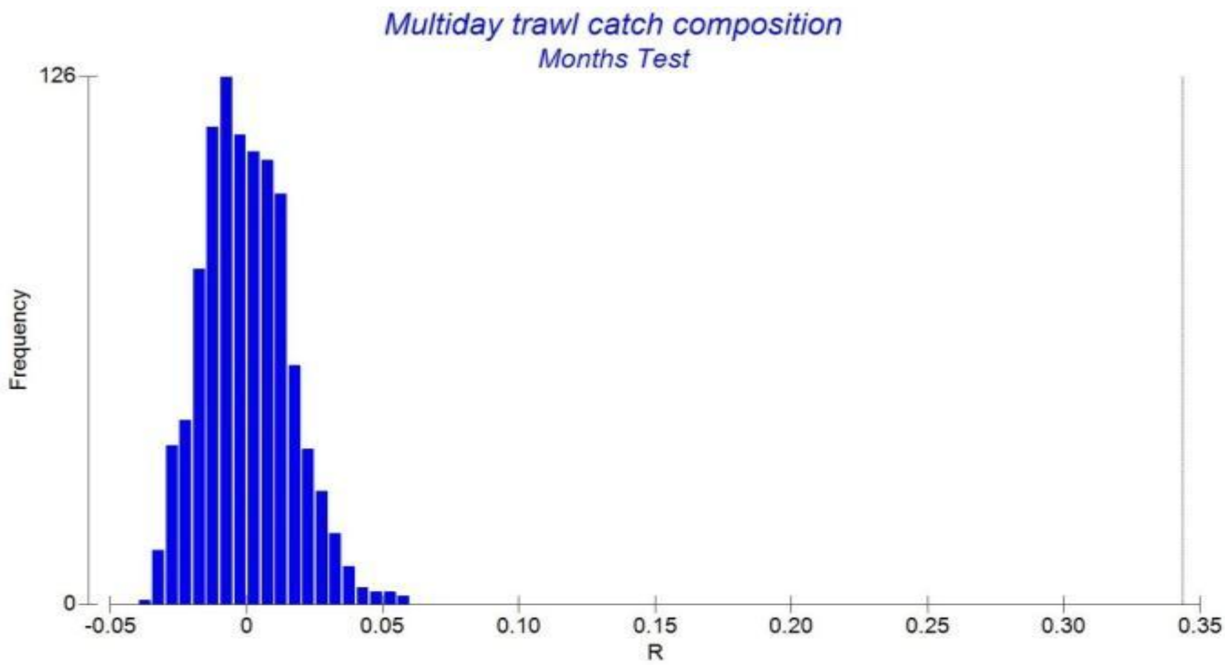

Fig.4.1.5.1 (b) Month-wise similarity in the catch composition of multi-day trawlers [ANOSIM Global R=0.343, P=0.001]

Table.4.1.5.1. Pair-wise monthly variation in species composition for single-day and multi-day trawls

Pairwise Tests	Single-day trawl		Multi-day trawl	
Months	**R Statistic**	**Significance Level**	**R Statistic**	**Significanc e Level**
January, February	0.785	0.001	0.219	0.001
January, March	0.980	0.001	0.260	0.001
January, April	0.979	0.001	0.147	0.001
January, August	0.953	0.001	0.416	0.001
January, September	0.918	0.001	0.272	0.001
January, October	0.871	0.001	0.384	0.001
January, November	0.906	0.001	0.497	0.001
January, December	0.356	0.001	0.515	0.001
February, March	0.426	0.001	0.338	0.001
February, April	0.556	0.001	0.239	0.001
February, August	0.925	0.001	0.276	0.001
February, September	0.958	0.001	0.234	0.001
February, October	0.913	0.001	0.518	0.001
February, November	0.907	0.001	0.517	0.001
February, December	0.918	0.001	0.514	0.001
March, April	0.141	0.060*	0.290	0.001
March, August	0.981	0.001	0.499	0.001
March, September	0.983	0.001	0.316	0.001
March, October	0.980	0.001	0.512	0.001
March, November	0.981	0.001	0.520	0.001
March, December	0.980	0.001	0.512	0.001
April, August	0.984	0.002	0.351	0.001
April, September	0.981	0.001	0.339	0.001
April, October	0.982	0.001	0.145	0.024*
April, November	0.984	0.001	0.186	0.020*
April, December	0.983	0.001	0.369	0.001
August, September	0.458	0.001	0.250	0.001
August, October	0.672	0.001	0.479	0.001
August, November	0.576	0.001	0.513	0.001
August, December	0.858	0.001	0.516	0.001
September, October	0.694	0.001	0.384	0.001
September, November	0.736	0.001	0.519	0.001
September, December	0.687	0.001	0.513	0.001
October, November	0.151	0.019*	0.118	0.039*
October, December	0.525	0.001	0.095	0.082*
November, December	0.649	0.001	0.100	0.092*

* Not significantly different (P>0.01)

The findings of cluster analysis as resemblance dendrogram plot and MDS analysis are shown in **Fig. 4.1.5.1 (c, d, e & f)**. The cluster analysis with SIMPROF test showed maximum resemblance of 86% (Distance: 14%) between March and April months and minimum resemblance of 2% (Distance: 98%) across all the months in the species composition of single-day trawl catch. However, maximum resemblance observed in species composition of multi-day trawls was 90.5% (Distance: 9.5%) between October and December whereas, the minimum resemblance of 48% (Distance: 52%) was observed between March and November.

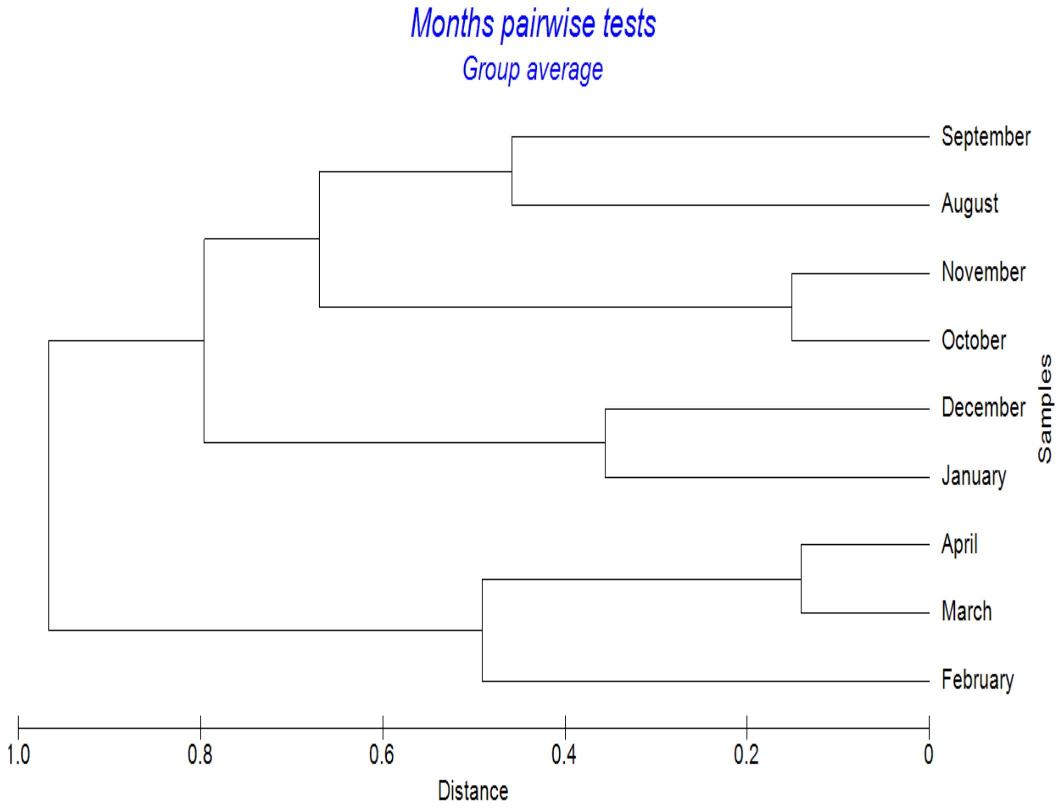

Fig. 4.1.5.1 (c) Dendrogram showing month-wise similarity in the catch composition of single-day trawlers [Global R=0.776, P=0.001]

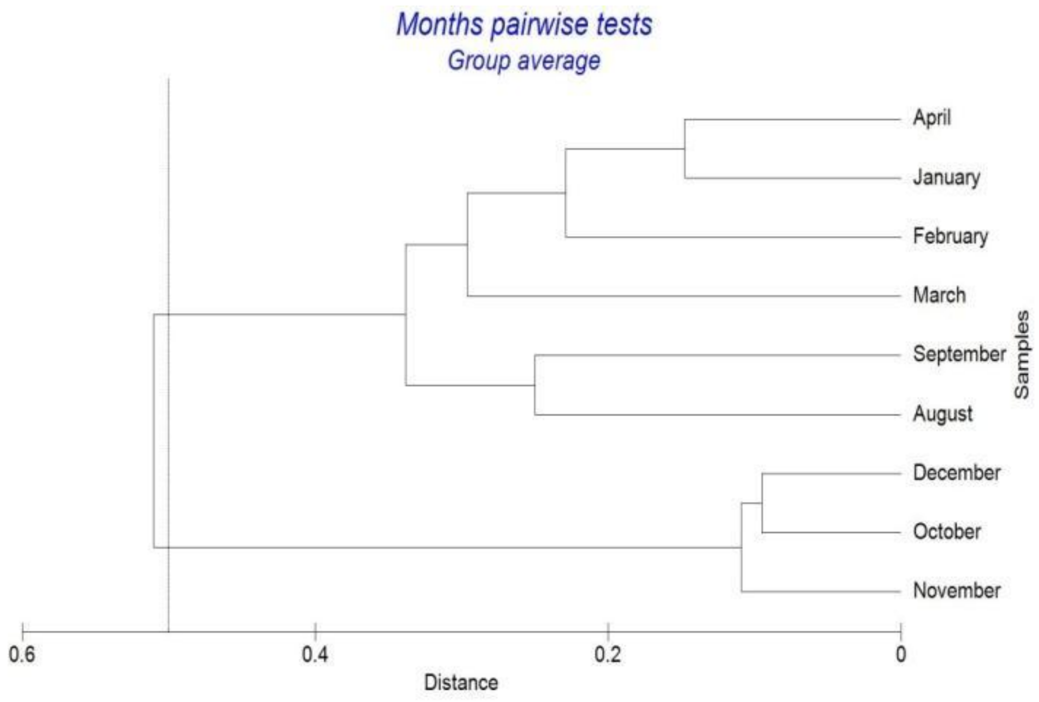

Fig. 4.1.5.1 (d) Dendrogram showing month-wise similarity in the catch composition of multi-day trawlers [Global R=0.343, P=0.001]

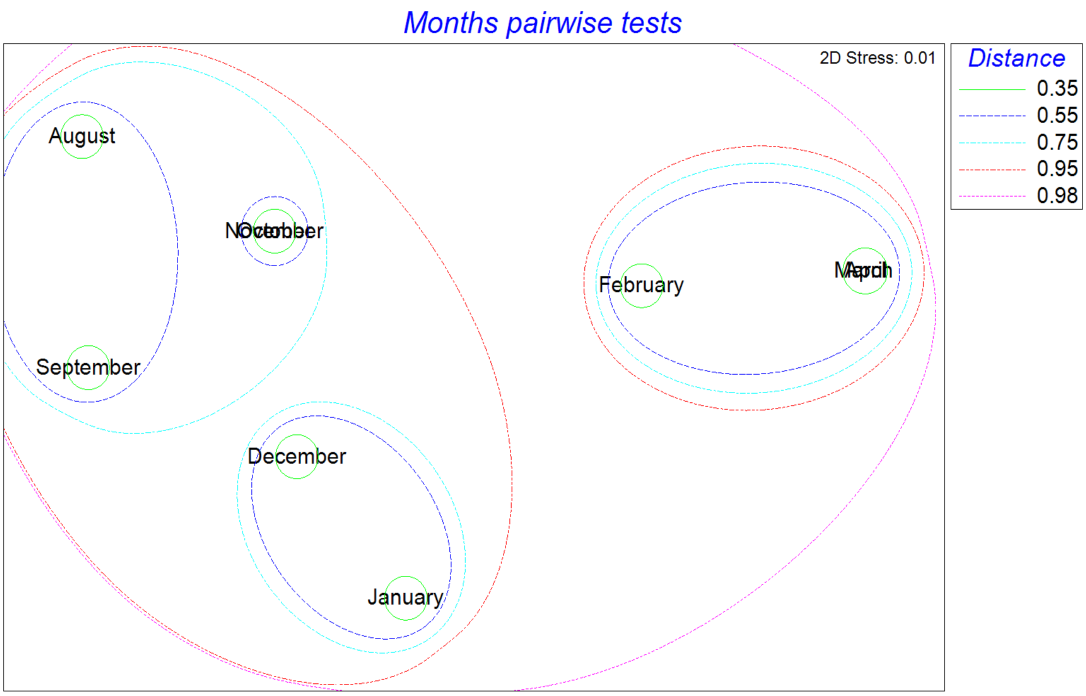

Fig. 4.1.5.1 (e) Multidimensional scaling (MDS) of month-wise similarity in the catch composition of single-day trawlers [Global R=0.776, P=0.001]

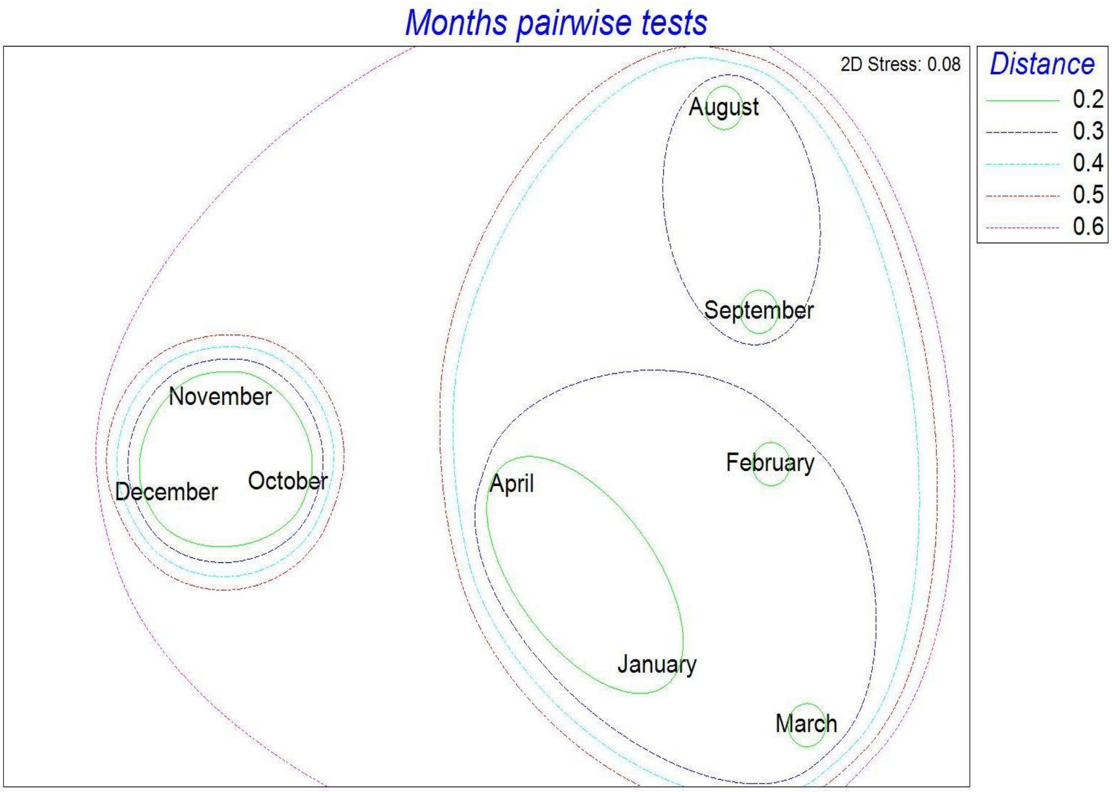

Fig. 4.1.5.1 (f) Multidimensional scaling (MDS) of month-wise similarity in the catch composition of multi-day trawlers [Global R=0.343, P=0.001]

4.1.5.2. Seasonal variation in species composition

Significant seasonal variation in species composition was observed for single-day trawl [P=0.001] but the variation was not significant for multi-day trawl [P>0.001]. The global R values (black vertical line) for single-day trawl [ANOSIM Global R=0.567] was found to be different from the samples permuted global R value (Blue histogram) (**Fig. 4.1.5.2 (a & b)**) which clearly indicates dissimilarities in species composition among the seasons. But the global R values (black vertical line) overlapped in case of multi-day trawl [ANOSIM Global R=0.074] which evidently suggests absence of any significant dissimilarly among the seasons.

The degree of dissimilarity depends on the ANOSIM global R value which ranges from 0 to 1 and therefore, it was negligible in multi-day trawls whereas it was much higher in the case of single-day trawls.

The findings of cluster analysis as resemblance dendrogram plot are shown in (**Fig. 4.1.5.2 (c & d)**). The cluster analysis with SIMPROF test showed maximum resemblance of 80% (Distance: 20%) between winter and post-monsoon and no resemblance between pre and post-monsoon in the species composition of single-day trawl catch. However, maximum resemblance observed in species composition of multi-day trawls was 96% (Distance: 4%) between winter and pre-monsoon whereas, the minimum resemblance of 86% (Distance: 14%) was observed between pre and post-monsoon. Pair-wise seasonal variation in species composition for single-day and multi-day trawls were depicted in **Table 4.1.5.2**

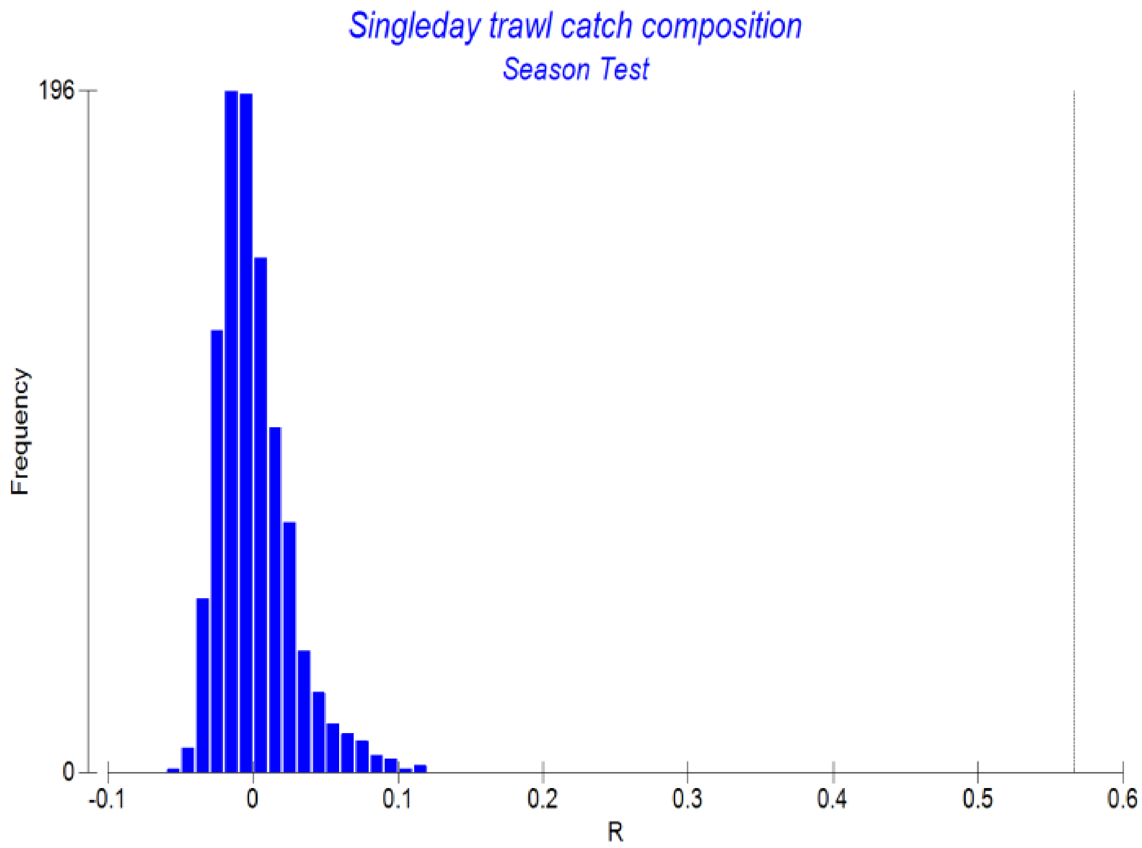

Fig. 4.1.5.2 (a) Seasonal similarity in the catch composition of single-day trawlers [Global R=0.567, P=0.001]

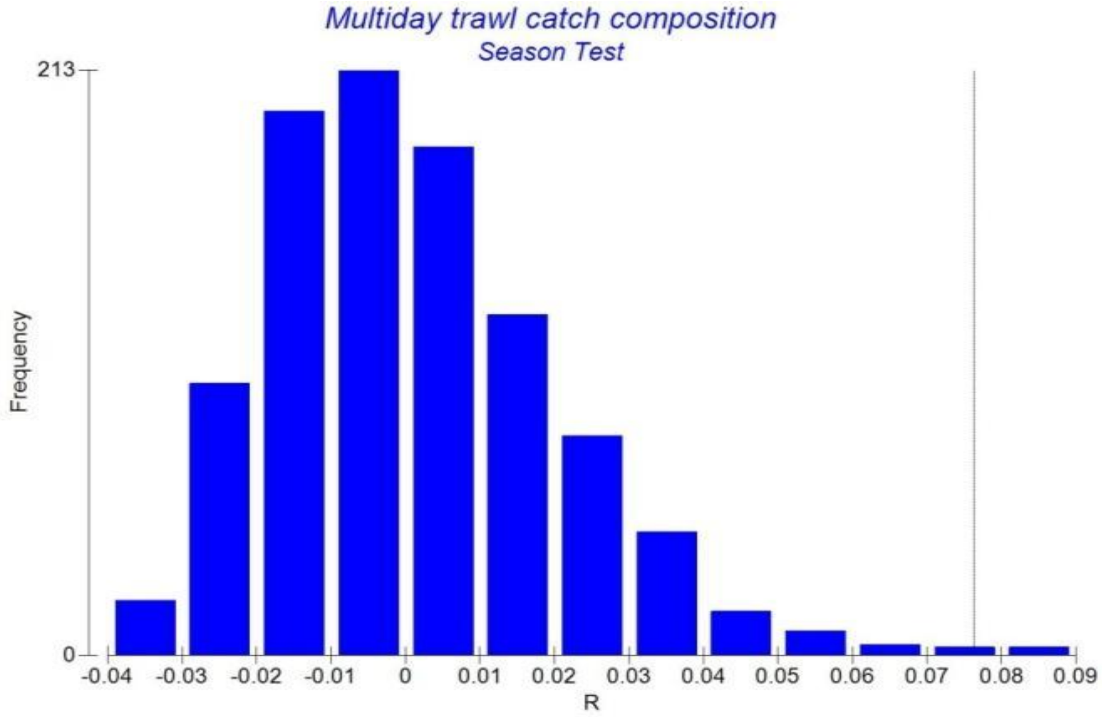

Fig. 4.1.5.2 (b) Seasonal similarity in the catch composition of multi-day trawlers [Global R=0.074, P=0.005]

Table 4.1.5.2 Pair-wise seasonal variation in species composition for single-day and multi-day trawls

Pairwise Tests	**Single-day trawls**		**Multi-day trawls**	
Seasons	**R Statistic**	**Significance Level %**	**R Statistic**	**Significanc e Level %**
Winter, pre monsoon	0.657	0.1	0.037	16.9
Winter, post monsoon	0.199	0.1	0.076	0.2
Pre monsoon, post monsoon	1	0.1	0.139	0.1

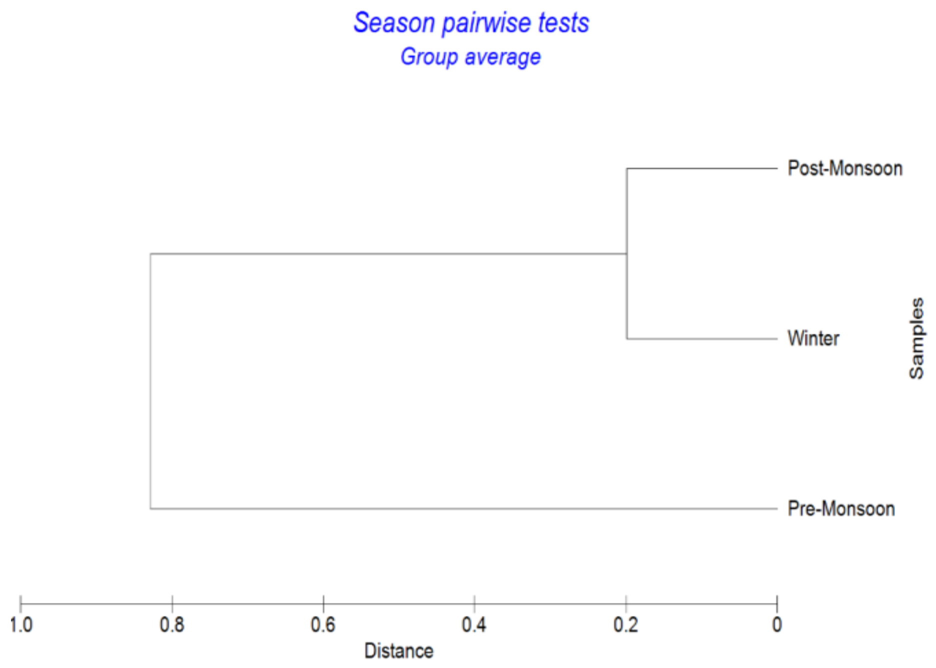

Fig. 4.1.5.2 (c) Dendrogram showing seasonal similarity in the catch composition of single-day trawlers [Global R=0.567, P=0.001]

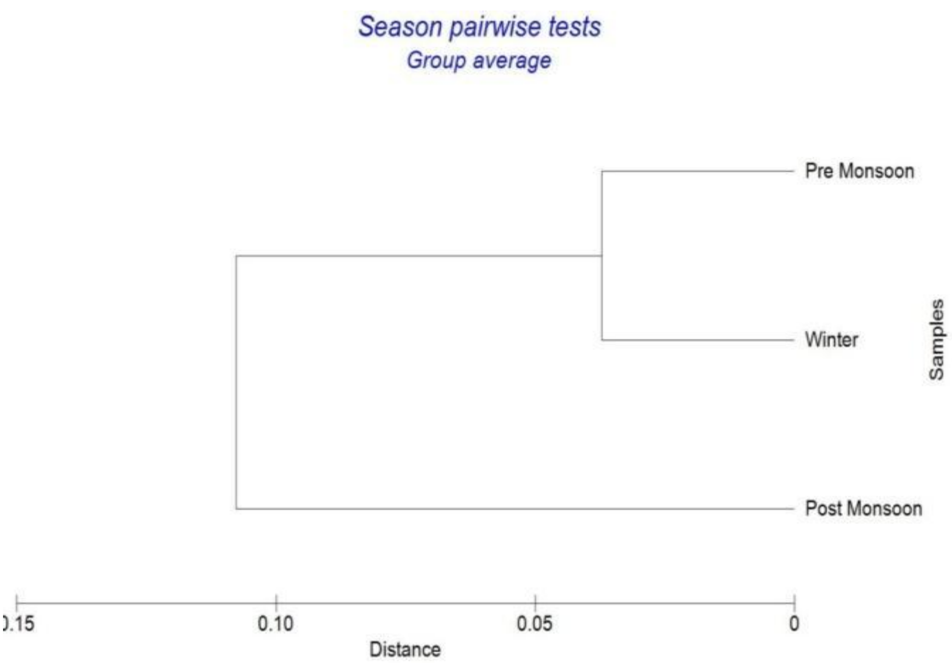

Fig. 4.1.5.2. (d) Dendrogram showing seasonal similarity in the catch composition multi-day trawlers [Global R=0.074, P=0.005

4.2. Carbon footprint of single-day and multi-day trawlers

4.2.1. Pre-harvest phase carbon footprint

The average carbon foot print of fishing craft made up of wood, which is commonly used as boat building material, is summarized in **Table 4.2.1.1**. Other components such as painting and coating materials, fitting and fixtures and other mechanical installations such as main engine, winch, warp, propeller, and anchor have also been processed for their additive effect on carbon footprint during the manufacturing process of craft **(Table 4.2.1.1)**. The materials used for manufacturing of these components were taken in to consideration along with electricity and fuel consumption used during the manufacturing also taken into calculation. Life spans of each components of the boat were anticipated and the CO_2e calculated accordingly. A single-day trawler contribute to average of -0.01590 kg CO_2 equivalent/kg fish at the construction of boat where as it was -0.01687kg CO_2 equivalent/kg fish for multi-day trawl.

The carbon footprint credited due to both types of fishing methods is summarised in **Table 4.2.1.2**. The carbon footprint of multi-day trawl made up of HDPE &PP as well as PA & PP (0.030and 0.056 kg CO_2e respectively credited for each kg fish harvested) was found to be higher compared to the single-day trawl net (0.017and 0.032kg CO_2e respectively credited for each kg fish harvested) made up of same materials. The carbon footprints of nets made up of polyamide (nylon) showed higher footprint compared to high density polyethylene. The float and sinker material and amount were same for the trawl net made up any material but it was varied in quantity from single-day trawl to multi-day trawl.

Table 4.2.1.1 Estimated carbon footprint of wooden boat (Single-day (a) and Multi-day trawler (b)) in Gujarat

(a) Craft type: Single-day trawler (Average catch /boat/ annum=117139.20kg)							
Components	**Materials used**	**Weight (Kg)**	**Electricity consumption (KWh)**	**Fuel consumption (L)**	**Kg CO_2 equivalent/boat/annum**	**Lifespan of material (yr)**	**Kg CO_2 equivalent /kg Fish**
Main craft	wood	35000	600	250	-4033.62	10	-0.03443
Nails, nuts bolts and other metallic assemblies	Iron	700	NA	NA	105.00	10	0.00090
Fibre glass coating	FRP	1500	NA	NA	1120.50	10	0.00957
Paint	Polyester	15	NA	NA	15.75	02	0.00013
Engine	Steel	700	NA	NA	350.00	10	0.00299
Propeller and assembly	Steel & Brass (50:50)	120	NA	NA	104.40	05	0.00089
Rudder and steering assemblage	Iron	200	NA	NA	60.00	05	0.00051
Fuel tank	Iron	70	NA	NA	10.50	10	0.00009
Mast	Iron	1000	NA	NA	150.00	10	0.00128
Winch	Iron	800	NA	NA	120.00	10	0.00102
Warp wire	Iron	900	NA	NA	135.00	10	0.00115
Single-day trawler total							**-0.01590**

(b) Craft type: Multi-day trawler (Average catch /boat/ annum=97465.95kg)							
Components	**Materials used**	**Weight (Kg)**	**Electricity consumption (KWh)**	**Fuel consumption (L)**	**Kg CO_2 equivalent/Boat/annum**	**Lifespan of material**	**Kg CO_2 equivalent/kg Fish**
Main craft	wood	40000	600	250	-4633.62	10	-0.04754
Nails, nuts bolts and other metallic assemblies	Iron	1000	NA	NA	150.00	10	0.00154
Fibre glass coating	FRP	2100	NA	NA	1568.70	10	0.01609
Paint	Polyester	21	NA	NA	22.05	02	0.00023
Engine	Engine	1100	NA	NA	550.00	10	0.00564
Propeller and assembly	Steel & Brass (50:50)	150	NA	NA	130.50	05	0.00134
Rudder and steering assemblage	Iron	200	NA	NA	60.00	05	0.00062
Fuel tank	Iron	90	NA	NA	13.50	10	0.00014
Mast	Iron	1200	NA	NA	180.00	10	0.00185
Winch	Iron	1000	NA	NA	150.00	10	0.00154
Warp wire	Iron	1100	NA	NA	165.00	10	0.00169
Multi-day trawler total							**-0.01687**

Table 4.2.1.2 Estimated carbon footprint of commonly used fishing nets in Gujarat

Gear type: Single-day trawl net (average catch /boat/ annum=117139.20kg)					
	Weight (kg) per Net	**Annual consumption (Net)**	**Kg CO_2 e/ Annum**	**Catch (kg)/Boat**	**Kg CO_2ecredited/kg fish**
Netting material and their ratio					
HDPE & PP (80:20)	85	5	1225.02	117139.20	0.010
PA & PP (80:20)	85	5	2979.76	117139.20	0.025
Float material					
ABS	200	100	394.10	117139.20	0.003
Sinker material					
Cast Iron	200	50.00	75.00	117139.20	0.004
	Single-day trawl made up of HDPE & PP total				**0.017**
	Single-day trawl made up of PA & PP total				**0.032**
Gear type: Multi-day trawl net (average catch /boat/ annum=97465.95 kg)					
	Weight (kg) per Net	**Annual consumption (Net)**	**Kg CO_2 e/ Annum**	**Catch (kg)/Boat**	**Kg CO_2 credited/kg fish**
Netting material and their ratio					
HDPE & PP (80:20)	90	7	1815.91	97465.95	0.019
PA & PP (80:20)	90	7	4417.06	97465.95	0.045
Float material					
ABS	252	126	496.57	97465.95	0.005
Sinker material					
Cast Iron	350	87.50	131.25	97465.95	0.006
	Multi-day trawl made up of HDPE & PP total				**0.030**
	Multi-day trawl made up of PA & PP total				**0.056**

The conversion of HDPE, PP, PA, ABS and cast iron to carbon dioxide equivalent is achieved by multiplying with the standard conversion factor viz. 2.789, 3.256, 4.160, 3.941, 1.50 Kg CO_2 equivalent/kg material consumed).

4.2.2. Harvest phase-carbon footprint

Catch rate i.e., CPUH and catch per boat of single-day and multi-day trawler is shown in **Table 4.2.2.1**. The annual average catch of single-day and multi-day trawler have been worked out as 117139.20 kg and 97465.95 kg respectively by multiplying the annual average catch rate (CPUH) 61.01 and 50.37 kg/h of the corresponding gears with the actual fishing hours of 1920 and 1930 hr per year of each gear respectively. It was observed that a single-day trawler usually conducted two trawling operations of 4 hour each in a day whereas a multi-day trawler conducted 3 trawling operations of 3 hours each in a day. Due to the state-imposed monsoon fishing ban for 60 days, a single-day trawler operated for 240 days whereas a multi-day trawler could operate only for 215 days in a year. Due to longer voyage period of 10-15 days, longer preparation period between consequent voyages and crew fatigue, a multi-day trawler generally lost 25 days of active fishing days compared to single-day trawler. The details of carbon footprint credited due to fishing is summarised in the **Table 4.2.2.2**. Higher carbon footprint was estimated in the case of multi-day trawler (0.79 kg CO_2 equivalent/kg fish) compared to that of single-day trawler (0.68kg CO_2 equivalent/kg fish).

Table 4.2.2.1 Catch and catch rate (CPUH) of major fishing gears contributing to the Gujarat marine capture fisheries during 2006-17

Year	Mechanized single-day trawler			Mechanized multi-day trawler		
	Catch	Effort	Catch per unit hour	Catch	Effort	Catch per unit hour
	(1000 kg)	(fishing hours)	(kg/h)	(1000 kg)	(fishing hours)	(kg/h)
2006	48026	966638	49.68	264973	3605978	73.48
2007	44261	834677	53.03	243516	4032773	60.38
2008	49962	809178	61.74	296296	3964223	74.74
2009	25727	371057	69.33	324457	4455182	72.83
2010	20236	356907	56.70	306238	4715031	64.95
2011	28523	458425	62.22	332695	6607043	50.35
2012	16279	339091	48.01	376440	7218878	52.15
2013	29385	299446	98.13	407802	8945010	45.59
2014	28312	343562	82.41	358032	9472920	37.80
2015	16658	237166	70.24	379424	9296158	40.82
2016	20993	451205	46.53	410004	10369299	39.54
2017	18038	210846	85.55	403513	8781238	45.95
Mean	28867	473183	61.01	341949	6788644	50.37

Table 4.2.2.2 Estimated carbon footprint of harvest phase in Gujarat

Vessel type	Mean CPUH	Fishing duration (H)	Catch (kg)/day	Fuel (l)/day	Fuel consumption (l)/ kg fish	Kg CO_2 equivalent/kg fish
Single-day Trawler	61.01	8	488.08	100.40	0.21	0.68
Multi-day Trawler	50.37	9	453.33	110.12	0.24	0.79

Conversion of diesel to carbon dioxide equivalent is achieved by using the standard conversion factor i.e. 1 L diesel = 3.241 kg of CO_2equivalent (DEFRA, 2012)

4.2.3. Post harvest phase-carbon footprint

Major source of carbon in the post-harvest phase is contributed by the supply chain processes such as transportation, usage of ice and processing. Carbon footprint of ice is mentioned in **Table 4.2.3.1**. Carbon footprint of fish subjected to storage using ice and processing is mentioned in **Table 4.2.3.2** and **Table 4.2.3.3**. The carbon footprint of multi-day trawler on account of use of ice for on-board preservation (0.43kg CO_2 equivalent/kg fish) was found to be higher compared to the single-day trawler (0.23kg CO_2 equivalent/ kg fish). The carbon footprint from processing units surges during off season (June to August) (**Table 4.2.3.3**). The carbon footprint of processed fish (usually frozen fish) during post harvest phase was found to be 0.82 kg CO_2 equivalent for every kg of fish.

Table 4.2.3.1 Estimated carbon footprint of ice plant in Gujarat

Months	Mean electricity consumed (KWh/kg ice)	Kg CO_2 equivalent/kg Ice
January	0.31	0.44
February	0.31	0.44
March	0.32	0.45
April	0.31	0.44
May	0.42	0.60
August	0.31	0.44
September	0.32	0.45
October	0.32	0.45
November	0.31	0.44
December	0.31	0.44
Annual mean	0.32	0.46

The conversion of electricity to carbon dioxide equivalent is achieved by multiplying with the standard conversion factor i.e. 1.4226 kg per KWh electricity consumed (DEFRA, 2012)

Table 4.2.3.2 Estimated carbon footprint of ice due to on-board fish preservation in Gujarat

Boat type	Mean CPUH	Fishing duration (H)	Catch (kg)/day	Ice (kg)/day	Kg Ice consumed/kg fish for on board preservation	Kg CO_2 equivalent due to ice/kg fish on-board preservation
Single -day trawler	61.01	8	488.08	240.00	0.49	0.23
Multi-day trawler	50.37	9	453.33	425.00	0.93	0.43

Conversion of ice to carbon dioxide equivalent is achieved by multiplying with conversion factor (0.46) derived from Table 4.2.3.1

Table 4.2.3.3 Estimated carbon footprint of processing plant during fish processing and preservation in Gujarat

Months	Electricity consumed (KWh/kg fish) during processing	Kg CO_2 e per kg fish processed from electricity	Mean diesel consumed (l/kg fish)for processing during power cut	Kg CO_2 e per kg fish processed using diesel during power cut	Total Kg CO_2 e per kg fish processed
Jan	0.62	0.88	0.002	0.006	0.89
Feb	0.49	0.70	0.001	0.003	0.70
Mar	0.44	0.62	0.002	0.006	0.63
Apr	0.47	0.67	0.001	0.003	0.67
May	0.48	0.68	0.001	0.003	0.68
June	0.97	1.38	0.001	0.003	1.38
July	0.76	1.09	0.004	0.013	1.10
Aug	1.17	1.66	0.005	0.016	1.68
Sept	0.30	0.42	0.001	0.003	0.42
Oct	0.48	0.68	0.002	0.006	0.69
Nov	0.35	0.50	0.001	0.003	0.51
Dec	0.37	0.53	0.001	0.003	0.53
Annual average	0.58	0.82	0.002	0.006	0.82

4.2.4. Transportation phase-carbon footprint

In the present study, the carbon footprints of different modes of transportations have been summarized in **Table 4.2.4.1**. The results revealed that 3-wheeler light motor carrier contributed highest with footprint of 0.000179 kg CO_2 e/kg load/km, while 4-wheeler heavy carrier contributed the lowest with 0.000019 kg CO_2e/kg load/km carbon footprint.

Table 4.2.4.1 Estimated carbon footprint of processing plant during fish processing and preservation in Gujarat

Type of Vehicle	Mean mileage (km/l)	Mean transportation capacity (kg)	Mean diesel used (l/kg/km)	Kg CO_2 e/kg load/km
3-wheeler light motor carrier	20	750	0.000067	0.000179
4-wheeler light motor carrier	15	2500	0.000027	0.000072
4-wheeler heavy carrier	7	20000	0.000007	0.000019
4-wheeler heavy insulated van	5	25000	0.000008	0.000021

4.2.5. Gross carbon footprint from all the phases excluding transportation phase

Estimated carbon footprint (CO_2 equivalent per kg fish) of all the phases of fish production excluding transportation phase is summarized in **Table 4.2.5.1** which indicated that carbon footprint of multi-day trawler (2.05 and 2.08 kg CO_2 equivalent for the production of every kg of fish) was comparatively higher than that of single-day trawler (1.72 and 1.73 kg CO_2 equivalent for production of every kg of fish).

Table 4.2.5.1 Estimated carbon footprint (CO_2 equivalent per kg fish) of all the phases excluding transportation phase of fish production from capture fisheries in Gujarat

Craft and gear type	Pre-harvest phase(CO_2 e per kg fish)		Harvest phase(CO_2 e per kg fish)	Post-harvest Phase(CO_2 e per kg fish)		Total excluding transportation phase (CO_2 e per kg fish)
	Craft	Gear	Fishing	Onboard preservation using ice	Processing	
Single-day trawler using net made of HDPE and PP	-0.016	0.017	0.666	0.23	0.82	1.72
Single-day trawler using net made of PA and PP	-0.016	0.032	0.666	0.23	0.82	1.73
Multi-day trawler using net made of HDPE and PP	-0.017	0.030	0.787	0.43	0.82	2.05
Multi-day trawler using net made of PA and PP	-0.017	0.056	0.787	0.43	0.82	2.08

4.3. Economic performance of trawlers

The mechanized trawlers were grouped into two categories based on the number of days involved in fishing for the purpose of study. They are single-day and multi-day boats having single and up to 7-21 days of fishing respectively. Specification and particulars of both types of trawlers operating in Gujarat are given in **Table 4.3.1**

A single-day trawler operated throughout the year but operated more frequently only for six months during the peak fishing season from August to January. These boats are made of wood having an overall length ranging from 40 to 45 feet. The fishing hours ranged from 6-8 h depending on the fishing season. These vessels are fitted with engines whose capacities ranged from 88 to 99 hp. On an average, a single-day trawler conducts 215 fishing trips in a year with an average of 25 trips per month during peak season.

Table 4.3.1 Specification and particulars of fishing craft deployed for trawling in Gujarat waters

Particulars	Single-day Trawlers	Multi-day Trawlers
Crew size (numbers)	5	7
Avg. trip duration (days)	1	15
Expected life or durability in years	18	25
Annual average fishing days	240	215
Average duration (days)	1	15
Avg. trips per month	25	2
Avg. trips in a year	240	20
Fuel consumption (liters / trip)	100	1650
Average catch / trip (kg)	488	4873

In case of multi-day trawlers, overall length of the vessels ranged from 45-60 feet. Fishing trips lasted up to 21days in lean season. The horse power of engines varied from 100 to 400. It was found that trawlers of Gujarat have been fitted with high-speed engines imported from China in the recent past to increase their efficiency. They consumed on an average 1650 liters of diesel per trip depending on the fishing season and voyage duration. The crew size went up to 7 to 8 in multi-day trawler while it was restricted to 5 in single-day trawler. Wood is used as the primary material for boat building in Gujarat. Lifespan of single and multi-day trawlers is generally taken as 18 and 25 years respectively. Mangrol and Veraval are the two most important boat building yards of Saurashtra coast supplying boats thought Gujarat and neighboring states.

The multi-day trawlers are provided with a fish hold capacity of 4000-12000 kg depending upon the size of boat while it is confined to 1000-4000 kg in single-day trawlers due to shorter duration of fishing trips. Multi-day trawler on an average undertook 20 trips with 215 days of fishing in a year. Single-day trawler carries3 blocks of ice and 100 liters of diesel per trip, while the multi-day trawler carries 80 blocks of ice and an average of 1650 liters of diesel per trip depending upon the season and abundance of catch. Moreover, a single-day trawler ventures only up to a depth of 40m, but in the case of multi-day trawler, the depth of operation extends from 40 to 200m depending upon the targeted resource and potency of fishing ground.

Magnetic compass and wireless are mostly used as navigation and communication equipment in single-day trawler. However, few trawlers also carry GPS for ease of the locating grounds. In addition, multi-day trawlers use VHF for communication, and Echosounder and SONAR for detecting the fish shoals and ground to increase the proficiency for an enhanced catch rate. VHF and DART are used while at sea for signaling in distress and communication between other units and shore-based help centers.

Total fixed cost was estimated for single-day and multi-day trawlers operated in Gujarat waters by collecting the information from trawl owners selected randomly from Veraval, Mangrol and Porbandar. The details of total fixed cost are given in **Table 4.3.2**

The boat cost is the major input required initially for both type of trawlers. More powerful engines with increased horse power are used in multi-day trawler which cost higher than that of single-day unit. The items of capital cost include expenses for hull, engine, winch and accessories, gears (nets), otter board, ropes, batteries, navigational and communication equipments. The average cost of hull for single-day unit was 8 lakhs rupees and 30 lakhs for the multi-day trawl unit. The engine costs nearly 2.5 lakhs and 5 lakhs rupees and the net cost was Rs. 2.9 lakhs and 4.25 lakhs rupees for single-day and multi-day trawl units respectively. The total capital investment in a single-day trawler amounted to nearly 16 lakhs rupees and for multi-day trawl it goes up to 49 lakhs.

Table 4.3.2 Details of expenditure incurred under fixed costs for single-day and multi-day trawler of Gujarat

Particulars	**Single-day Trawlers (Rs.)**	**Multi-day Trawlers (Rs.)**
Boat cost	800000	3000000
Engine	250000	500000
Winch and other accessories	90000	150000
Steering and wheel box	15000	50000
Propeller, rod and assemblage	55000	100000
Chain, bolts and fittings, etc.	15000	20000
Mast and accessories	35000	50000
Otter board	32000	50000
Net with accessories	290000	425000
Anchor	20000	35000
Diesel tank	-	40000
Water tank	-	15000
Batteries and electrical fittings	10000	40000
Compass	2000	2000
VHF	-	25000
Fish finder	-	30000
GPS	10000	30000

The percentage share of all the items of capital investment for both types of trawlers are given in **Fig. 4.3.1.1**.Cost of boat hull was shared highest among all the capital investment followed by the cost of engine and accessories in multi-day trawl, whereas the accessories including the shaft, propeller, gear, and other engine fittings. However, boat hull cost in single-day trawl also remains as highest contributor to the total capital investment followed by the cost of net and accessories and engine & accessories.

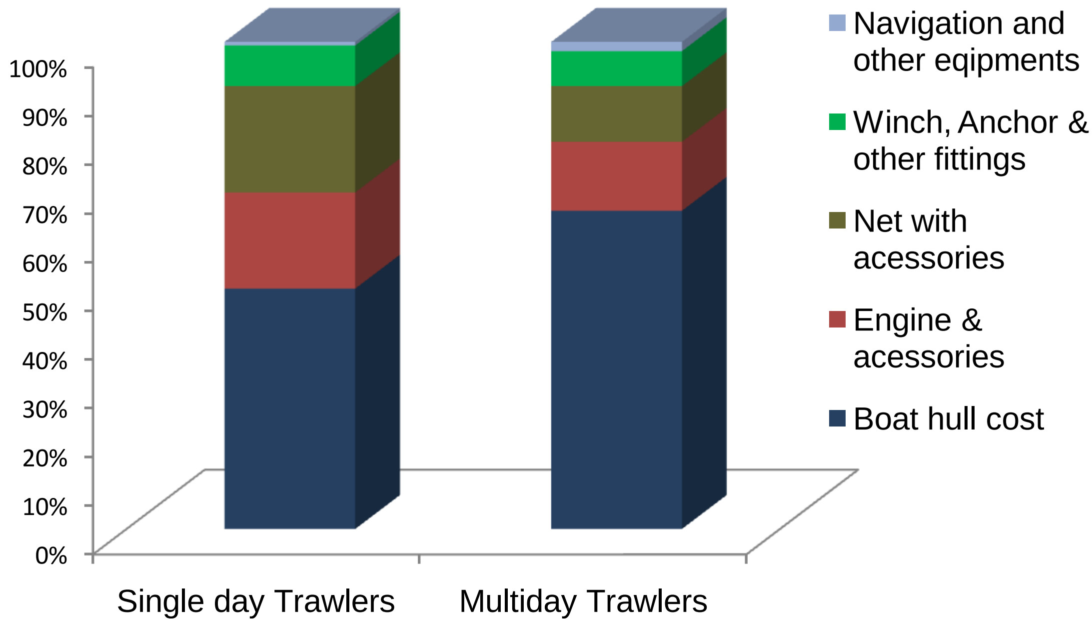

Fig. 4.3.1 Percentage share of different capital cost for both single-day and multi-day trawlers operated from Gujarat

4.3.1. Economic performance of mechanized fishing in Gujarat

Analysis showed that the single-day trawlers used up to 66% of operating cost for fuel and 22% for wages of crew members per trip. In case of multi-day trawlers, 60% of operating cost was spent on fuel and 26% on wages for labour. Higher operating cost for multi-day trawlers is due to more days spent on voyage. The details of operating cost are shown in **Fig. 4.3.1.1.**Single-day trawlers pent 3 % of its total operating cost per trip towards ice for keeping samples in fresh condition. However, multi-day trawler spent 4% towards ice and salt to store the fish in fresh condition.

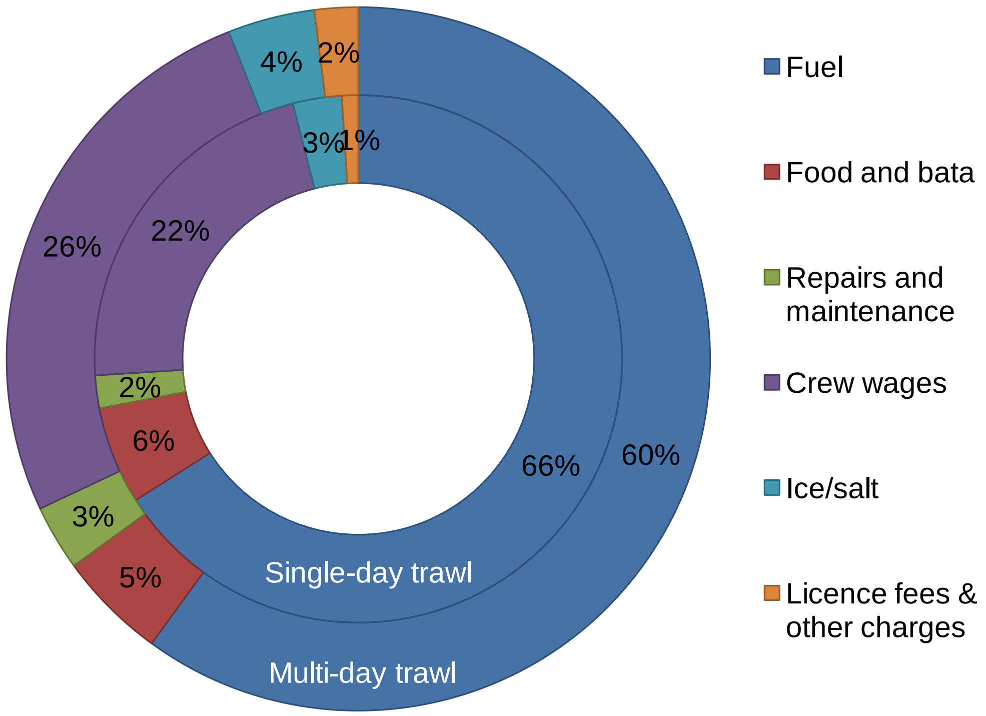

Fig. 4.3.1.1 Percentage share by different operating costs for both single-day and multi-day trawlers operated from Gujarat

4.3.2. Costs and returns per trip of trawlers operating from Gujarat coast

The details of cost and returns per trip for the mechanized trawler units are given in **Table 4.3.2.1**. The fixed cost includes interest for initial fixed investment @ 7% per annum and its depreciation @ 10% per annum. With an average 20 fishing trips in a year for multi-day trawler (voyage duration ranging between 7-21 days), the fixed cost was worked out as Rs. 24,596/- per trip while the operational cost for the multi-day unit accounted for Rs. 1, 84,047/- per trip and the fuel cost calculated at 60% (Rs. 1, 09,725/-) per trip. The per-trip earnings for the multi-day trawler unit were averaged to Rs. 3, 70,000/- with an average net profit of Rs. 1, 61,386/- per trip.

Table 4.3.2.1 Average costs and returns (Rs. /trip) of mechanized trawlers in Gujarat

S. No	Particulars	Single-day trawler	Multi-day trawler
1	Fuel cost	6650	109725
2	Crew wages	2160	48000
3	Food and bata	600	9000
4	Ice &salt	300	8000
5	Repairs and maintenance	229	5500
6	License &other charges	331	3791
7	**Total operating cost (1 to 6)**	**10270**	**184017**
8	Depreciation @10 % per annum	318	426
9	Interest on fixed capital @7 % per annum	472	16072
10	**Total fixed cost (8+9)**	**791**	**24596**
11	**Total cost (7 +10)**	**11062**	**208613**
12	**Gross revenue (GR)**	**22000**	**370000**
13	**Net profit (12-11)**	**10938**	**161387**

On the contrary, the single-day trawler undertook on an average of 240 fishing trips in a year. The fixed costs for these units were calculated as Rs. 791 per trip and the operational cost as Rs. 10,270/- per trip. The operational cost shares 92% of the total cost per trip, out of which fuel and wages for the crew together shares nearly than 80 %. The gross revenue per trip amounted to Rs. 22, 000/- in all fishing seasons with a total cost of Rs. 11,062/- spent per trip. Major reason for the lower net profit of Rs. 10,938/- for single-day trawler may be due to short voyage, low-value catch and limited capability of fishing unlike multi-day trawler.

Table 4.3.2.2 Economic and financial indicators of mechanized fishing per trip in Gujarat

S. No	Particulars	Single-day trawler	Multi-day Trawler
1	Labour productivity (kg/crew/trip)	97.6	696.4
2	Operating ratio	0.467	0.497
3	Input-Output ratio	0.369	0.368
4	Fuel efficiency Kg/ lit Rs/lit	4.8 220.00	2.95 224.20
5	Gross Value Added (GVA) (Rs.)	13097.00	209386.00
6	GVA to GR (%)	59.53	56.59
7	B-C Ratio	1.99	1.77
8	Net profit ratio	0.50	0.44

The economic and financial indicators calculated from the average fixed and operational cost of trawlers operated from Gujarat are shown in details in **Table 4.3.2.2**. The capital productivity (operating ratio) indicators showed that both single-day and multi-day trawlers were equally efficient having values 0.467 and 0.497 respectively. Labour productivity is the average quantity of product generated per labourer. Labour productivity for single-day trawlers was worked out at 97.6 kg/ crew/trip whereas in multi-day trawlers, it was 696 kg/ crew /trip. The input-output ratio for single-day trawler was estimated at 0.369 which was almost similar to the value estimated for multi-day trawler (0.368). In terms of fuel efficiency, the single-day trawlers were better than multi-day units. The gross value added for multi-day trawler was much higher (Rs. 2, 09,386.00) than that calculated for single-day unit (Rs.13, 097.00). The contribution of gross value added to gross revenue in case of multi-day trawlers was 56.59% compared to 59.53% for Single-day trawler. In terms of catch per liter of diesel, it was calculated as 4.80 & 2.95 kg of fish for single-day and multi-day trawler respectively. However, the corresponding values were Rs 220.00 & Rs. 224.20 in terms of revenue for single-day and multi-day unit respectively.

4.4. Fish quality of selected commercially important species

4.4.1. Temporal changes in biochemical parameters (TMA & TVBN)

The changes in trimethyl amine (TMA) and total volatile base nitrogen (TVBN) levels, pH, and TPC (total plate count) (mean ± SD) of selected fishes during 0^{th}, 5^{th}, 10^{th} and 15^{th} day post storage in ice and the means (histograms) with different alpha labels in each category of fishes varies significantly (P≤0.01) are shown in **Table 4.4.1 (a &b)** and **Fig. 4.4.1.1** & **Fig. 4.4.1.2**. The increases in TMA and TVBN levels were found to be significant (P≤0.01) during the storage time for all the fishes. The TMA value ranged between 1.23-2.35 mg N/100g on 0^{th} day which became 7.02-8.65 mg N/100g respectively after 15 days of storage in ice. Similarly, the TVBN value ranged between 17.87-19.27 mg N/100g on 0^{th} day which became 33.69-35.33 mg N/100g after 15 days of storage in ice. The TMA and TVBN levels during storage period were found to be gradually increasing and significantly different at each point of observation (1^{st} day, 5^{th} day, 10^{th} day and 15^{th} day).

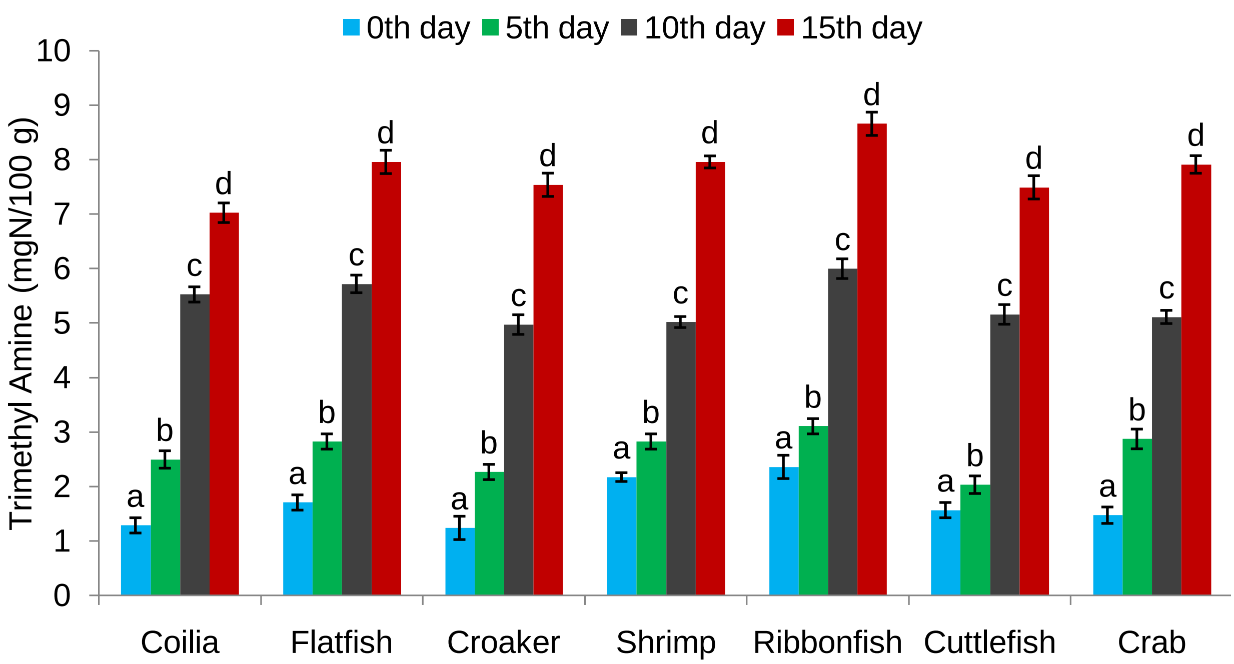

Fig. 4.4.1.1 Temporal changes in TMA level of selected fish groups during post storage in ice.

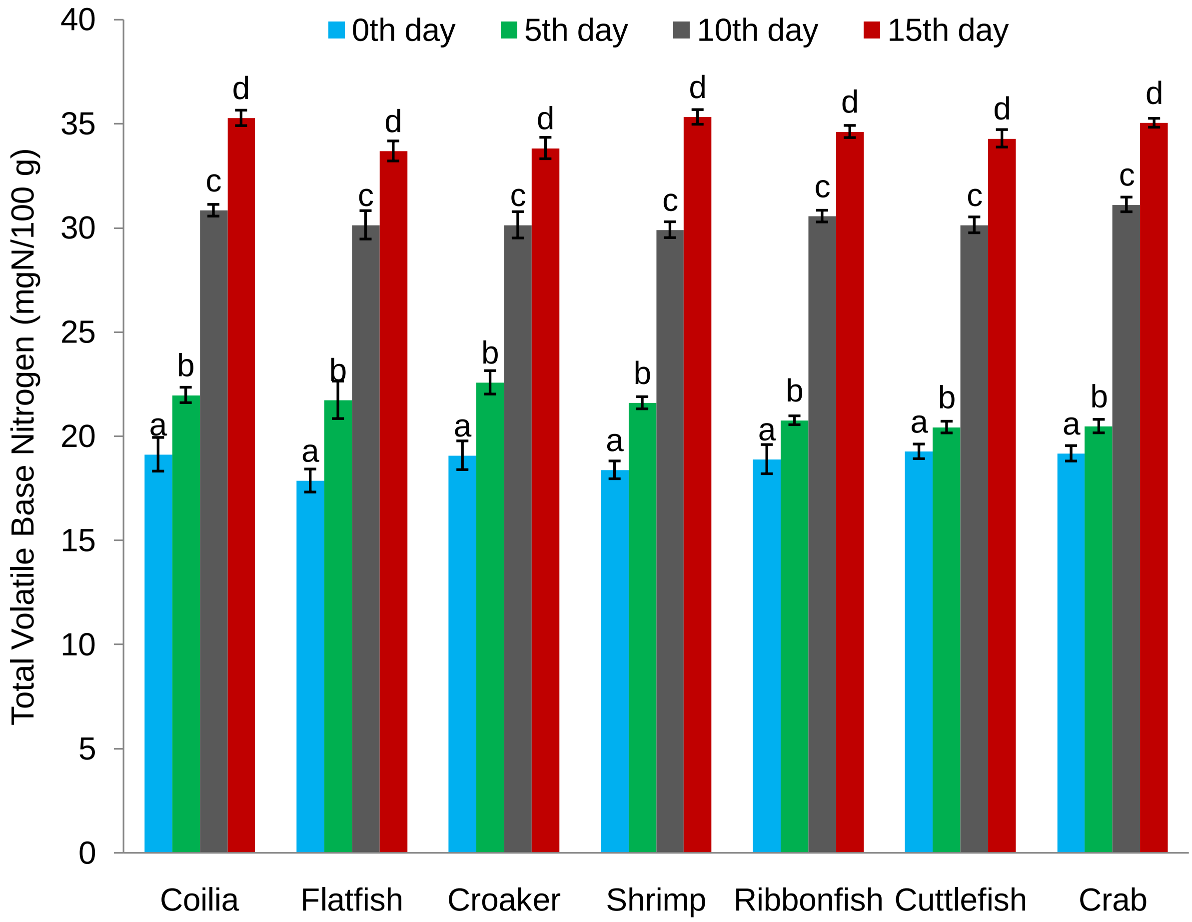

Fig. 4.4.1.2 Temporal change in TVBN level of selected fish groups during post storage in ice.

4.4.2. Temporal changes in physical parameter (pH)

The pH value ranged between 6.52 to 6.83 on 0^{th} day but showed a significant decrease during 5^{th} day ranging between 6.47 to 6.59 except for cuttlefish where no significant difference in pH level was observed compared to 0^{th} day. The pH further increased significantly during 10^{th} and 15^{th} day in the muscle tissue sample of all the fishes ranging between 7.19 to 7.30. The changes pH (mean ± SD) of selected fishes during 0^{th}, 5^{th}, 10^{th} and 15^{th} day post storage in ice and the means (histograms) with different alpha labels in each category of fishes varies significantly (P≤0.01) are shown in **Table.4.4.1 (c)** and **Fig. 4.4.2.1**.

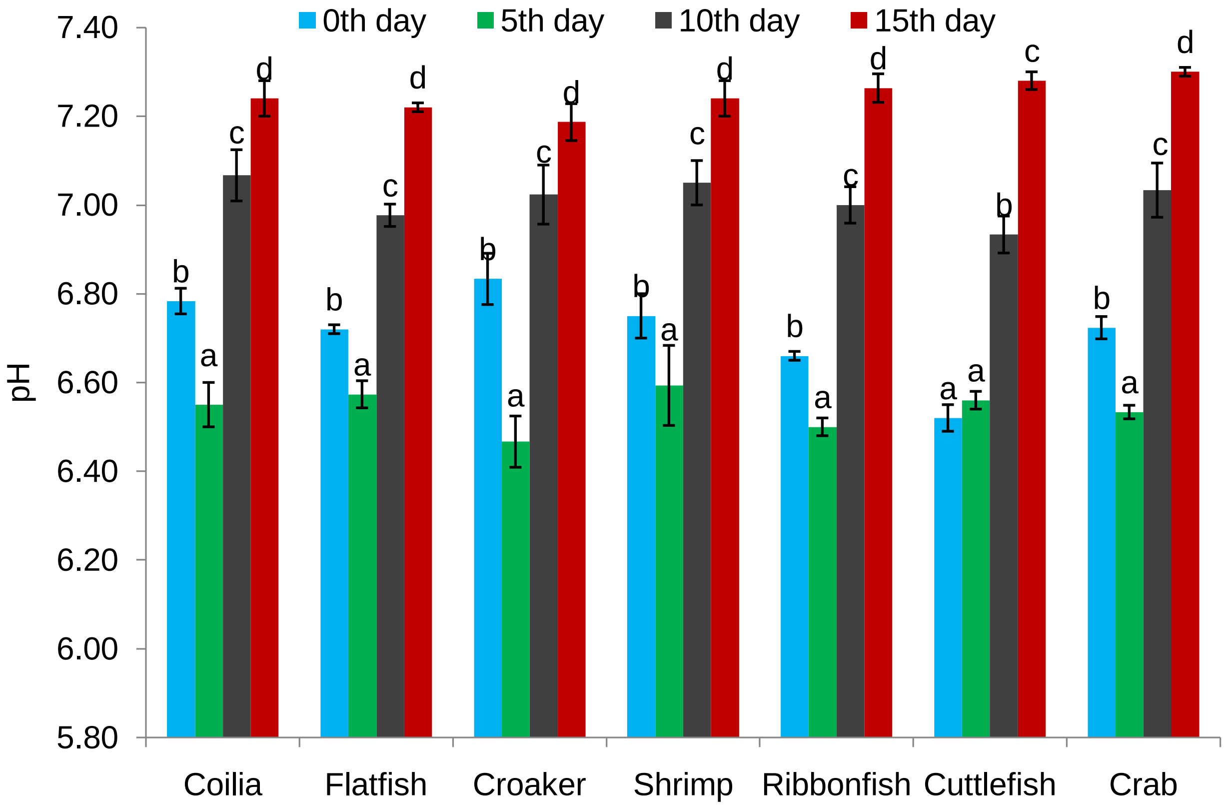

Fig. 4.4.2.1 Temporal changes in pH level of selected fish groups during post storage in ice.

4.4.3. Temporal changes in microbial parameters (TPC)

The TPC value ranged between2.23 to 2.61 log CFU/mg on 0th day and did not differ significantly on 5th day for most of the fishes except for *Coilia* and Crab where it increased significantly compared to 0th day. The TPC showed significant increase on 10th and 15th day in the muscle tissue sample of all the fishes ranging between 7.43 to 7.81 log CFU/ mg. The changes in TPC (total plate count) (mean ± SD) of selected fishes during 0th, 5th, 10th and 15th day post storage in ice and the means (histograms) with different alpha labels in each category of fishes varies significantly (P≤0.01) are shown in **Table 4.4.1 (d)** and **Fig. 4.4.3.1**.

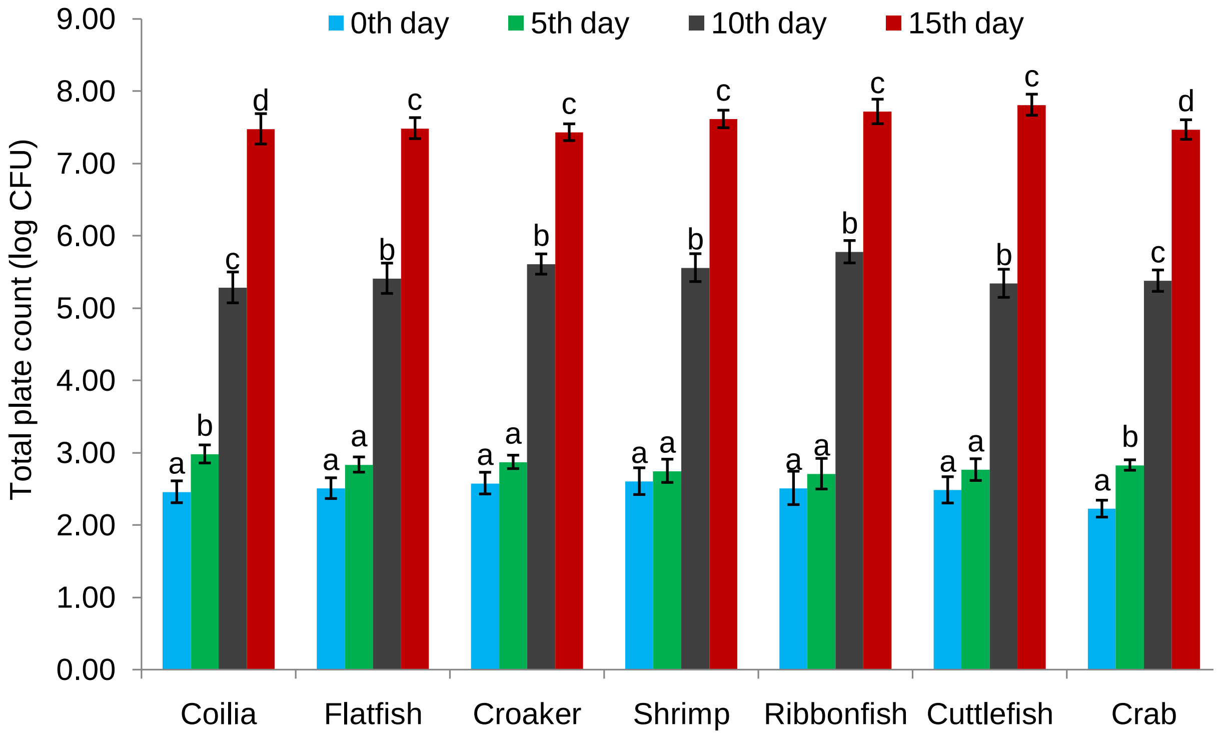

Fig. 4.4.3.1 Temporal change in TPC (log CFU) level of selected fish groups during post storage in ice.

Table 4.4.1.1 Temporal change in TMA, TVBN, pH and TPC level of selected fishes and shellfishes during 0^{th}, 5^{th}, 10^{th} and 15^{th} day post storage in ice

	Coilia	Flatfish	Croaker	Shrimp	Ribbonfish	Cuttlefish	Crab
(a) Trimethyl Amine (TMA) (mg N/100 g)							
0^{th} day	1.28 ± 0.14^{a}	1.70 ± 0.14^{a}	1.23 ± 0.21^{a}	2.17 ± 0.08^{a}	2.35 ± 0.21^{a}	1.56 ± 0.14^{a}	1.47 ± 0.15^{a}
5^{th} day	2.49 ± 0.16^{b}	2.82 ± 0.14^{b}	2.26 ± 0.14^{b}	2.82 ± 0.14^{b}	3.10 ± 0.14^{b}	2.03 ± 0.16^{b}	2.87 ± 0.18^{b}
10^{th} day	5.52 ± 0.14^{c}	5.71 ± 0.16^{c}	4.97 ± 0.18^{c}	5.01 ± 0.10^{c}	5.99 ± 0.18^{c}	5.15 ± 0.18^{c}	5.11 ± 0.12^{c}
15^{th} day	7.02 ± 0.18^{d}	7.95 ± 0.21^{d}	7.53 ± 0.21^{d}	7.95 ± 0.11^{d}	8.65 ± 0.21^{d}	7.49 ± 0.21^{d}	7.91 ± 0.16^{d}
(b) Total volatile base nitrogen (TVBN) (mg N/100 g)							
0^{th} day	19.13 ± 0.81^{a}	17.87 ± 0.55^{a}	19.09 ± 0.69^{a}	18.39 ± 0.43^{a}	18.90 ± 0.70^{a}	19.27 ± 0.35^{a}	19.18 ± 0.37^{a}
5^{th} day	21.98 ± 0.37^{b}	21.75 ± 0.90^{b}	22.59 ± 0.56^{b}	21.61 ± 0.29^{b}	20.77 ± 0.21^{b}	20.44 ± 0.28^{b}	20.49 ± 0.32^{b}
10^{th} day	30.85 ± 0.28^{c}	30.15 ± 0.68^{c}	30.15 ± 0.63^{c}	29.91 ± 0.38^{c}	30.57 ± 0.28^{c}	30.15 ± 0.38^{c}	31.13 ± 0.35^{c}
15^{th} day	35.28 ± 0.37^{d}	33.69 ± 0.48^{d}	33.83 ± 0.51^{d}	35.33 ± 0.35^{d}	34.63 ± 0.29^{d}	34.30 ± 0.42^{d}	35.05 ± 0.21^{d}
(c) pH							
0^{th} day	6.78 ± 0.03^{b}	6.72 ± 0.01^{b}	6.83 ± 0.06^{b}	6.75 ± 0.05^{b}	6.66 ± 0.01^{b}	6.52 ± 0.03^{a}	6.72 ± 0.03^{b}
5^{th} day	6.55 ± 0.05^{a}	6.57 ± 0.03^{a}	6.47 ± 0.06^{a}	6.59 ± 0.09^{a}	6.50 ± 0.02^{a}	6.56 ± 0.02^{a}	6.53 ± 0.02^{a}
10^{th} day	7.07 ± 0.06^{c}	6.98 ± 0.03^{c}	7.02 ± 0.07^{c}	7.05 ± 0.05^{c}	7.00 ± 0.04^{c}	6.93 ± 0.04^{b}	7.03 ± 0.06^{c}
15^{th} day	7.24 ± 0.04^{d}	7.22 ± 0.01^{d}	7.19 ± 0.04^{d}	7.24 ± 0.04^{d}	7.26 ± 0.03^{d}	7.28 ± 0.02^{c}	7.30 ± 0.01^{d}
(d) Total Plate Count (TPC) (log CFU/ g)							
0^{th} day	2.46 ± 0.15^{a}	2.51 ± 0.14^{a}	2.58 ± 0.15^{a}	2.61 ± 0.19^{a}	2.51 ± 0.23^{a}	2.49 ± 0.18^{a}	2.23 ± 0.12^{a}
5^{th} day	2.98 ± 0.13^{b}	2.84 ± 0.11^{a}	2.87 ± 0.09^{a}	2.75 ± 0.16^{a}	2.71 ± 0.21^{a}	2.77 ± 0.15^{a}	2.83 ± 0.07^{b}
10^{th} day	5.29 ± 0.21^{c}	5.41 ± 0.21^{b}	5.61 ± 0.14^{b}	5.56 ± 0.19^{b}	5.78 ± 0.15^{b}	5.34 ± 0.19^{b}	5.38 ± 0.15^{c}
15^{th} day	7.48 ± 0.21^{d}	7.49 ± 0.15^{c}	7.43 ± 0.12^{c}	7.62 ± 0.12^{c}	7.72 ± 0.17^{c}	7.81 ± 0.15^{c}	7.47 ± 0.14^{d}

4.4.4. Temporal changes in sensory parameter

Sensory analysis results of fish groups are shown in **Table 4.4.4.1**. At the beginning of the storage period, the sensory analysis values by the panelist determined in a range of 8.9 to 9.00 for the all the attributes like appearance, color, odour, texture and overall acceptance of the fishes at 0^{th} day of storage. All sensory parameters correlated with time. According to the scale and values given by panelist all the fish groups are in best quality in 0^{th} day and maintained good quality up to 5^{th} day of storage. However points between 7 to 5 shows moderate quality which maintained up to 10 to 15 days and falls to 5 points by the end of 15 days and considered as not acceptable.

By contrast the appearance of the fishes, which was quite prominent and fresh on day 0, became fade with advancement of the storage period **(Fig. 4.4.4.1)**. At the 10^{th} day appearance became increasingly weaker and reached to a total dull in at the end of 15^{th} day in most of the fish groups.

Color of fish groups shows significant differences with advancement of storage period and shows near to unacceptable at the onset of 15^{th} day onwards **(Fig. 4.4.4.2)**. More over the fresh natural color of the skin was observed in day 0 and fade moderately in day 5^{th} to 10^{th}.

Texture of the fish also a freshness indicator which changes from very firm and stiffness in 0^{th} day to firm in 5^{th} day and soft, sunken and burst condition was observed in 10^{th}, 15^{th} and 20^{th} day of post storage in ice. The values for the said texture quality also decreased with the increase in storage time **(Fig. 4.4.4.3)**.

The odour of the fish also an excellent freshness indicator having strong values near to 9 in all fish groups at 0^{th} day. Significant variation between the storage time was observed with respect to values marked by the panelist are shown in **(Fig. 4.4.4.4)**. However the values attributes as per the Fresh, Neutral, fishy, stale and spoilt odour of the fish encountered in 0^{th}, 5^{th}, 10^{th}, 15^{th} and 20^{th} day of post storage respectively.

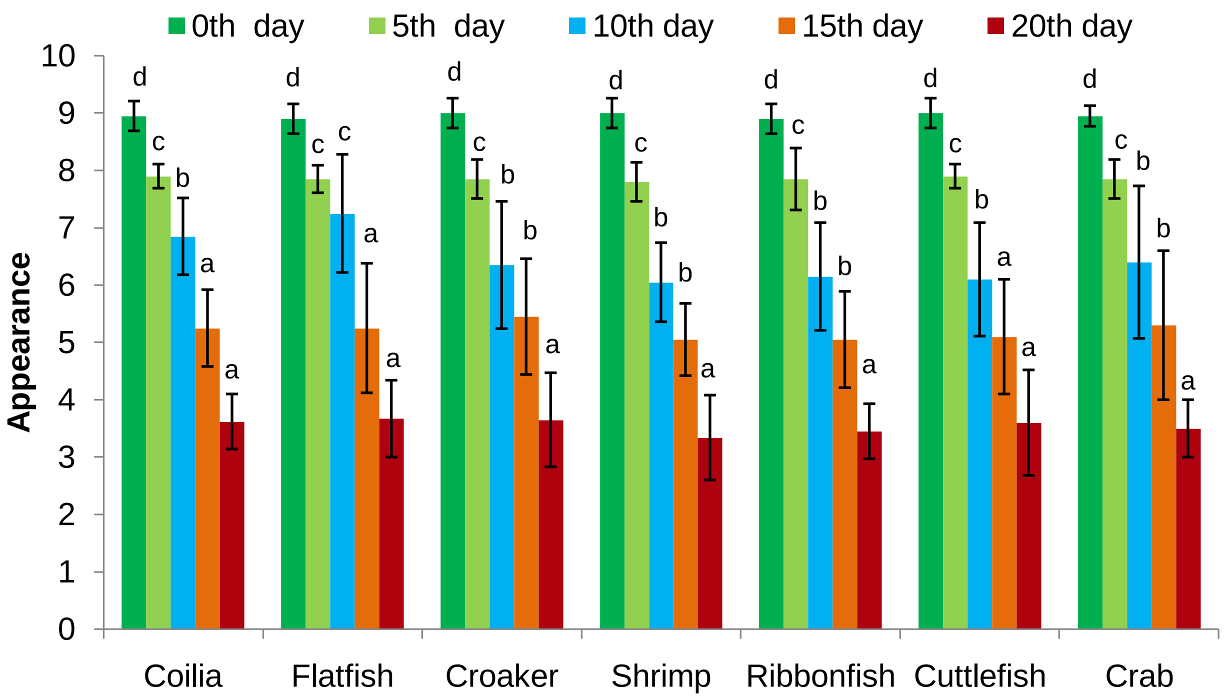

Fig. 4.4.4.1 Temporal change in appearance of selected fish groups during post storage period in ice.

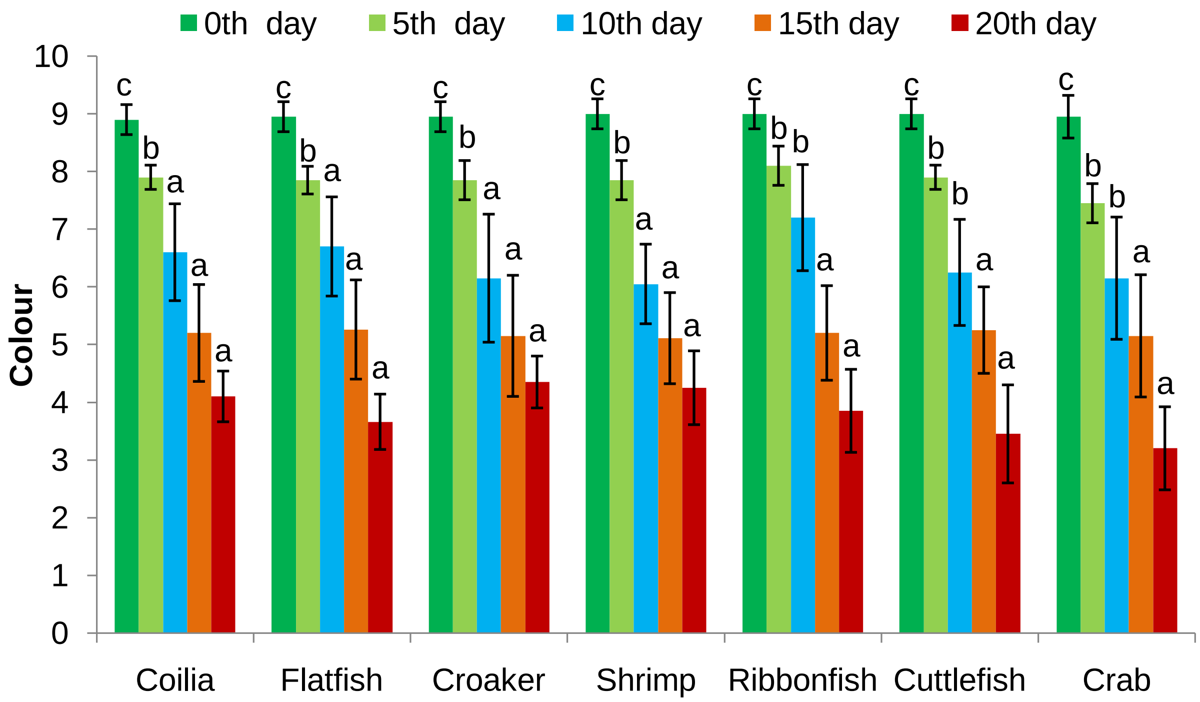

Fig. 4.4.4.2 Temporal change in Colour of selected fish groups during post storage period in ice.

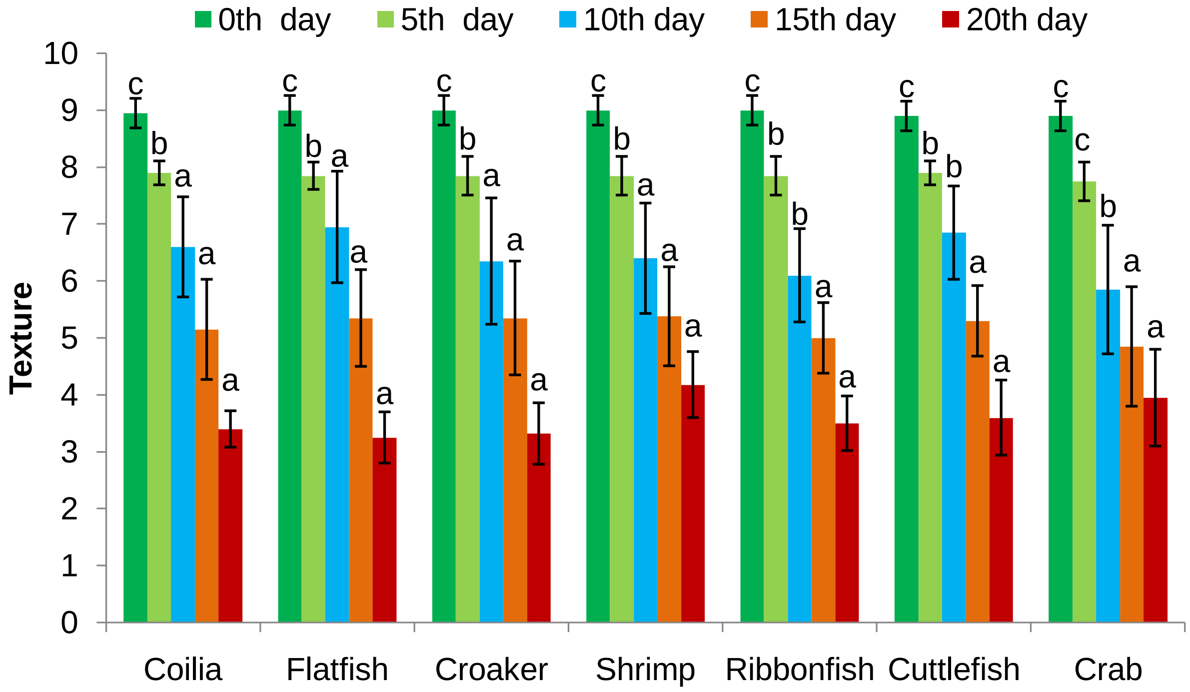

Fig. 4.4.4.3 Temporal changes in Texture of selected fish groups during post storage period in ice.

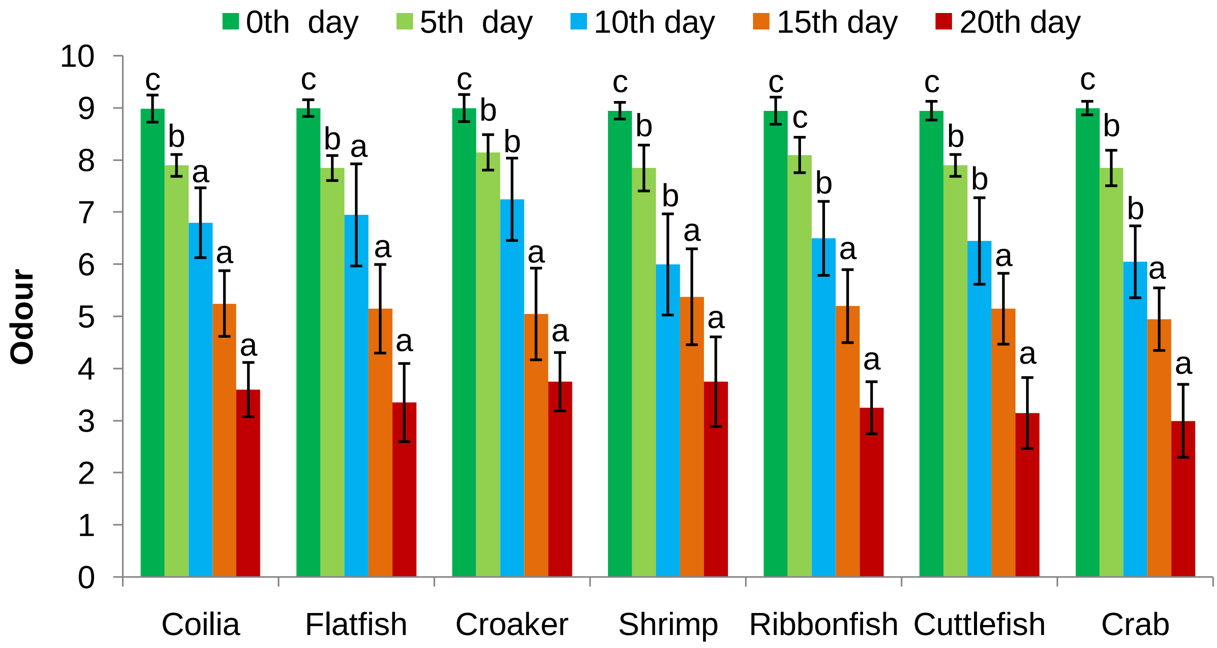

Fig. 4.4.4.4 Temporal change in Odour of selected fish groups during post storage period in ice.

The decreasing values according to the storage time for the overall acceptance of the selected fish groups were shown in **(Fig.4.4.4.5),** which shows a significant difference with the duration of storage. Score of 5 or below was considered as the threshold limit for declare unacceptable to the fish by considering the overall acceptance features which look into all phases of the sensory aspect of the fishes.

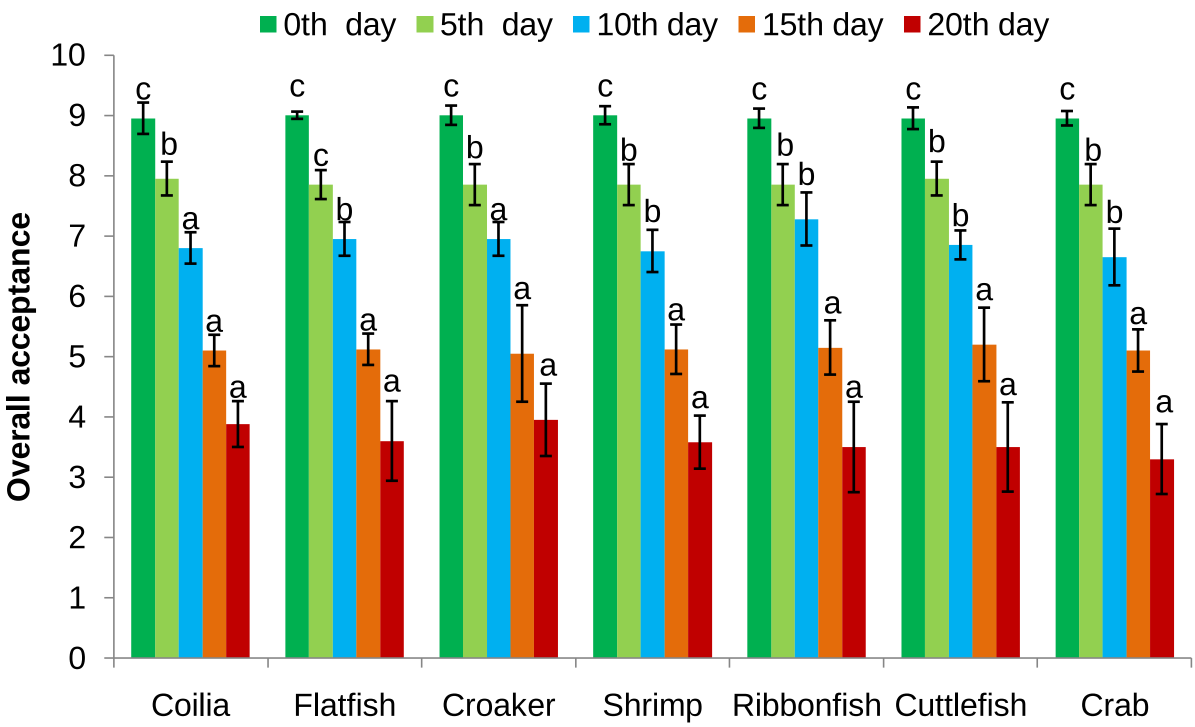

Fig. 4.4.4.5 Temporal change in Overall Acceptance of selected fish groups during post storage period in ice.

Table 4.4.4.1 Temporal change in appearance, colour, texture, odour and overall aceptance level of selected fishes and shellfishes during 0th, 5th, 10th, 15th and 20th day post storage in ice

	Coilia	Flatfish	Croaker	Shrimp	Ribbonfish	Cuttlefish	Crab
Appearance							
0th day	8.95 ± 0.26c	8.90 ± 0.26 c	9.00 ± 0.26 c	9.00 ± 0.26 c	8.90 ± 0.26c	9.00 ± 0.26 c	8.95 ± 0.18c
5th day	7.90 ± 0.21b	7.85 ± 0.24 b	7.85 ± 0.34 b	7.80 ± 0.34 b	7.85 ± 0.54 b	7.90 ± 0.21 b	7.85 ± 0.34 b
10th day	6.85 ± 0.67a	7.25 ± 1.03 b	6.35 ± 1.11 a	6.05 ± 0.69 a	6.15 ± 0.94 a	6.10 ± 0.99 b	6.40 ± 1.33 b
15th day	5.25 ± 0.67a	5.25 ± 1.13 a	5.45 ± 1.01 a	5.05 ± 0.63 a	5.05 ± 0.84 a	5.10 ± 1.00a	5.40 ± 1.30 a
20th day	3.62 ± 0.48a	3.67 ± 0.67 a	3.65 ± 0.82 a	3.34 ± 0.74 a	3.45 ± 0.48 a	3.60 ± 0.92a	3.50 ± 0.50 a
Colour							
0th day	8.90 ± 0.26c	8.95 ± 0.26 c	8.95 ± 0.26 c	9.00 ± 0.26 c	9.00 ± 0.26 c	9.00 ± 0.26 c	8.95 ± 0.37c
5th day	7.90 ± 0.21b	7.85 ± 0.24 b	7.85 ± 0.34 b	7.85 ± 0.34 b	8.10 ± 0.34 b	7.90 ± 0.21 b	7.45 ± 0.34 b
10th day	6.60 ± 0.84 a	6.70 ± 0.86a	6.15 ± 1.11 a	6.05 ± 0.69a	7.20 ± 0.92b	6.25 ± 0.92 b	6.15 ± 1.06 b
15th day	5.20 ± 0.84 a	5.26± 0.86 a	5.15 ± 1.05 a	5.11 ± 0.79 a	5.20 ± 0.82 a	5.25 ± 0.75a	5.15 ± 1.06 a
20th day	4.10 ± 0.44 a	3.66 ± 0.48 a	4.35 ± 0.45 a	4.25 ± 0.64 a	3.85 ± 0.72 a	3.45 ± 0.85a	3.20 ± 0.72 a
Texture							
0th day	8.95 ± 0.26c	9.00 ± 0.26 c	9.00 ± 0.26 c	9.00 ± 0.26c	9.00 ± 0.26 c	8.90 ± 0.26 c	8.90 ± 0.26c
5th day	7.90 ± 0.21b	7.85 ± 0.24 b	7.85 ± 0.34 b	7.85 ± 0.34b	7.85 ± 0.34 b	7.90 ± 0.21 b	7.75 ± 0.34 c
10th day	6.60 ± 0.88a	6.95 ± 0.98 a	6.35 ± 1.11 a	6.40 ± 0.97 a	6.10 ± 0.82b	6.85 ± 0.82 b	5.85 ± 1.13 b
15th day	5.15± 0.88a	5.35 ± 0.85a	5.35 ± 1.00 a	5.38 ± 0.87 a	5.00 ± 0.62 a	5.30 ± 0.62 a	4.85 ± 1.05 a
20th day	3.40 ± 0.32 a	3.25 ± 0.45a	3.32 ± 0.54 a	4.18± 0.58 a	3.50 ± 0.48 a	3.60 ± 0.66 a	3.95 ± 0.85 a

	Odour						
	Coilia	Flatfish	Croaker	Shrimp	Ribbonfish	Cuttlefish	Crab
0^{th} day	8.99 ± 0.26^{c}	9.00 ± 0.16^{c}	9.00 ± 0.26^{c}	8.95 ± 0.16^{c}	8.95 ± 0.26^{c}	8.95 ± 0.18^{c}	9.00 ± 0.13^{c}
5^{th} day	7.90 ± 0.21^{b}	7.85 ± 0.24^{b}	8.15 ± 0.34^{b}	7.85 ± 0.44^{b}	8.10 ± 0.34^{c}	7.90 ± 0.21^{b}	7.85 ± 0.34^{b}
10^{th} day	6.80 ± 0.67^{a}	6.95 ± 0.98^{a}	7.25 ± 0.79^{b}	6.00 ± 0.97^{b}	6.50 ± 0.71^{b}	6.45 ± 0.83^{b}	6.05 ± 0.69^{b}
15^{th} day	5.25 ± 0.63^{a}	5.35 ± 0.85^{a}	5.05 ± 0.88^{a}	5.38 ± 0.92^{a}	5.20 ± 0.70^{a}	5.15 ± 0.68^{a}	4.95 ± 0.60^{a}
20^{th} day	3.60 ± 0.52^{a}	3.35 ± 0.75^{a}	3.75 ± 0.56^{a}	3.75 ± 0.86^{a}	3.25 ± 0.50^{a}	3.15 ± 0.68^{a}	3.00 ± 0.70^{a}
	Overall Aceptance						
0^{th} day	8.95 ± 0.26^{c}	9.00 ± 0.06^{c}	9.00 ± 0.16^{c}	9.00 ± 0.15^{c}	8.95 ± 0.16^{c}	8.95 ± 0.18^{c}	8.95 ± 0.12^{c}
5^{th} day	7.95 ± 0.28^{b}	7.85 ± 0.24^{b}	7.85 ± 0.34^{c}	7.85 ± 0.34^{b}	7.85 ± 0.34^{b}	7.95 ± 0.28^{b}	7.85 ± 0.34^{b}
10^{th} day	6.80 ± 0.26^{a}	6.95 ± 0.28^{a}	6.95 ± 0.28^{b}	6.75 ± 0.35^{b}	7.28 ± 0.44^{b}	6.85 ± 0.24^{b}	6.65 ± 0.47^{b}
15^{th} day	5.10 ± 0.26^{a}	5.12 ± 0.26^{a}	5.05 ± 0.80^{a}	5.12 ± 0.41^{a}	5.15 ± 0.45^{a}	5.20 ± 0.61^{a}	5.10 ± 0.35^{a}
20^{th} day	3.88 ± 0.38^{a}	3.60 ± 0.66^{a}	3.95 ± 0.60^{a}	3.58 ± 0.44^{a}	3.50 ± 0.75^{a}	3.50 ± 0.74^{a}	3.30 ± 0.58^{a}

4.4.5. Correlation between the parameters and storage period

The ICMSF (1986) has established an aerobic mesophilic count limit of 7 log cfu/g for fish that is fit for human consumption. This value (7 log cfu/g) was calculated to reached on 14th day of storage using the regression equation for the TPC i.e., log CFU/ g=1.900+0.358xday (R^2=0.927) **(Fig. 4.4.5.1)**. Therefore, a storage period of 14 day in ice may be considered as the acceptable. Strong correlation between TPC and TMA as well as TPC and TVBN was also noticed in the present study. Considering TPC of 7 log cfu/g for fish as the safe and acceptable yard stick for acceptance and the regression relationship between TPC and TMA (TMA=5.1+1.146*TPC, R^2=0.966) **(Fig. 4.4.5.2)**, as well as TPC and TVBN (TVBN=12.30+3.048*TPC, R^2=0.964) **(Fig. 4.4.5.3.)**, the acceptable limit for TMA and TVBN could be 13.5 and 34.0 mg N/ 100g respectively.

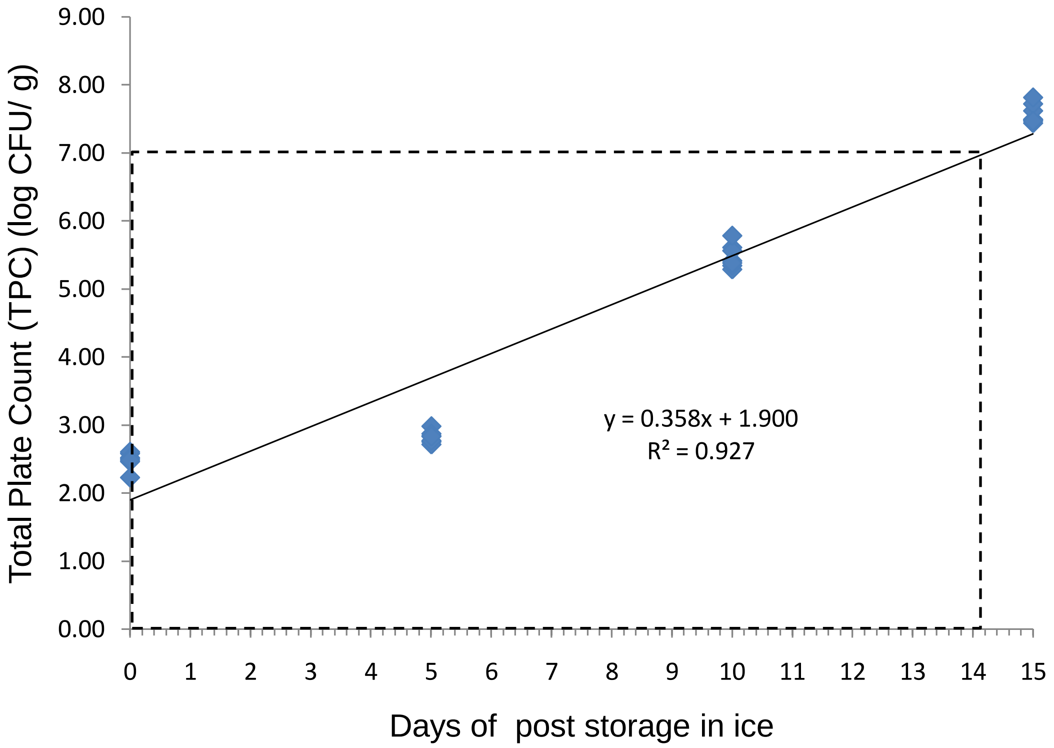

Fig. 4.4.5.1 Correlation between Total Plate Count (TPC) (log CFU/ g) and number of days post storage in ice

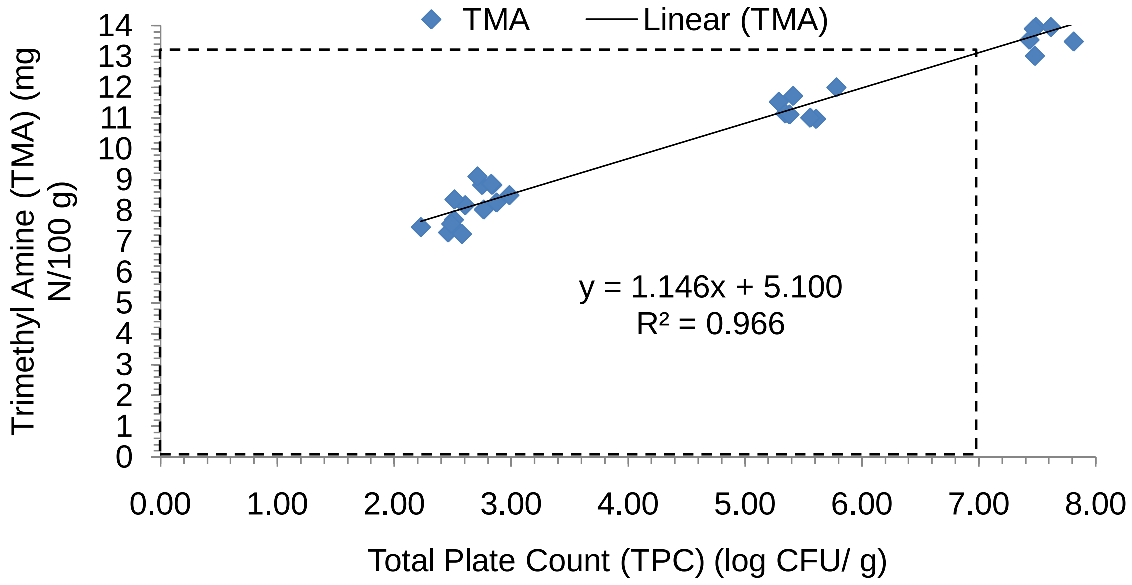

Fig. 4.4.5.2 Correlation between Total Plate Count (TPC) (log CFU/ g) and Trimethyl Amine (TMA) (mg N/100 g)

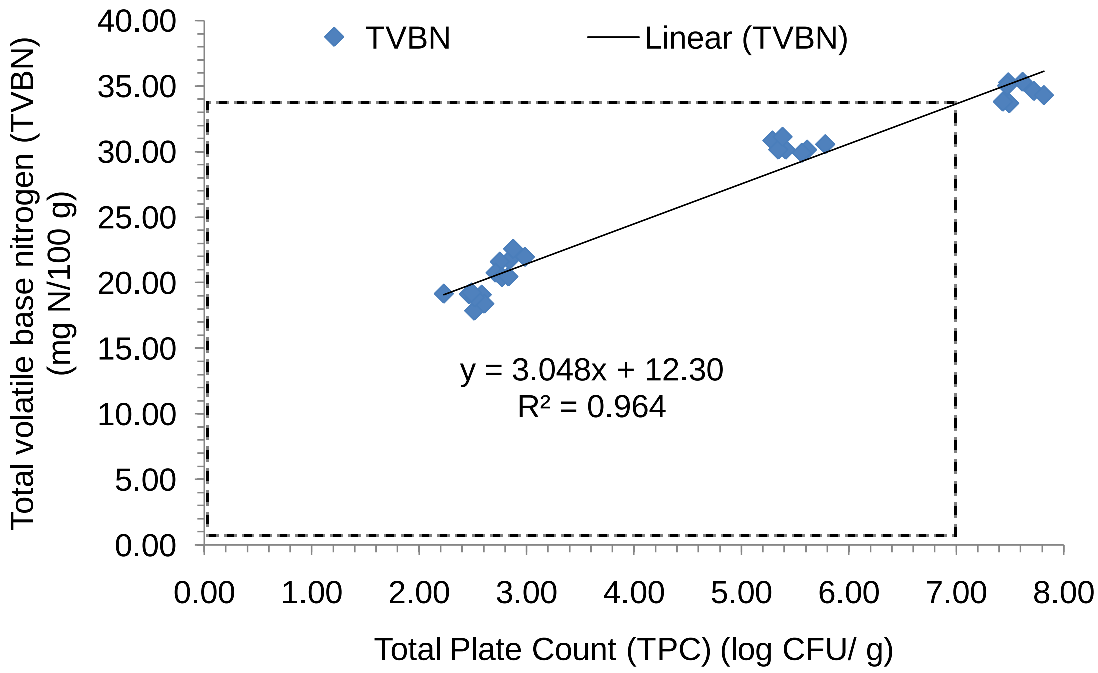

Fig. 4.4.5.3 Correlation between Total Plate Count (TPC) (log CFU/ g) and total volatile base nitrogen (TVB-N) (mg N/100 g)

Considering overall acceptance value of 5 for fish as the threshold limit for acceptance, the regression equation for Acceptance values = 8.989+ (-0.218 x day), R^2=0.98 **(Fig. 4.4.5.4)**. The freshness characteristic of the all fishes was strong between 1 and 9 days, slowly decreasing in intensity to a bland, relatively freshness stage by day 10. Unacceptable quality was evident by day 15. As spoilage progressed, fish became unacceptable between days 15 and 20. Result of this study indicate that the shelf life of selected fishes stored in ice as determined by the overall acceptability sensory scores, chemical quality and microbiological data is 15 days.

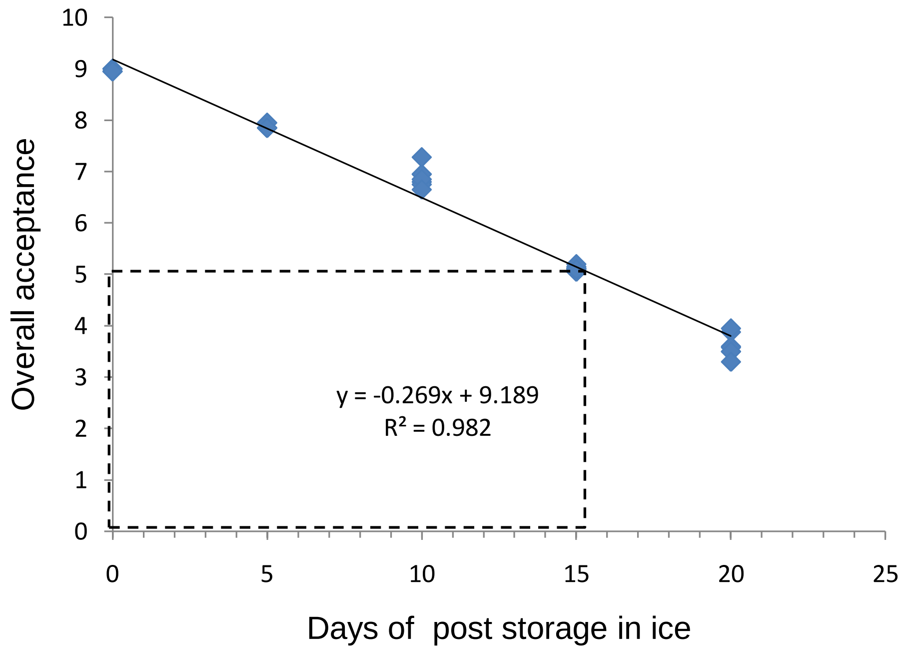

Fig. 4.4.5.4 Correlation between overall acceptance and number of days post storage in ice in sensory evaluation

Discussion

5. DISCUSSION

5.1. Catch composition and characteristics of trawl fishery

5.1.1. Spatio-temporal distribution of trawl catch

The total catch of multi-day trawlers per unit time was found to be less compared to that of single-day trawlers. This could be due to the selective retention of high-value resources and high discard by multi-day trawlers. Contrary to this, single-day trawlers tend to retain the catch more due to limited geographic range of fishing operation and duration of fishing. The fishing grounds of multi-day trawlers extended horizontally from the border of north-western territorial waters southwards up to Mangalore coast in the depth range 30 m to 200 m based on the resource availability and nature of target species. Fishing areas between 50 to 200 m off Gujarat coast were observed to be the least abundant. This could be the reason for multi-day trawlers of Gujarat to venture far towards south for fishing. The maximum horizontal spread of fishing grounds from coastline was observed off Gulf of Khambhat and adjacent to Mumbai waters, mainly due to wider continental shelf area supporting coastal marine fishery. Single-day trawlers mainly operated in the near-shore waters up to 40 m depth due to the nature of target resources and limited time-window available for fishing.

The low-value bycatch was found to be lesser while the discard was relatively higher in multi-day trawlers compared to single-day units. As the voyage of single-day trawler is restricted to a day, the geographic range of fishing ground is limited to a nominal distance from the fishing harbor. This compels the single-day trawlers to retain all the low-value bycatch. As a result, they seldom discard any portion of the catch. On the other hand, multi-day trawlers cover far off fishing grounds resulting in longer duration of fishing and selectively retaining high-value resources during long voyages. This leads to high discard and low by-catch. Discarding untargeted and low-value fishes during the last couple of days of voyage is a usual practice followed by multi-day trawlers.

Highest abundance of total catch as well as low-value bycatch observed in multi-day trawlers during post-monsoon and winter could be due to the revival of fisheries after the mandatory fishing ban. The spatio-temporal changes in abundance was also apparent during the present study where abundance of resource was found to shift gradually towards north from post-monsoon to pre-monsoon whereas, abundance of bycatch shifted gradually from winter to post-monsoon. This was probably due to the recruitment of juveniles from the spawning events during monsoon season. The lowest abundance of target species in the northern portion off Veraval during post-monsoon could be responsible for the highest discard that was observed from the same region during the particular period.

The higher abundance of total catch during pre-monsoon was mainly due to the abundance of *Acetes* sp. caught in huge quantities and retained due to lesser abundance of other high-value resources during this period. Thereby, *Acetes* usually considered as bycatch during other seasons became a lucrative seasonal fishery during this period reducing the abundance of low-value bycatch to the minimum. However, this also leads to increased discard during this period. At the same time, discard is high during pre-monsoon due to excess catch of *Acetes* sp. beyond the holding capacity of the trawler which compels fishermen to discard a portion of the excess catch. The higher abundance recorded in the case of single-day trawlers operating in inshore waters during winter could also be very well influenced by relatively warmer inshore waters. Spatio-temporal variation in abundance of total catch was also observed in case of single-day trawlers where the highly-abundant Veraval waters during pre-monsoon became less abundant as winter approached.

5.1.2. Spatio-temporal distribution of selected commercially important fish resources of Gujarat

Ribbonfish, one of the most important marine fish resources of Gujarat comprised 14.48 % of the total marine fish landing of the state (CMFRI, 2017). Mechanized multi-day trawlers contributed 78.70% towards ribbonfish landings of Gujarat. It has high market demand in the International markets. The multi-day mechanized trawlers target these resources in the highly-abundant fishing grounds. The present study recorded higher abundance during post-monsoon in the Gulf of Khambhat and off Maharashtra. This could be attributed to the availability of its most preferred food item (*Acetes* spp.) in the region. Earlier researchers also reported distribution of juveniles of this fish in all the three seasons with almost similar trend. High abundance was reported along Saurashtra coast, especially along south Suarashtra coast (below 20˚48′ N) at depth above 30 m in summer and post-monsoon and above 50 m in winter. Southern Saurashtra coast is close to the mouth area of the Gulf of Khambhat, a highly productive zone influenced by the large amount of nutrients brought in by many perennial and seasonal rivers and high tidal range (Azeez *et al.,* 2016). This is a detritus rich zone that provides a preferred feeding habitat for *Acetes* spp. (Deshmukh, 2002), leading to higher levels of their abundance. The abundance of sub-adults of ribbonfish along Saurashtra coast continued to increase towards both northern and southern side. It was highest (19-23 kg h^{-1}) in the offshore (>50 m depth) off Devbhoomi Dwarka, inshore (30-50 m depth) off Porbandar and south to Gir-Somnath districts. The comparison of spatio-temporal distribution of juveniles and sub-adults revealed that sub-adults were more common along the northern region of Saurashtra coast *i.e.,* off Devbhoomi Dwarka District (Azeez *et al.,* 2016).

Winter season recorded the highest dominance of squid resources followed by post-monsoon and pre-monsoon. The resource was abundantly exploited from southern Maharashtra and Goa coast during winter. The abundance shifted to area off Gulf of Khambhat and northern most region off Gulf of Kutch and scanty distribution along the near-shore waters off Mumbai and off-shore waters of southern Maharashtra coast in the depth range 150 to 200 m. Similar studies on Indian squid by Bhendekar *et al.* (2018) reported that as season advanced, the trawl fishing fleet for Indian squid became more scattered moving towards north in the latitudinal range 17ºN to 20ºN with reduced catch per hour. Annual bathymetric distribution of squid fishing fleet showed that most of the efforts were concentrated in 30 to 50 m depth. The annual latitudinal variability in trawl fisheries for Indian squid revealed three different fishing patterns. Fishers targeted Indian squid in 17ºN to 16ºN latitude with the fishing fleet concentrating in 20-40 m depth during August. In September, the fleet moved further down to 16ºN to 15ºN in 40-60 m depth. As season advanced, the trawl fleet for Indian squid became more scattered moving towards north in the latitudinal rage of 17ºN to 20ºN.

5.1.3. Trawl catch composition

The similarity in Margalef species richness index (d) for the catch of single-day and multi-day trawlers could be attributed to negligible variation in the number of species caught by both types of trawlers. However, the Pielou's Evenness index (J') for the catch of single-day trawler was found to be lower than that of multi-day units which indicates that the relative abundance of various species caught was more uniform in multi-day trawlers compared to single-day trawlers. The practice of sorting and discard of non-lucrative species by multi-day trawlers and selective retention of high-value fishes is one of the factors responsible for the uniformity. On the other hand, single-day trawlers landed most of the species caught refraining from excessive sorting which resulted in uneven retention of many species. Simpson index and Shannon-Wiener index which consider both species richness and relative abundance were found to be lower in the case of single-day trawlers compared to multi-day units which indicates that the species diversity of catch was higher for multi-day trawlers. The lower Simpson index and Shannon-Wiener index observed in single-day trawler could be due to excessive abundance of certain species (*Acetes* spp.) caught during a particular season (Pre-monsoon) of the year. On the contrary, species evenness was found to be more or less similar for multi-day trawlers which do selective and targeted fishing throughout the year.

5.1.3.1. Monthly variation in species composition

Significant variation in the monthly species composition was observed for both single and multi-day trawler. The degree of dissimilarity depends on the ANOSIM global R value which ranges from 0 to 1. The value of R is less in multi-day trawler [ANOSIM Global R=0.343] compared to the single-day units [ANOSIM Global R=0.776]. This could be attributed to the targeted exploitation, excessive sorting and selective retention of high-value resources throughout the year by multi-day trawlers. Unlike single-day trawlers, multi-day units more liberally change the fishing grounds in search of target fishery resources which increase the opportunity of capturing desired commercially important species and therefore, high variations in species composition may not be expected. However, single-day trawlers confine their operation to a limited geographic range and therefore subjected to temporal changes in resource availability.

5.1.3.2. Seasonal variation in species composition

Significant variation in the seasonal species composition was observed for single-day trawler [P=0.001] but the variation was not significant for multi-day trawler [P>0.001]. As the degree of dissimilarity depends on the ANOSIM global R value which ranges from 0 to 1, it was negligible in case of multi-day trawlers [ANOSIM Global R=0.074] whereas it was much higher in the case of single-day units[ANOSIM Global R=0.567]. Due to limited geographic range for fishing operation, single-day trawlers, unlike multi-day units, strongly depend on the availability of resources which changes from season to season. They usually exploit certain commercial species in a targeted manner until such time these resources become less abundant and thereafter change their target species depending on the seasonal availability and market demand. This could be the reason for significant seasonal variation found in species composition of single-day trawlers. Studies from Vishakhapatnam waters by Behera *et.al.* (2017) also reported that the mean catch rates of total bycatch differed significantly between seasons with higher catch rates post fishing ban period.

5.2. Carbon footprint of single-day and multi-day trawlers

The fisheries sector in Gujarat has undergone tremendous improvement and expansion during the last couple of decades. The ever-growing demand for fish and fishery products in domestic and international market has resulted in exponential growth of fisheries. Thereby, most of the fish stocks of the state have been either fully exploited or are on the verge of over-exploitation. Furthermore, the impact of climate change due to global warming is adversely impacting the resilience of most of the marine ecosystems. Therefore, it is essential to understand the environmental impact of various fisheries activities of the state. One such attempt has been made in the present study to estimate the carbon footprint of two major fish capture systems of the state i.e. single-day and multi-day trawl fishing methods. Different phases of production i.e., pre-harvest, post- harvest, harvest and integrated transportation have been investigated to assess the life cycle of carbon in every phase of production in order to understand their global warming potential (GWP) which has been expressed as the carbon footprint (kg CO_2-e for kg fish produced)of the production process.

5.2.1. Pre-harvest phase

Major source of carbon in pre-harvest phase is contributed by craft and gear building materials as well as energy, such as electricity and fossil energy utilized during manufacture process. Wood, contrary to all other manufacturing materials, acts like a carbon sink as trees accumulate carbon during photosynthesis and hence has negative carbon footprint when used as a construction material. Though it releases huge amount of carbon during combustion, it behaves as carbon sink when used as building material due to its carbon sequestration history. However, other activities during the construction process such as transportation of wood and other accessories, use of electricity and fuel energy, other boat building materials, assemblies contribute positively to the carbon footprint of the phase. According to an earlier study, kiln-dried timber shows negative carbon foot prints of 1.2 kg of CO_2 equivalent per kg of wood (Abbott, 2008).The negative carbon footprint in boat building of multi-day trawler (-0.01687 kgCO_2 equivalent for every kg fish produced) was found to be higher compared to the single-day trawlers (-0.01590 kgCO_2 equivalent for every kg fish produced) due to more usage of timber in the former.

The netting material of trawls is usually high-density polyethylene (HDPE) or polyamide (PA), whereas ropes made of polypropylene (PP) are used for securing, deploying and retrieving the nets. In an ideal condition, the netting material to rope ratio of 80:20 in terms of weight is followed for preparing a fully functional gear unit. For vertical opening of the trawl net, floats and sinker made of Acrylonitrile butadiene styrene (ABS) and cast-iron chain respectively are used. The carbon footprint of multi-day trawl made of HDPE & PP as well as PA & PP was found to be higher compared to the single-day trawl made of same materials. The carbon footprint of different netting materials in the same gear type was found to be different. Nets made of polyamide (nylon) showed higher footprint compared to high-density polyethylene. This implies that the usage of fishing gears made of HDPE could be eco-friendlier due to their lower carbon budget. As there is no previous published study from Indian waters to compare the results, the present study provides information about the carbon footprint of fishing gears as well as craft in the pre-harvest phase.

5.2.2. Harvest phase

Multi-day trawlers recorded lesser catch rate (CPUH and catch per boat) compared to single-day units because of excessive onboard sorting of high-value fishes and on-the-spot discard of low-value resources due to limited storage capacity and longer voyage period. On the contrary, single-day trawlers do not discard and instead land the non-targeted incidental catch as low-value bycatch due to shorter voyage duration. Major source of carbon in harvest phase is contributed by the combustion of fuel used for propulsion of fishing vessel. Because of comparatively higher catch due to retention of low-value bycatch and relatively low fuel consumption, single-day trawlers recorded lesser carbon footprint compared to multi-day units during harvest phase. The fuel consumed by single-day and multi-day trawler was 0.21 and 0.24 L respectively for the capture of every kg of fish which may be compared to the fuel consumption value of bottom trawling (0.43 l/kg fish) and pelagic trawling (0.098 l/kg fish) conducted in Norwegian waters (Winther *et al.,* 2009). Similarly, in another study, the fuel consumption values have been reported as 0.09, 0.28, 0.11 and 1.04 kg fuel/ kg fish for pelagic, demersal, flat fish and shrimp trawlers respectively (Schau, 2012).In the present study, it was practically difficult to trace out the exact usage of bottom and pelagic trawling operations from each category of craft as the operators liberally used separate gears depending on the availability of resources and therefore, there is no dedicated trawler which performs pelagic or demersal trawling exclusively. Moreover, there are not many previous published studies from Indian waters to compare the results of the present study except the study conducted in Visakhapatnam waters of India where the carbon footprint during the harvest phase has been reported as 1.604 $kgCO_2e$ for each kg fish harvested by all categories of mechanized craft which is almost double the values estimated in the present study (Ghosh *et al.,* 2014).

5.2.3. Post-harvest phase

Major source of carbon in the post-harvest phase is the supply chain. In the event of local circulation for domestic market, the carbon input per kg of harvested fish is credited by transportation and storage using ice. However, in the case of distant circulation and export, the major carbon input is contributed by processing plant and transportation. The carbon footprint of multi-day trawler due to the use of Ice for on-board preservation was found to be higher compared to the single-day unit mainly due to longer voyage duration because of which it consumes almost double the amount of ice compared to a single-day trawler. In most instances, excessive ice is also used to prevent the deterioration of high-value target species for more lucrative returns. The present values of carbon footprint from the usage of ice during onboard storage appears to be higher compared to the values observed from Visakhapatnam waters where it has been reported as 0.032 kgCO_2 equivalent due to Ice for on board preservation of every kg of fish during mechanized fishing (Ghosh *et al.,* 2014). The carbon footprint from processing units surges during off season (June to August) due to lesser availability of commodity (fishes) as a result of which the energy efficiency of the processing plants plummets. The carbon footprint of processed fish (usually frozen fishes) during post-harvest phase was found to be 0.82 kgCO_2 equivalent for every kg of fish which is higher compared to the reported value of 0.05 kgCO_2 equivalent for every kg of processed fish from Visakhapatnam (Ghosh *et al.,* 2014). In another study, the carbon footprint of processed cod fillets (frozen) during post-harvest phase was reported as 0.7 kgCO_2 equivalent for every kg of fish frozen in China (Winther *et al.,* 2009).

5.2.4. Transportation phase

Transportation is an integral part of each of the previously mentioned phases and has been considered as a variable factor that contributes to the carbon foot print. Since it was not practical to map out each and every route and mode of transportation, in the present study, the carbon footprints of different modes of transportation have been expressed as kgCO_2 equivalent that will be credited to the system due to transportation of each kg load of commodity to a unit distance of km by any given mode of transportation. Thus the expression can be used to calculate the actual carbon footprint depending upon the distance, mode and weight of the commodity during various phases of production such as (1) transportation of wood during boat building process and gear and craft transportation, (2) transportation of ice and fuel (diesel) prior to fishing voyage, (3) transportation of harvested fishes to the domestic market and (4) transportation of fishes to the processing plants for preservation and subsequent transportation for inter-state circulation or export.

Results of the present study could be compared with the carbon footprint of transportation phase where 0.00093 and 0.00091 kgCO_2 equivalent was found to be credited to the system due to transportation of each kg load of commodity to a unit distance km by 18 and 22 tones lorry respectively in Norway rural areas (Winther *et al.,* 2009). The values by same mode of transportation have been observed to be slightly lower i.e., 0.00076 and 0.00067 kgCO_2 equivalent respectively for the transportation of every kg load to a unit distance of km using European motorway (Winther *et al.,* 2009). The carbon footprint of different modes of transportation varies considerably depending on the condition of road, load carrying capacity, engine performance and fuel quality, and therefore spatial variation is quite usual.

5.2.5. Gross carbon footprint from all the phases excluding transportation phase

Estimated carbon footprint (CO_2 equivalent per kg fish)of all the phases of fish production excluding transportation phase indicated that carbon footprint of multi-day trawler (2.05 and 2.08 kgCO_2 equivalent for the production of every kg of fish) was comparatively higher than that of single-day trawler (1.72 and 1.73 kgCO_2 equivalent for production of every kg of fish). According to previous studies, the carbon footprint has been found to vary from species to species. The carbon footprint for the exploitation of various species such as Atlantic horse mackerel, Atlantic mackerel, Hake, Blue whiting and other species has been reported as 1.44, 0.88, 6.46, 1.54 and 2.26 kgCO_2 equivalent for the production of every kg of fish respectively by the coastal trawling activity along the Glacian water of North-west Spain (Iribarren *et al.*, 2011), which might be considered equivalent to the single-day trawling activity along Gujarat. In the same study, the carbon footprint for the exploitation of the species such as hake, megrim, angler fish and cuttlefish has been reported as 6.96. 8.41, 10.43 and 6.39 kgCO_2 equivalent for the production of every kg of fish respectively by the offshore trawling activity along the Glacian water of North-west Spain (Iribarren *et al*., 2011), which might be considered equivalent to the multi-day trawling activity along Gujarat.

The carbon footprint of single-day trawler in the present study could also be compared to that of earlier study where similar carbon footprint values have been reported from North America, Europe (1.7 $kgCO_2$ equivalent for the production of every kg of fish) and Africa (1.8 $kgCO_2$ equivalent for the production of every kg of fish) (Parker *et al.,* 2018). The carbon footprint of multi-day trawler in the present study was also similar to that of global fisheries (2.2 $kgCO_2$ equivalent for the production of every kg of fish) (Parker *et al.,* 2018). However, the carbon footprint of both the gears was found to be much lower compared to that of Asia, Oceania and China where it has been reported as 2.5, 2.8 and 3.7 $kgCO_2$ equivalent respectively for the production of every kg of fish (Parker *et al.,* 2018).The carbon footprint of both the motorized gear types in the present study was also found to be lower compared to the global average motorized fishing craft carbon footprint of 2.3 $kgCO_2$ equivalent for the production of every kg of fish (Parker *et al.,* 2018) which indicates that the fisheries in the region is more ecofriendly compared to other parts of the world. However, there is no previous published study from Indian waters to compare the results of the present study except for the study conducted in Visakhapatnam waters where carbon footprint of 1.404 $kgCO_2$ equivalent for the production of every kg of fish has been reported as an average total value from both the motorized and mechanized craft (Ghosh *et al.,* 2014).

5.3. Economic performance of trawlers

The mechanized trawlers operating in Gujarat coast were categorized into single-day and multi-day trawlers. A single-day trawler operates throughout the year but more frequently during the peak fishing season from August to January due to the availability of high-value target resources in shallower zone of single-day trawling ground. The abundance of these resources decreases with the end of winter.

The actual towing hours of single-day trawler in the present study was varied from 6-8 hours a day which compares with findings of earlier study reported by Aswathy *et al.,* (2011). However, the total fishing trips per year observed in the present study is much higher (240 trips) compared to 180 to 200 trips per year in Kerala. Sathiadhas *et al.,* (2005) reported 4 crew members for single-day trawlers operated from Kerala coast. Single-day trawlers of Gujarat operate with 5 crew members. According to the present study, single-day trawlers are installed with engines of 88-99 hp, much higher than that reported from Kerala waters (35-75 hp) by Hassan and Sathiadhas (2009). This might be the result of intra & inter sector competition to get higher catch rates in lesser time.

The voyage period of multi-day trawlers in Gujarat varies from 7-21 days. Whereas the multi-day trawlers of Kerala waters undertake voyage ranging from 9 and 12 days as reported by Aswathy *et al.,* (2011) and Hassan & Sathiadhas (2009) respectively. Average number of trips in a year undertaken by Kerala trawlers equipped with engines having 124-170 hp was reported as 30-40 (Aswathy *et al.,* 2011). However, findings of the present study revealed that Gujarat trawlers are fitted with high power engines up to 400 hp and conducted up to 21 trips per year. The elevated engine power and longer voyage duration enable the multi-day trawlers of Gujarat to extend their fishing grounds from northern most waters of Indian Territory to off Mangalore coast up to depth of 200m. It was found that trawlers of Gujarat have been fitted with high-speed engines imported from China in the recent past to increase their efficiency. They consumed on an average 1650 liters of diesel per trip depending on the fishing season and voyage duration. As reported by Aswathy *et al.,* (2011) diesel consumption was limited to 500 to 1000 liters per trip with an average consumption of 100 to 200 liters per day in Kerala.

With the increase in size of vessels, the dimensions of the gear also had to be changed to achieve maximum efficiency. The trawlers operating off Gujarat area uses specially designed resource-specific gear targeting shrimps, fishes (ribbon fishes) and cephalopods and these trawl nets are given local names accordingly. These nets vary in terms of mesh size, length of head rope, foot rope and other accessories according to the target species and are used in specific time, season and area as per the abundance of resource. Multi-day trawlers use fish finding devices for better catch per effort. The netting materials used in Gujarat were HDPE, PA and PP combination.

5.3.1. Economic performance of mechanized fishing in Gujarat

The average cost incurred in Gujarat for construction of hull of single-day and multi-day trawler was rupees 8 lakhs and 30 lakhs respectively. Single-day trawlers used up to 66% of operating cost for fuel and 22% for wages of crew members per trip. In case of multi-day trawlers, 60% of operating cost was spent on fuel and 26% on wages for labor. High operating cost for multi-day trawler is due to more days spent on voyage. Similar studies in Kerala waters reported that single-day trawler spent 40% operating cost for fuel and 39% for labor and multi-day spent 62% and 22% towards fuel and labor respectively (Hassan and Sathiadhas, 2009). Higher amount of fuel is expended by single-day trawlers to reach their ground daily and come back to the berthing base but multi-day trawlers though undertake long voyages in the sea expended less amount of fuel for locating ideal fishing ground by using modern equipment like SONAR, Echo-sounder, Radio phone etc. More number of crew and number of days inside sea increases the labor cost of multi-day trawler compared to single-day unit. Huge quantity of ice is used for keeping the catch in fresh condition in multi-day trawlers due to prolonged operational period. They also used salt to keep low-value fishes in an acceptable condition for supplying to the fish meal plants and for drying.

5.3.2. Costs and returns per trip of trawlers operating from Gujarat

Depreciation is the permanent and continuing decline in the value of capital asset, which in the case of mechanized trawl fishing units comprised of hull, engine, gear, winch and other accessories which varies according to the life span of component. The prime reason for the larger production and revenue in the case of multi-day units is that they are well equipped with fish finding devices which help them to locate more valuable resources such as cuttlefish, squids, shrimps etc. and they have capacity to store large amount of catch. An important issue in the case of multi-day trawlers is that they do not pay attention to low-value fishes due to limitation in storage and longer voyage period. The total fixed cost per trip calculated for the present study as Rs. 24,596/- and Rs. 791/- for multi-day and single-day respectively was higher than those reported for Kerala as Rs.15,681/- and Rs. 431/- (Aswathy *et al.,* 2011). The higher fixed cost for trawlers of Gujarat was due to their robust initial capital investment in both the trawlers. Narayankumar *et al.* (2009) reported Rs. 56, 376/- as the average operating cost for a multi-day trawler (6-10 days fishing duration) at national level, Rs. 63,607/- for east coast and Rs. 49,146/-for west coast. In the present study, the average cost incurred in Gujarat for construction of hull of single-day and multi-day trawler was rupees 8 lakhs and 30 lakhs respectively.

With an average 20 fishing trips in a year for multi-day trawler (voyage duration ranging between 7-21 days), the fixed cost was worked out as Rs. 24,596/- per trip while the operational cost for the multi-day unit accounted for Rs. 1,84,047/- per trip and the fuel cost calculated at 60% (Rs. 1, 09,725/-) per trip. The per-trip earnings for the multi-day trawler unit were averaged to Rs. 3, 70,000/- with an average net profit of Rs. 1, 61,386/- per trip. Adoption of modern fishing methods coupled with increased export demand for sea food commodities has led to higher CPUE and increase in gross revenue over the years. The lower net profit (Rs.10, 937/-) in case of single-day trawler is due to short voyage, low-value catch and limited capability of fishing compared to multi-day trawler (Rs.1,61,386/-).The per day profit works out almost the same for both types of trawlers as estimated in the present study.

The capital productivity (operating ratio) indicators showed that both single-day and multi-day trawlers are equally efficient having values 0.467 and 0.497 respectively which are good economic indicators as more than 50% of the gross revenue is available for meeting fixed cost and other expenses. Labor productivity for single-day trawlers was worked out at 97.6 kg/crew/trip whereas in multi-day trawlers, it was 696 kg/crew/trip. Study by Narayankumar *et al.* (2009) reported labor productivity of 388 kg per crew per trip in multi-day trawler and 53 kg per trip per crew in single-day respectively. Hassan and Sathiadas (2009) calculated the labor productivity for single-day unit to 39 kg/laborer whereas in multi-day trawlers it was 193 kg/laborer from Kerala. In the present study, input-output ratio for single-day trawler was estimated at 0.369 which was almost similar to the value estimated for multi-day trawler (0.368). In terms of fuel efficiency, the single-day trawlers were better than multi-day units. Although single-day trawler land higher quantity of catch per liter diesel used, multi-day trawler gets better price per liter of diesel used. This is the consequence of high sorting practice in multi-day trawler targeting high-value resources rather than landing the entire catch like single-day trawler. Increased costs of fishing per trip, reduced catch and subsequent decline in the returns-per-trip have become important constraints affecting the economic returns from different methods of fishing. In mechanized fishing, among single-day and multi-day trawling methods, multi-day fishing earned comparatively higher returns due to economies of scale.

5.4. Quality of selected commercially important fish species

In the present study, clear and significant increase in TMA and TVBN was observed during the postmortem analysis. TMA is produced due to the microbial catabolism by the reduction of trimethylamine oxide (TMAO). In this study, though the increase in TMA was significant from 5th day onwards, the rate of increase was very high as per 10th and 15th day of observation which would have resulted from significant increase in bacterial counts (CFU/g) during this period. Findings of the present study agree well with several previous studies where an increase in TMA and TVBN levels has been observed (Cakli *et al.,* 2007; Kilinc *et al.,* 2007; Ozden *et al.,* 2007). The use of TMA and TVBN as indicators of freshness has been controversial as per some other studies where, TMA and TVBN have not been found to show any clear tendency of increase during storage period and has been detected only during very advanced stage of spoilage (Castro *et al.* 2006; Tejada *et al.,* 2007; Ozogul *et al.,* 2008). Therefore, these are considered more as an indicator of spoilage rather than freshness. Several TMA levels have been established such as 4 (Kostaki *et al.,* 2009), 5 (Masniyom *et al.,* 2002; Ozden *et al.,* 2007) and 8 (Kilinc *et al.,* 2007) mg TMA/100 g for certain fish as the rejection threshold (Mokrani *et al.,* 2018). Similarly, TVBN level of 25 to 35 mg TVBN/100 g is usually considered threshold limit for rejection (Connell, 1995; European Union, 1995; Masniyom *et al.,* 2002; Ozogul *et al.,* 2005).

The pH of live fish is usually found close to 7.0. However, in the present study, the initial pH of the fishes was found to be comparatively less (6.52 to 6.83) which indicate the possibility of high stress at the time of capture. Capture method like trawling confines fishes in very limited space which increases stress in them. In the stressed fishes, lactate levels increase and generate acidic pH, which in turn decreases myofibril organization and increases the oxidation of myoglobin and lipids (Haard, 2002). However, significant decrease in pH was observed after 5th day of mortality for all the fishes except for cuttlefish which could be due to the onset of glycogenolysis process during the initial postmortem stage that reduced the pH. However, the pH increased again possibly due to release of nitrogenated compounds from microbial decomposition. In the present study, the pH spiked again for all the fishes after 5th day postmortem analysis. This corroborates well with the significant increase in TPC observed on 10th and 15th day after mortality. As per many earlier studies, TPC limit of 7 log CFU/g is widely accepted as a threshold limit for rejection (Mokrani *et al.,* 2018). The limit was much below the threshold level by the end of 10th day post mortality in the present study. Post mortem pH varies from 5.5 to 7.1 depending on the season, species and other factors (Haard, 2002; Simeonidou *et al.,* 1997) and can even vary between 7.33 and 7.5 during storage in ice (Papadopoulos *et al.,* 2003).

Freshness is considered as one of the critical attributes while evaluating the quality of fish. With passage of time, the sensory parameters are gradually affected by biochemical and microbial actions resulting in loss of freshness which influences the acceptance of products on the part of consumer. Considering the midpoint of the scale i.e., 5 as the acceptable, all the fish samples were found to be in overall acceptance level till 15.5 days of storage (Overall acceptance = 9.189-0.269 x day, R^2=0.982). Nevertheless, the findings of the sensory analysis must be corroborated by the microbiological analysis. Microbiological standards as a critical parameter not only determines the acceptance but also safeguard the public health safety associated with consumption of products. The ICMSF (1986) has established an aerobic mesophilic count limit of 7 log cfu/g for fish that is fit for human consumption. This value (7 log cfu/g) reached on 14thday of storage was calculated using the regression equation for the TPC i.e., log CFU/g = 1.900 + 0.358 x day (R^2=0.927). Therefore, a storage period of 14 days in ice may be considered as acceptable based on microbiological and biochemical analysis. Strong correlation between TPC and TMA as well as TPC and TVBN was also noticed in the present study. Considering TPC of 7 log cfu/g for fish as the safe and acceptable yard stick for acceptance and the regression relationship between TPC and TMA (TMA = 5.1 + 1.146 * TPC, R^2=0.966), as well as TPC and TVBN (TVBN = 12.30 + 3.048 * TPC, R^2=0.964), the acceptable limit for TMA and TVBN could be 13.5 and 34.0 mg N/ 100g respectively. Based on the overall analysis of sensory, biochemical, physical and microbial parameters of selected fishes from trawlers, an optimum on board storage period of 15 days in ice can be considered as acceptable for human consumption.

Summary

SUMMARY

Gujarat ranked first in marine fish production among the nine maritime states of India with landings of 7.8 lakh tons during 2018 (FRAD, CMFRI, 2019). Out of the total marine fish landings from the state, more than 50% comes from trawlers both in terms of quantity and revenue besides higher CPUE compared to other gears. Both single-day and multiday trawlers operate from Gujarat.

Saurashtra coast of Gujarat was selected for the study due to its importance in trawl fisheries of the state. Sampling sites in 3 districts i.e. Veraval (20.905401ºN, 70.375217ºE) in Gir-Somnath, Mangrol (21.107787°N, 70.100019°E) in Junagarh and Porbandar (21.640813ºN, 69.596152°E) in Porbandar district were selected. Investigations were carried out on important aspects of single-day and multiday trawl fisheries of Gujarat during 2016-18 with the following four objectives

- To study the catch composition and characteristics of trawl fishery
- To estimate the carbon footprint by trawlers
- To evaluate the economic performance of selected trawl fishing systems
- To assess the fish quality of selected commercially important species

Assessment of catch composition and fishing characteristics revealed clearly demarcated operational trawling grounds for both type of craft operated from Gujarat. The operational area of multiday trawlers extended from northern most part on the west coast of India to Mangalore coast of Karnataka in the south up to 200m depth. Single-day trawlers operate in a limited depth zone of the state up to 40m. Fishing trips of single-day trawlers with an overall length varying from 12-14 m are restricted to a day. In contrast, multiday trawler with higher overall length and equipped with modern fishing and navigational equipment undertake longer voyages extending up to 21 days. Wood comprised the main boat building material.

Trawlers operating from Gujarat mostly targeted 3 major groups of resources i.e. ribbon fishes, shrimps and cephalopods. Based on these three primary target groups, fishing gear were designed and operated as per abundance of the resources. A single-day trawler generally carried 5-10 nets during a fishing trip while it varied from 10-22 nets in a multiday unit. The cod end mesh size trawl varied from 10-20 mm for shrimp, 20-30 mm for ribbonfish and up to 40 mm for cephalopod trawl. PA and HDPE comprised the main netting materials are used in the construction of trawl nets.

Seasonal variation in CPUE revealed that highest CPUE (per day in kg) from multi-day trawlers was during post-monsoon followed by winter and pre-monsoon while single-day unit recorded highest CPUE in pre-monsoon followed by winter and post-monsoon. Significant variation in the monthly species composition was observed both for single [P=0.001] and multi-day trawl [P=0.001]. The global R values (black vertical line) for single-day trawl [ANOSIM Global R=0.776] and multi-day trawl [ANOSIM Global R=0.343] were found to be different clearly indicating dissimilarities in species composition across the months. The cluster analysis of species composition of single-day trawler revealed maximum resemblance (80%) between winter and post-monsoon and marginal resemblance between pre and post-monsoon. However, in the case of multi-day unit, resemblance (96%) between winter and pre-monsoon and 86% between pre and post-monsoon was somewhat similar.

The mechanized fishing sector of Gujarat has grown exponentially with overcapitalization in the sector, advancement of techniques and skill with improvised and need based modification to the fishing system to bridge the demand-supply gap and to achieve higher rate of returns.

To understand the environmental wellbeing in the perspective of rapidly growing mechanized fisheries sector, estimation of carbon footprint of the single-day and multi-day trawlers was attempted in this study by following each step of the production process. Major source of carbon in pre-harvest phase is contributed by craft and gear building materials as well as energy, such as electricity and fossil fuel utilized during manufacture process. Single-day trawler contributed on an average of -0.01590 kgCO_2equivalent/kg fish where as it was -0.01687 kgCO_2equivalent/kg fish for multi-day trawl during pre-harvest phase for construction of boat. The carbon foot print values estimated for multi-day trawl made up of HDPE & PP as well as PA & PP are 0.030 and 0.056 kg CO_2e respectively/kg fish. This was found to be higher compared to the corresponding values of single-day trawl (0.017 and 0.032 kgCO_2e/kg fish respectively). Higher carbon footprint was estimated in the case of multi-day trawler (0.79 kgCO_2 equivalent/kg fish) compared to single-day trawler (0.68 kgCO_2equivalent/kg fish) in the harvest phase. The post-harvest phase accounted for energy consumption by the supply chain. The carbon footprint of multi-day trawler was higher due to the use of Ice for on-board preservation (0.43 kgCO_2equivalent/kg fish) compared to the single-day unit (0.23 kgCO_2equivalent/ kg fish) and was found to be 0.82 kgCO_2 equivalent for every kg of fish in processing. Estimated carbon footprint (CO_2 equivalent/ kg fish) of all the phases of fish production excluding transportation phase was found to be higher in the case of multi-day trawler compared to that of single-day trawler.

On an average, a single-day trawler conducts 240 fishing trips in a year with a average of 25 trips per month during the peak season whereas an average of 215 days of fishing was carried out by a multi-day trawler with about 20 trips per year. The boat cost is the major input required initially for both type of trawlers. The operational cost summed up to Rs. 10,270/- per trip for single-day and Rs. 1, 84,017/- per trip for the multi-day unit. Gross revenue per trip was calculated as Rs. 22,000/- and Rs. 3, 70,000/- with net profit of Rs. 10,937/- and Rs. 1, 61,386/- for single-day and multi-day trawlers respectively. The economic and financial indicators of both the trawling systems were calculated to understand the economic feasibility of trawling operation. The capital productivity (operating ratio) indicators revealed that both single-day and multi-day trawlers are equally efficient having values 0.467 and 0.497 respectively. The input-output ratio of for single-day was estimated to 0.369 which was almost similar to the value estimated for multi-day trawl of 0.368. In terms of catch per liter of diesel, it was calculated as 4.80 and 2.95 kg of fish for single-day and multi-day trawler respectively. However, the corresponding values were Rs 220.00 & Rs. 224.20 in terms of revenue for single-day and multi-day unit respectively. The single-day trawler contributed higher percentage of gross value added to the gross revenue i.e. 59.53 compared to 56.59 for multi-day trawler. Benefit-Cost ratio 1.99 and 1.77 and net profit ratio 0.50 and 0.44 was calculated for single-day and multi-day trawlers respectively.

Freshness is considered as one of the critical attributes while evaluating the quality of fish. With passage of time, the sensory parameters are gradually affected by biochemical and microbial actions resulting in loss of freshness which influences the acceptance of products on part of the consumer. Assessment of fish quality of selected commercially important fishes of the state revealed a strong correlation between TPC and TMA as well as TPC and TVBN. Considering TPC of 7 log cfu/g for fish (established by ICMSF, 1986) as the safe and acceptable yardstick, the acceptable limit for TMA and TVBN is 13.5 and 34.0 mgN/100g respectively. The shelf life of selected fishes stored in ice as determined by the overall acceptability sensory scores, chemical quality and microbiological data is 15 days.

The present study carried out pertaining to the overall characteristics of the multi-day and single-day trawling system followed in Gujarat waters would enlighten the stakeholders in marine fisheries sector about the proficiency and credibility of the prevailing mechanized fishing system in the long-term sustainability. The species-wise distributional maps showing the potential grounds with higher abundance of predominantly targeted resources in different seasons can be used as reference for resource-specific fishery. These maps would be beneficial to fishery managers in sustainable management of these resources by identifying the species-specific breeding and recruitment areas temporally as well as spatially.

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Appendix

APPENDIX I (a)

QUESTIONNAIRE (SINGLE DAY)

1.	Name of Landing Centre& Date	
2.	Name / Registration No. of Boat	
3.	Name of Owner	

4.	Boat (craft) Details						
OAL (Length)	Boat Material	Engine power (HP)	No. of Cylinder	Storage capacity	Diesel used per Trip	Ice used Per Trip	

5. Net (Gear) Details					
Types of Nets					
No. of Nets					
Net Material					
Mesh Size					
Head rope length					
Length of Net					
Weight of Each Net					
Type, Weight and No. of Floaters					
Type and Weight of Sinkers					
Durability					
No of net Replaced per month/ year					
Weight of spare net or Rope per month/year					

6.	Communication and other equipment used (✓)								
Mobile phone	Compass	GPS	VHF Radio phone	Sonar	Eco sounder	Life Jackets	………	……..	………..

7.	**Crew Details** (Total No. : ……………………………………..)			
	Type	**Number**	**Nature of work**	**Share/ Wages**
(i)				
(ii)				
(iii)				
(iv)				
(v)				

8.	Cost per Trip (Operational)	Quantity per Trip	Rate per unit	Total cost
(i)	Fuel (Diesel)			
(ii)	Ice (Block)			
(iii)	Food /Provisions			
(iv)	Wages			
(v)	Others if any			

9.	**Investment/ Fixed cost**	
	Cost of Craft (Boat)	
	Cost of Gear (Net)	
	Cost of Engine and fittings	
	Registration/License Fee	

10. **Returns**	Fish	Prawn	Cephalopods					Total (Rs)
Average returns per trip from fish sale								
Average returns per trip from By-catch								

11.	Operation Details	
Start Time from Harbour	Boat Speed	Direction

Haul	Net Shooting Time and Depth	Trawling speed and direction	Net Hauling Time and Depth
1			
2			
3			
4			

12.	**Catch Details**
No. Hauls per Day	
Total Catch per haul (kg/ Tray)	
Catch Discarded per haul (kg/ Tray)	
By-catch per Haul (kg/ Tray)	

13.	Commercial Catch	Catch per haul in Kg/Tray				
		Haul 1	Haul 2	Haul 3	Haul 4	Total
(i)	Ribbon Fish (Baga)					
(ii)	Squid (Narsingha)					
(iii)	Cuttle Fish (Makul)					
(iv)	Prawn					
(v)	Threadfin Breams (Rani/LalMachla)					
(vi)	Groupers (vekhli)					
(vii)	Sciaenid (Tudi/Dhoma)					
(viii)	Snappers (Raja)					
(ix)	White Pomfret (Pamplet)					
(x)	Black promfret (Halwa)					
(xi)	Bulls eye (Dola)					
(xii)	Sharks (Magra)					
(xiii)	Rays (Varada)					
(xiv)	Catfishes (Khaga)					
(xv)	Lizzard fish (Bhungar)					
(Xvi)	Acetes (Jawla)					

14	Discard/ Bycatch (Name)	Quantity	
		Kg/ Tray	Juvenile %
(i)			
(ii)			
(iii)			
(iv)			
(v)			
(vi)			

APPENDIX – I (b)

પ્રશ્નોત્તરી (સિંગલ ડે)/QUESTIONNAIRE (SINGLE-DAY)

1.	લેન્ડીંગ સેન્ટર નું નામ અને તારીખ	
2.	બોટ નું નામ / રજીસ્ટ્રેશન નં.	
3.	માલિકનું નામ	

4.	**Boat (craft) Details** બોટ ની વિગતો					
ટોટલ લંબાઈ	બોટનું મટીરીયલ	એન્જીન પાવર (HP)	સિલિન્ડરની સંખ્યા	સ્ટોરેજ કેપેસિટી	એક ટ્રીપમાં વપરાતું ડીઝલ	એક ટ્રીપમાં વપરાતું બરફ

5. **Net (Gear) Details** નેટ (જાળ) ની વિગતો					
જાળના પ્રકારો					
ટોટલ જાળ ના નં.					
જાળ નું મટીરીયલ					
કણ નું કદ					
હેડ રોપની લંબાઈ					
જાળની લંબાઈ					
દરેક જાળનો વજન					
બોયા (ફ્લોટર) નો પ્રકાર, વજન અને નં.					
વજનીયા (સીંકર) નો પ્રકાર અને વજન					
ટકાઉપણું					
મહિના/વર્ષમાં કેટલી વખત જાળ બદલાવો					
મહિના/વર્ષ માં સ્પેરમાં રાખેલ જાળ કે રોપ નો વજન					

6.	સંદેશાવ્યવહાર તથા વપરાતા અન્ય સાધનો (✓)								
મોબાઈલ ફોન	કમ્પાસ	GPS	VHF રેડીયો ફોન	સોનાર	ઈકો સાઉન્ડર	લાઈફ જેકેટસ	અન્ય	....	....

7.	ક્રુ (માણસો) ની વિગતો (ટોટલ નં. : ....)			
	પ્રકાર	નંબર	કાર્ય નો પ્રકાર	ભાગીદારી/ભથ્થું
(i)				
(ii)				
(iii)				
(iv)				
(v)				

8.	એક ટ્રીપમાં થતો ખર્ચ **(Operational)**	એક ટ્રીપનો જથ્થો	એક યુનિટનો ભાવ	ટોટલ ખર્ચ
(i)	ફ્યુલ (ડિઝલ)			
(ii)	બરફ (બ્લોક) (લાદી)			
(iii)	ખોરાક/રાશન			
(iv)	ભથ્થું			
(v)	અન્ય જો હોય તો			

9.	**Investment/ Fixed cost** રોકાણ/ ફિક્સ ખર્ચ	
	બોટનો ખર્ચ	
	જાળનો ખર્ચ	
	એંજીન અને ફીટીંગનો ખર્ચ	
	રજીસ્ટ્રેશન (લાઈસન્સ ફી)	

10. **Returns**						
આવક	માછલી	પ્રોન (જીંગા)	માકુલ	નરશિંગા		ટોટલ (રૂ.)
એક ટ્રીપની માછલી વેંચાણથી થતી અંદાજીત આવક						
એક ટ્રીપના કુટા થી થતી આવક						

11.	Operation Details (માછીમારીની વિગતો)	
હાર્બર થી શરૂઆત નો સમય	બોટની સ્પીડ	દિશા

હૌલ	જાળ નાખવાનો સમય અને ઊંડાઈ	GPS પોઝિશન	ટ્રોલીંગની સ્પીડ અને દિશા	GPS પોઝિશન	જાળ ઉપાડવાનો સમય અને ઊંડાઈ
1					
2					
3					
4					

12.	**Catch Details** પકડાશની વિગતો
એક દિવસમાં કેટલા હૌલ	
એક હૌલ ની ટોટલ પકડાશ (કિગ્રા/ટ્રે)	
એક હૌલનો નકામો માલ (કિગ્રા/ટ્રે)	
એક હૌલ નો કુલ કુટો (કિગ્રા/ટ્રે)	

13.	સામાન્ય રીતે મળતી પકડાશ	એક હૌલની પકડાશ (કિગ્રા/ટ્રે)				
		હૌલ ૧	હૌલ ૨	હૌલ ૩	હૌલ ૪	ટોટલ
(i)	રિબન ફીશ (બગા)					
(ii)	સ્ક્વીડ (નરશિંગા)					

(iii)	કટલ ફીશ (માકુલ)					
(iv)	જીંગા					
(v)	થ્રેડફીન બ્રીમ(રાણી/લાલ માછલા)					
(vi)	ગ્રુપર (વેખલી)					
(vii)	સાયેનીડ (તુડી/ધોમા)					
(viii)	સ્નેપર (રાજા)					
(ix)	વાઈટ પોમ્ફ્રેટ (પાપલેટ)					
(x)	બ્લેક પોમ્ફ્રેટ (હલવા)					
(xi)	બુલ્સ આઈ (ડોળા)					
(xii)	શાર્ક (મગરા)					
(xiii)	રેય્સ (વરાળા)					
(xiv)	કેટ ફીશ (ખાગા)					
(xv)	લીઝાર્ડ ફીશ (ભુંગર)					
(Xvi)	એસીટસ (જવલા)					

14.	કુટો (નામ)	જથ્થો	
		કિગ્રા/ટ્રે	બચ્ચાઓ (**%**)
(i)			
(ii)			
(iii)			
(iv)			
(v)			
(Vi)			
(vii)			

APPENDIX II (a)

QUESTIONNAIRE (MULTI DAY)

1.	**Name of Landing Centre& Date**	
2.	**Name / Registration No. of Boat**	
3.	**Name of Owner**	

4.	**Boat (craft) Details**						
OAL (Length)	Boat Material	Engine power (HP)	No. of Cylinder	Storage capacity	Diesel used per Trip	Ice used Per Trip	

5.	**Net (Gear) Details**				
Types of Nets					
No. of Nets					
Net Material					
Mesh Size					
Head rope length					
Length of Net					
Weight of Each Net					
Type, Weight and No. of Floaters					
Type and Weight of Sinkers					
Durability					
No of net Replaced per month/ year					
Weight of spare net or Rope per month/year					

6.	**Communication and other equipment used (✓)**								
Mobile phone	Compass	GPS	VHF Radio phone	Sonar	Eco sounder	Life Jackets	………	……..	…

7.	Crew Details (Total No. : ……………………………………..)			
	Type	Number	Nature of work	Share/ Wages
(i)				
(ii)				
(iii)				
(iv)				
(v)				

8.	Cost per Trip (Operational)	Quantity per Trip	Rate per unit	Total cost
(i)	Fuel (Diesel)			
(ii)	Ice (Block)			
(iii)	Food /Provisions			
(iv)	Wages			
(v)	Others if any			

9.	Investment/ Fixed cost	
	Cost of Craft (Boat)	
	Cost of Gear (Net)	
	Cost of Engine and fittings	
	Registration/License Fee	

10. Returns	Fish	Prawn	Cephalopods					Total (Rs)
Average returns per trip from fish sale								
Average returns per trip from By-catch								

11.	**Operation Details**			
Haul	Net Shooting		Net Hauling	
	Time and Depth	GPS	Time and Depth	GPS
1				
2				
3				
4				
5				

12.	**Catch Details**
No. Hauls per Day	
Total Catch per haul (kg/ Tray)	
Catch Discarded per haul (kg/ Tray)	
By-catch per Haul (kg/ Tray)	

13.	Commercial Catch	Catch per haul in Kg/Tray				
		Haul 1	Haul 2	Haul 3	Haul 4	Total
(i)	Ribbon Fish (Baga)					
(ii)	Squid (Narsingha)					
(iii)	Cuttle Fish (Makul)					
(iv)	Prawn					
(v)	Threadfin Breams (Rani/LalMachla)					
(vi)	Groupers (vekhli)					
(vii)	Sciaenid (Tudi/Dhoma)					
(viii)	Snappers (Raja)					
(ix)	White Pomfret (Pamplet)					
(x)	Black promfret (Halwa)					
(xi)	Bulls eye (Dola)					
(xii)	Sharks (Magra)					
(xiii)	Rays (Varada)					
(xiv)	Catfishes (Khaga)					
(xv)	Lizzard fish (Bhungar)					
(Xvi)	Acetes (Jawla)					

14	Discard/ Bycatch (Name)	Quantity	
		Kg/ Tray	Juvenile %
(i)			
(ii)			
(iii)			
(iv)			
(v)			
(Vi)			
(vii)			

APPENDIX – II (b)

પ્રશ્નોત્તરી (મલ્ટી ડે) / QUESTIONNAIRE (MULTI DAY)

1.	લેન્ડીંગ સેન્ટર નું નામ અને તારીખ	
2.	બોટ નું નામ / રજીસ્ટ્રેશન નં.	
3.	માલિકનું નામ	

4.	**Boat (craft) Details** બોટ ની વિગતો					
ટોટલ લંબાઈ	બોટનું મટીરીયલ	એન્જીન પાવર (HP)	સિલિન્ડરની સંખ્યા	સ્ટોરેજ કેપેસિટી	એક ટ્રીપમાં વપરાતું ડીઝલ	એક ટ્રીપમાં વપરાતું બરફ

5. **Net (Gear) Details** નેટ (જાળ) ની વિગતો					
જાળના પ્રકારો					
ટોટલ જાળ ના નં.					
જાળ નું મટીરીયલ					
કણ નું કદ					
હેડ રોપની લંબાઈ					
જાળની લંબાઈ					
દરેક જાળનો વજન					
બોયા (ફ્લોટર) નો પ્રકાર, વજન અને નં.					
વજનીયા (સીંકર) નો પ્રકાર અને વજન					
ટકાઉપણું					
મહિના/વર્ષમાં કેટલી વખત જાળ બદલાવો					
મહિના/વર્ષ માં સ્પેરમાં રાખેલ જાળ કે રોપ નો વજન					

6.	સંદેશાવ્યવહાર તથા વપરાતા અન્ય સાધનો (✔)								
મોબાઈલ ફોન	કમ્પાસ	GPS	VHF રેડીયો ફોન	સોનાર	ઈકો સાઉન્ડર	લાઈફ જેકેટસ	અન્ય	……..	………..

7.	ક્રુ (માણસો) ની વિગતો (ટોટલ નં. : ....)			
	પ્રકાર	નંબર	કાર્ય નો પ્રકાર	ભાગીદારી/ભથ્થું
(i)				
(ii)				
(iii)				
(iv)				

8.	એક ટ્રીપમાં થતો ખર્ચ**(Operational)**	એક ટ્રીપનો જથ્થો	એક યુનિટનો ભાવ	ટોટલ ખર્ચ
(i)	ફ્યુલ (ડિઝલ)			
(ii)	બરફ (બ્લોક) (લાદી)			
(iii)	ખોરાક/રાશન			
(iv)	ભથ્થું			
(v)	અન્ય જો હોય તો			

9.	**Investment/ Fixed cost** રોકાણ/ ફિક્સ ખર્ચ	
	બોટનો ખર્ચ	
	જાળનો ખર્ચ	
	એંજીન અને ફીટીંગનો ખર્ચ	
	રજીસ્ટ્રેશન (લાઈસન્સ ફી)	

10.	આવક	માછલી	પ્રોન (જીંગા)	માકુલ	નરશિંગા		ટોટલ (રૂ.)
એક ટ્રીપની માછલી વેંચાણથી થતી અંદાજીત આવક							
એક ટ્રીપના કુટા થી થતી આવક							

DAY……………

11.	માછીમારી ઓપરેશન ની વિગતો			
હૌલ	જાળ નાખતી વખતે		જાળ ઉપાડતી વખતે	
	સમય અને ઊંડાઈ	GPS	સમય અને ઊંડાઈ	GPS
1				
2				
3				
4				

12.	**Catch Details** પકડાશની વિગતો
એક દિવસમાં કેટલા હૌલ	
એક હૌલ ની ટોટલ પકડાશ (કિગ્રા/ટ્રે)	
એક હૌલનો નકામો માલ (કિગ્રા/ટ્રે)	
એક હૌલ નો કુલ કુટો (કિગ્રા/ટ્રે)	

13.	સામાન્ય રીતે મળતી પકડાશ	એક હૌલની પકડાશ (કિગ્રા/ટ્રે)				
		હૌલ ૧	હૌલ ૨	હૌલ ૩	હૌલ ૪	ટોટલ
(i)	રિબન ફીશ (બગા)					
(ii)	સ્ક્વીડ (નરશિંગા)					
(iii)	કટલ ફીશ (માકુલ)					
(iv)	જીંગા					

(v)	થ્રેડફીન બ્રીમ(રાણી/લાલ માછલા)					
(vi)	ગ્રુપર (વેખલી)					
(vii)	સાયેનીડ (તુડી/ધોમા)					
(viii)	સ્નેપર (રાજા)					
(ix)	વાઈટ પોમ્ફ્રેટ (પાપલેટ)					
(x)	બ્લેક પોમ્ફ્રેટ (હલવા)					
(xi)	બુલ્સ આઈ (ડોળા)					
(xii)	શાર્ક (મગરા)					
(xiii)	રેય્સ (વરાળા)					
(xiv)	કેટ ફીશ (ખાગા)					
(xv)	લીઝાર્ડ ફીશ (ભુંગર)					
(Xvi)	એસીટસ (જવલા)					

14	કુટો (નામ)	જથ્થો	
		કિગ્રા/ટ્રે	બચ્ચાઓ (**%**)
(i)			
(ii)			
(iii)			
(iv)			
(v)			
(Vi)			
(vii)			

Abbreviation

ABBREVIATION

ANOVA	:	ANALYSIS OF VARIANCE
CFU	:	COLONY FORMING UNITS
CMFRI	:	CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
CPUE	:	CATCH PER UNIT EFFORT
DEA	:	DATA ENVELOPMENT ANALYSIS
EU	:	EUROPEAN UNION
FAO	:	FOOD AND AGRICULTURE ORGANIZATION
FFPs	:	FINNISH FISH FOOD PRODUCT
FRAD	:	FISHERY RESOURCE ASSESSMENT DIVISION
GHG	:	GREENHOUSE GASES
GIS	:	GEOGRAPHIC INFORMATION SYSTEM
GPS	:	GLOBAL POSITIONING SYSTEM
GR	:	GROSS REVENUE
GVA	:	GROSS VALUE ADDED
GWP	:	GLOBAL WARMING POTENTIAL
ISO	:	INTERNATIONAL ORGANIZATION FOR STANDARDIZATION
LCA	:	LIFE CYCLE ANALYSIS
LVB	:	LOW-VALUE BYCATCH
MDF	:	MULTI-DAY FISHING
MDS	:	MULTI DIMENSIONAL SCALING
MHC	:	MYOSIN HEAVY CHAIN
M-IBM	:	INBOARD MOTORIZED
M-OBM	:	OUTBOARD MOTORIZED
NM	:	NON-MOTORIZED
SOFIA	:	THE STATE OF WORLD FISHERIES AND AQUACULTURE
TBA	:	THIOBARBITURIC ACID
TMA	:	TRIMETHYLAMINE
TPC	:	TOTAL PLATE COUNT
TVB-N		TOTAL VOLATILE BASE NITROGE