Investigations on the Structural and Operational Changes of Ring Seine Fishing Systems of Kerala and its Life Cycle Assessment (LCA)

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by

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Certificate

This is to certify that the thesis entitled ***"Investigations on the Structural and Operational Changes of Ring Seine Fishing Systems of Kerala and its Life Cycle Assessment (LCA)"*** *submitted by* ***Mr. Dhiju Das P.H*** *(Reg. No. 3732) is an authentic record of research work carried out by him under my guidance and supervision at Central institute of Fisheries Technology, Kochi, Kerala in partial fulfilment of the requirement for the award of Ph.D.degree in Faculty of Marine Sciences, Cochin University of Science and Technology, Kochi, Kerala and no part of this has previously formed basis for the award of degree or associateship in any University or Institution. I further certify that all the relevant corrections and modifications suggested by the audience during the pre-synopsis seminar and recommended by the Doctoral Committee of the candidate has been incorporated in the thesis.*

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Declaration

I, Dhiju Das P.H., do hereby declare that the thesis entitled ***"Investigations on the Structural and Operational Changes of Ring Seine Fishing Systems of Kerala and its Life Cycle Assessment (LCA)"*** *is a genuine record of research work carried out by me under the guidance of* ***Dr. Leela Edwin****, Head, Fishing Technology Division, Central institute of Fisheries Technology, Kochi, Kerala in partial fulfilment for the award of Ph.D. degree under the Faculty of Marine Sciences, Cochin University of Science and Technology, Kochi, Kerala and no part of the work has previously formed the basis for the award of any degree, diploma, associateship, or any other title or recognition from any University/Institution.*

Kochi-682 018 ***Dhiju Das P. H.***
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Dhiju Das P.H

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Abbreviations

%	:	Percentage
₹	:	Rupees
ABS	:	Acrylonitrile Butadiene Styrene
ADP	:	Abiotic Depletion Potential
AP	:	Acidification Potential
CML	:	Centre of Environmental Science, University of Leiden, The Netherlands
CPUE	:	Catch per Unit Effort
Cr	:	Crore
EEZ	:	Exclusive Economic Zone
EP	:	Eutrophication Potential
EVA	:	Ethylene Vinyl Acetate
FRP	:	Fibre Reinforced Plastic
ft	:	Feet
g	:	Gram
GaBi	:	Ganzheitlichen Bilanzierung (German for holistic balancing)
GAM	:	Generalized Additive Models
GDP	:	Gross Domestic Production
GPS	:	Global Positioning System
GWP	:	Global Warming Potential
HDPE	:	High Density Polyethylene
HTP	:	Human Toxicity Potential
hp	:	Horsepower
ISO	:	International Standard Organization
kg	:	Kilogram
km	:	Kilometer
kwh	:	Kilowatt-Hour

LCA	:	Life Cycle Assessment
LCIA	:	Life Cycle Impact Assessment
L_{OA}	:	Length Over All
m	:	Meter
MAETP	:	Marine Aquatic Eco-toxicity Potential
max.	:	Maximum
min	:	Minutes
mm	:	Millimeter
MT	:	Metric Tonnes
Ø	:	Diameter
OBM	:	Outboard Motor
ODP	:	Ozone Depletion Potential
ODV	:	Ocean Data Viewer
PA	:	Polyamide
PE	:	Polyethylene
PFZ	:	Potential Fishing Zone
POCP	:	Photochemical Ozone Creation Potential
POFP	:	Photochemical Oxidant Formation Potential
PP	:	Polypropylene
rpm	:	Revolutions Per Minute
sq. km	:	Square Kilometer
t	:	Tonne
TETP	:	Terres-trial Eco-Toxicity Potential
UHMWPE	:	Ultra High Molecular Weight Polyethylene
UV	:	Ultra Violet
VHF	:	Very High Frequency

Chapter

1

INTRODUCTION

• Contents •

1.1 Introduction

Fisheries is recognized as a strong and effective employment and income generator to large sections of the society and fish and fishery products are the most internationally traded food commodity in the world (FAO, 2012). Marine fish is a major source of relatively cheap protein (Andy & Safaloah, 2006). Fish consumption has undergone major changes in the past four decades and the world per capita fish consumption has been increasing steadily, from an average of 9.9 kg in the 1960s to 11.5 kg in the 1970s, 12.5 kg in the 1980s, 14.4 kg in the 1990s, 15.9 kg in the 2000s, 18.6 kg in the 2010s and reaching 19.2 kg in 2012 (FAO, 2014). Fish contributes to food security in many regions of the world, providing a valuable supplement for diversified and nutritious diets. Fish is highly nutritious and it provides not only high-value protein, but also represents an important source of a wide range of essential micronutrients, minerals and fatty acids (WHO, 2003). In fact, populations in developing countries depend on fish as part of their daily diets. For them, fish and fishery products often represent an affordable source of animal protein when compared with other animal protein sources (Sugiyama *et al*., 2004). Fishing is an ancient occupation, a diverse range of fishing gear and practices from small-scale artisanal to large-scale industrial systems are used for fish capture. According to FAO (2014) about 58.3 million people are involved in fisheries around the world. This includes about 37% people who are directly dependent on fishing for their livelihood and the rest is involved in ancillary activities such as processing, marketing, and supporting activities (Matthews *et al*., 2012). Among all people employed in the fisheries and aquaculture sector, 84 percent are from Asia. More than half of the world's population lives within 60 km of the shoreline and this is expected to rise to three quarters by the year 2020 (Anon, 1992a). Over the past century, fishing has changed from being a livelihood to a real industry. Development in craft technology, mechanization, introduction of synthetic materials, acoustic fish detection, electronic navigation, and remote sensing are the major developments that have taken place in the evolution of fishing methods and practices (Hameed & Boopendranath, 2000).

The industrialization of the world fisheries set off in the early nineteenth century, when steam trawlers were introduced in England. Within 50 years of development, these trawlers had become highly sophisticated fishing machines, equipped with engines, radar and acoustic fish finder technologies. When World War II ended, the fishing fleets of the developed world were ready to take on the world's oceans (Pauly *et al*., 2002) and along with this technology also started to spread to other less developed parts of the world. Throughout the 1950s and 60s, the enormous expansion of global fishing effort led to an increase in catches, initially well exceeding human population growth. For a while, it seemed that the marine resource was inexhaustible, and that launching new boats would automatically lead to higher catches (Pauly *et al*., 2002). Unfortunately, this has proven to be a false assumption, and global catches have steadily been declining since the late 1980s, by approximately 0.7 million tonnes per year (Pauly *et al.*, 2002). Moreover, there have been major changes in species catch composition, from high value demersal species such as cod, to low value pelagic species such as herring and anchovies (Lutchman & Hoggarth, 1999), the average size of fishes has decreased (Palumbi, 2001), but the global fishing effort continued to increase. The world capture fishery production rose from 25 million tonnes in 1955 to 91.3 million in 2012, of which 79.7 million was contributed by marine capture fisheries (FAO, 2014). The most important commercially used capture methods in the world are trawling and purse seining.

Of the total world marine catch of over 91.3 million tonnes of fish, 23 major species alone represent about 40 percent of the total marine catch and small pelagics represent the two-thirds of these species (FAO, 2014). Pelagic fishes are highly migratory and generally show shoaling behaviour. Pelagics comprise different taxonomic groups, which contribute to their rich species diversity and abundance. Though over 240 species of pelagics occur along the Indian coast (Pillai & Ganga, 2008), the important varieties belonging to the pelagic group are clupeids comprising of wolf herring, oil sardines, hilsa, anchovies (*Coilia* sp*.*, *Setipinna* sp*, Stolephorus* sp*, Thrissina* sp*, Thryssa sp,* and others), bombay duck, half beaks, full beaks, flying fishes, ribbon fishes, carangids (horse mackerel, scads, leather jackets), Indian mackerel, seer fishes, tunas, bill fishes, barracudas, mullets and unicorn cod. Among the pelagic resources, oil sardine, mackerel, ribbon fishes, Bombay duck and carangids are the major contributors. The variations in abundance of any one or all of them would affect the total production.

1.2 Indian Fisheries Sector

India is having a coastline of about 8128 km, an exclusive economic zone of 2.02 million sq. km and a continental shelf area of 0.5 million sq. km (Ayyappan & Diwan, 2007). The total fishermen population of India is about 4.06 million (CMFRI, 2012b). The fisheries sector contributed 0.7% to the Gross Domestic Product (GDP) and 3.6% to the agricultural component during 2011-12 (GoI, 2012).

By the end of 19th century, fishing took a new thrust. Around 1890s trawler-fishing was introduced in Europe, and over the years this new technology was transferred to India. India's first National Five Year Plan was launched, increasing the fish production and creating adequate technological and infrastructural facilities for this purpose were intended top priorities (Jayaraman, 1996). The first two Five Year plans emphasized the need for an expanding fishery to provide an inexpensive protein source to increase the health of the Indian poor (Salagrama, 2002). During 1953, modernization of the Indian fisheries started with the commencement of the Indo-Norwegian Project. Initially the project aimed at the mechanisation of traditional craft and later development programs switched to European-type boats and small boats with in-board motors, the so-called mechanized boats. In early sixties, the experiment of bottom otter trawl was successful and became popular with the mechanized boat fishermen (Bavinck, 2001) and in fishing gear, nylon nets were replaced with the conventional hemp, cotton and linen yarns in gillnets (Mahadevan *et al*., 1988).

In the same period (1960s) new international markets for prawns opened, mainly because of high demand from the US and Japan (Kocherry,

2000) and fishing suddenly became a lucrative business. Entering into the prawn export trade was the turning point in the annals of fishing history in India, and is often referred to as the pink gold rush (Bavinck, 2001). The exciting returns from exportable varieties encouraged the introduction of mechanised boats on a large scale (Balakrishnan & Alagaraja, 1984).

In the subsequent National Five-Year Plans, modernization of indigenous crafts and the introduction of mechanized boats were given high priority for the development of marine fisheries sector. The government provided subsidy schemes and loans for fishermen. The so-called, blue revolution was to complement India's green revolution in agriculture. The export demand coupled with high value of prawns added to the speed of growth of mechanized fishing fleets (Sathiadas & Panikkar, 1989). In order to cope with the modernization, the State Fisheries Departments had to make substantial investments in the infrastructure. It established boatyards and harbours for the mechanized boats, training centres for fishermen to teach them how to handle the new techniques, and ice plants and cold storage facilities for preservation of the catch. Soon, trawlers were introduced in all Indian maritime states. The 1960s and 1970s saw a gradual build up of the infrastructure for marketing, augmenting the growth of the mechanized sector. The initial beneficiaries of the trawling technique were traditional fishermen. Within a short time however, fishery underwent a significant structural change in which capitalists from outside the fisher folk community began investing directly in production. These financiers first invested in processing and export trade, but later, these entrepreneurs invested directly in production by purchasing trawl boats, and hiring wage labour crews to operate them (Hapke, 2001). What once was a low caste-based occupation and a way of life became a modern export-oriented industry, organized along capitalist lines (Hapke, 2001). Consequently, a shift of fishing activities from rural areas to urban areas took place (Panikkar & Sathiadhas, 1993). This shift from rural areas to urban regions contributed to a drastic growth in the marine fisheries sector. The marine production has progressively increased nearly six times during the past 50 years (Ayyappan & Diwan, 2007).

The marine fisheries sector in India has witnessed a phenomenal growth during the last five decades both quantitatively and qualitatively. India has been one among the top 10 fish producing countries of the world since 1960; with its position changing between the third and the seventh rank. Currently India ranked the seventh in fish production, contributing about 4.27% (3.40 million tonnes) to the world marine capture production of about 79.70 million tonnes (FAO, 2014). Almost 90% of the fish production was obtained from within 70m depth covering an estimated area of 100,000 km^2. The subsistence fisheries during the early 50's produced about 0.5 million tonnes annually (Srinath & Pillai 2008).

As per Edwin *et al*. (2014a) vessel installed with an inboard engine for propulsion and fishing is defined as a mechanised fishing vessel, motorised vessel uses outboard engines for propulsion and a traditional/artisanal fishing vessels are without engines. There are 1,99,141 fishing vessels in marine fisheries of India of which 36.5% are mechanised 36.9% are motorised and 26.60% are traditional artisanal vessels (CMFRI, 2012b). The sector-wise contributions during the year 2014 were: mechanized 75%, motorized 23% and artisanal 2% (CMFRI, 2015). The pelagic fin fishes comprised 57% of the total marine landings of India.

Region-wise and resource-wise estimates of marine fish production were made along with the effort expended by different types of gears. Estimates of the fishery resource assessment shows that the west coast is the most productive region with 64% of the total landings among this southwest region rank first comprising of Kerala, Karnataka and Goa contributed 33% of the total production followed by Northwest region comprising Maharashtra and Gujarat recorded 31%, Southeast region consisting of Andhra Pradesh, Tamil Nadu and Puducherry contributed 30%, Northeast region, comprising of West Bengal and Orissa contributed 6% to the total production (CMFRI, 2015). Among these states, Kerala ranks third in marine fish production of India, first and second positions ranked by Gujarat and Tamil Nadu respectively.

1.3 Kerala Fisheries Sector

Fisheries in Kerala is a very important economic activity of the state and a flourishing sector with varied resources and potential. Kerala is situated on the west coast of the Indian subcontinent (8.5074° N, 76.9730° E). The total land area of the state is estimated as 38863 km^2. The coastal line of the Arabian Sea sprawling on the western part of the state is 590 km in length. The inshore sea area falling within the territorial limit of the state (22 km) is about 13,000 km^2. The continental shelf area of the sea adjoining the Kerala state is 39139 km^2 and an Exclusive Economic Zone of 1,47,740 km^2. This part of the sea is considered as the most productive portion of the Arabian Sea. Marine fisheries profile of Kerala and India are shown in Table 1.1. There are 222 fishing villages and 187 marine fish landing centers spread across nine coastal districts of the state, viz., Kasaragod, Kannur, Kozhikode, Malappuram, Thrissur, Ernakulam, Alappuzha, Kollam and Thiruvananthapuram. Among this, Ernakulam district ranks first with 1.41 lakh tonne of marine production (CMFRI, 2015). The number of fishermen in Kerala has been estimated at 0.61 million, of which about 0.15 million are actively engaged in marine fishing and 98% are traditional fishermen (CMFRI, 2012a).

Table 1.1: Marine fisheries profile of Kerala and India

		Kerala	India
Length of coastline (km)	:	590	8,118
Continental shelf (km^2)	:	39,139	5,30,000
Exclusive Economic Zone (km^2)	:	1,47,740	20,20,000
Fishing villages (No.)	:	222	3,432
Fish landing centres (No.)	:	187	1,535
Fishermen families (No.)	:	1,18,937	8,74,749
Fisher population (No.)	:	6,10,165	40,56,213
Active Fishermen (No.)	:	1,45,396	10,47,082
Marine fishing fleet (No.)		21,781	1,99,141
Mechanised fishing boats (No.)	:	4,722	72,749
Motorised fishing boats (No.)	:	11,175	73,410
Non-motorised fishing boats (No.)	:	5,884	52,982
Fish production (2015) (x10^6 t)*		0.57	3.6

(Source: CMFRI, 2012a;b; DAHDF, 2012; *CMFRI, 2015)

Marine fish landings along the Kerala coast have been showing a declining trend during the past two years. In 2014, 0.57 million tonnes of marine fish were landed, showing a decline of 20 % (0.67 million tonnes) and 15% (0.58 million tonnes) over the previous years 2013 and 2014 respectively. Kerala marine fisheries sector contributed the 17.8% of the total marine production of the country.

Over the years, the fishing practices along the Kerala coast had undergone tremendous changes and the region in the depth range of 0-50m has been thoroughly exploited. Pelagic fish stocks such as the oil sardine and mackerel has been the main contributors to the landings in the state.

The share of fisheries sector to Gross State Domestic Product (2004-05 prices) varied between 1.81 and 1.29, during the period from 2005-06 to 2010-11 (State Planning Board, 2012). Annual per capita consumption of fish and prawns in Kerala is the highest among Indian states, being 25.4 kg among rural population and 23.4 kg among urban population.

Marine fisheries play a pivotal role in the economy of the coastal fisher folk of Kerala. Export of marine products from Kerala recorded a growth of 7.7% in quantity during 2012-13 than that in 2011-12. Currently the State's share is over 6.71 lakh tonnes of marine fish per annum and stands third among the maritime States of India in fish production. Seafood exports from India, during 2012-13, has been 0.93 million tonnes, valued at ₹.1,88,560 million (MPEDA, 2013). Contribution of Kerala to the seafood exports from India, during this period, has been 0.17 million tonnes (18.22%), valued at ₹.34,359 million (17.93%). The seafood export of Kerala during 2012-2013 are shown in the Fig 1.1. Annually, Kerala earns approximately ₹.1, 200 crores from export of marine fish products and approximately ₹.600 crores from domestic sales (NETFISH, 2014). The marine export profile of Kerala and India from 2007- 2013 are shown in Table 1.2.

Table 1.2 Marine export profile of India and Kerala from 2007- 2013

Year	India		Kerala		% share of Kerala over India	
	Quantity (in MT)	Value (₹. In Cr.)	Quantity (in MT)	Value (₹. In Cr.)	Quantity	Value
2007-08	541701	7620.93	100319	1430.95	19	19
2008-09	602834	8607.95	100780	1572.18	17	18
2009-10	678436	10048.52	107293	1670.02	16	17
2010-11	813091	12901.46	124615	2002.10	15	16
2011-12	862021	16597.23	155714	2988.34	18	18
2012-13	928215	18856.26	166399	3435.85	18	18

Marine fishing fleet of Kerala consists of 21,781 fishing boats constituted by 4,722 (21.7%) mechanised, 11,175 (51.3%) motorised and 5,884 (27.0%) non-motorised fishing vessels (CMFRI, 2012a). The marine fish landings are mainly contributed by the mechanised (56%) and motorised

(42%) sectors (Mohamed *et al*., 2013). The growth of mechanised, motorised and traditional fishing fleet in Kerala, during 1980-2010 period, is depicted in Fig. 1.1. The number of mechanised vessels increased from 983 in 1980, to 5088 in 1998, 5504 in 2005 and decreased to 4722 in 2010 (Ravi *et al*., 2014). Trawlers constituted 76% of the mechanised fleet of Kerala in 1980, 88% in 1998 and 72% in 2005. In 2010, trawlers constituted about 77.9% of the total mechanised fleet of Kerala, followed by purse seiners and mechanised ring seiners (11.8%), gillnetters (9.7%) and liners (0.6%) (CMFRI, 2012a). Among coastal districts, maximum number of mechanised vessels are based at Ernakulam (33.63%), followed by Kozhikode (22.55%), Kollam (21.03%), Malappuram (7.48%), Kannur (6.88%), Thrissur (4.13%), Kasaragod (3.49%) and Alappuzha (0.80%) (Fig. 1.2). Mechanised fleet of Kerala forms 6.51% of the total mechanised boats in India.

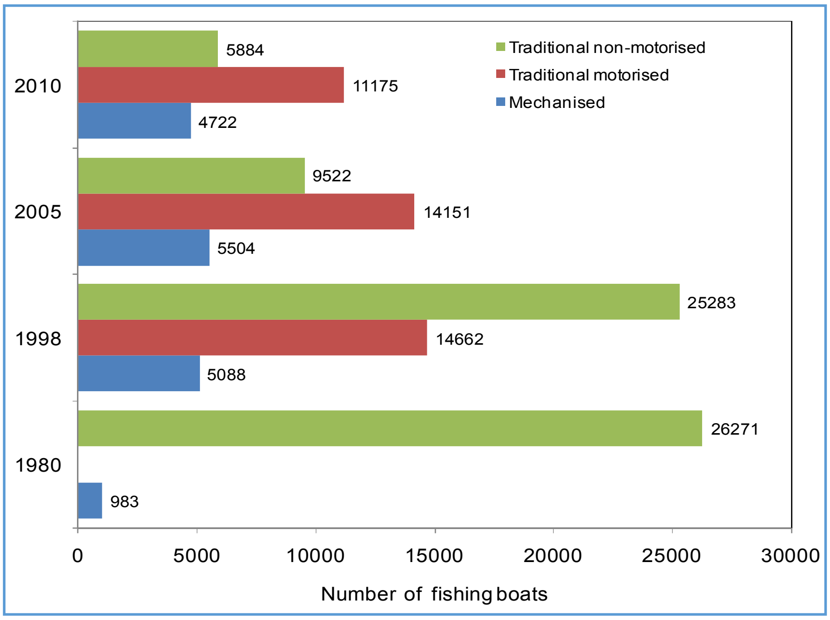


Fig. 1.1 Changes in fleet size of mechanised, motorised and non-motorised fishing boats of Kerala during 1980-2010 (Source: Anon 1981; CMFRI, 2006; DoF 2007; CMFRI, 2012a; b).

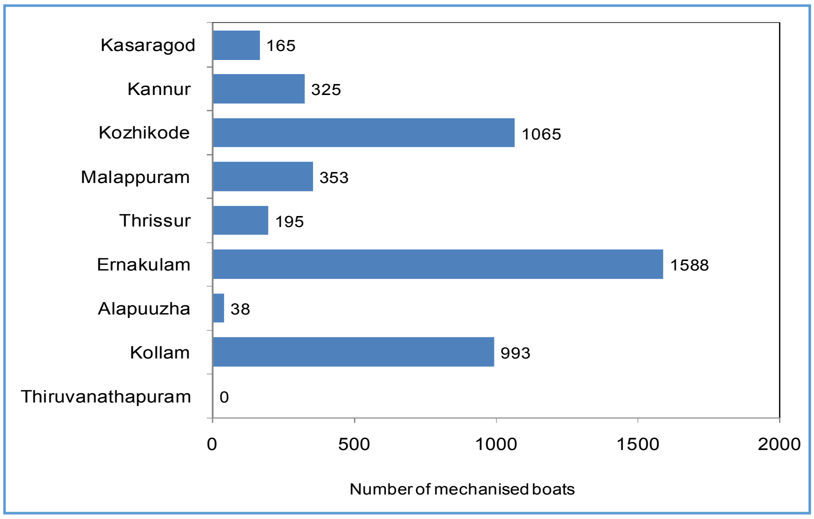


Fig. 1.2 Distribution of mechanised fishing boats among coastal districts of Kerala during 2010 (Source: CMFRI, 2012a)

Pelagic resources contributed 66% of the total marine fish landings of Kerala. Major resources contributing to the Kerala pelagic landings were oil sardine (57.4%), carangids (14.4%) and Indian mackerel (13.7%) (CMFRI, 2015). The variations in abundance of any one or all of them would affect the total production. Fishery independent factors, such as the water chemistry, oceanographic parameters, meteorological variables and food availability in coastal waters play crucial roles in determining abundance of pelagic fishery.

Major fish landing centres of the state are Vizhinjam in Thiruvananthapuram district; Thankassery, Sakthikulangara and Neendakara in Kollam district; Thottappally and Arthunkal in Alappuzha district; Thoppumpaddy (Cochin fisheries harbour), Munambam fisheries harbour and Kalamukku in Ernakulam district; Munakkakadavu, Chavakkadu and Puthenkadappuram in Thrissur district; Ponnani, Thanur and Parapanangadi in Malappuram district; Beypore, Puthiyappa and Chombala in Kozhikode district; Azheekal, Ayikkara and Tellicherry in Kannur district; and Cheruvathur, Kasaba, Hosdurga and Thaikadappuram in Kasargod district. (Edwin *et al*., 2014b).

1.4 Growth of Capture Fisheries of Kerala

Fishing capture technology innovation includes the catching of aquatic animal, using any kind of gear techniques, operated from a vessel. Utilization of fishing techniques varies, depending upon the type of fisheries, and can go from a basic and little hook connected to a line to huge and complex mid water trawls or seines operated by large fishing vessels.

The size and autonomy of a fishing vessel is largely determined by its ability to handle, process and store fish in good condition on board, and thus these two characteristics have been greatly influenced by the introduction and utilization of ice and refrigeration machinery. Other technological developments especially hydraulic hauling machinery, fish finding electronics and synthetic twines have also had a major impact on the efficiency and profitability of fishing vessels.

Fishing strategies have continuously advanced all through written history. The opportunity doors for advancement have been especially good in recent decades with advances in synthetic fibre technology, mechanization of gear handling, improved performances of vessels and motorization, computer processing for gear design, navigation aids, and fish detection to mention only a few technologies.

A wide variety of fishing gears and practices ranging from small-scale artisanal to advanced mechanised systems are used for fish capture in Kerala. Most important among these fishing gears are trawls, seines, lines, gillnets and entangling nets and traps. The modern sector was introduced in 1953 at Neendakara, Shakthikulangara region under the initiative of Indo-Norwegian project (INP). The novel facilities introduced in fishing industry by Indo-Norwegian project accordingly are mechanically operated new boats with new fishing nets. Soon after mechanization, motorization programme gained momentum in Kerala especially in Alleppey, Ernakulam and Kollam districts. Mechanised purse seining was introduced in the late 1970s. Introduction and popularization of synthetic fishing gear materials, trawling in mid-1950s, mechanised purse seining in the late 1970s, introduction of ring seines in commercial fishing in 1986 and their subsequent mechanization are some of the significant developments which caused growth of capture fisheries in Kerala. Adoption of modern technologies such as echosounder and GPS on a wider scale over the last decade, enabled precision fishing. The mechanized sector plays an important role in the fishery contributing to about 66%, followed by the motorized sector contributing 27% and the artisanal sector contributing 7%. The mechanization provides a wide opportunity to the fishing industry in Kerala. In the meantime the socio-economic conditions of mariners also improved.

Over the years, there has been continuous build-up of fleet capacity, both in terms of number of individual fleet and fishing power of the individual fishing units constituting the fleet categories. Fishing power of the units under different categories has been increasing continuously, in terms of installed engine horsepower, vessel and gear dimensions and capacities. The introduction of a new class of craft fitted with diesel engine in huge plank built/ fiber glass/ steel built craft for facilitating the operation of a large ring seine is a recent innovation in the marine fishery sector of Kerala.

1.5 Surrounding Net Fishery of Kerala with Special Reference to Ring Seine

Surrounding nets are roughly rectangular walls of netting rigged with floats and sinkers which after detection of the presence of fish are cast to encircle the fish school. Surrounding nets are generally operated in the surface area. Purse seines are the predominant type of surrounding nets (Meenakumari *et. al*., 2009). Purse seine fishing is one of the most aggressive, efficient and advanced fishing methods. It is aimed mainly at catching dense, mobile schools of pelagic fish and includes all the elements of searching, hunting and capture. The schools of fishes are surrounded and impounded by means of large surrounding net.

Beach seines have been used through the ages almost all over the world. According to Brandt (2005), seine nets (*sagene*) were used early Greeks in third millennium BC. Later Romans employed a large gear which they called '*sagena'*, and as they occupied very large areas of Europe this net was introduced by them to many countries. In France, the gear is known as 'seine' or 'senne' and, in the British Isles, as 'seine net' the gear is now known all over the world. They are usually deeper than the depth of the water. The top edge is framed with a float line and lower edge with a lead line. It is set in semi-circle at some distance from the shore and then hauled ashore onto the beach using long ropes. During hauling, the beach seine filters the enclosed waters from the surface to the bottom. As soon as the wing tips come within the reach of the fishermen they bring the lead line of both wings together in order to gather the fish towards the center. The bunt part with the catch inside is the last part to be brought ashore. In purse seines, a pursing arrangement is incorporated in order to close the net at the bottom after surrounding a shoal of fish. This facilitated the operation of net in deeper waters.

A purse seine is made of long wall netting framed with float line and lead line and having purse rings hanging from the lower edge of the gear, through which a purse line made from steel wire or rope which allow the pursing of the net (Nedlec, 1982; Brandt, 1984). Thus a bowl like space is created in which the fishes are enclosed and prevented from escaping. Modern purse seines were introduced in commercial fisheries more than a hundred years ago (Skogsberg, 1923). Description of the purse seines and their operation have been given by Ben-Yami (1994), Masthawee (1986), Sainsbury (1996), Hameed & Boopendranath (2000) and others. Advances in purse seining were supported by the introduction of high tenacity synthetic twines of high specific gravity, improvements in vessel technology and gear handling equipment's such as puretic power block, fish aggregation techniques, acoustic fish detection and remote sensing techniques (Traung, 1955; 1960; 1967; Kristjonsson, 1959;1964; 1971; Fyson, 1986; Ben-Yami, 1994 and Hameed & Boopendranath, 2000).

In some parts of the world, purse seining produces the largest single catches of pelagic fishes. Purse seine fishery for tuna is carried out over a far greater geographical area. Purse seines are also used to catch the demersal fish such as cod by modifying its design to operate close to the bottom. However, the major contributor to the purse seine fisheries of the world is the vast number of smaller vessels landing small pelagic species. A conservative estimate of percentage of the world catch caught by surrounding nets fisheries would be 25 to 30 % of the world catch. (Ben Yami, 1994).

Boat seines and shore seines are the age old fishing methods of Kerala marine fisheries. The different regional names of boat seines, are *arakollivala, ayilakouivala, choodavala, discovala, deppavala, ringvala, kudukkuvala, thanguvala, kollivala, koruvala, mathkollivala, paithuvala* (Pillai *et. al.,* 2000). According to FAO (1984) *thanguvala* is a lampara-type net with 150 m in length and operated from beach landing canoes (*thanguvallams*) of length 15 m, beam 1.4 m, and depth 0.85 m. The earlier versions of *thanguvallams* were made as dugout canoes. The first trials with motorization of the *thanguvallam* were made by the Indo-Norwegian Project in Neendakara around 1955. In September 1980, new motorization trials were started by the Kerala Fishermen's Welfare Corporation in Purakkad near Alleppey with inboard diesel engine of 9 hp, outboard diesel engine of 5 hp, and outboard kerosene engine of 7 hp. With a continuous improvement, the motorization program was a grand success and it spread throughout the entire coast of Kerala. Commercial purse-seine fishing started during the late seventies in Cochin, Kerala (Jacob *et al.,* 1987) and the process of large scale motorisation of country craft began in the early eighties. The eighties was an important period in the development of marine fisheries in Kerala. In the first half of the period the motorized sector grew rapidly and the adoption and popularization of ring seines in the mid-eighties was the single most significant development in the post motorisation of Kerala fisheries.

1.6 Structure of Ring Seine Net

Although there is great variation in the details of ring seines, not only in different fisheries but in each individual fishery, nevertheless there has evolved a certain basic design. The structure of the ring seine has many features of the purse seine and of the lampara. All three are kept on the surface of the water by a similar float line strung with floats, and are hung vertically in the water by a heavily weighted lead line. The ring seine, like the purse seine, has purse rings along its lower edge. Some of the chief structural differences between the ring seine and the purse seine are that the purse seine is made of comparatively heavy tarred webbing, is practically uniform throughout its entire length, and is practically square on the ends; while the ring seine, like the lampara, is made of light webbing, is gathered on the ends, and is made in three parts: a central bunt of thick webbing and two end portions or wings. The relative lengths of bunt and wings vary greatly.

The introduction of ring seine, offered an efficient alternative gear for operation from the boat seine craft *thanguvallam* in the artisanal sector. Along with CIFT's introduction and popularisation of ring seines in Cochin and Kasaragod areas, other developments were initiated by fishermen (Rajan, 1993) contributing to easy acceptance of ring seines. According to Shyam *et al.* (2012), modification of the traditional boat seine vessels to make it more efficient resulted a most popular seining method for the pelagics along Kerala coast.

Typical cotton *thanguvala* of the early sixties described by Kuriyan *et al.* (1962) had a length of 42m and a depth of 5.2m. The mini- purse seine introduced by CIFT with an overall length of 250m and a depth of 15m at the wing end and 33m at the bunt. It is seen that the number of ring seine units as per estimates of 1992 was 2229 and the number further rose to 2875 by 2005 (SIFFS, 1992; GoK, 2005) as against the 300 recommended by the Central Institute of Fisheries Technology (Panicker *et al.,* 1985). A number of variations have occurred in the design of the gear due to innovations by the traditional fishermen (Edwin & Hridayanathan, 1996; D'Cruz, 1998; SIFFS, 1999; Vijayan *et al.,* 2000). The impact of transition from the traditional boat seine, *thanguvala* or *koruvala* operated from *thanguvallam* (traditional boat seine craft) to the present-day ring seine has been studied by Achari (1993).

Many authors have studied the structural variations of ring seines of Kerala. According to the census conducted by SIFFS the ring seines are classified according to the type of craft, mesh size and size of gear (Anon, 1992b). Rajan, (1993) classifies ring seines based on the number of craft used for operation. Balan and Andrews (1995) have studied the contribution of ring seines towards marine fisheries. The various changes that have taken place in the exploitation pattern of marine fishery were studied by Alagaraja *et al.* (1994). The design and operational aspects of the ring seines prevalent in the Alleppey- Cochin coast was described by Edwin and Hridayanathan (1996). Rajan (1993) describes the salient features of the ring seine unit along Kerala coast. The technical efficiency of the two types of ring seines operated along Ambalapuzha coast was studied by (Edwin & Hridayanathan, 1997). The size of gear as reported by Edwin and Hridayanathan (1996) showed that average length of a *thanguvala* of Alleppey region was 630m and depth 100m with a mesh 18-20mm. The *thanguvala* reported by D'Cruz (1998) showed that the *thanguvala* had further grown in dimensions and due to the large size of the nets, trolleys are used for transportation of the gear. The studies by Kurup & Radhika (2003) showed that the ring seines of Kerala had a length of 800-1700m with bunt mesh size of 16mm. Large ring seines up to 900m length and 90m depths were reported by Krishna *et al.* (2004) from Thrissur District and such gear could not be lifted manually. Edwin *et al.* (2010) reported ring seines with a mesh size of 20 mm with a length and depth of 600-1000 m and 83-100 m respectively and having a weight of 1500 to 2500 kg is targeted to catch the pelagic shoaling fishes like the sardines and mackerel in Ernakulam district. Edwin & Das (2015) describe the regional and structural variation of ring seine fishing systems of Kerala in detail.

1.7 Evolution of Ring Seine Fishery

The ring seine or mini purse seine gear was first introduced by the Central Institute of Fisheries Technology as new gear for the traditional craft (Panicker *et al*., 1985). After the popularisation of ring seine, the *koruvala* and *kollivala* become obsolete. Nair and Chidambaram (1951) reported during the period 1895, oil sardines were caught in boat seines (*paithuvala, odamvala,* etc.) for day fishing. Nair and Chidambaram (1951) have conducted a detailed study about the craft and gear employed for exploiting small pelagic fishery, fishing method and fishing seasons during which they observed the seine nets (*mathikollivala* and *ailakollivala*) made of hemp with 50-60 ft in length.

Pramod (2010) states that ban on purse seining initiated in the eighties to prevent loss of livelihood for traditional fishers, and an improvised gear called “ring seine” was developed from a traditional seine gear. Ring seine operation started in Kerala with plank built canoes. The large and medium sized plank built canoes locally called as *thanguvallam* and dugout canoes are used for the operation of the gear. There is no difference in the pattern of operation by these two categories of canoes except in the size of the net. The plank canoes use bigger size (length and breadth) of nets depending up on its accommodation capacity. There is also considerable variation between regions in the number of craft used for a ring seine unit. The ring seiners with 30 to 32 ft L_{OA} having 8 to 15hp or 9.9 hp Suzuki engines used for propulsion of the craft was reported by D’Cruz (1998). However, in certain cases, two engines are also used in a single unit. These are necessitated by the total load of the large gear, 20-30 crew members and bulky catch.

Presently in Kerala the ring seine belt extends from Muthalampozhi in Thiruvananthapuram district to Talapady in Kasaragod (Edwin & Das, 2015). Each region has its own peculiarities in construction and operation of the gear. After the success of the ring seine fishery it spread to the other parts of the country including Andaman and Nicobar Islands and contribute 8.8 to 18.3 % of the total marine production of the country with 2.01 to 6.63 lakhs tonnes (Sivadas *et al.,* 2015). In the state of Kerala ring seine contributed major share to capture fisheries (50.11%). Out of this, it contributes 92 % of sardine, 41.8% of mackerel, 82.8% of white baits, 13.3 % of carangids (CMFRI, 2013).

1.8 Operational Efficiency of Ring Seine Gear

Invention of polyamide by W. H. Carothers (USA) in 1935 witnessed a drastic improvement in the quality of fishing gear materials. After the invention of polyamide in 1940-41 J. R. Whinfield & J. T. Dickson (UK) developed polyester and Natta (Italy) invented polypropylene in 1954. Introduction of these petrochemical based synthetic fibres help world fishing industries to reach new heights (Sambasivan, 2012).

Polyamide (PA) is the first synthetic material used for replacing cotton/hemp in India for fishing gear in 1962 (Meenakumari *et al.,* 1993). Weathering causes loss of strength, extensibility, general durability and appearance because of the modification or break down of molecular structure of polymers (Achhammer *et al*., 1953; Winslow and Hawkins, 1967 & Liu *et al.,* 1995). Many authors studied the effect of weathering and UV exposure in fishing net materials (Meenakumari & Ravindran, 1985; Meenakumari & Radhalakshmi, 1988; Meenakumari *et al.,* 1985; Thomas & Hridayanathan, 2006)

The major problem associated with the ring seine fishery is its periodic repair or replacement of polyamide webbings due to tear and wear and attack of marine cetaceans during the time of fish aggregation and brailing the catch. Loss of revenue during the days of repair and the repairing charges are additional burden to fishermen. Attack of dolphin during the fishing operation was identified as one of the major operational hurdles during the ring seine operation.

There is a high chance of fish escapement during ring seine operation by swimming under the lead line and the open ends of the net. Hence, the efficiency of the fishing operation mainly depends upon the sinking speed of the gear, water current and speed of effective closing of both ends. The peculiarity of ring seines, which are mostly operated in depths of 10-30m, is that the bottom of the net touches the seabed, unlike deep sea oceanic purse seine operations. Faster sinking speed prevents the escapement of fish shoal which move opposite to the direction of fishing operation and escape through the open ends and bottom portions of the gear. The extra sinkers used for increased sinking speed in ring seines, can tear the webbing when operation is carried out in muddy waters. The excess lead line weight increase the pursing time, also increases the total weight and cost of the gear and makes handing/ operation more cumbersome. Hence further sinking speed studies are required in the case of this gear.

1.9 Spatial Distribution of Fishing Grounds

The most prominent feature of the pelagic fisheries is their seasonal migration and extreme annual fluctuations (Pillai & Ganga 2008; Pillai & Nair 2010). The effort expended in locating these pelagic shoals leads to wastage of fuel and time which makes fishing operation uneconomical. Spatial information and mapping tools throw light on the distribution and abundance of pelagic fishes (Watson *et al.,* 2006). The spatial distribution knowledge of fisheries data for reliable vision of the fishing grounds and the ability to analyze the variability of species composition in the resulting regions leads towards its sustainable management (Babcock *et al.,* 2005) and helps us in protecting the marine ecosystem from stress (Botsford *et al.,* 1997) in the long term. According to Hadil and Richard (1991), pelagic fish tends to move towards the coastal waters between 13-40 meters depth during the calm seasons and tends to move into deep waters and offshore during the rough season. Another important characteristic of pelagics is its area specific abundance. Many researchers have studied the spatial analysis and seasonal variation of the fisheries worldwide (Wilde & Paulson, 1989; Silvano & Begossi, 2001; Wang *et al.*, 2003; Axenrot & Hansson, 2004). The west coast of India including Kerala coast experiences intense rainfall activity during the summer monsoon season, and is also influenced by large cloud cover (Suprit & Shankar, 2008) which adversely affects the satellite aided fishing and fishery forecasting (Ravichandran *et al.,* 2012). In these circumstances time series catch data aided models will help to predict the fishing zones more accurately.

1.10 Environmental Impact of Ring Seine

Studies are conducted worldwide to improve the fishery management for sustainability and factors affecting fishery environment, including studies on the direct environmental impact of fishing activity like impact on harvested organisms, discards, sea bottom damage, etc. Other than the direct impact, impact of fishing gear, craft, fuel usage, antifouling paint, production of ice, transportation, discharge of wastes and loss of fishing gear at sea were also studied. To think about the advanced methodology for fishery impact assessment, Life Cycle Assessment (LCA) is considered as it uses full impact assessment methodology and its suitability for quantifying the impact associated with fisheries are proven (Pelletier *et al.,* 2007). Mechanized and motorized fish harvesting systems are dependent on fossil fuels which are non-renewable and releases high levels of carbon dioxide to the atmosphere contributing to greenhouse effect. In this scenario energy analysis of ring seine fishery are relevant in relation to fisheries LCA due to the accepted importance of fuel consumption for fleet operations and associated environmental impacts. Environmental analysis of Indian capture fisheries are limited to greenhouse gas emission and mainly related to fuel consumption per kilogram of landed fish and it will mask the other factors like materials used for vessel and gear construction, maintenance, life span etc.

Ring seine fishing play a major role in the state fish landing. However in depth studies on this fishery is limited. This study deals with the analysis of structure, operational changes of ring seine fishery of Kerala and approaches to improve the design and energy efficiency of ring seine through material substitution and reduced carbon footprint.

1.11 Rationale and Objectives of the Study

The increase in number and size of craft, gear and engine power of the ring seine fishing system has resulted in significant increase in fishing capacity. Low load bearing capacity near bunt portion and vulnerability of the upper panels by the attack of dolphin and puffer fish are serious threats to ring seine operation resulting in loss of fishing days and maintenance cost. Low sinking speed results in the escapement of shoals from below the net. More successful commercial exploitation of active pelagic shoals require ring seine with high sinking speed. The effort expended in locating the ring seine targeted pelagic shoals leads to wastage of fuel and time. Information on season wise area of operation and spatial distribution of fish abundance is required for efficient location of fishing ground. Unscientific use of mesh size is another serious issue causing capture of juveniles. High quantity of low durable synthetic material use in fishing gear cause serious issues to the environment. The increasing size of the fishing unit and expanding fleet size in the ring seine fishing is a cause of concern from the point of view of environmental degradation due to increased carbon emission. Studies on LCA and carbon footprint of ring seine operation is a pre requisite in scientific management of the fishery. In this context of increasing concern on the above aspects of ring seine fishery an in depth investigation of the structural and operational changes and Life Cycle Assessment (LCA) of ring seine fishing systems of Kerala were conducted.

The main objectives of the present study are:

- To scientifically document the design variation of ring seines and trace the evolution of the ring seine fishing systems operated along the Kerala coast
- To study the impact of environmental factors on the life of the gear
- To analyse parameters affecting sinking speed of the gear and methods to increase its operational efficiency
- To conduct spatial and seasonal analysis of ring seine fishing grounds
- To conduct LCA and estimate carbon foot print of the ring seine fishery
- To propose a new design of ring seine for increasing operational efficiency and reducing carbon foot print

Chapter

2

MATERIALS AND METHODS

Contents

2.1 Area of Study and Data Collection

Thirty major ring seine centres between Talapady, Kasargod to Poovar, Thiruvananthapuram including fishing harbours and fish landing centres of Kerala, were visited during the study and details on design and construction of ring seine fishing vessels, gear, operation, engine and other relevant information were collected from fishermen, net makers, boatyard operators and other stakeholders. Field visits and interviews using structured questionnaires were the main tools to collect details of fishing vessel and fishing gear. Representative samples from each category of craft and gear from important landing centres in the coastal districts (Fig. 3.1) were examined, to obtain design and operational details. The motorized and mechanized fishing vessels were surveyed as per FAO standards (Fyson, 1986). The gear designs were documented following FAO conventions (FAO, 1975 & 1978; Nedlec, 1982). Census data on fishing boats was sourced from Marine Fisheries Census-2010 (CMFRI, 2012a,b) for identification of important landing centres. The Department of Fisheries, Kerala; Kerala State Co-operative

Federation for Fisheries Development Ltd. (MATSYAFED), other fishermen societies and log books maintained by fishing vessels operators are used as secondary data source.

2.2 Technical Survey of Craft and Gear

The field studies for the technical survey of craft and gear involved extensive field survey and data collection lasting for three months from July to September 2012. This has resulted in documenting valuable information about the operational and technical aspects of ring seine operation. Ring seine operating fishermen of different age groups from varying socio-cultural background were interviewed using an unstructured questionnaire with open-ended questions. People who seemed comparatively more knowledgeable among the group were contacted individually and in-depth interviews were held with them. The questionnaire used for collection of data in this regard is given as Annexure-1.

2.3 Field Trials, Data Collection and Analysis

Daily operational details were collected from the selected 36 active data providing ring seine units operating from *Kalamukku* landing center, Ernakulam (Fig-2.1) with structured questionnaire during the period June 2012 to May 2014. The ring seine units are classified based on targeted species into *thanguvallams* and *choodavallams*. Based on construction material, the vessels are classified as wooden, steel and FRP ring seiners and based on the mode of propulsion categorised into motorised and mechanised units. Details of units selected are given under Chapter-7 (Table 7.1)

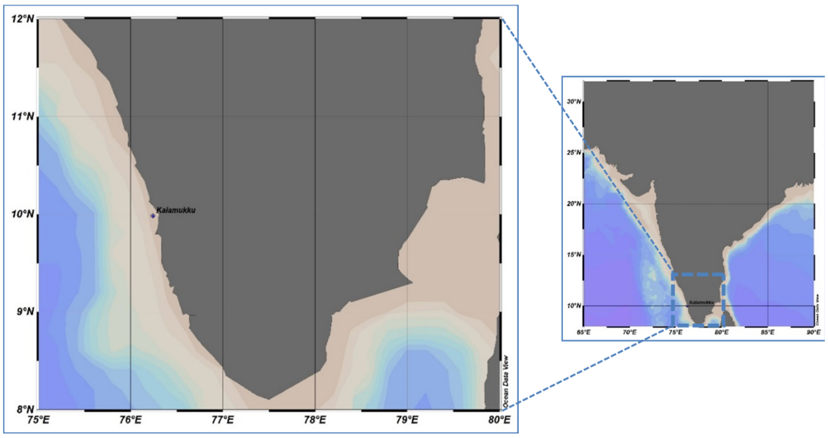


Fig - 2.1 Study area, *Kalamukku* landing center

2.4 Durability of Ring Seine Gear

An 18 month durability study of most commonly used ring seine polyamide webbing of 210Dx2x3 with 20mm mesh size was conducted. Exposure studies were conducted in natural marine weather conditions and simulated conditions in accelerated weathering equipment (ATLAS Xenotest Alpha+). The elongation and breaking load of ring seine webbing panels were measured using Shimadzu AG-1 Universal Testing Machine. Studies on life of ring seine gear were conducted using webbing samples collected from five different locations of gear at the end of 3, 6, 9 and 10 months of continuous operation. The opinion from experienced fishermen was also sought while selecting the area more prone to damage. Collected samples were tested for elongation and breaking strength after conditioned in humidifier with a minimum period of 24 hours.

2.5 Sinking speed and operational efficiency

Theoretical calculation of sinking speed was based on the modified method derived based on Dickson (1980); FAO (1990) and Misund *et al.,* (1992) for seine nets operated along the shallow waters. To study the sinking speed and sinking pattern in actual sea conditions, under water experiments were conducted in the clear waters of the Lakshadweep Sea. Three different mesh sizes of experimental panels with 10 m in length and 50 meters in depth were used for the study. Simrad PI depth sensors and professional Scuba divers were engaged for under water data collection.

2.6 Spatial and Seasonal Distribution of Fishing Grounds

Data on species wise daily landing information and fishing area (GPS locations) were collected to study the species wise seasonal distribution of ring seine fishing grounds. One way analysis of variance was conducted to test the effect of season on fishing area. Standardized semi variogram on season wise sardine and mackerel fishing area was computed and plotted for analyzing the spatial distribution of fish abundance. For analytical purpose, months were grouped into seasons: pre monsoon (February-May), monsoon (June-September) and post monsoon (October-January). The analyses comprises of characterization and illustration of fish yield (abundance) distribution using geostatistical analysis and estimation of yield abundance in terms of spatial parameters using statistical modeling techniques.

2.7 Life Cycle Assessment of Ring Seine and Carbon Footprint Studies

Quantity wise material used for construction for all size classes of ring seine craft and gear were collected from centers surveyed to study the Life Cycle Assessment of ring seine fishery. Month wise ring seine landing data were collected from CMFRI, Cochin. For analysing energy expended for operation, details of fuel use were collected from different size classes of mechanised and motorised ring seiners operated along the Kerala coast. The data were analysed using GaBi 6 LCA software package (ISO-14040) (ISO, 2006). The global warming potential was calculated in carbon dioxide equivalents (CO_2-Eq.). The residence time of the gases in the atmosphere is calculated for a period of 100 years and is customary. The detailed methodology, data collection procedure and analyses methods are discussed in the respective chapters.

Annexure-I

RING SEINE CRAFT AND GEAR SURVEY PROFORMA

State	Village	Craft	Gear	Engine	Date

General Information

1.	Type of Fishing Vessel	Motorised/ Mechanised		
2.	Vessel name:			
3.	Owners name			
4.	Address			
5.	Contact No.			
6.	Registration No.			
7.	Location			
8.	Craft's local name			
9.	Gear's local name			
Structural Details		Mother vessel	Carrier vessel (No….)	
10.	L_{OA} (m)			
11.	Length at waterline (m)			
12.	Breadth/ Beam Max. (m)			
13.	Depth (m)			
14.	Freeboard (m)			
15.	Year built			
16.	Boat construction material	Wood / steel / FRP		
17.	Make of engine			
18.	HP of the engine	……….@………….rpm		
19.	Rpm Maximum			
20.	Model no:			
21.	Onboard Electronic equipments and Make	RT/VHF GPS Echo sounder Chart		
22.	Beacon			
23.	Propeller details	Size	Dia.	Pitch
		No. of Blade	Wt. & Material	
24.	Propeller Nozzle Details			
25.	Reduction gear details	Reduction ratio	Make	

Craft construction Details		**Material**	**Quantity**
26.	Hull thickness (skin and frames)		
27.	Hull strength members (Keel, deadwood, engine bearers, stringers, Size etc.)		
28.	Deck (Deck, Deck beams) Size,		
29.	Deck house (wheel house)		

30.	Outfit (Purse line winch, insulation, fuel tanks etc.)		
31.	Fastenings (for wooden construction)		
32.	Aluminium sheathing (for wooden hulls)/FRP sheating		
33.	Machinery (Main engine, shafting and propeller)		
34.	Deck equipment	Purse line winch, power block etc.	
35.	Order of construction		
36.	Fish hold volume		
37.	Net Tonnage of the vessel (Kg)		
38.	Fish hold capacity		
39.	Fish hold material of construction		
40.	Use of refrigeration units (Details)		
41.	Number of man days for construction		
42.	Periodicity of dry docking		
43.	Anti fouling method used		
44.	Amount of fouling material		
45.	Type of steering system		
46.	Rudder shaft:		
47.	Rudder size		
48.	Diesel capacity:		No. of Tank:
49.	Water capacity:		No. of Tank:
50.	Ice storage m^3 Yes/No		
51.	No. of 12V/24V Battery		
52.	Other details, if any:		

Gear Details

	Structural Details	Total	Bunt
53.	Length		
54.	Depth		
55.	Float line length		
56.	Lead line length		

57.	Total Wt.	
58.	Number of bunt areas	
59.	Bunt Position	
60.	No. gear unit in a fleet of net onboard	
61.	Bycatch Reduction Device (DWN)	

	Material	Main Webbing	Bunt	Selvedge
62.	Webbing material			
63.	Twine size (dia. in mm)			
64.	Mesh size (mm)			
65.	No of meshes in section length			
66.	No of meshes in section width			
67.	Treatment, if any			
68.	Colour			
69.	Life of net (mm/yy)			
70.	How net is discarded after use?			

	Ropes	Head rope/ Float line	Foot rope/ lead line
71.	Material		
72.	Rope size (dia. in mm)		
73.	Length (m)		

	Floats	Type 1	Type 2
74.	Material		
75.	Shape		
76.	Size (dia in mm)		
77.	Total number used		
78.	Number of master float		
79.	Number of units in one fleet		
80.	Number of meshes between two floats		
81.	Arrangement on float line (No. per unit length)		

	Sinkers	
82.	Material	
83.	Outer Dia. (mm)	
84.	Inner Dia. (mm)	
85.	Shape	

86.	Weight (g)	
87.	Total number used	
88.	Arrangement on lead line (No. per unit length)	
	Purse line Rings	
89.	Material	
90.	Outer Dia. (mm)	
91.	Inner Dia. (mm)	
92.	Weight (g)	
93.	Total number used	
94.	Arrangement on Sinker line (No. per unit length)	
	Hanging coefficient	
95.	Foot rope	
96.	Head rope	
97.	Number of man- days used for construction:	
98.	Time period of maintenance	

Operational details

99.	Fishing area/port	
100.	Season (fishing)	
101.	Local crew or not	
102.	Cruising speed	
103.	Fishing speed	
104.	No. of Hauls/day	
105.	Fish school detection method	
106.	Time of fishing	
107.	Depth range of fishing operation	
108.	Duration of fishing trip	
109.	Number of operations per day	
110.	Number of fishing days/ month	
111.	Fishing operation time	
112.	Target catch	

113.	Major bycatch		
114.	Use of bycatch		
115.	Total Crew onboard		
116.	Net Hauling method		
117	Fuel consumption per hour of operation		
118.	Specific fuel consumption		
119.	Total operational expense per day		
120.	Landing area and catch disposal		
Capital Investment		Cost	Life
121.	Mother Vessel		
122.	Carrier Vessel		
123.	Gear		
124.	Engine		
Accessories			
125.	Lights:		
126.	Anchor, signals		
127.	Any other Accessories		
128.	LSA, FFA		
129.	Quantity of net damaged/year		
130.	Cost required for its repair/year		
131.	% of damage	Animals	Natural Damage
132. Additional Information if any			

Annexure-II

PROFORMA FOR INDIVIDUAL FISHING TRIPS

Name of Vessel Date :

Time and Place of Departure SL. No :

Time of Arrival

No. of persons taking part in the ring seine net operation:

Weather condition of the day

Number of operations per day

	1st operation	2nd operation	3rd operation	4th operation
Time spent for searching the shoal				
Time spent for surrounding the net.				
Time spent for Hauling the net.				
Time spent for resetting the net				
Total catch per operation				
Depth of Operation				
GPS Location of Operation				
Distance from Shore				
Sea water Temperature				
Target species caught				
Other species caught	1	1	1	1
	2	2	2	2
	3	3	3	3
	4	4	4	4
	5	5	5	5

FUEL EXPENDITURE

Quantity of fuel used per day

	Lube Oil	Kerosene	Petrol	Diesel
For main vessel (in lit.)				
For carrier vessel (in lit.)				

Reason for non-fishing days

Operational Expenses (in Rs.)

1) Crew share
2) Total Fuel
3) Boat maintenance
4) Food Expenditure
5) Travel Expenditure
6) Ferry Rent
7) Miscellaneous

Yield

Total Catch (in Kg.)____________________

Major Species Caught (in Kg.)____________________

Total Returns from fish selling (in Rs.) ____________________

Actual returns excluding all operational expenditure and crew share (in Rs.) ____________________

Quantity of Juvenile fish/Species

DATA SHEET FOR LENGTH WEIGHT MEASUREMENTS

Name of vessel: Date:

Species caught : SL. No:

No.	Length (mm)	Weight (g)	No.	Length (mm)	Weight (g)
1.			26.		
2.			27.		
3.			28.		
4.			29.		
5.			30.		
6.			31.		
7.			32.		
8.			33.		
9.			34.		
10.			35.		
11.			36.		
12.			37.		
13.			38.		
14.			39.		
15.			40.		
16.			41.		
17.			42.		
18.			43.		
19.			44.		
20.			45.		
21.			46.		
22.			47.		
23.			48.		
24.			49.		
25.			50.		

Chapter

3

REGIONAL VARIATIONS IN DESIGN OF RING SEINES AND THEIR OPERATION

Contents

3.1 Introduction

The structure of the ring seine has many features of the purse seine and lampara net. All three gears are kept on the surface of the water by a similar float line strung with floats, and are hung vertically in the water by a heavily weighted lead line. The ring seine, like the purse seine, has purse rings along its lower edge. Some of the chief structural differences between the ring seine and the purse seine are that the purse seine is made of comparatively heavy webbing, is uniform throughout its entire length, and is square on the ends; while the ring seine, like the lampara, is made of light webbing.

The structure of ring seines vary widely depending on the method of operation, gear handling, depth of operation, target species and vessel characteristics. The ring seine gear is essentially made of three parts: a central bunt of thick webbing and two end portions or wings. The relative lengths of bunt and wings vary greatly. The width of the bunt is one-tenth to almost one-twelfth of the net. Other important parts are selvedge, rings, body net, floats and sinkers. Mainly two types of ring seines gear are in operation along the Kerala coast. They are the *thanguvala* with mesh size of 16-22 mm having length ranging from 600 to 1500m and depth from 83 to 110m and weight 1500 to 3500 kg and are targeted to catch the pelagic shoaling fishes like the sardines and mackerel. The second one is the *choodavala* or the *discovala* with a mesh size of 8 - 10 mm, length of 250 to 500 m, depth of 45 - 75 m and is mainly targeted to catch the anchovies. It is operated within 30 m depth.

The main objective of this chapter is to scientifically document the variation in designs of ring seine gear presently operated in Kerala and to analyse their regional variations.

3.2 Materials and Methods

The centres selected for study are given in Fig. 3.1. All ring seine landing centres along the Kerala coast were surveyed. Thirty known centers were surveyed in order to compare the regional differences in the craft, gear and operation. The motorized and mechanized fishing vessels were surveyed as per FAO standards (Fyson, 1986). Documentation of designs of fishing gear were done as per FAO (1975&1978); Nedlec (1982). Engine horse power and other details of engine and onboard equipment were collected from crew members and verified at fishermen co-operative societies. Details of onboard machinery/ accessories used were collected. Method of operation was studied by onboard participation in data collection from the major centers. The questionnaire shown in Chapter-2 (Annexure-1) was used for data collection.

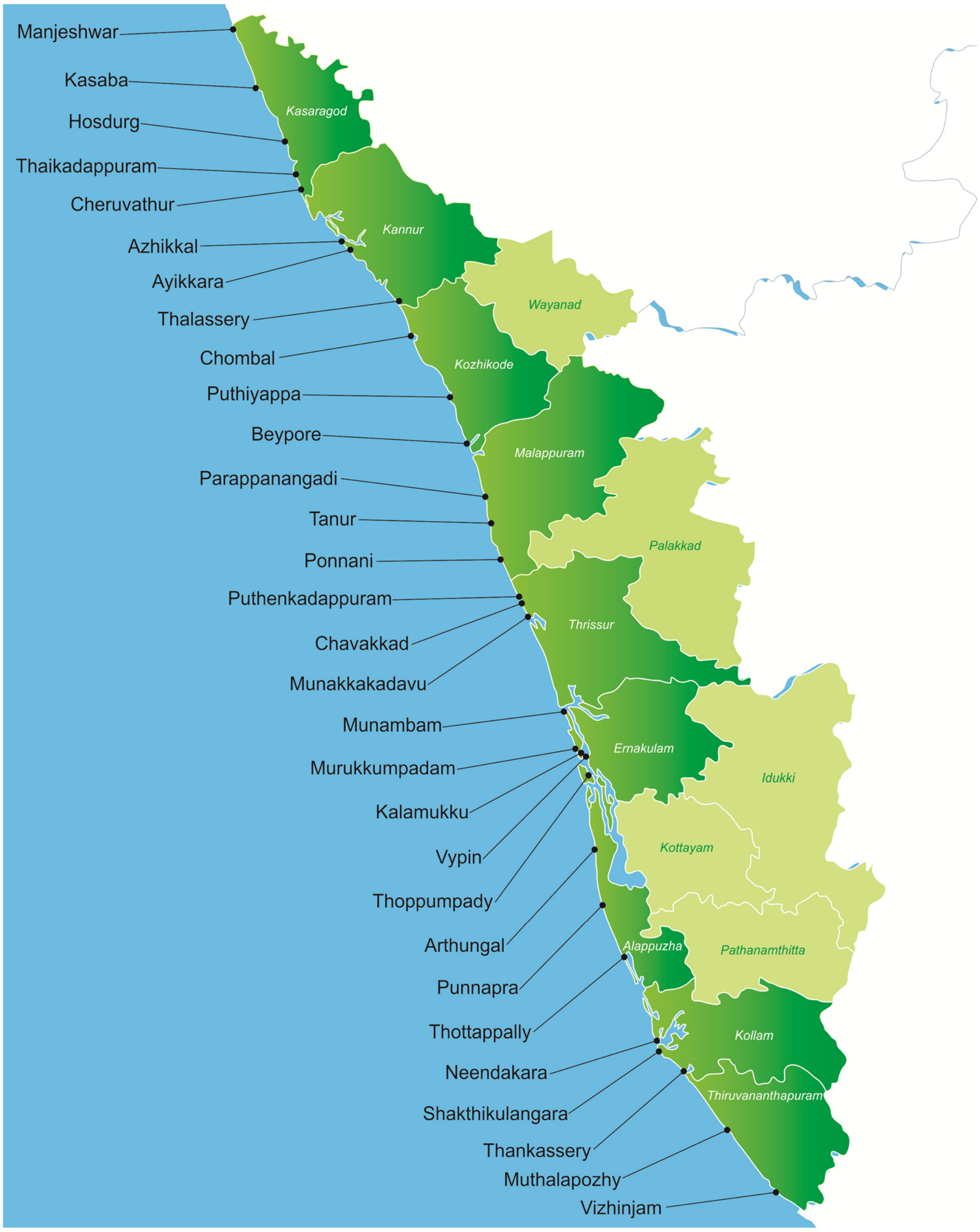


Fig. 3.1 Map of Kerala showing coastal districts and fish landing centres selected for the study

3.3 Result and Discussion

The structure of ring seine including the details of main body, selvedge, bunt, floats, sinkers, purse ring, etc. are scientifically documented and designs drawn. The details of ring seine vessel, their classifications and types of operation ie, one boat motorized ring seine with skiff operation, mechanized ring seine operation and one boat ring seine without skiff operation are given below.

3.3.1 Structure of Ring Seine

Major structural parts of ring seine fishing gear are given in Fig.3.2.

3.3.1.1 Main Body

The main body of the net extends from one end to the other end of the net except the bunt region. It is the largest part of the net and facilitates surrounding of the fish shoal during operations. It is made by joining together large sections of netting of appropriate mesh sizes to retain the target fish. The material used is polyamide (PA) as it has high specific gravity to increase the sinking speed during operation. Knotted PA webbing of 210Dx1x2, 210Dx1x3, 210Dx2x2 and 210Dx2x3 are used with different mesh combinations for main body construction.

Shape of the ring seine is maintained by the arrangement of webbing panels which are vertically arranged one after another to make the main body. The arrangement and the depth of the panels varied with region. Deepest point of ring seine unit is towards centre and depth reduces towards the wings. In southern parts of the state, the reduction start from the bunt immediately after the center portion and in Ernakulam it is restricted to last 10 to 20 panels whereas in Thrissur to Kasaragode, it is limited to last three to four panels.

3.3.1.2 Bunt

The region in the ring seine net where the catch is accumulated is called the bunt. Because of the excess strain it has to withstand, it is made up of heavier netting than the main body. The position and number of bunts vary depending on the type of operation and usually a single bunt is placed at the centre. The width of the bunt is usually equal to or more than the length of the boat. In the region between Thiruvananthapuram to Alappuzha, mechanized and motorized ring seines have only one bunt and it is situated at the centre of the netting. In the Alappuzha to Kozhikode region, two bunts were observed in large ring seines. More than two bunts were observed in ring seines (*ranivala),* operated in the Kozhikode - Kasaragode belt. Materials used for bunt construction also varied from region to region. Alappuzha, Ernakulam, Thrissur, Malappuram and Kozhikode regions commonly use HDPE for bunt construction where as in other parts of Kerala, thicker twines of PA are used. In bunt, the panels are attached in horizontal manner to get more strength while holding the catch.

3.3.1.3 Selvedges

Selvedges or guarding strips of strong webbing are used for strengthening the main webbing and to protect it from damage during operations. It is provided in the upper, lower and side edges of the main body of the net. It consists of a few rows of large meshes of thicker twine. The upper selvedge is attached to the float line also called the head rope and the lower selvedge to the lead line or foot rope. Kannur and Kasaragod districts use PA webbing exclusively for fabrication of selvedge and in other areas, HDPE webbings are used for selvedge construction. The depth of the meshes in selvedge units varied from five to fifty.

3.3.1.4 Second Selvedge (*Chuttumvala*)

Chuttumvala is a long piece of webbing to which the main body of the net is attached. It is provided in the upper and lower side of the main body of the net just after the selvedge. It consists of a few rows of thicker twine with same mesh size as main body webbing. The depth of *chuttumvala* meshes varied from 30 to 100. PA and HDPE are used for the *chuttumvala* construction. In Kozhikode and Malappuram districts, PA webbings are used for c*huttumvala* construction whereas in Thrissur, Ernakulam, Alappuzha districts HDPE is used. *Chuttumvala* is absent in other districts of Kerala and in *ranivala* and *choodavala.*

3.3.1.5 Floats

Cylindrical or spindle or apple shaped plastic floats are used in ring seine. Total buoyancy of float is maintained at 1.5 to 3.5 times the total under water weight of the ring seine net and its accessories. Higher buoyancy is provided in the bunt area in order to counteract the sinking force due to weight of heavier netting (PA) in this area and the weight of fish while concentrating the catch. The float is hung directly on the float line or attached to a line which is then attached to the main float line.

3.3.1.6 Sinkers

Spindle shaped sinkers are attached to the lead line to attain 0.5 -2.5 kg weight per meter for ring seine. Lead of approximate weight of 100-200 g are used as sinkers. Sinkers are attached to the ring seine gear by threading to the sinker line.

3.3.1.7 Purse Lines

Polypropylene are used for purse line. Purse lines are 10 – 20 % longer than the total length of ring seine. Purse line ropes of 16mm to 28mm are commonly used.

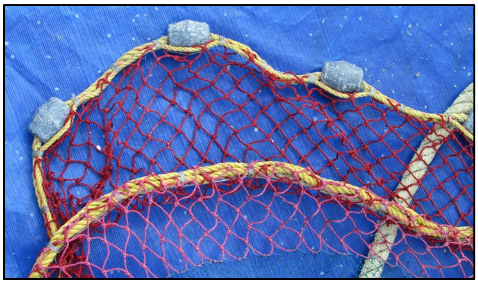
3.3.1.8 Hanging Coefficient

The most common horizontal hanging coefficient on main body is 0.5 to 0.75 and for bunt is 0.47 to 0.65.

The Ring seine gear

Ring seine main body

Ring seine bunt regions

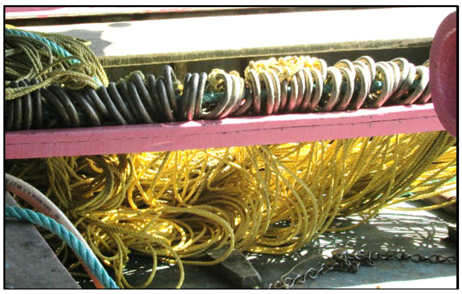


Ring seine lead line with selvedge

Ring seine float line with selvedge

Ring seine *chuttumvala* (second selvedge)

Purse line rope



Ring seine purse line ring with bridles

Fig. 3.2 Important structural parts of ring seine

3.3.1.9 Purse Rings

Steel or brass rings are used as purse rings. The size of purse rings depends on the size and weight of the gear. These in turn depend on the size of the boat. Purse ring weight varied from 0.5 kg to 1.5 kg. Number of rings varied with the length of the ring seine and the number of purse rings varied from 20 to 90.

3.3.2 Types of Ring Seines

3.3.2.1 Design of a Typical Large Mesh Ring Seine (*Thanguvala*)

A typical *thanguvala* of 1000 m in length and 90 m in depth is described. The bunt is made of horizontally placed rectangular sections of webbing. A single section of bunt is 20 mm meshes with 2000 meshes in length and 300 meshes in depth. The top section is made of polyethylene material of 20 mm stretched mesh size, as the weight of the catch is concentrated at this area during hauling and the remaining portion of the bunt is made of 20 mm nylon webbing. *Thanguvala* unit is made up of 114 sections of webbing. The required shape is given by reducing the depth by 50 meshes from the last 22 section onwards and proceeds to the wing-end. The wings are made of nylon webbing of 18-20 mm mesh size. The *chuttumvala* (selvedge) is 50 meshes in depth and is found at the top and the bottom portion of the webbing. It is made of polyethylene material with a mesh size of 22 mm. This portion is attached to the main webbing by attaching one mesh of the main body to each *chuttumvala* mesh. The top selvedge with a mesh size of 26 mm and 10 meshes in depth is made of polyethylene. The top selvedge is hung on polypropylene rope of 6 mm diameter which is passed through every mesh. The bottom selvedge with a mesh size of 80 mm and depth of 11 meshes is attached to the *chuttumvala* at the five meshes for every selvedge mesh. Apple shaped floats, cylindrical and spindle shaped floats made of plastic are used. The spindle shaped floats have a diameter of 130 mm, cylindrical floats have a diameter of 120 mm and weight 80 g and 90 g. Apple floats have a diameter of 90 mm and weighs 35 g each. 7500 such floats are used on this gear. Spindle shaped lead sinkers each weighing 200 g were used. 5000 such sinkers are used on this gear. The floats and sinkers are hung on the polypropylene ropes of 12 mm diameter called the float line and sinker line respectively. The rings are made of brass and each ring weighed 1.5 kg. The diameter of the rings is 160 mm. 90 such rings were used on this gear.

3.3.2.2 Design of a Typical Small Mesh Ring Seine (*Choodavala*)

A typical *choodavala* of 270 m in length and 54 m in depth is described. *Choodavala* unit is made up of 54 sections of webbing. The sections are rectangular and attached side to side vertically. One such section has 5400 meshes in depth and 600 meshes in width. The bunt is made of horizontally placed rectangular sections of webbing and the top section is made of polyethylene of 10 mm stretched mesh size, as the weight of the catch is concentrated at this area during hauling and the remaining portion of the bunt is made of 10mm nylon knotted webbing. The required shape is given by reducing the depth of 45 meshes from the last 21 sections onwards and proceeds to the interval of every section. The wings are made of nylon webbing of 10 mm mesh size. The *chuttumvala* is 33 meshes in depth and is found at the top and the bottom portion of the webbing. It is made of polyethylene material with a mesh size of 20 mm. The top selvedge with a mesh size of 40 mm and 3 meshes in depth is made of polyethylene. The bottom selvedge with a mesh size of 40mm and 60 mm with 3 and 7 meshes respectively in depth are attached to the *chuttumvala*. Shape and size of floats using for *choodavala* is same as *thanguvala* floats. 2200 floats are used on this gear size. Spindle shaped lead sinkers each weighing 100 g were used. 1000 such sinkers are used on this gear. The floats and sinkers are hung on the polypropylene ropes of 6 mm & 10 mm diameter called the float line and sinker line respectively. The rings were made of brass/steel and each ring weighed 1 kg. The diameter of the rings is 120 mm. 25 such rings were used on this gear.

Design of representative important catalogues of ring seines are given in Fig. 3.3 to 3.29.

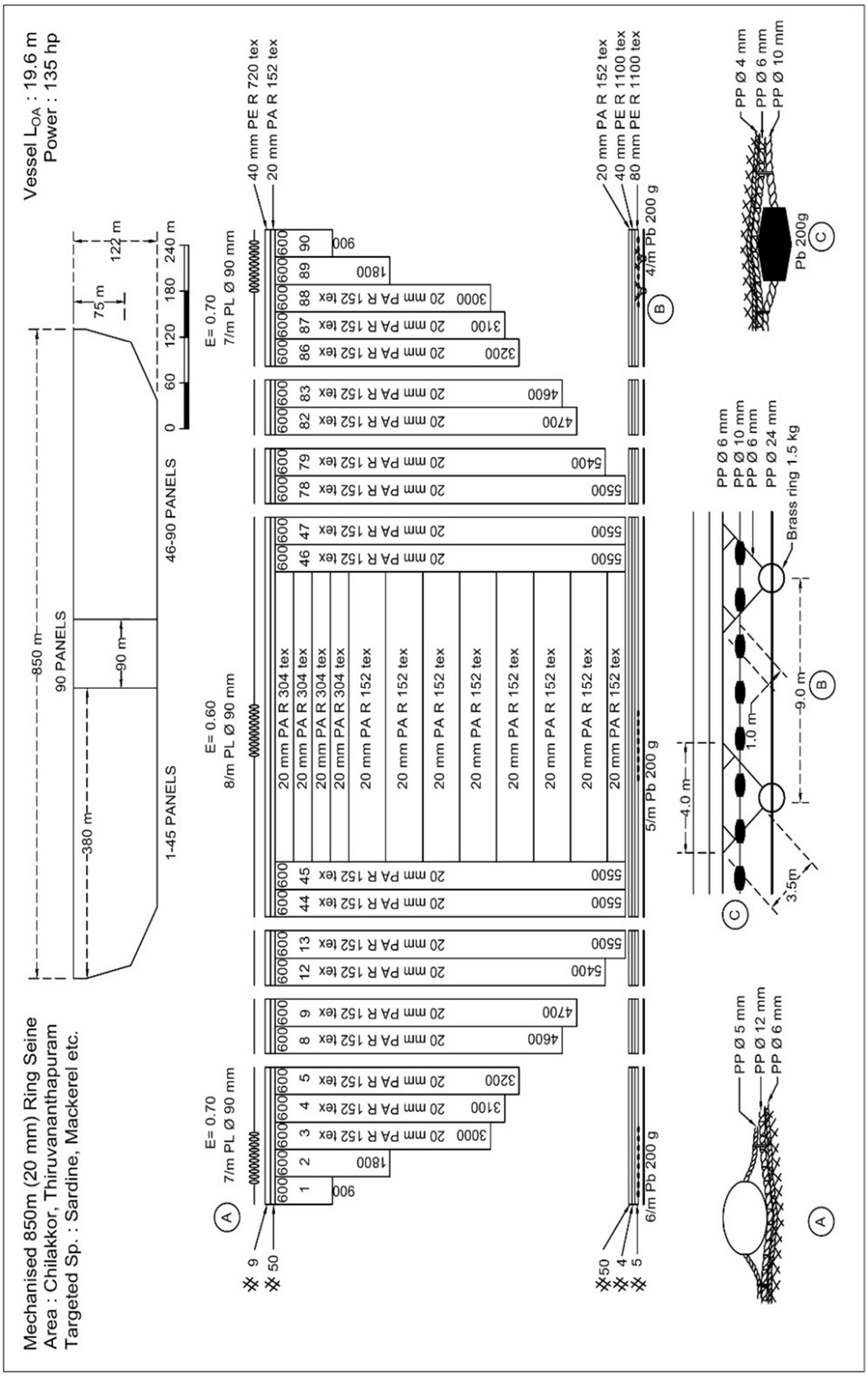


Fig. 3.3 Design details of 850 m ring seine of Chilakkor, Thiruvananthapuram

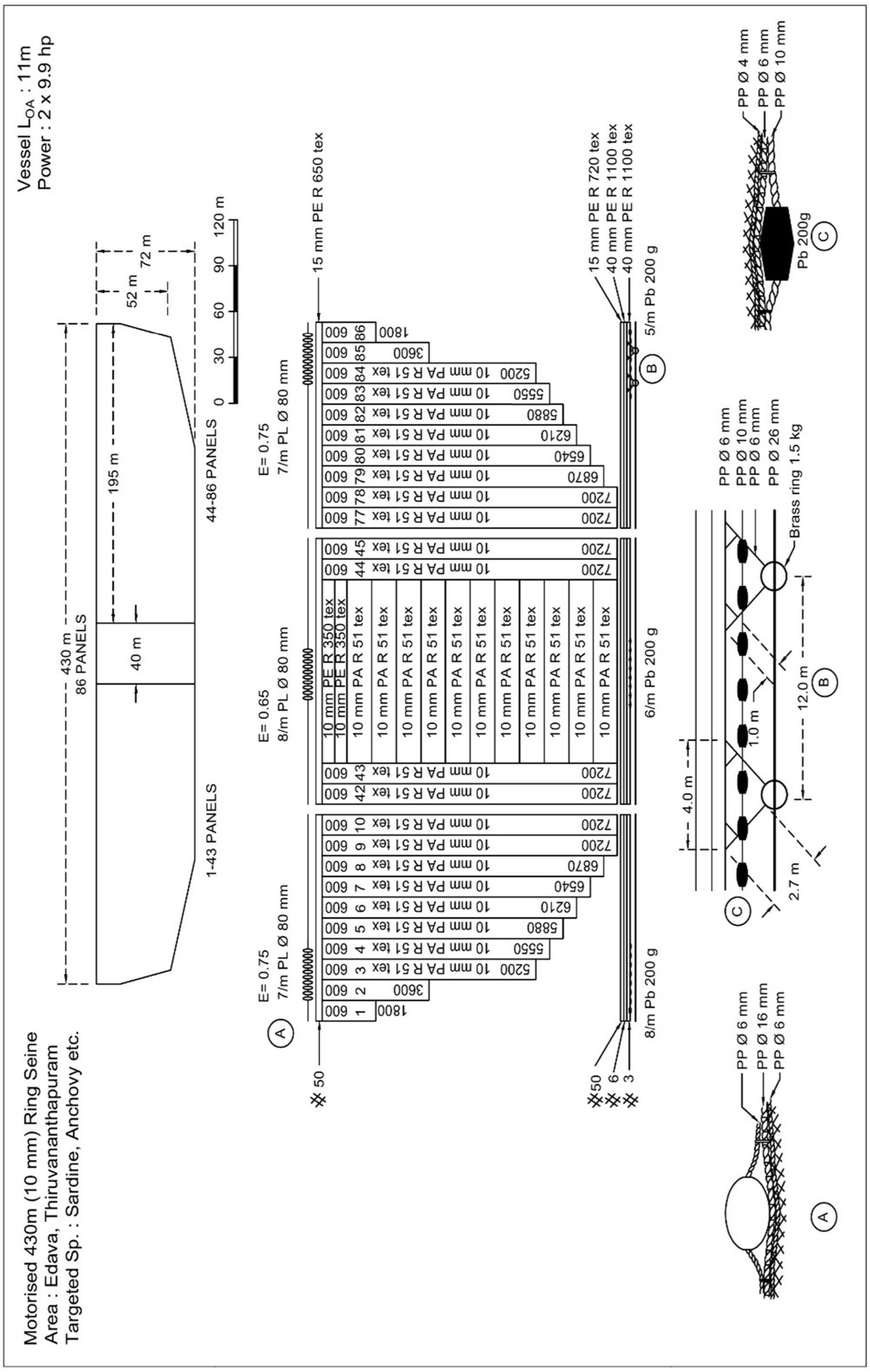


Fig. 3.4 Design details of 430 m ring seine of Edava, Thiruvananthapuram

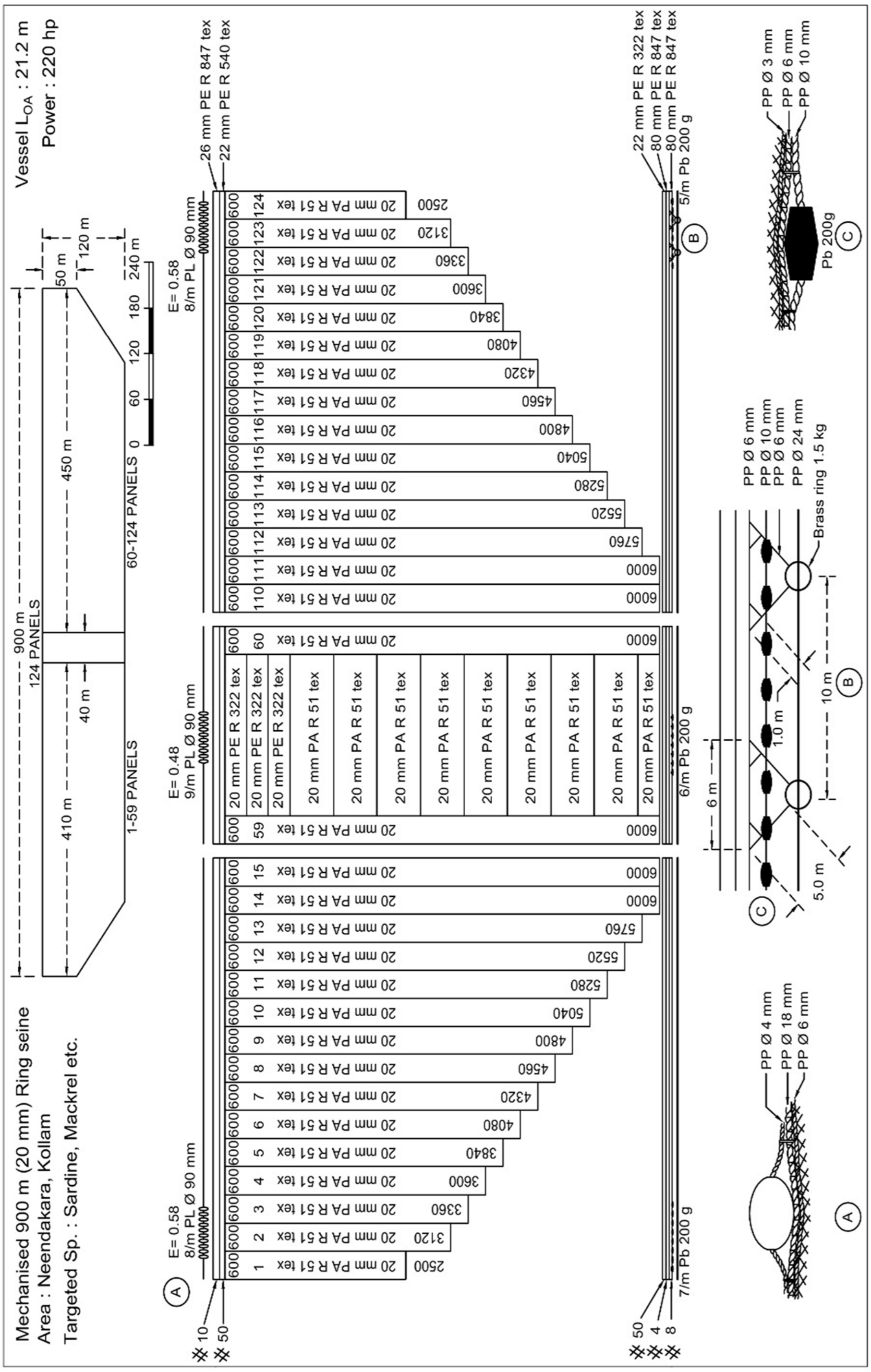


Fig. 3.5 Design details of 900 m ring seine of Neendakara, Kollam

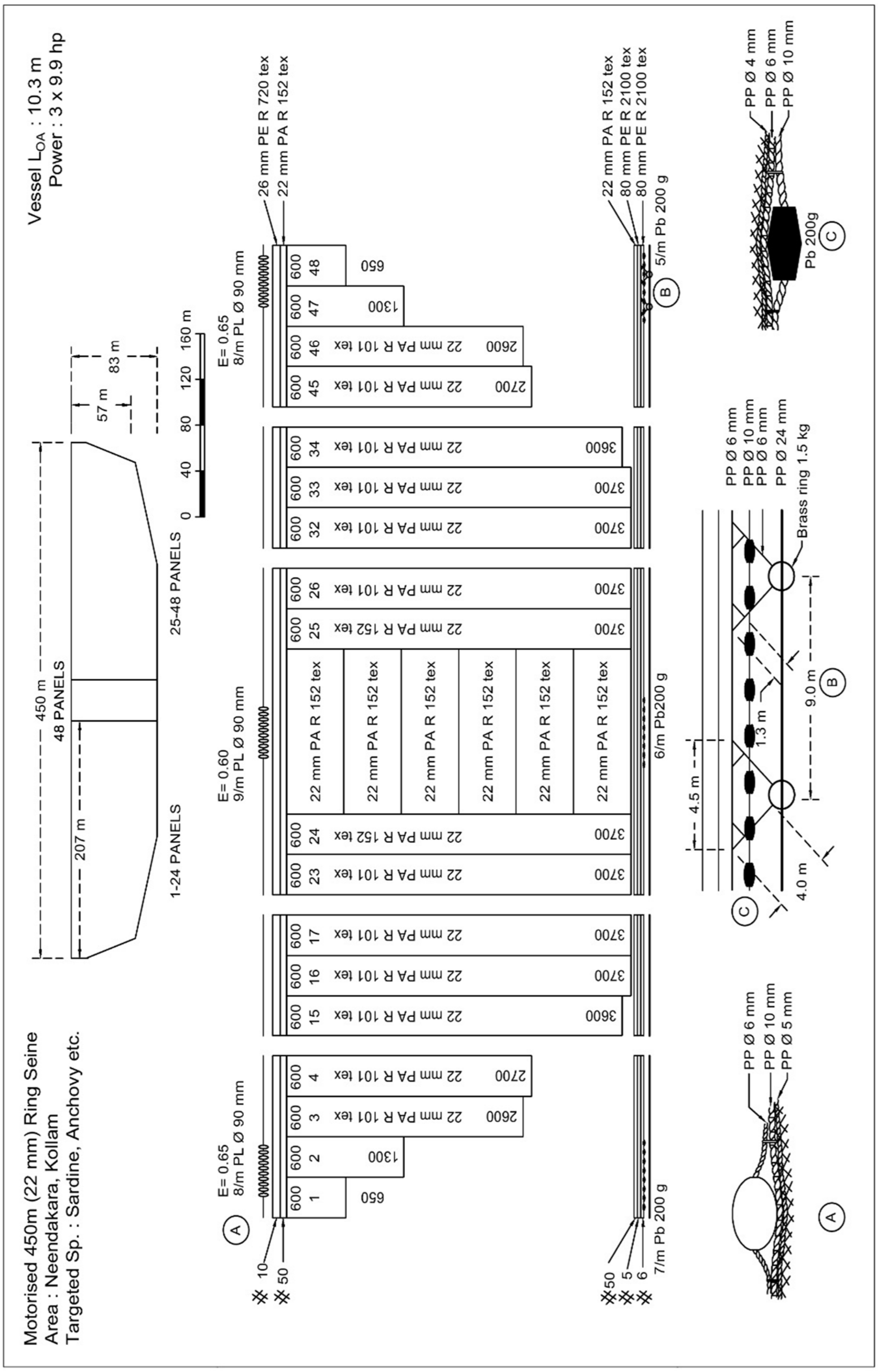


Fig. 3.6 Design details of 450 m ring seine of Neendakara, Kollam

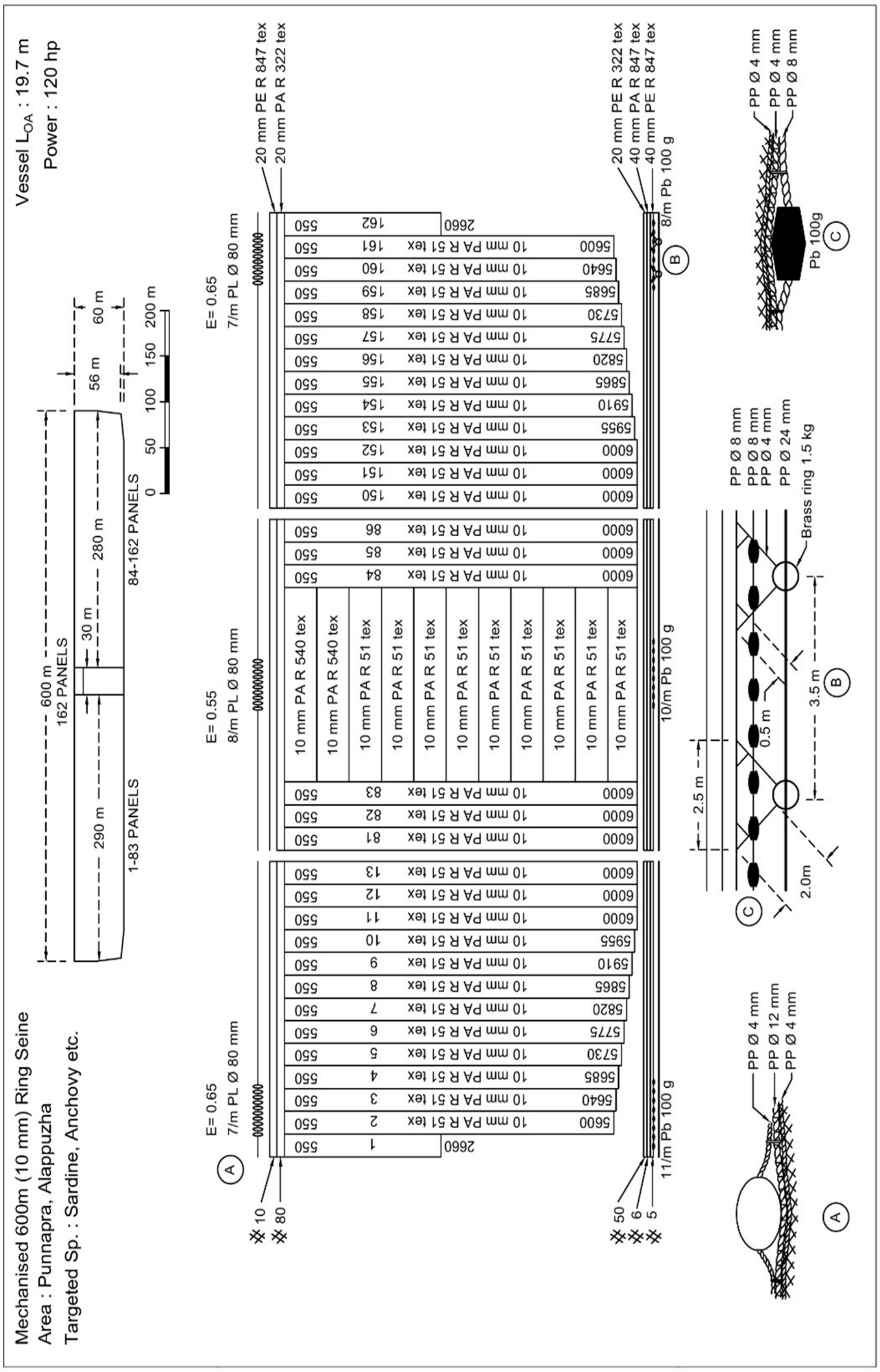


Fig. 3.7 Design details of 600 m ring seine of Punnapra, Alappuzha

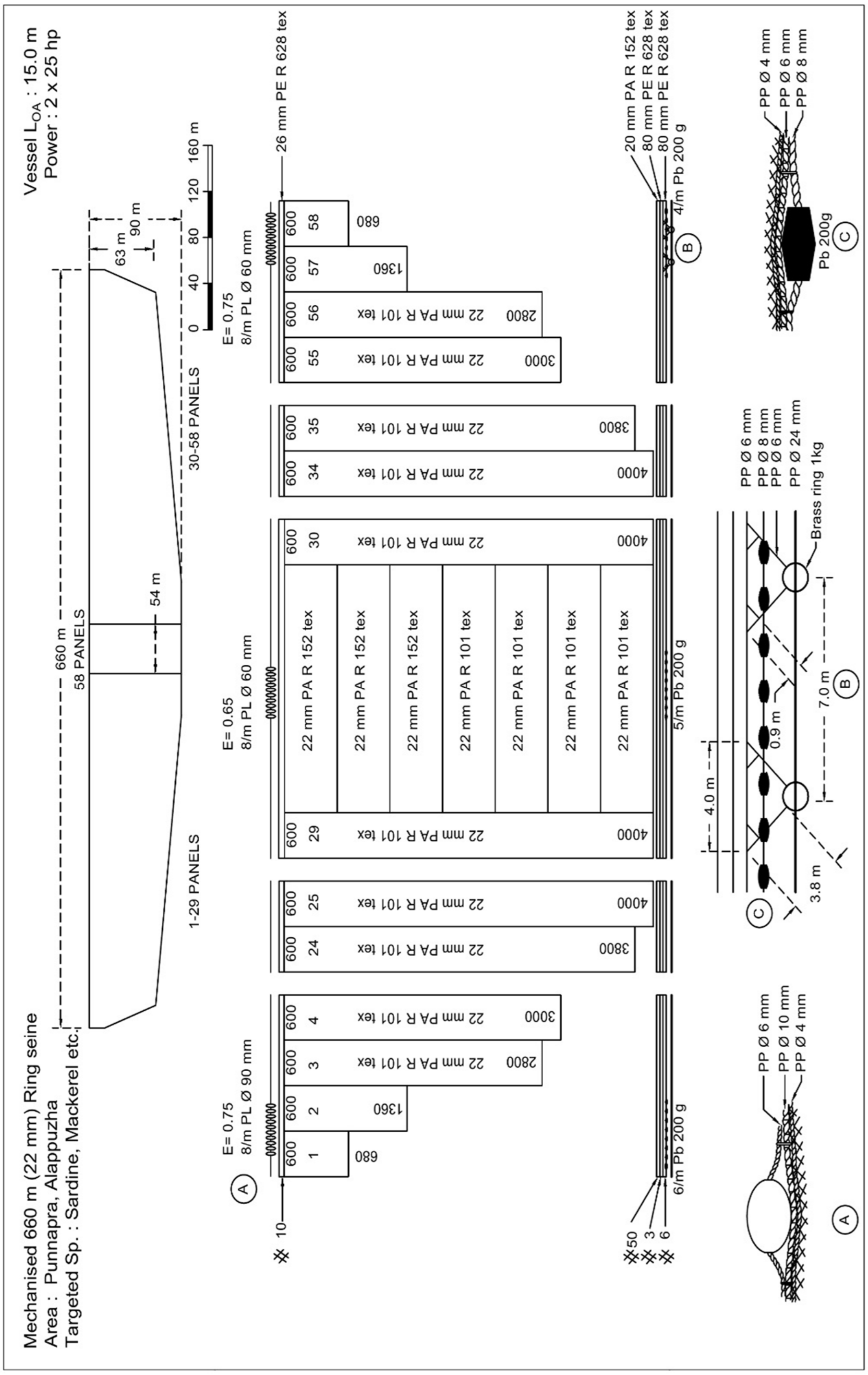


Fig. 3.8 Design details of 660 m ring seine of Punnapra, Alappuzha

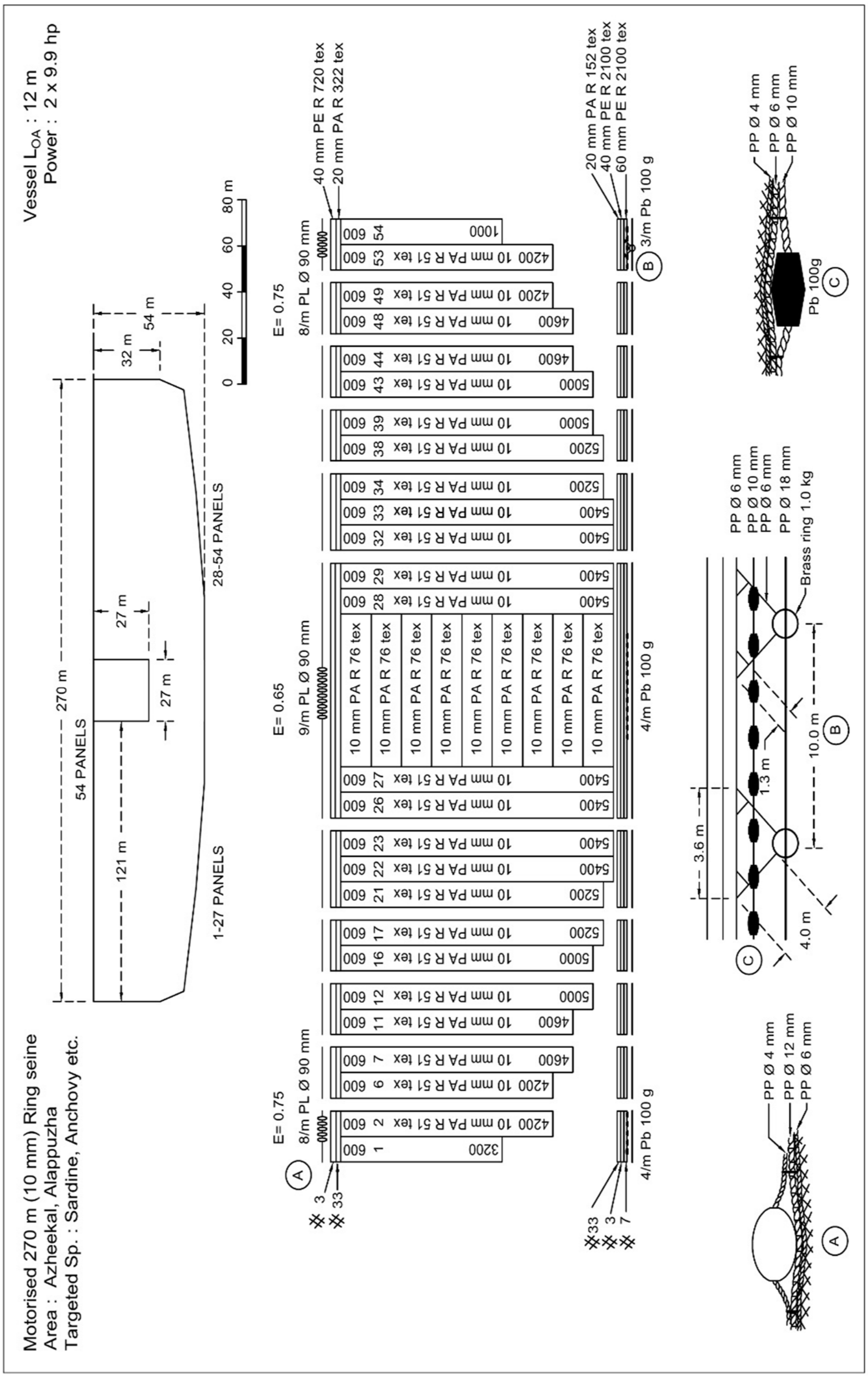


Fig. 3.9 Design details of 270 m ring seine of Azheekal, Alappuzha

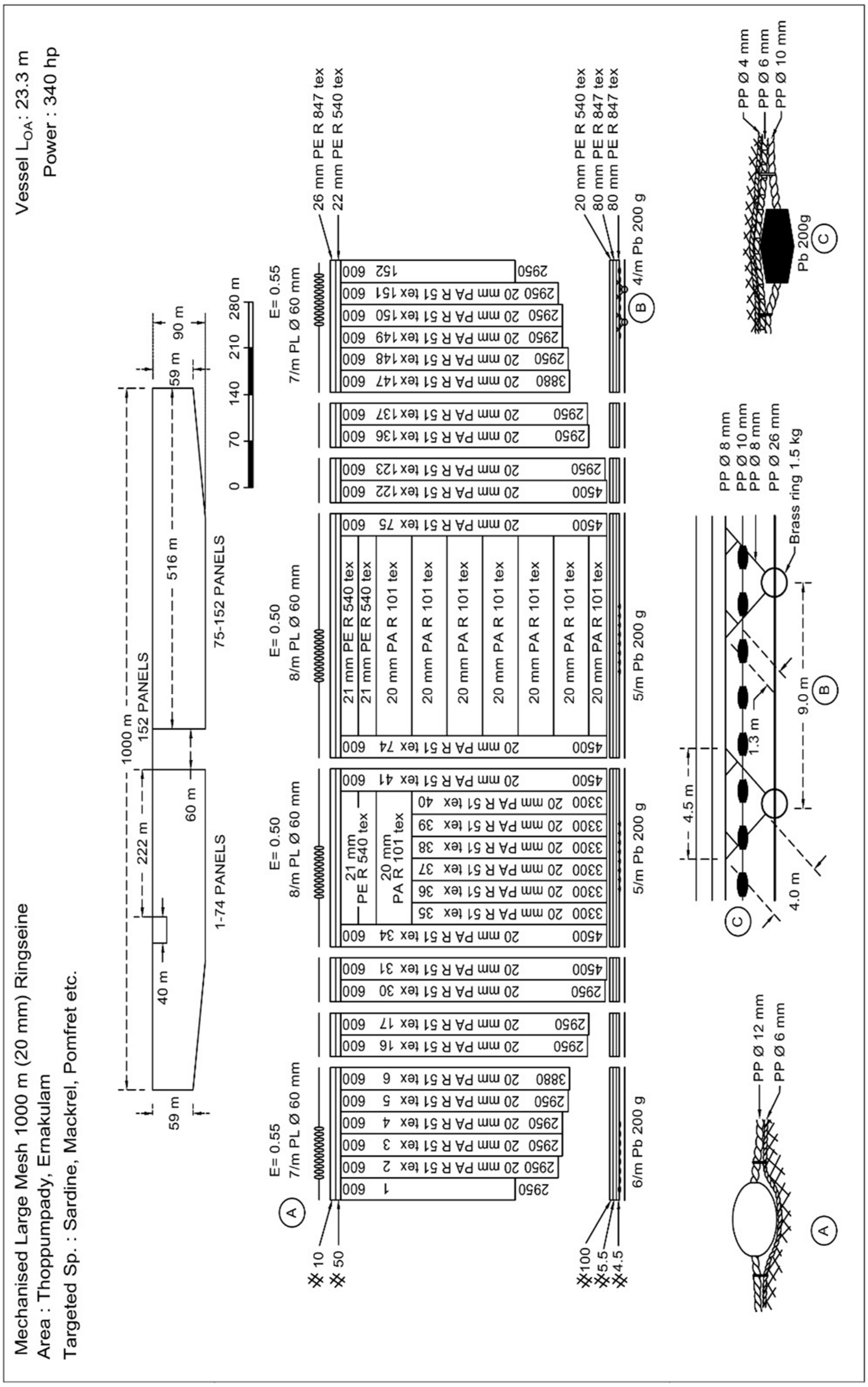


Fig. 3.10 Design details of 1000 m ring seine of Thoppumpady, Ernakulam

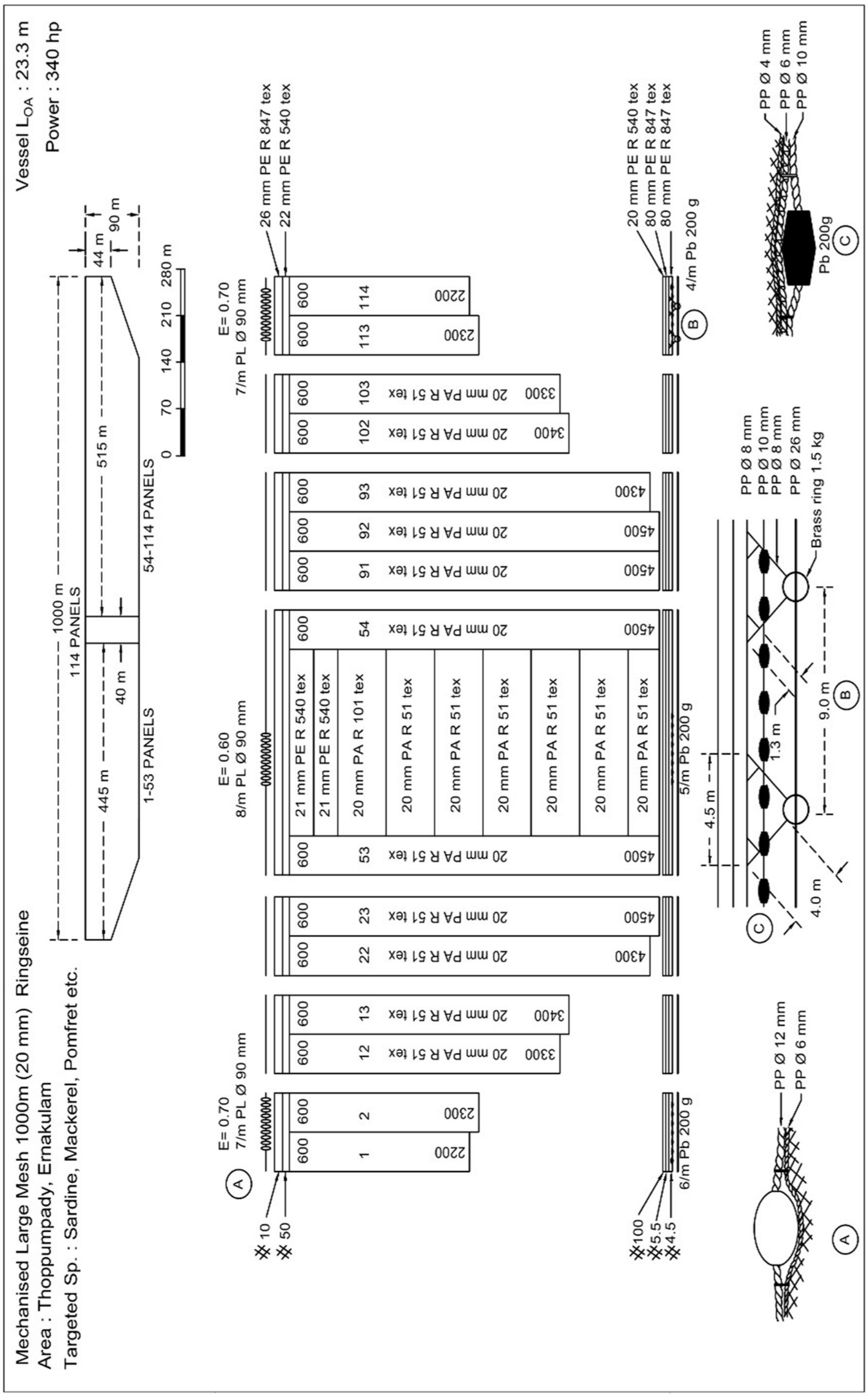


Fig. 3.11 Design details of 1000 m ring seine of Thoppumpady, Ernakulam

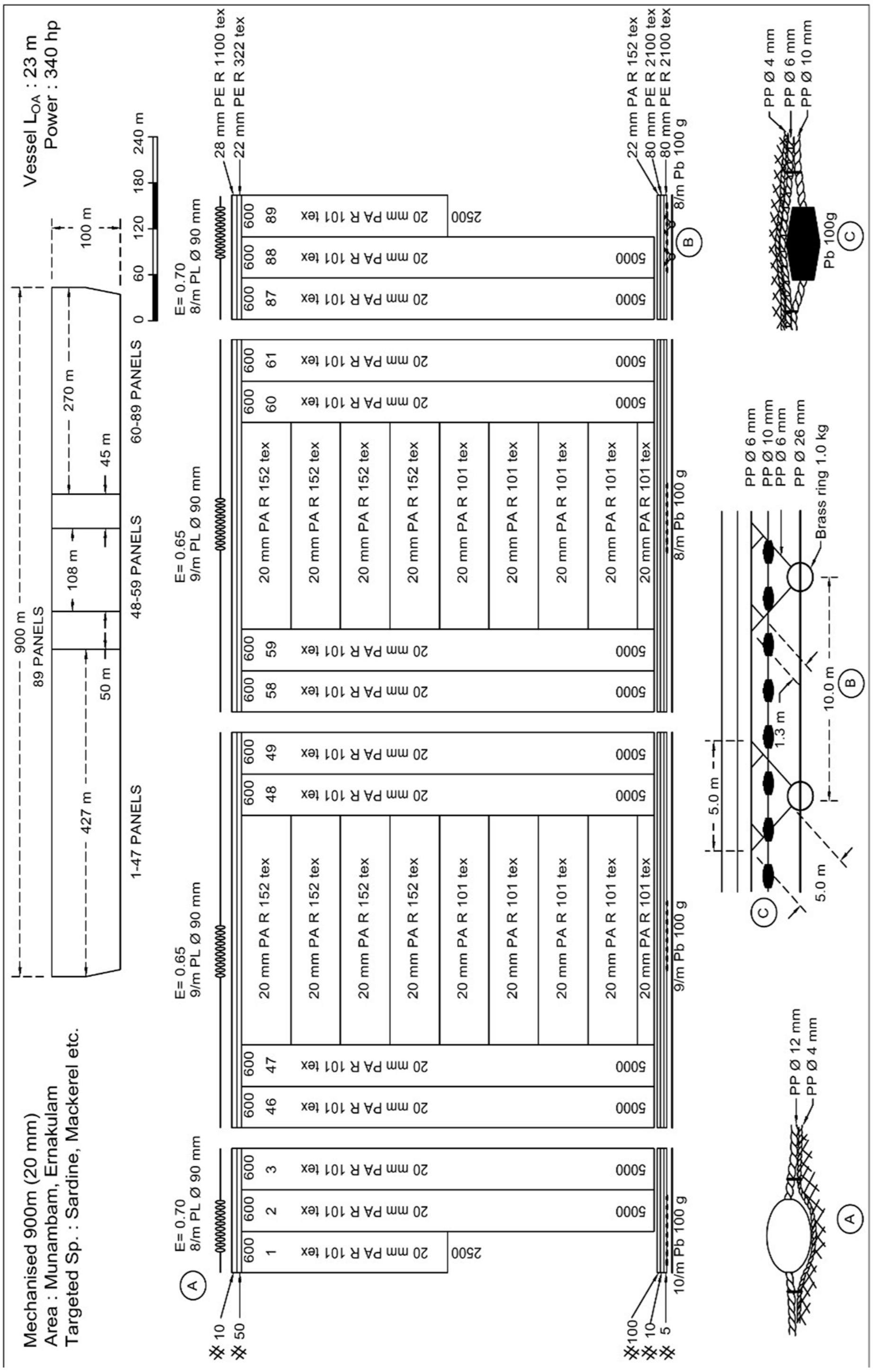


Fig. 3.12 Design details of 900 m ring seine of Munambam, Ernakulam

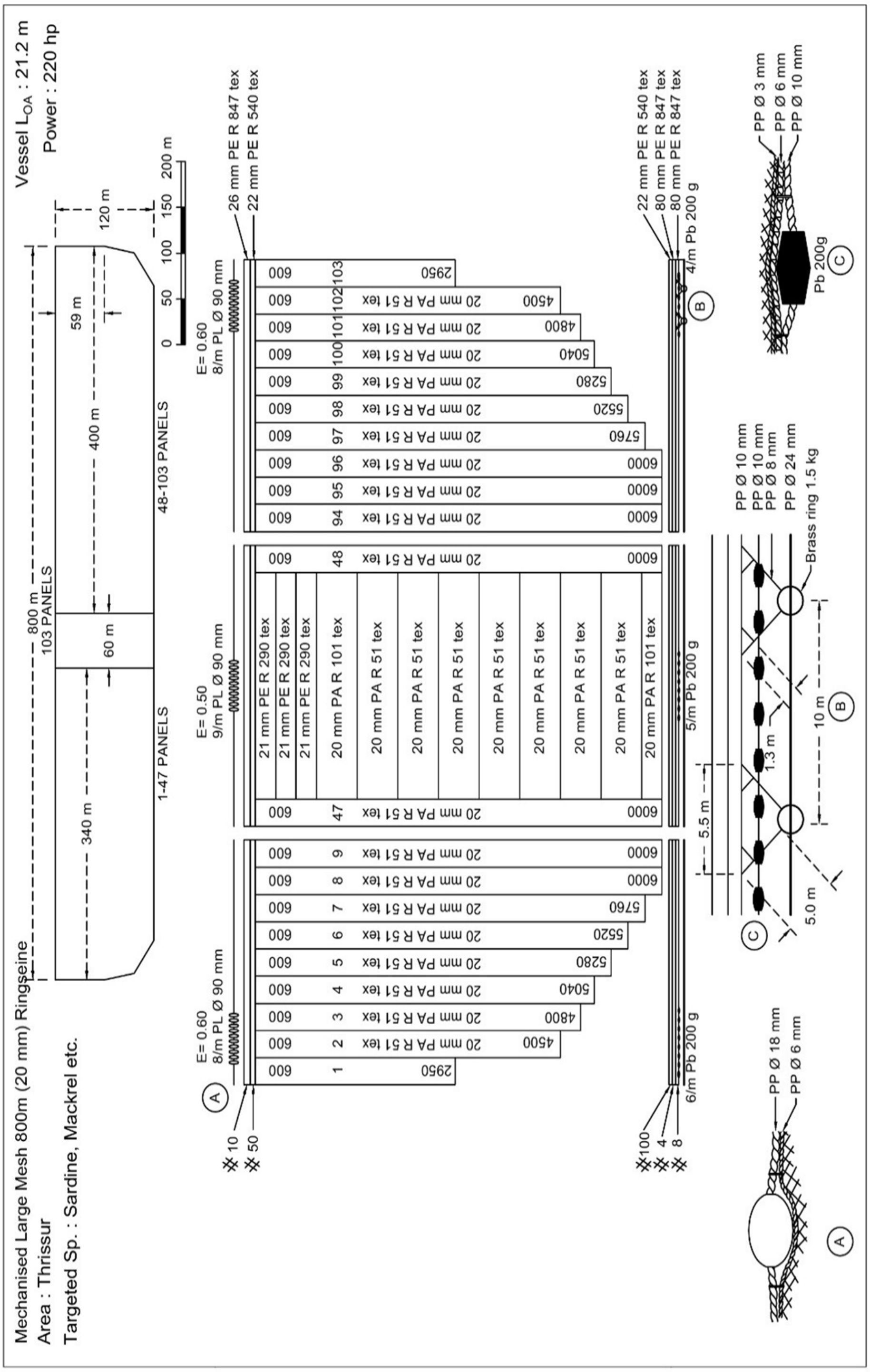


Fig. 3.13 Design details of 800 m ring seine of Thrissur

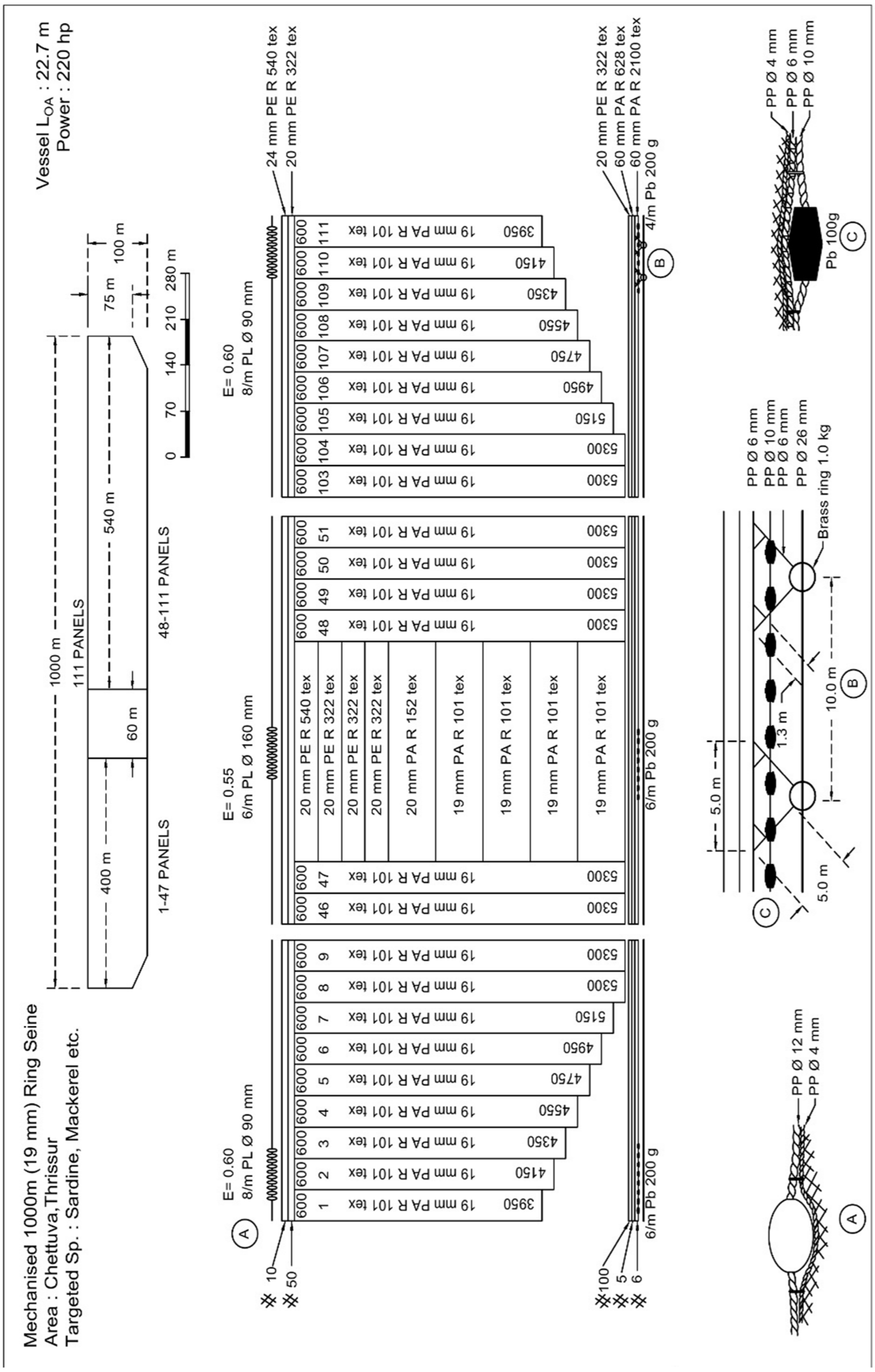


Fig. 3.14 Design details of 1000 m ring seine of Chettuva, Thrissur

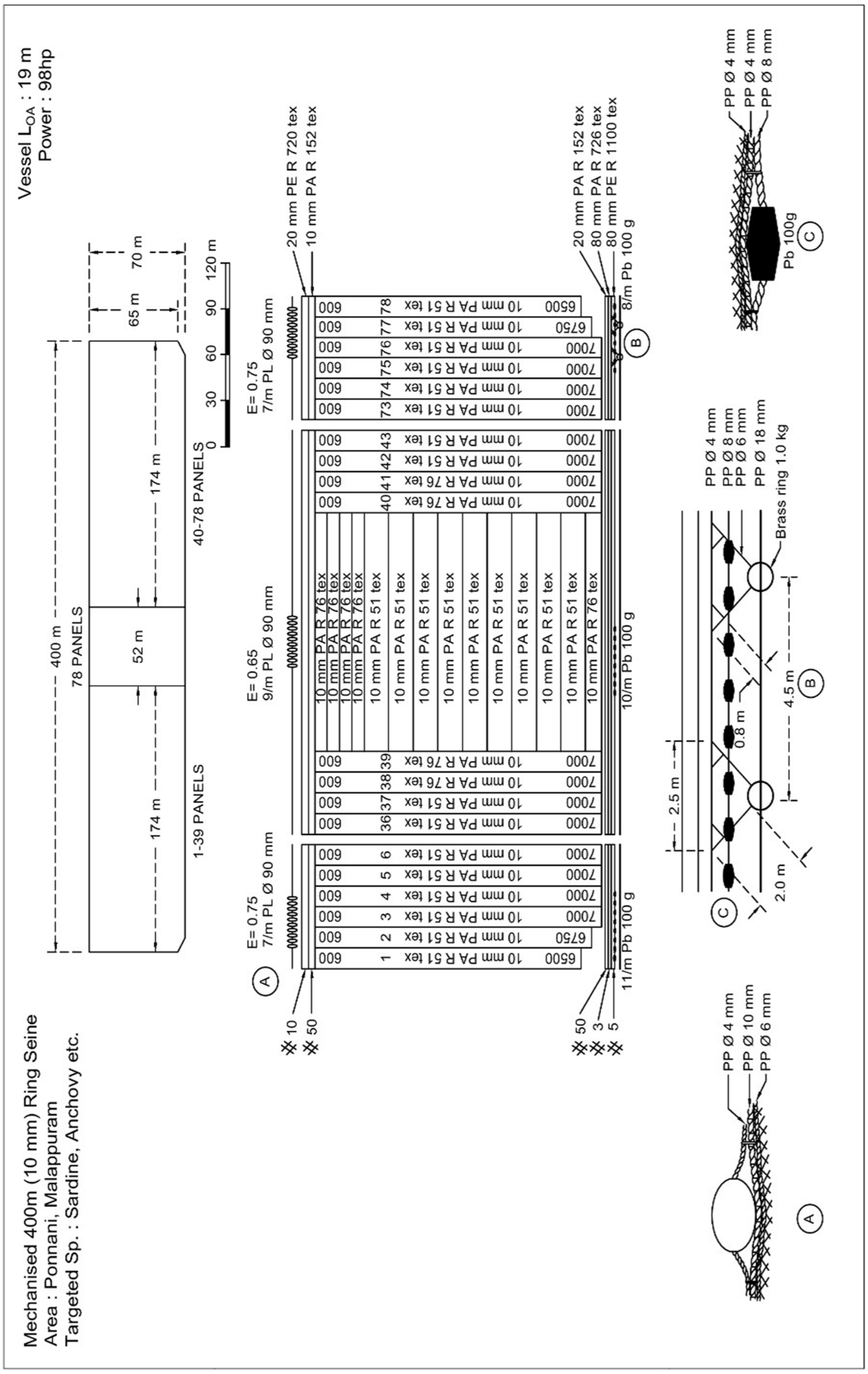


Fig. 3.15 Design details of 400 m ring seine of Ponnani, Malappuram

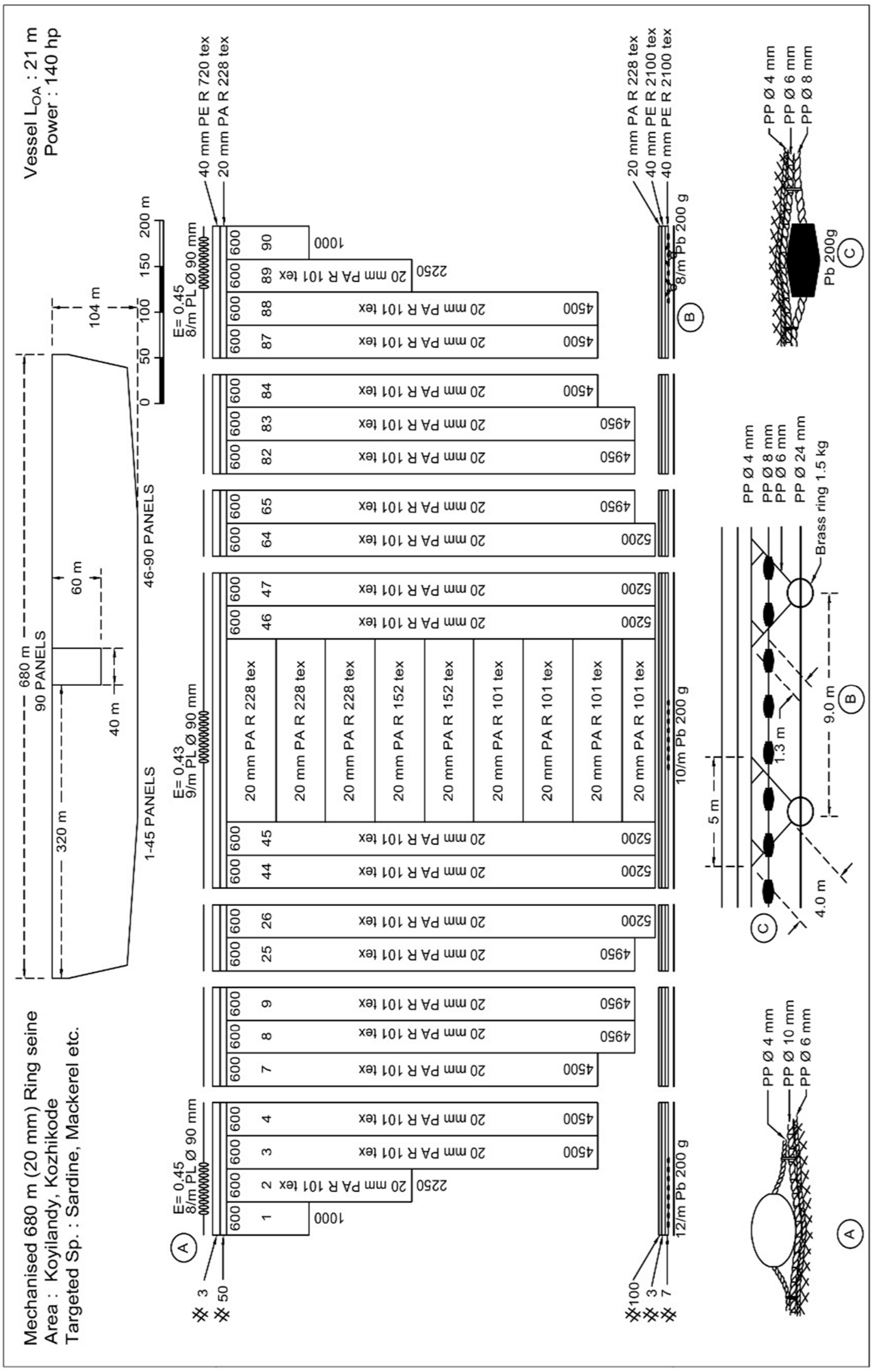


Fig. 3.16 Design details of 680 m ring seine of Koyilandy, Kozhikode

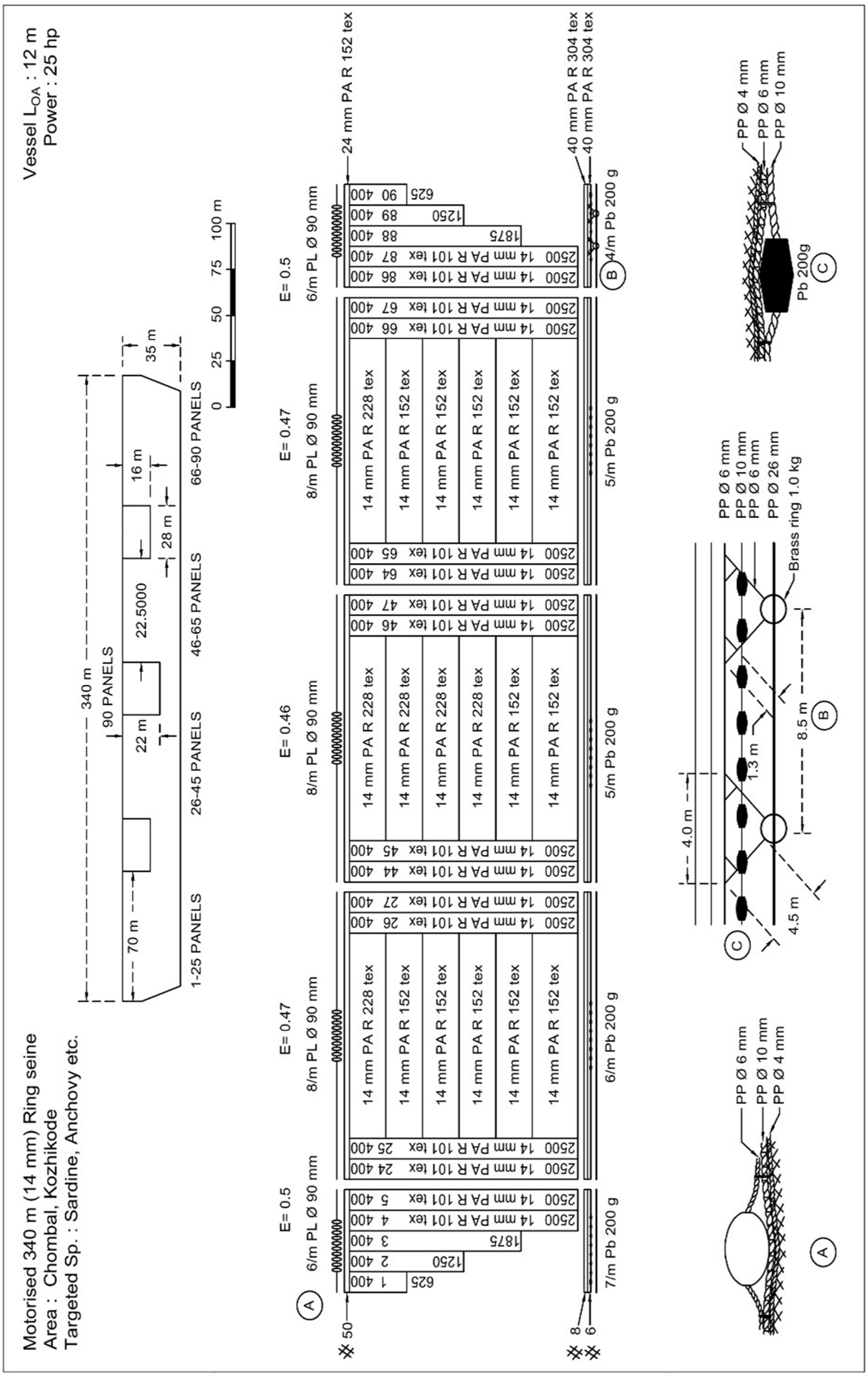


Fig. 3.17 Design details of 340 m ring seine of Chombal, Kozhikode

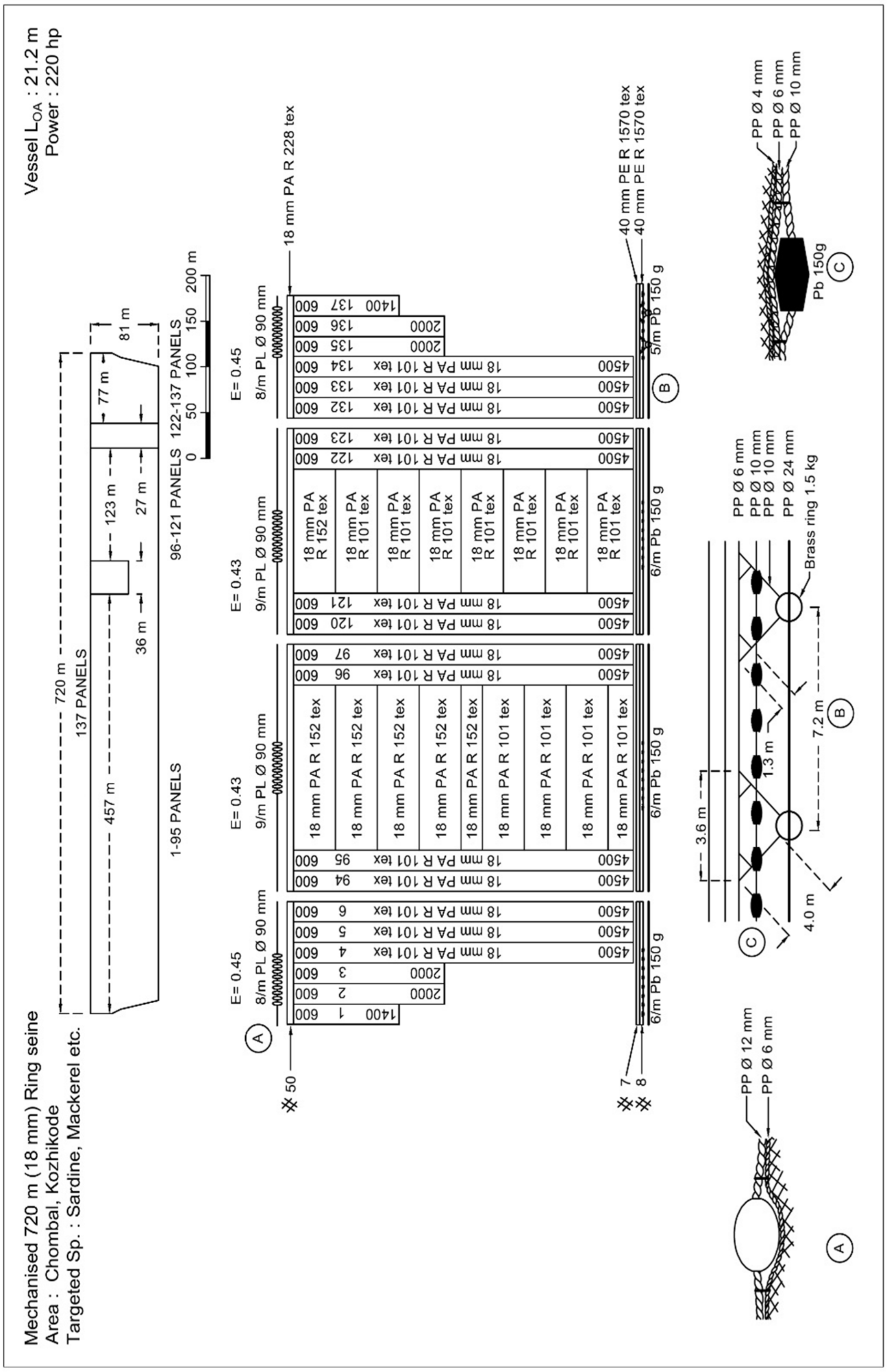


Fig. 3.18 Design details of 720 m ring seine of Chombal, Kozhikode

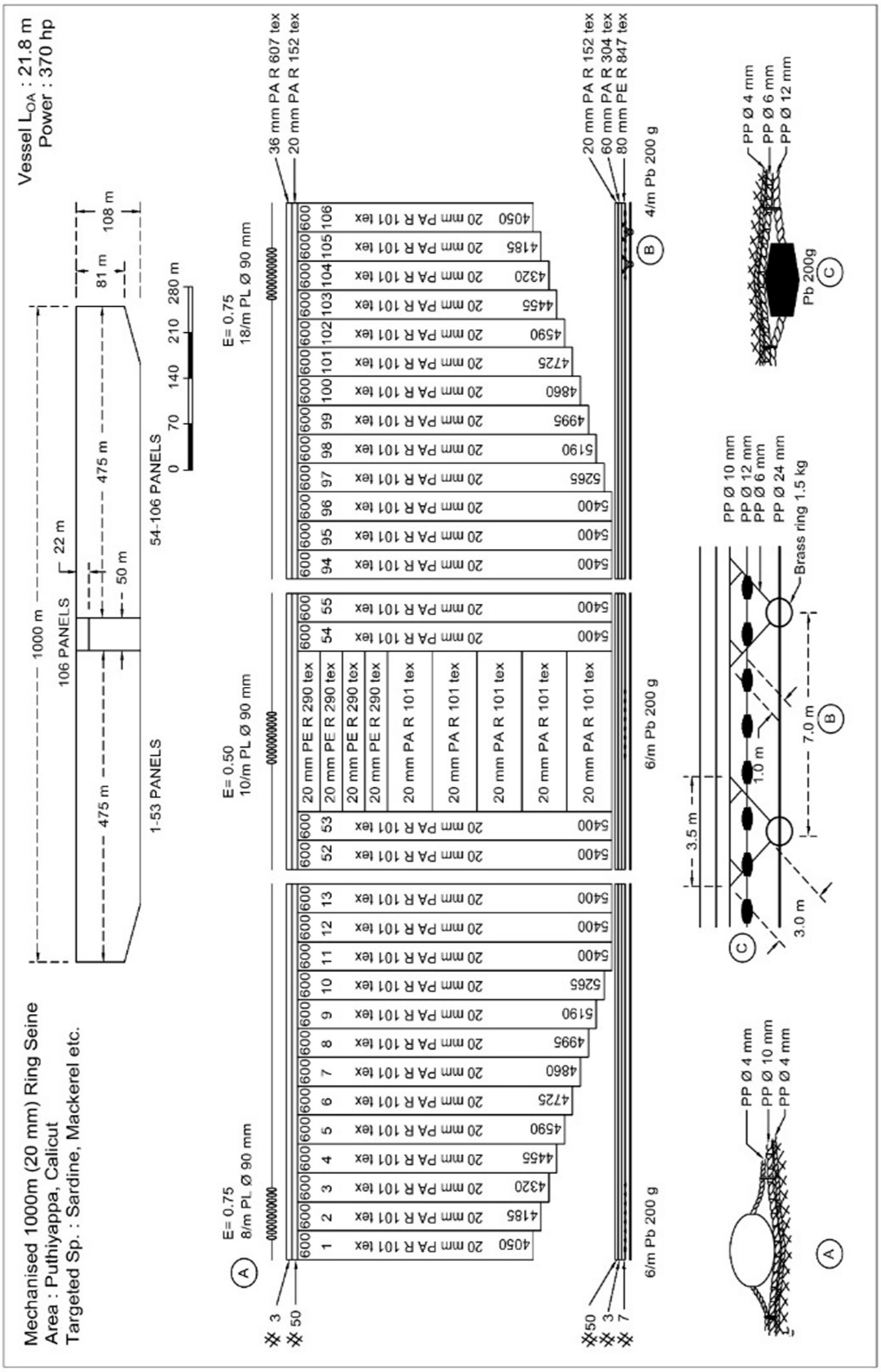


Fig. 3.19 Design details of 1000 m ring seine of Puthiyappa, Calicut

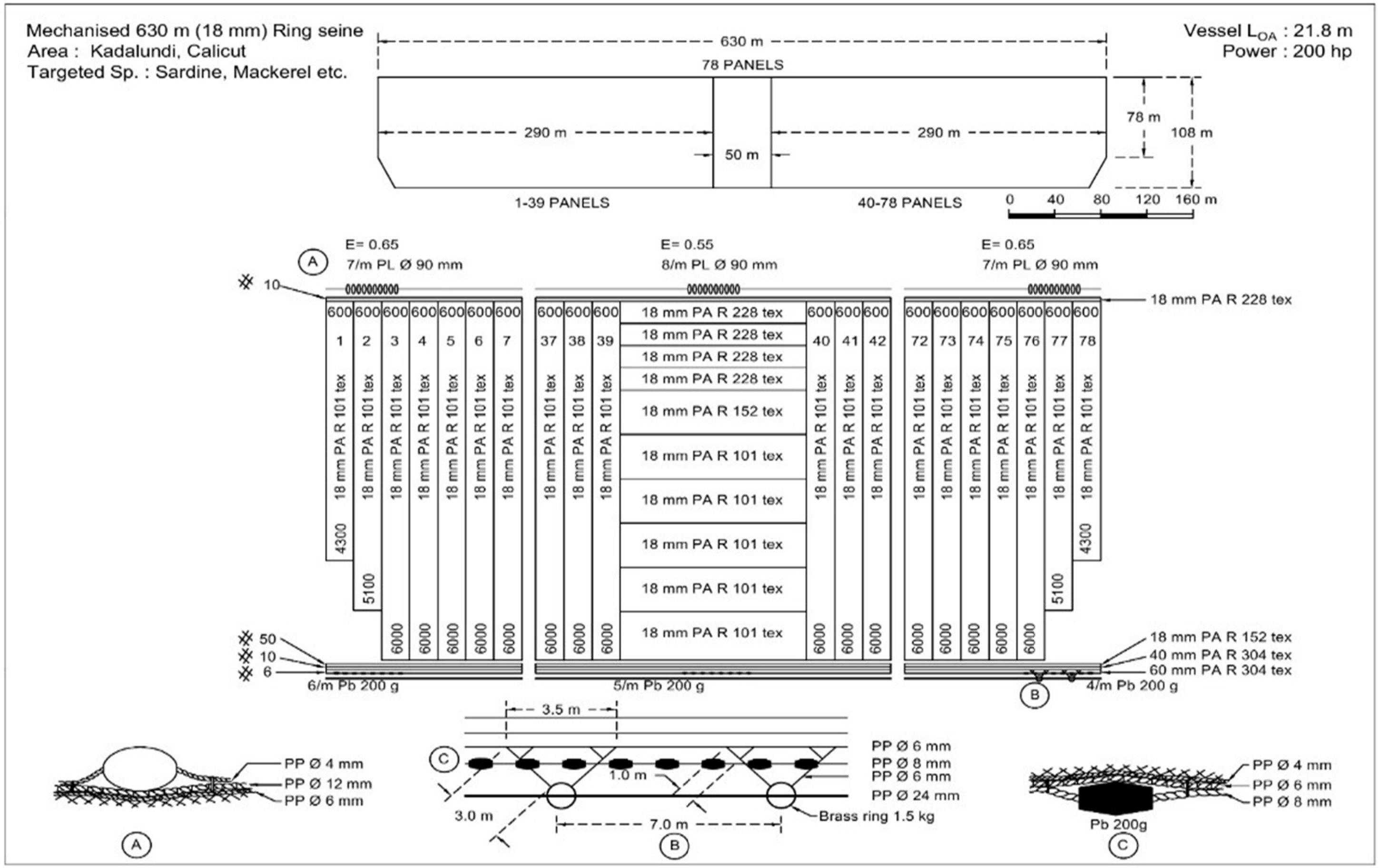


Fig. 3.20 Design details of 630 m ring seine of Kadalundi, Calicut

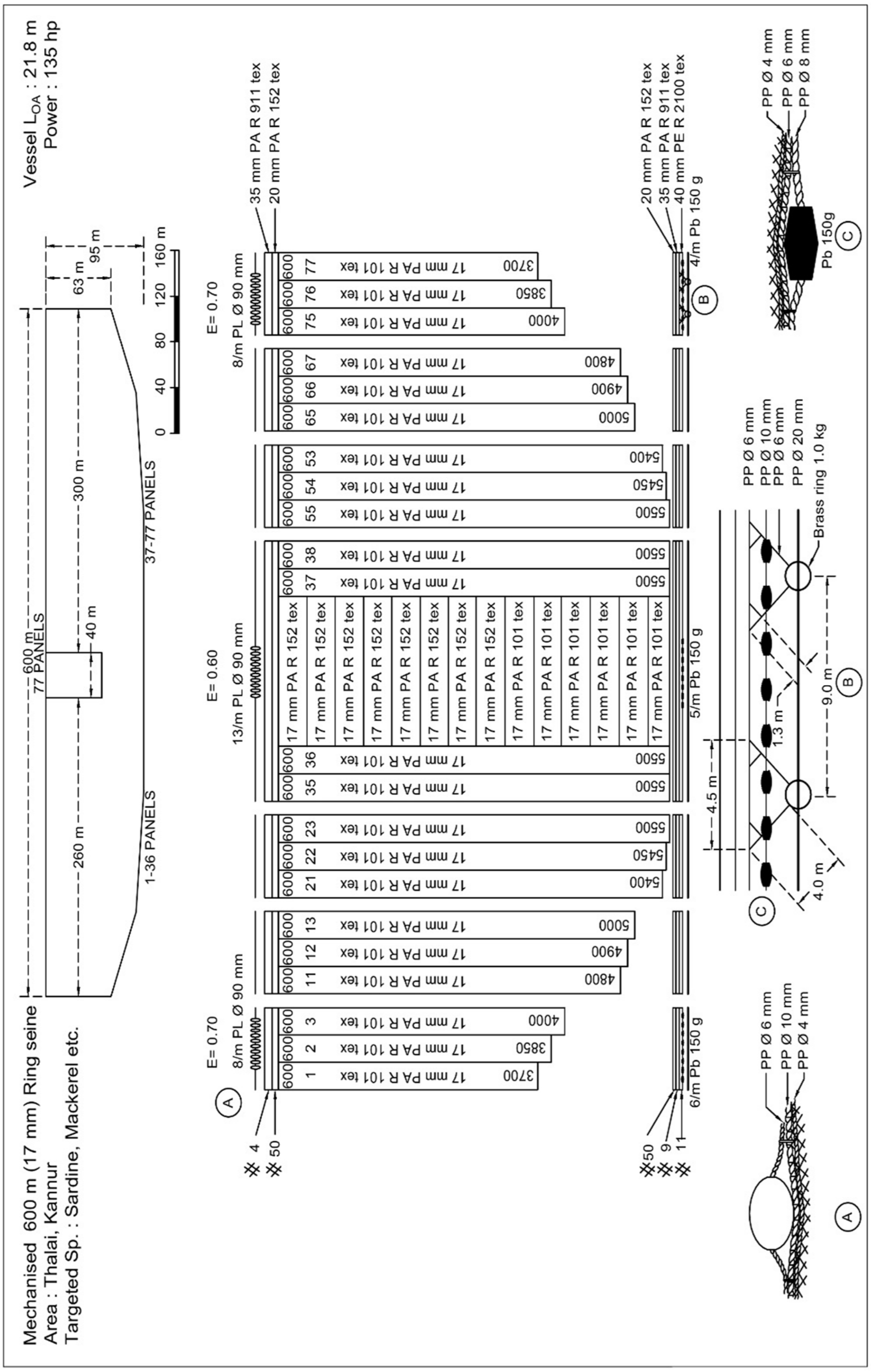


Fig. 3.21 Design details of 600 m ring seine of Thalai, Kannur

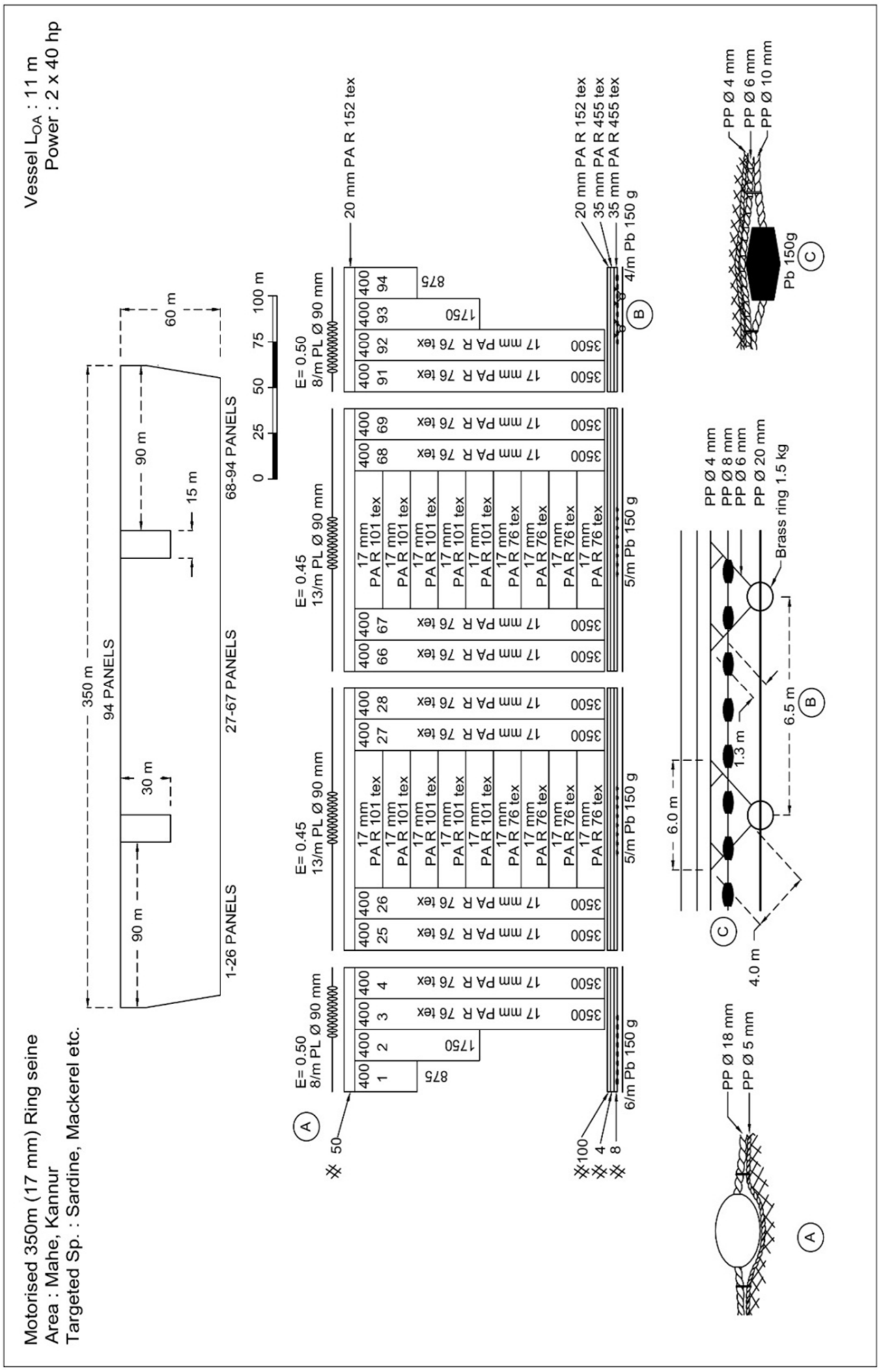


Fig. 3.22 Design details of 350 m ring seine of Mahe, Kannur

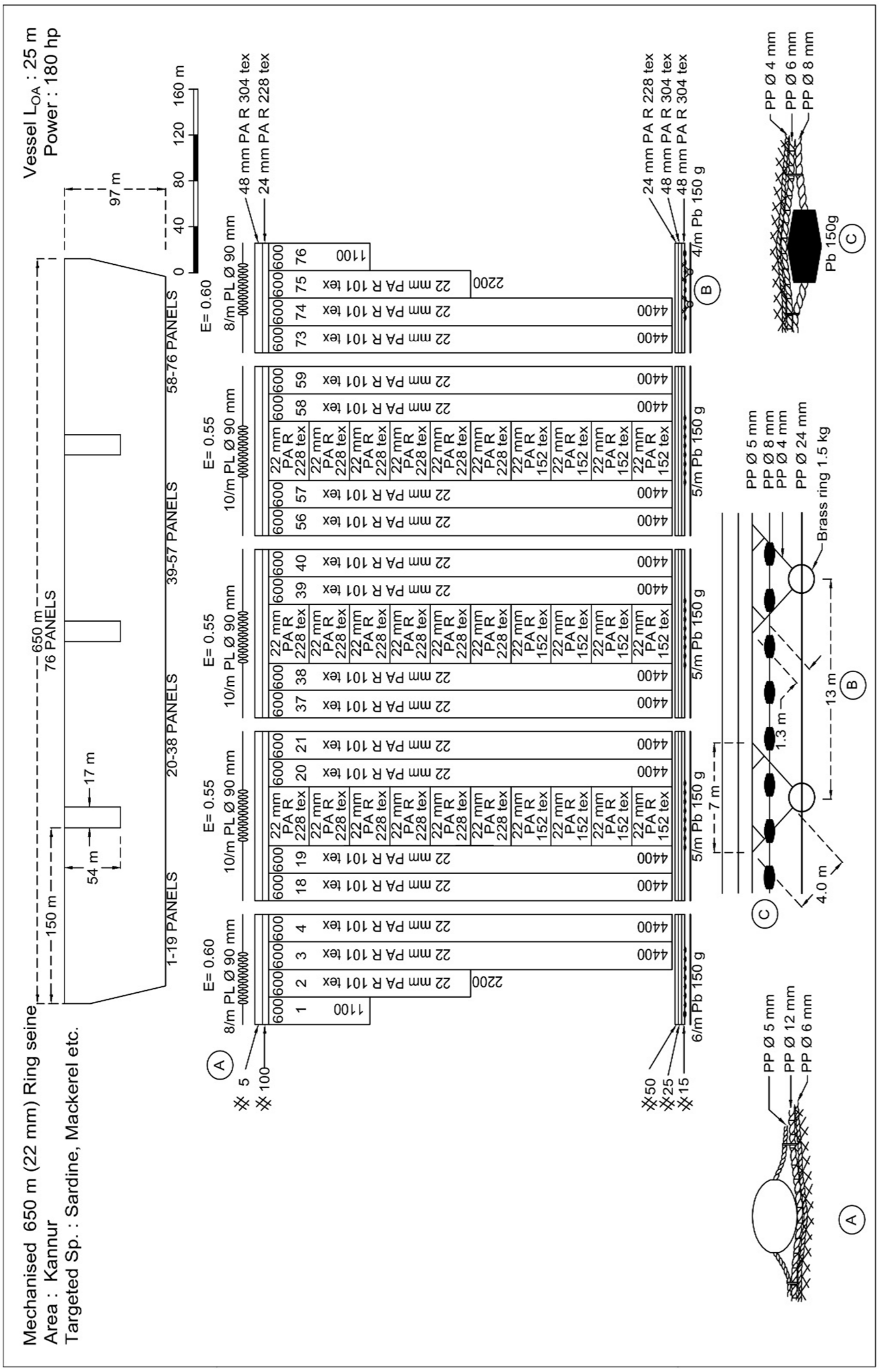


Fig. 3.23 Design details of 650 m ring seine of Kannur

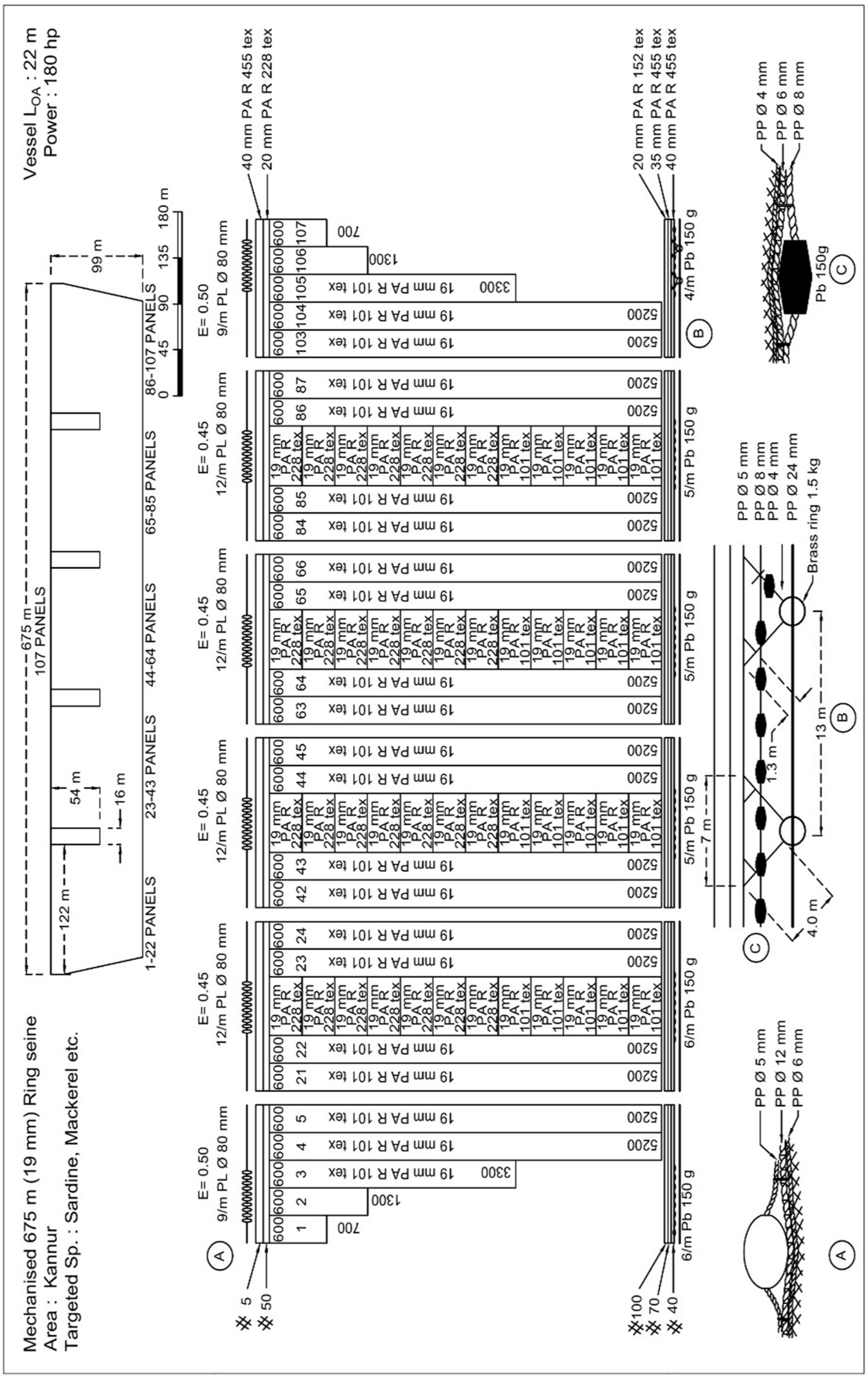


Fig. 3.24 Design details of 675 m ring seine of Kannur

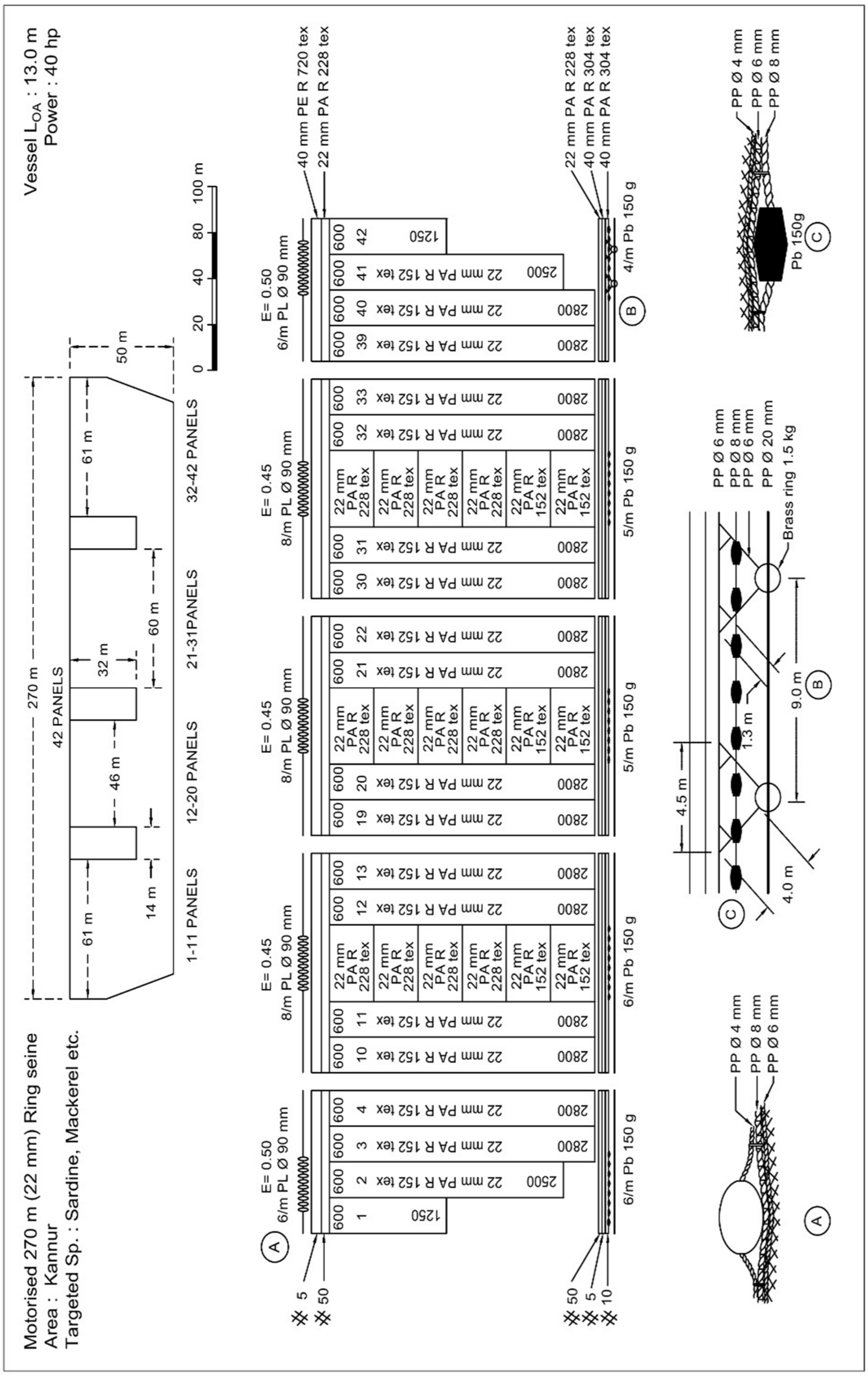


Fig. 3.25 Design details of 270 m ring seine of Kannur

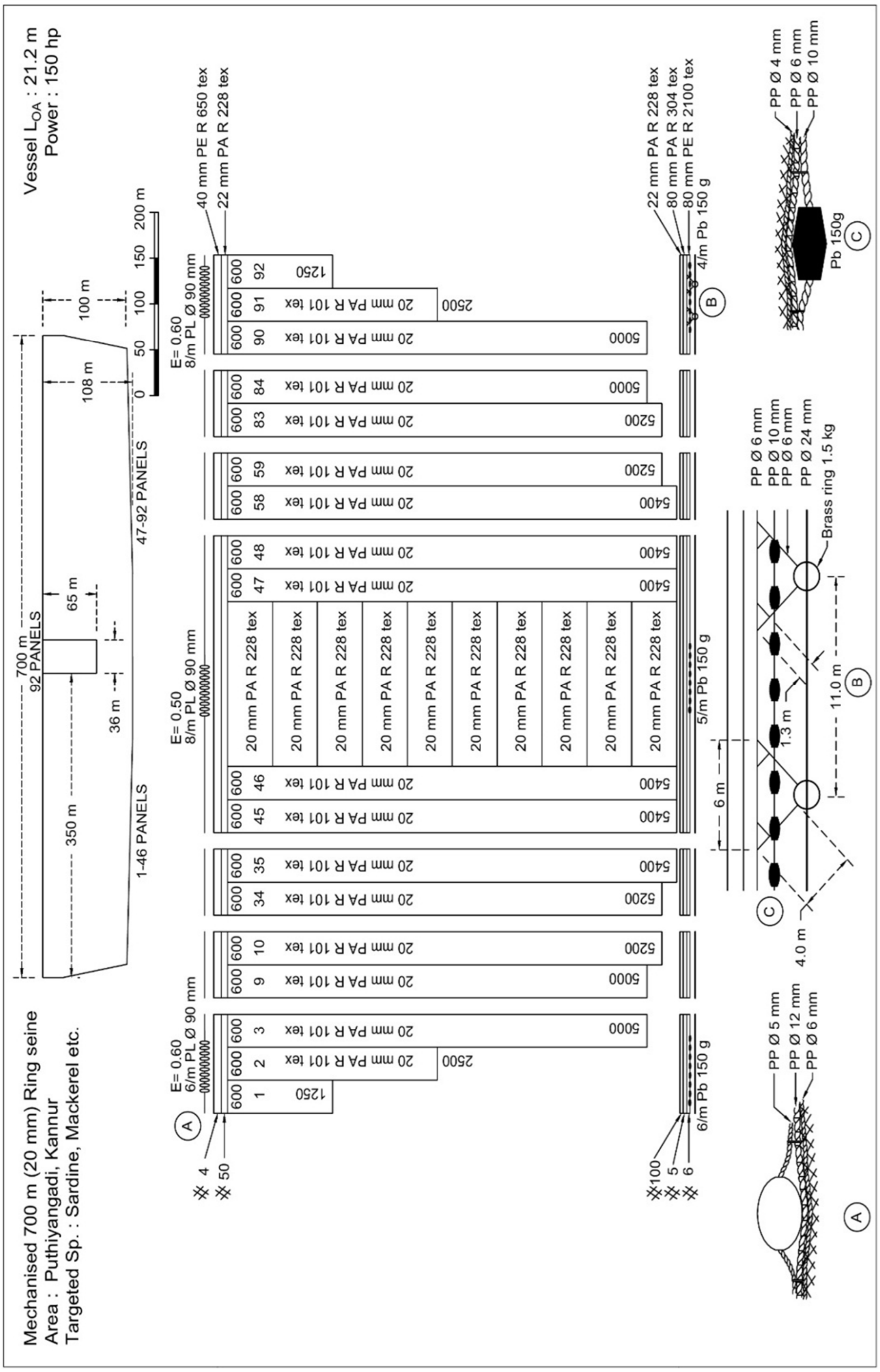


Fig. 3.26 Design details of 700 m ring seine of Puthiyangadi, Kannur

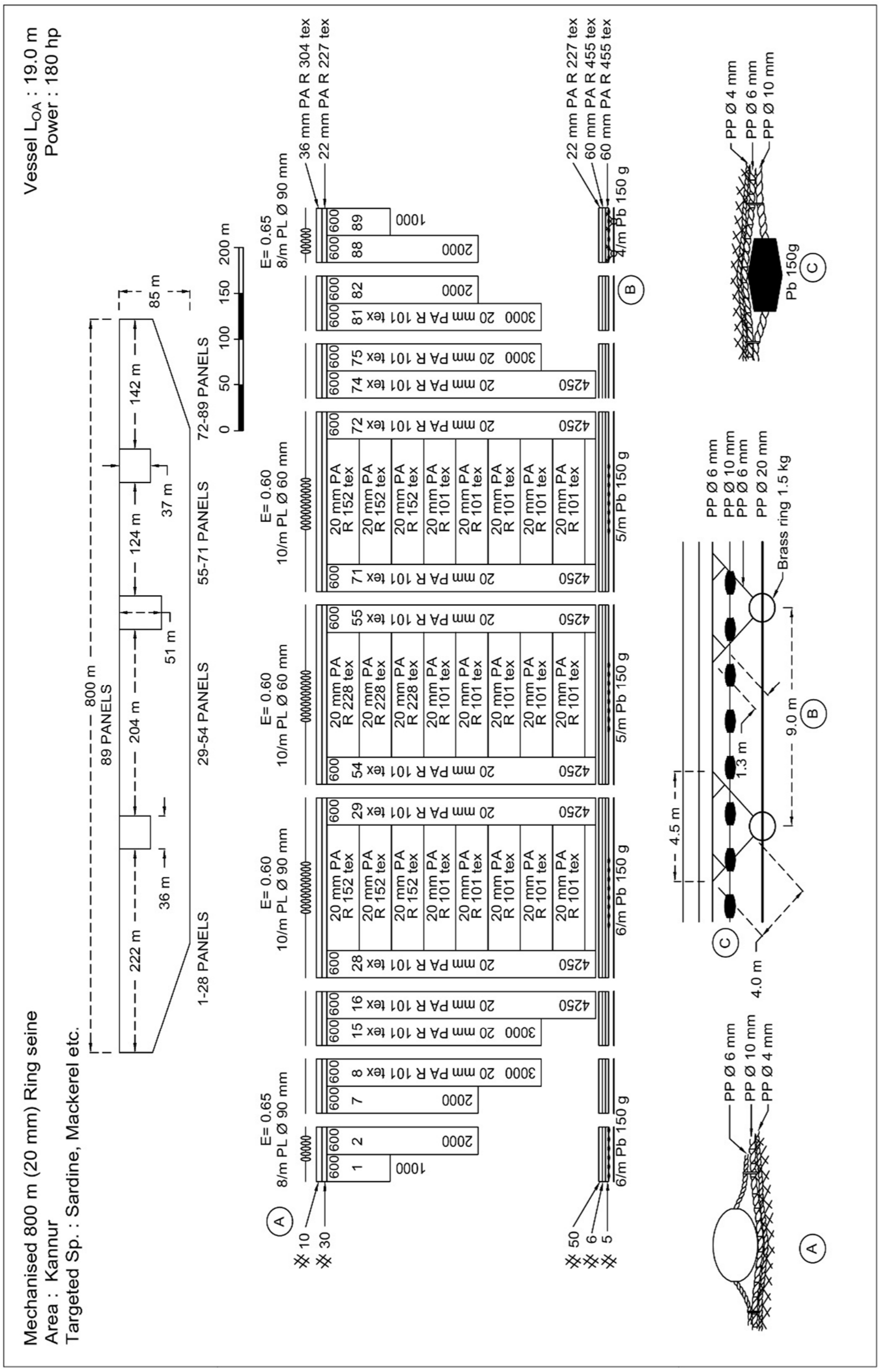


Fig. 3.27 Design details of 800 m ring seine of Kannur

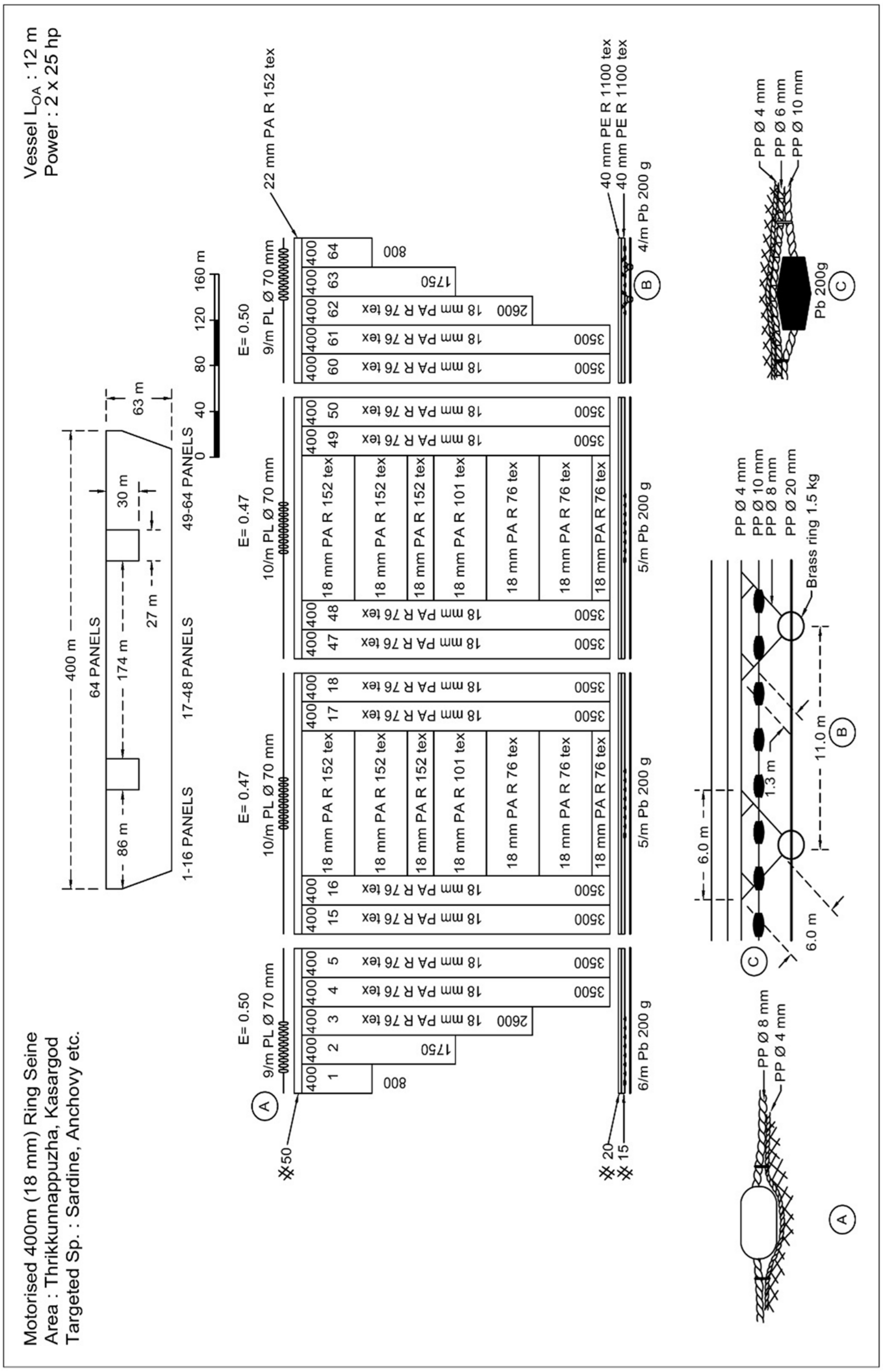


Fig. 3.28 Design details of 400 m ring seine of Thrikkunnappuzha, Kasaragod

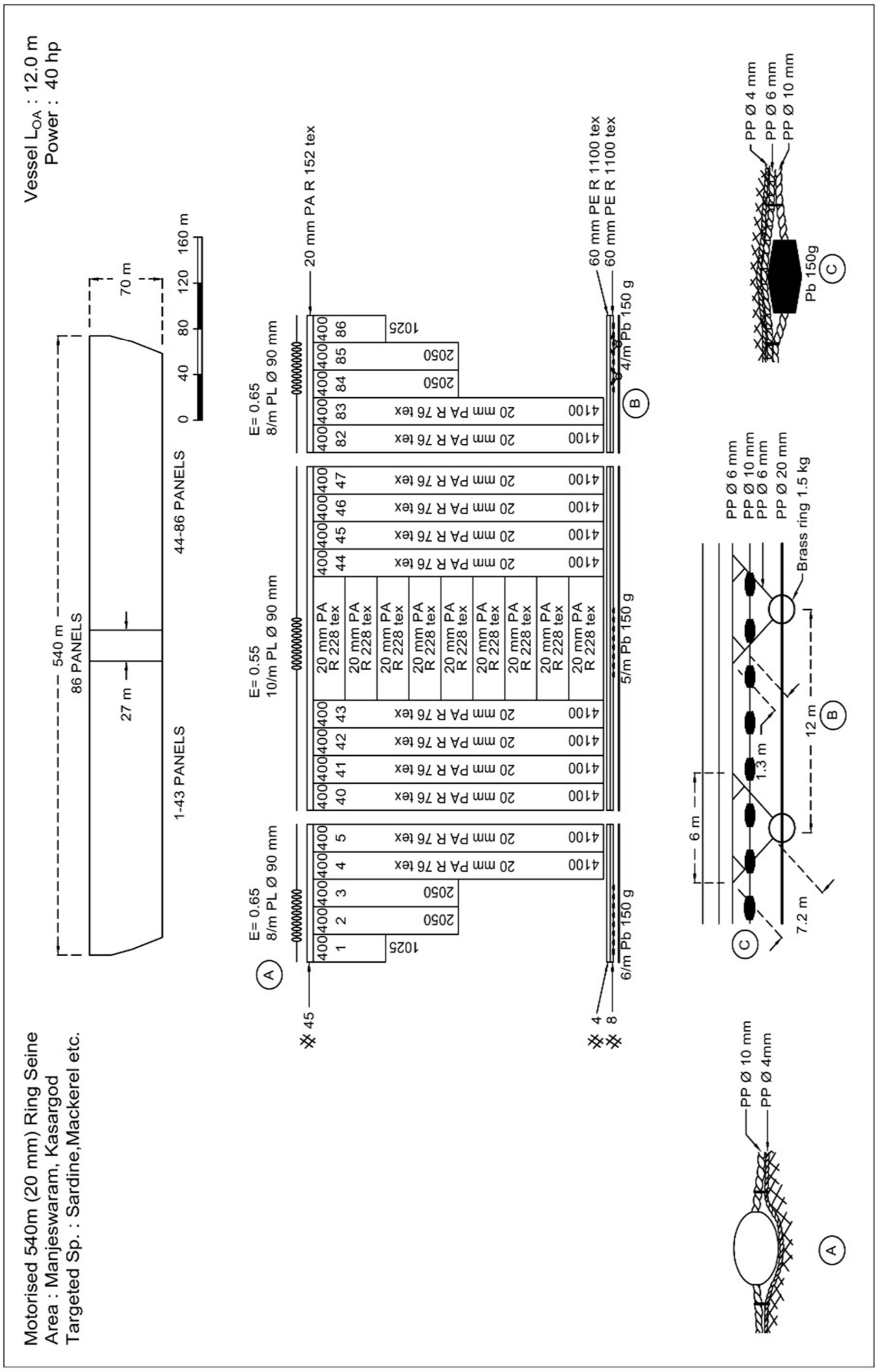


Fig. 3.29 Design details of 540 m ring seine of Manjeswaram, Kasaragod

3.3.3 Ring Seine Fishing Vessels

The introduction of ring seine offered an efficient alternative gear for operation from the boat seine craft *thanguvallam* in the artisanal sector. With CIFT's introduction and popularisation of ring seines in Cochin, other improvisation were initiated by fishermen in Kasaragod areas (Rajan, 1993) contributing to easy acceptance of ring seines. The ring seiners of Kerala are classified mainly in to two classes; outboard engine propelled motorized and the inboard engine driven mechanized ring seiners. The motorized ring seine fishery depict regional, operational and structural differences. Among mechanized ring seine units regional differences are limited and are similar in all districts.

3.3.3.1 Motorized Ring Seiners

Three types of motorized ring seine are commonly operated in Kerala (Fig 3.30 & 3.31).

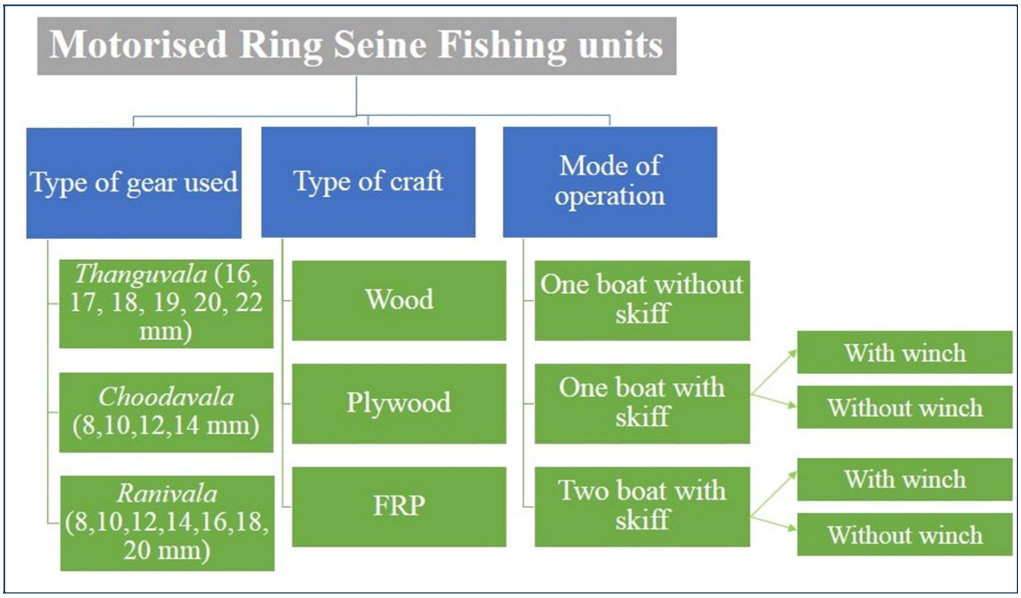


Fig. 3. 30 Classification of Motorised ring seiners of Kerala

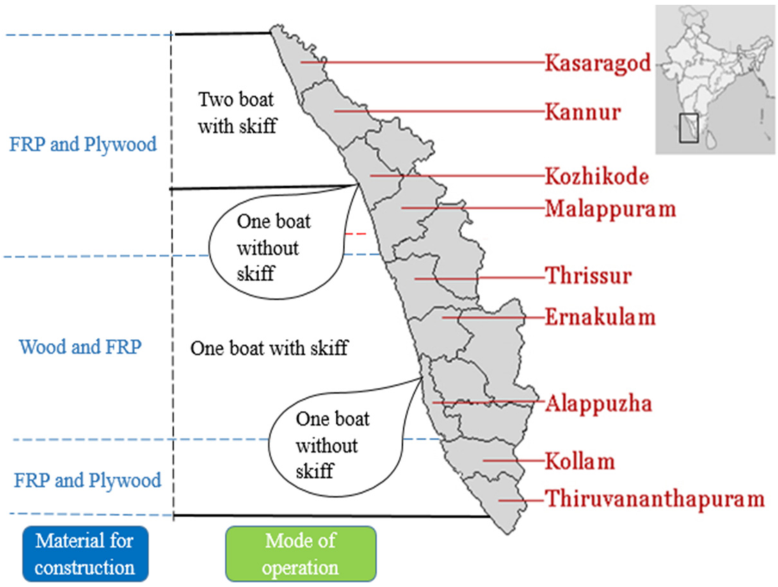


Fig. 3.31 Distribution of Motorised Ring Seine

Large motorized ring seine vessels made of wood or FRP with an assisting skiff vessel are commonly observed in Thiruvananthapuram to Kozhikode districts. The fishing vessels used for operation are of 7.6-14.6 m and propelled with 25 and/or 40 hp outboard engine. Two types of fishing gear are used in such units i) 200- 500 m in length and 40-60 m in depth with mesh size of 10-14mm and ii) 350-650 m in length and 50-70 m in depth with mesh size of 16-22mm. Large motorized units have one additional carrier vessel for transporting the catch to the landing center.

One boat operation with a small FRP boat in near shore waters is widely prevalent in the districts of Alappuzha, Ernakulam and Kozhikode. In Alappuzha this type of fishing is locally known as *sundarivala* and in Kozhikode as *ossamvala*. The ring seine unit comprises of a 6.1-7.6 m wood /FRP fishing vessel propelled by one or two 9.9 hp outboard engines using a fishing gear of 130 -210 m in length and 35-45 m in depth with a mesh size of 8-10 mm.

The third type of motorized ring seine fishing unit is the *ranivala*, which is a common practice in the northern part of Kozhikode district, Kannur and Kasargod. *Ranivala* unit consists of three to six numbers of motorized craft, one large craft with fishing gear (ring seine) and known as *valavallam* of 9.8 – 11.6 m L_{OA} fitted with 25 hp or two 9.9 hp or a combination of 25 hp and 9.9 hp OBM engines for propulsion.

3.3.3.2 Mechanised Ring Seiners

The number of mechanised ring seiners are less, compared to the motorised units. The common construction materials for mechanised ring seiners are steel, wood and FRP (Fig 3.32). The wooden ring seiner are restricted to an L_{OA} of 70 m and the newly constructed inboard ring seiner are either steel or FRP construction. In northern districts like Kasaragod, Kannur and northern side of Calicut region mechanised ring seiners are of FRP construction (Fig 3.33). In southern region of Kerala coast steel and FRP ring seiners are in operation. In central Kerala steel ring seine units dominated and the number of skiff (carrier) vessels associated with a mechanised ring seine fishing unit also varied with region. In Kozhikode and Malappuram districts ring seiners with three to four carriers vessels are a common sight.

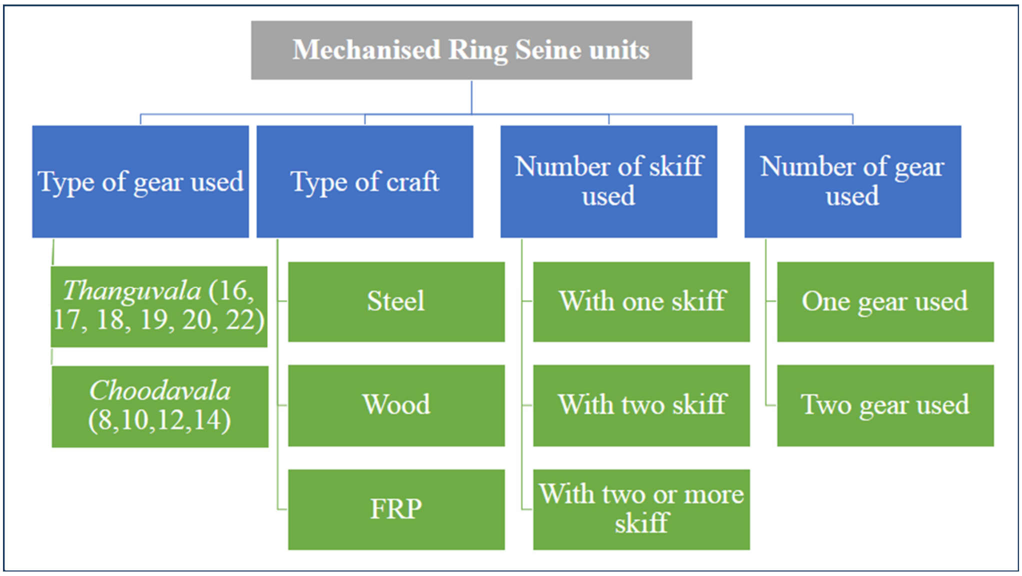


Fig. 3. 32 Classification of the Mechanised Ring seine units

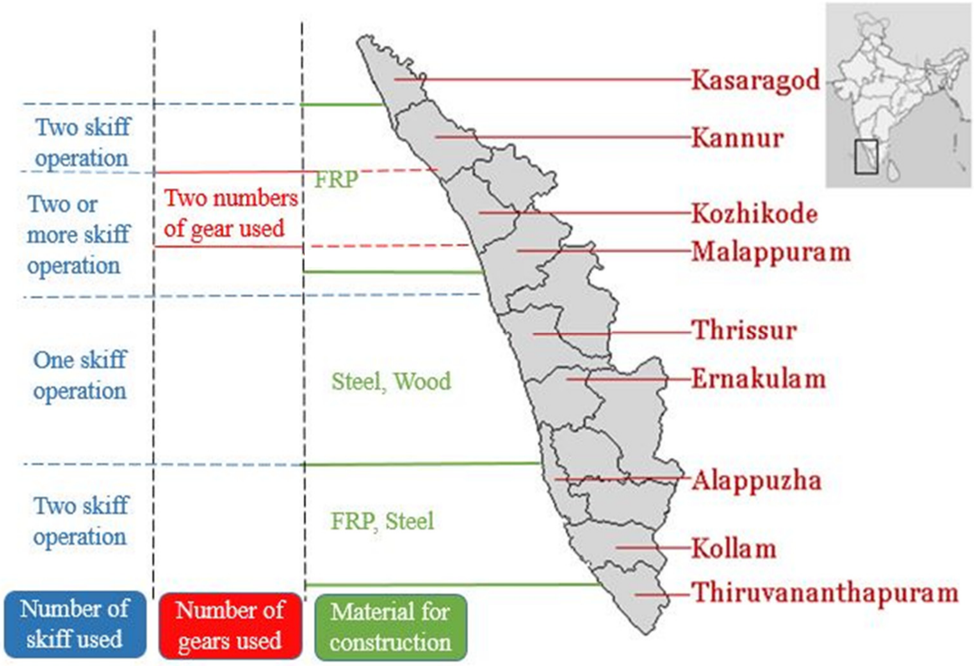


Fig. 3. 33 Distribution of Mechanised Ring Seine

3.3.4 Ring Seine Operation

Ring seine is operated from a single boat or a pair of boats. The fishing unit leaves the landing centre at around 5 am. The fishing operation consists of active search, chase and interception of the shoal. One or two experienced fishermen standing at the aft of the craft is responsible for the detection of the shoals. Once the shoal is detected, its direction of movement, direction of current, wind etc., are monitored to determine the mode of operation of the net. If the shoal movement and the water current are in same direction, more area has to be encircled as quickly as possible in order to trap the fast moving fish. If the movement of shoal and water current are in opposite directions the chances for successful operation is high.

After the shoal identification, the crew leader signals for the preparation of shooting of net. On getting the signal, one of the crew members (*chattakaran*) jumps into the water holding one end of the net, the remaining net is carried by the boat around the fish shoal very fast and returns to the start point and encircling takes 8-12 minutes. After encircling the shoal, the purse line is pulled mechanically / manually which closes the bottom of the seine. Pursing may take around 10 to 15 minutes. This is followed by hauling onboard the head rope and netting panels until it reach bunt portion. The entire net now looks like a bag and the fishes are concentrated at the bunt region. Large mechanized ring seiners use large scoop net called the "brailer" for transferring the catch onto the main vessel which is operated with the help of winch operated crane fixed on the deck at the aft part.

In a two boat ring seiner, one vessel searches for the shoal and on finding the shoal, this vessel signals to the main vessel to start operation by encircling the shoal. Encircling of the shoal is carried out by the *valavallam* and after this is done the two vessels together haul up the gear either mechanically or manually. Time taken to complete a haul varies from 30 minutes to 3 hours depending upon the size of the catch. Usually after the first catch, fishermen will search for more shoals and then start the return trip. The boat usually reaches back at the landing centre by 2 pm. The average time taken for operation in mechanized units is around 12 h and for motorized vessel is 8 h. Operational details of ring seines of Kerala are given in Fig.3.34 to 3.39.

Fig. 3. 34 One boat motorized ring seine with skiff in operation

Fig. 3. 35 Mechanized ring seine in operation

Fig. 3. 36 One boat ring seine without skiff in operation

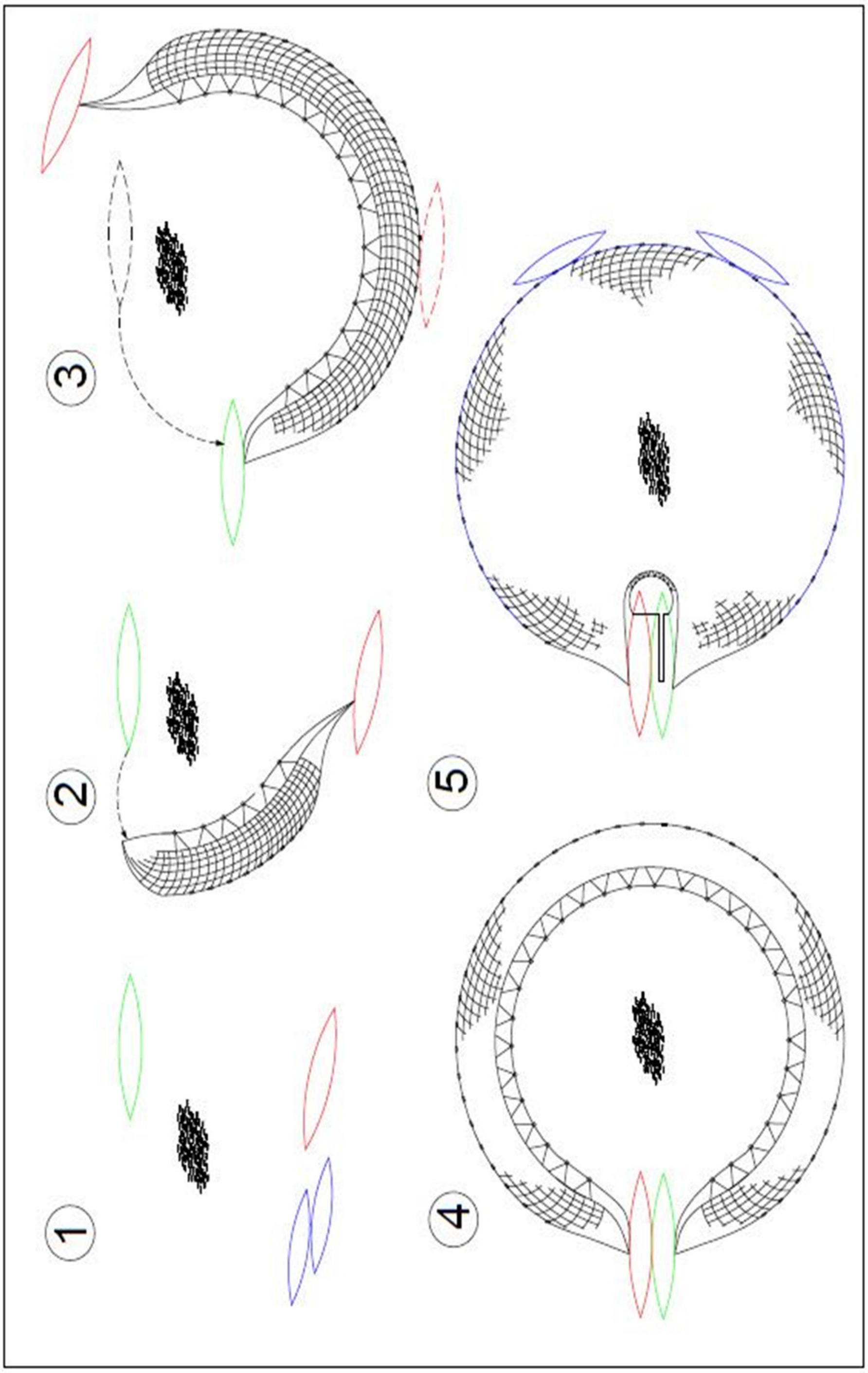


Fig. 3. 37 a. *Ranivala* Operation

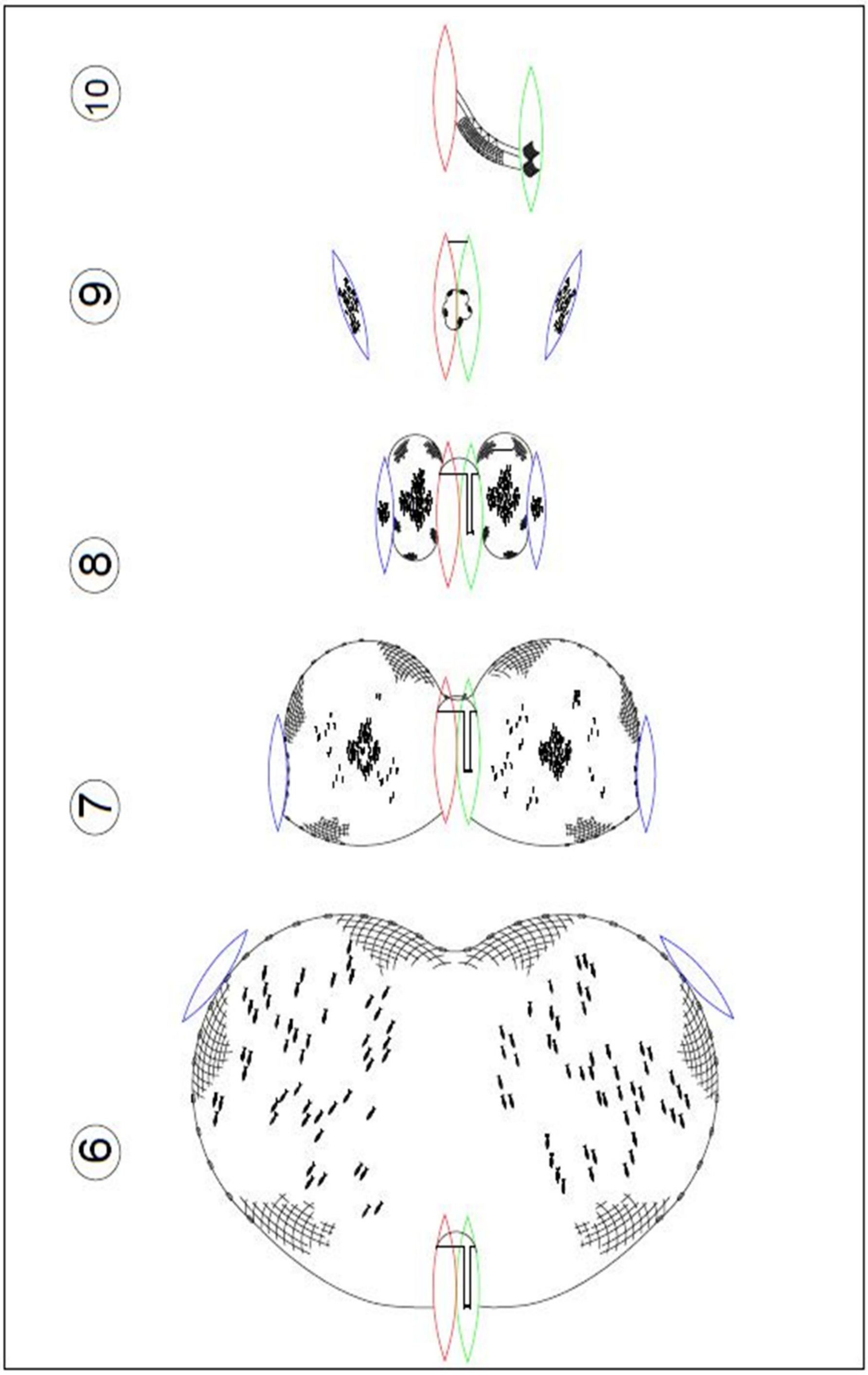


Fig. 3. 37 b. *Ranivala* Operation

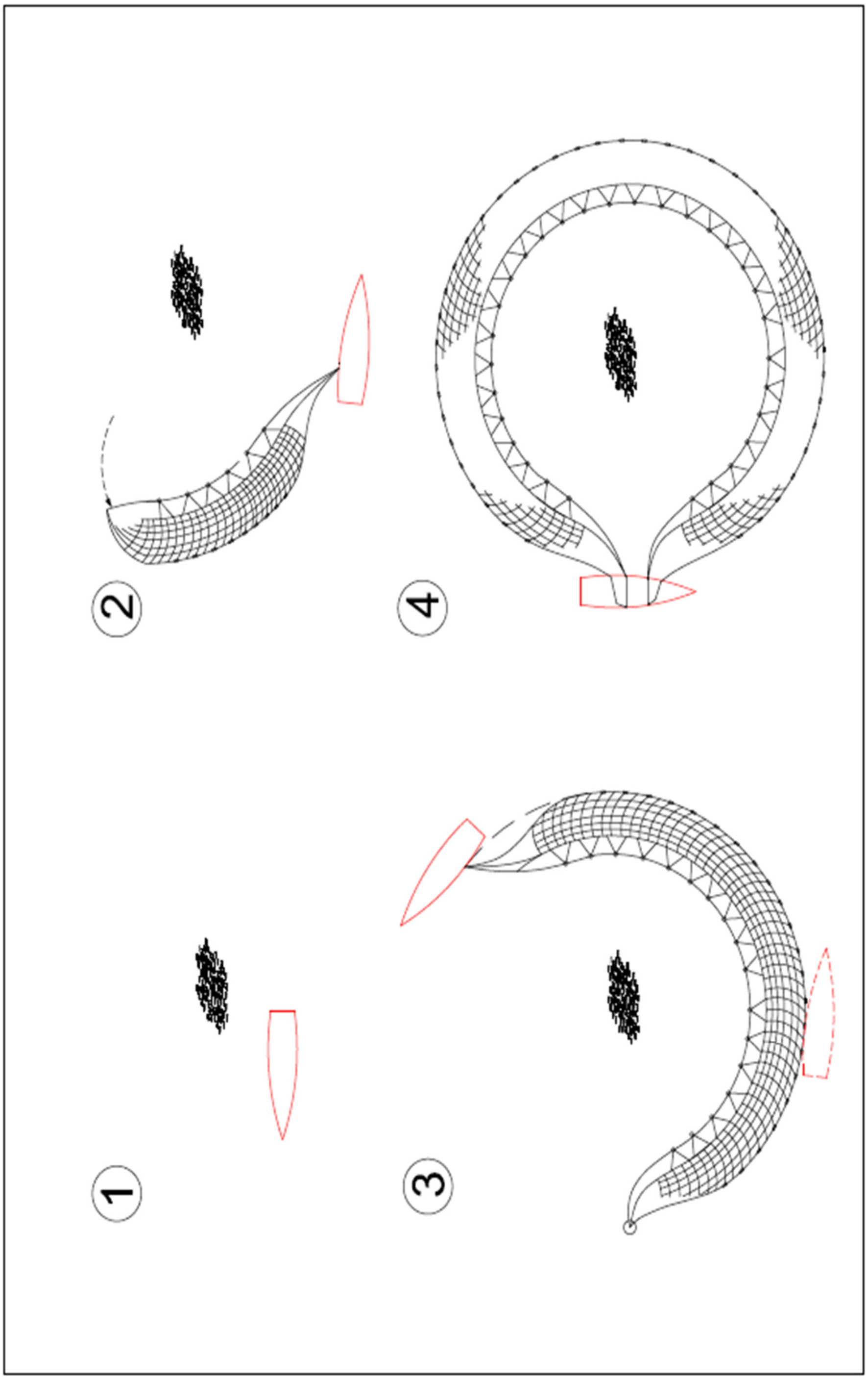


Fig. 3. 38 a. Motorised Ring Seine Operation

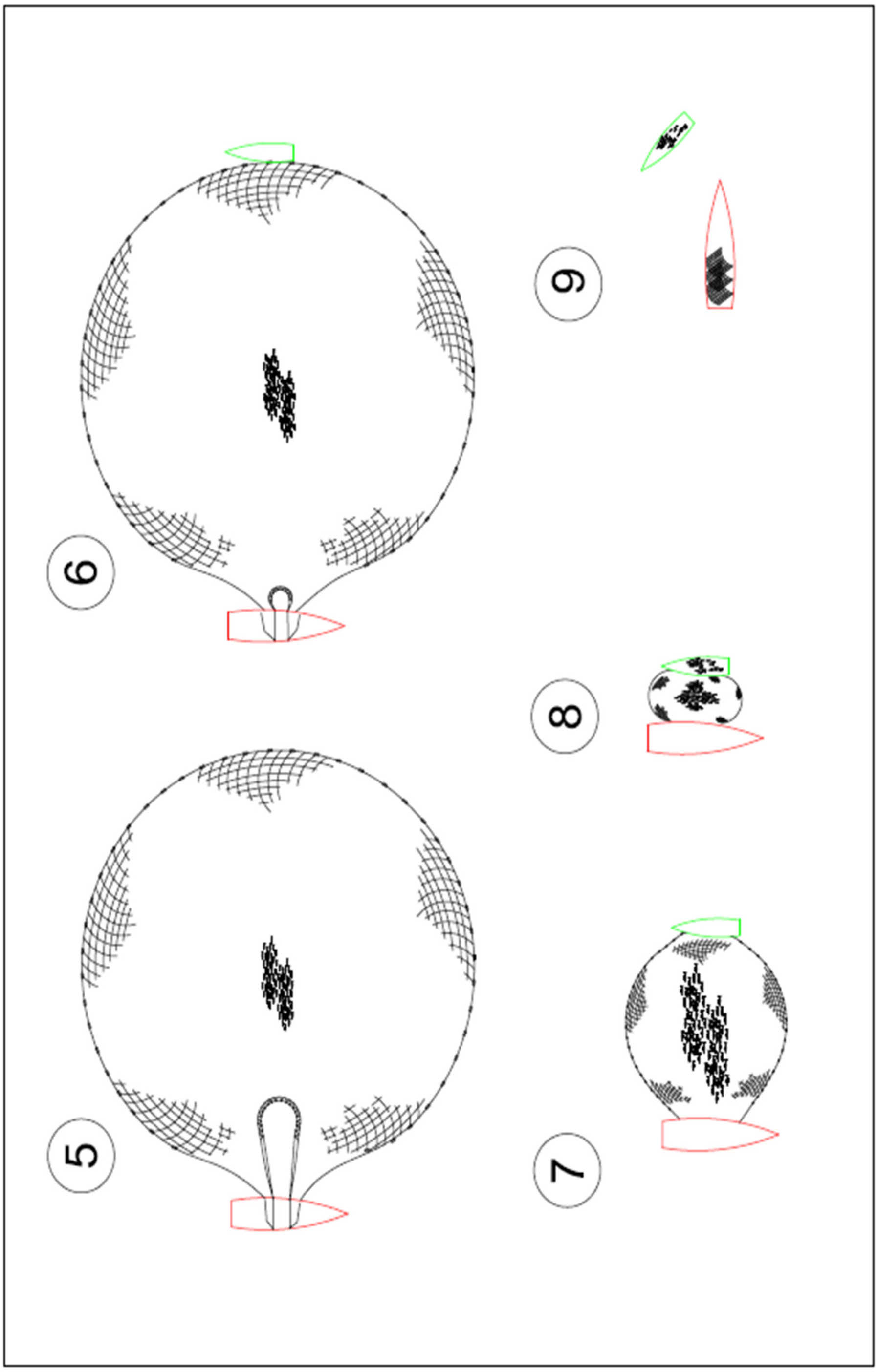


Fig. 3.38 b Motorised Ring Seine Operation

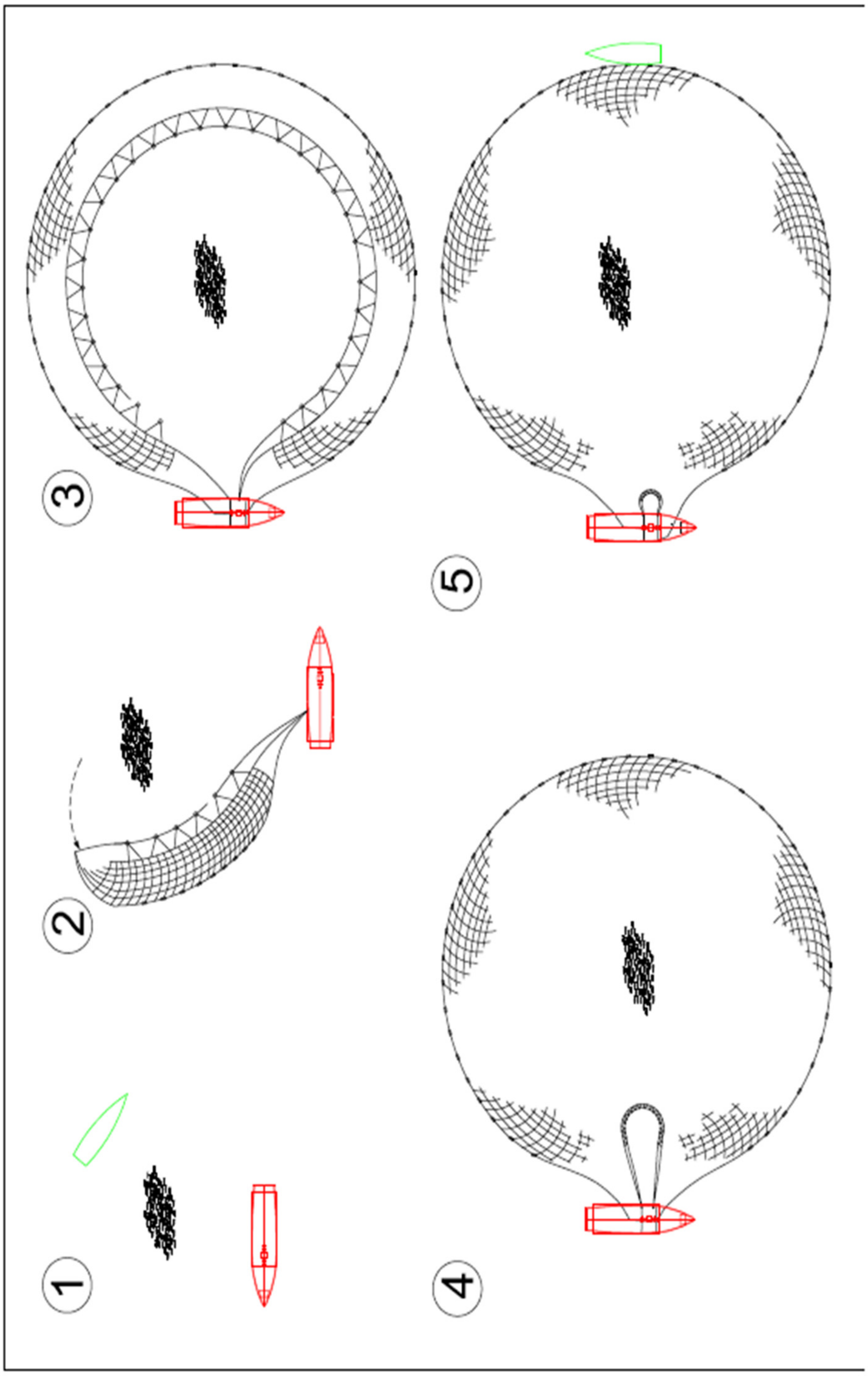


Fig. 3.39 a. Mechanised Ring Seine Operation

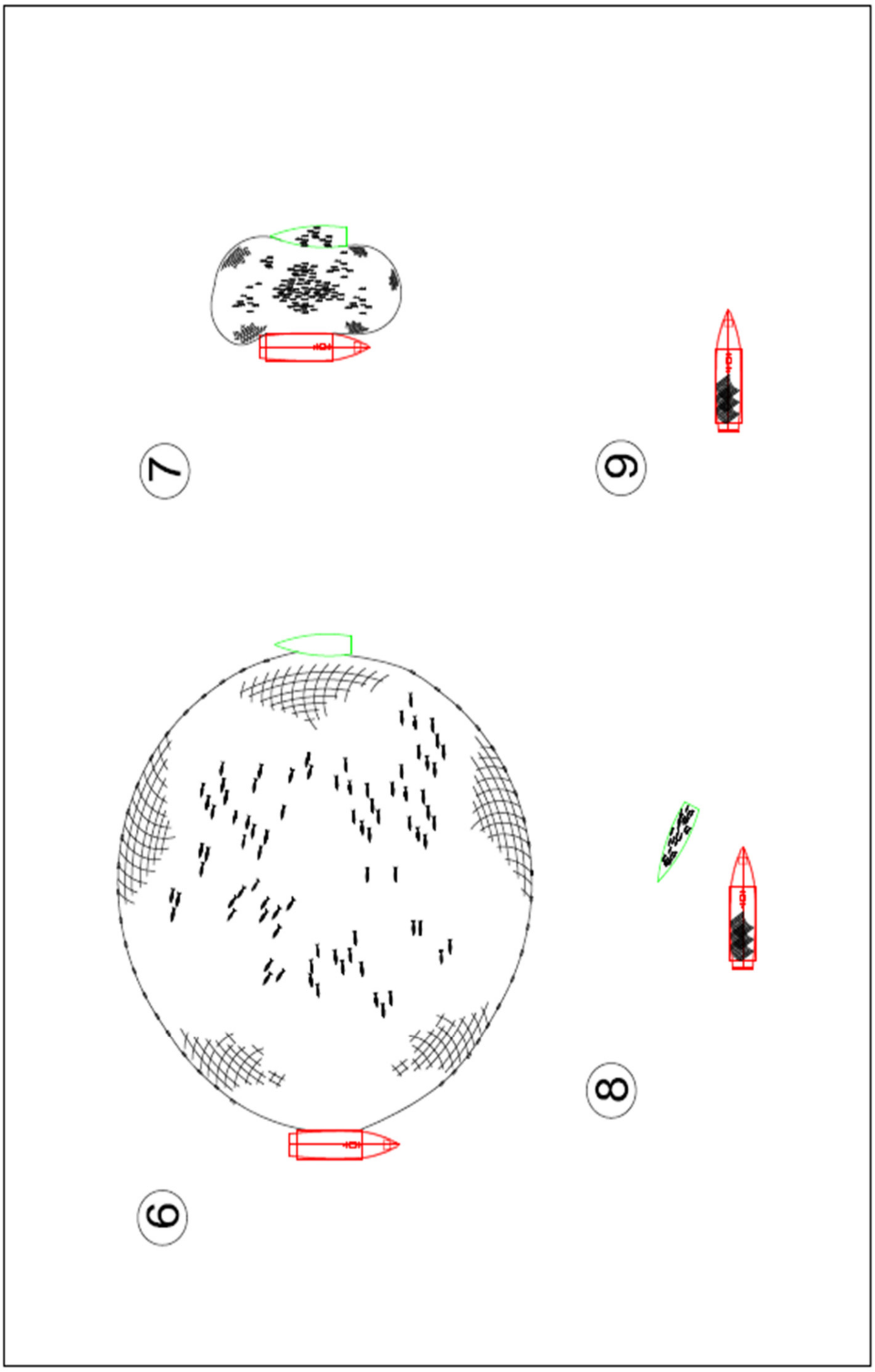


Fig. 3. 39 b. Mechanised Ring Seine Operation

3.4 Conclusion

For the past 30 years ring seine spread to all coastal districts of Kerala with regional variations. The main body is made up of different mesh sizes of polyamide webbings. Panels of uniform mesh size are attached vertically to form the main body. The arrangement and the depth of the gear varied from region to region. Deepest area of ring seine is at the centre and depth reduces towards the wings. The number of bunts in a unit varied from one bunt (Thiruvananthapuram to Alappuzha), two bunts (Alappuzha to Kozhikode) and more than two bunts (Kozhikode to Kasaragode). In Kozhikode and Malappuram districts, PA webbings are used for selvedge (*chuttumvala*) construction whereas in Thrissur, Ernakulam, Alappuzha districts, HDPE is used. *Chuttumvala* is absent in other districts of Kerala and in *ranivala* and *choodavala*. Total buoyancy of float is maintained at 1.5 to 3.5 times under water weight of the ring seine net and its accessories and high buoyancy is provided in bunt area.

The ring seiners of Kerala are classified mainly into two classes; outboard engine propelled motorized and the inboard engine driven mechanized ring seiners. The motorized ring seine fishery depict regional, operational and structural differences. Among mechanized ring seine units, regional differences are limited and are similar in all districts. Ring seine is operated from a single boat or a pair of boats and single day operation is practiced in Kerala. Depending upon the region of operation and number of vessel engaged, ring seine operations varied.

One boat motorized ring seiner with skiff in Alappuzha

One boat motorized ring seiner in Ernakulam

Two boat motorized ring seiner in Kasargod

Mechanized FRP ring seiner in Kannur

Mechanized steel ring seine in Ernakulam

Plate-1. Ring seine craft

Plate-2. Ring seine gear

Plate-3. Ring seine operation

Plate-4. Ring seine landing

Chapter

4

STRUCTURAL CHANGES IN THE RING SEINE FISHING SYSTEM

Contents

4.1 Introduction

In purse seines, a pursing arrangement is incorporated in order to close the net at the bottom after surrounding a shoal of fish. This facilitated the operation of net in deeper waters. Purse seines are the predominant type of surrounding nets which are generally operated in the surface area. Surrounding nets are roughly rectangular walls of netting rigged with floats and sinkers which after detection of the presence of fish are cast to encircle the fish school. Purse seine fishing is one of the most aggressive, efficient and advanced fishing methods. It is aimed mainly at catching dense, mobile schools of pelagic fish and includes all the elements of searching, hunting and capture.

Boat seines and shore seines are age old fishing methods of Kerala. According to Pillai *et al.* (2000) the regional names of boat seines have been documented as, *arakollivala, ayilakollivala, choodavala, discovala, deppavala, ringvala, kudukkuvala, thanguvala, kollivala, koruvala, mathikollivala* and *paithuvala*. According to FAO (1984), *thanguvala* is a lampara-type net of 150 m length and operated from beach landing canoes known as *thanguvallams.* These boats had dimensions of 15m length, 1.4m breadth, and 0.85m depth. The first trial of the motorization of *thanguvallams* was made by the Indo-Norwegian Project in Neendakara in 1955. This trial was unsuccessful due to the vibration of the installed inboard diesel engine which caused leaking problems in the stitched canoes. Moreover, the high operating costs of a petrol outboard engine was also not acceptable to the fishermen.

In September 1980, new motorisation trials were started by the Kerala Fishermen Welfare Corporation in Purakkad near Alappuzha with inboard diesel engine of 9 hp, outboard diesel engine of 5 hp, and outboard kerosene engine of 7 hp. With continuous improvement, the motorisation program became a success and it spread along the entire coast of Kerala. Commercial purse-seine fishing started during the late seventies in Cochin, Kerala (Jacob *et al.,* 1987) and the process of large scale motorisation of country craft began in the early eighties.

The structure of the ring seine has many features similar to the purse seine. The ring seine, like the purse seine, has purse rings along its lower edge. Some of the chief structural differences between the ring seine and the purse seine are that the purse seine is made of comparatively heavy webbing, is practically uniform throughout its entire length, and is square on the ends; while the ring seine, is made of light webbing, is gathered on the ends. It was operated from a plank built canoe of 15 m length propelled by a 9.9 hp engine. Although banned under the KMFR Act 1980, which was later revoked, the ring seine is immensely popular in Kerala fisheries. The emergence of the ring seine caused two major artisanal gears of Kerala namely *koruvala* and *kollivala* to become obsolete (Alagaraja *et al.,* 1994).

The ring seine fishery first introduced in Kerala and quickly spread to other parts of the country. Rohit & Naik (1998) reported the information about the ring seine introduced in Malpe fisheries harbor, Karnataka. Mohanraj *et al.* (2011) reported the introduction of ring seine boats for commercial exploitation of pelagic fish resources of Puducherry coast. Vijaykumaran & Chittibabu (2005) reported 15-20mm mesh sized ring seine in Orissa coast. Shiledar (2009) reported the introduction of mini purse seine in the MH-1 zone of Maharastra coast. Burayya (2006) reported introduction of *ringvala* (ring seine) along Kakinada coast made of silk yarn having a total length of about 315-350 m and breadth of about 34-40 m. Ring seines contribute 5.2 % of Karnataka and 8% of Goa total marine landings during 2010 (CMFRI, 2011). Rajeswari *et al.* (2013) elaborated the three types of ring seines operated in the Andhra Pradesh coast. Ring seines with 10‑25 mm mesh size were studied by Arur *et al.* (2014) in Andaman and Nicobar Islands. Presently the ring seine fishery is spread among the entire country except West Bengal and Lakshadweep Islands.

4.2 Materials and Methods

The analysis of data obtained under the study 'Regional variations in design of ring seines and their operation' (Chapter-3) shows that the craft, gear and method of operations has evolved over the period from 1985-2014. The present status was obtained from the survey conducted under this doctoral programme. This data on craft and gear was then compared with the work of Panicker *et al.* (1985); D'Cruz (1998); Krishna *et al.* (2004); Edwin *et al.* (2010); Edwin *et al.* (2014b); etc.

4.3 Result and Discussion

4.3.1 Changes in the Fishing System

It is observed that there has been a drastic increase in the size of the gear with a commensurate increase in size of the fishing vessel and horsepower of the engine. The dimensions of the gear rose incrementally over the years and the size of the vessel and horsepower also increased subsequently.

4.3.1.1 Dimensions of the Gear and Mesh Sizes

The gear is a wall of nylon knotless webbing and is mainly used to catch sardines, mackerel and small fishes like anchovy. The mini- purse seine introduced by CIFT, which is a modified innovative version of the *thanguvala*, had an overall length of 250 m and a depth of 15 m and 33 m at the wing end and the bunt respectively (Fig. 4.1) and pursing was done with the help of rings (Panicker *et al.,* 1985). The size of gear as reported by Edwin and Hridayanathan (1996) in south central Kerala region was 630m and depth 100 m with a mesh of 18-20 mm (Fig. 4.2). The ring seine of smaller mesh size (8 - 10 mm) is used to target small fish like anchovy and operate in shallow waters. The report by D'Cruz (1998) showed that the gear had grown in dimensions and due to the large size of the nets, trolleys are used for transportation of the gear. Large ring seines up to 900m length and 90 m depth were reported by Krishna *et al.* (2004) from Thrissur district of Kerala. Edwin *et al.* (2010) reported that for a gear with mesh size of 20 mm, length ranged from 600 to 1000 m, depth ranged from 83 to 100 m and weight ranged from 1500 to 2500 kg, were operated from a fishing vessel of L_{OA} 70-76 feet long powered by inboard engine, hold a crew of 35-45 (Fig. 4.3). Change in Dimensions of the gear and targeted species are given in Table 4.1.

In the past thirty years, the size of the ring seines have grown at least three to four times in proportion to the extent of about 1500 m in length and 100m in depth in Cochin area (Fig.4.4 & Fig.4.5).

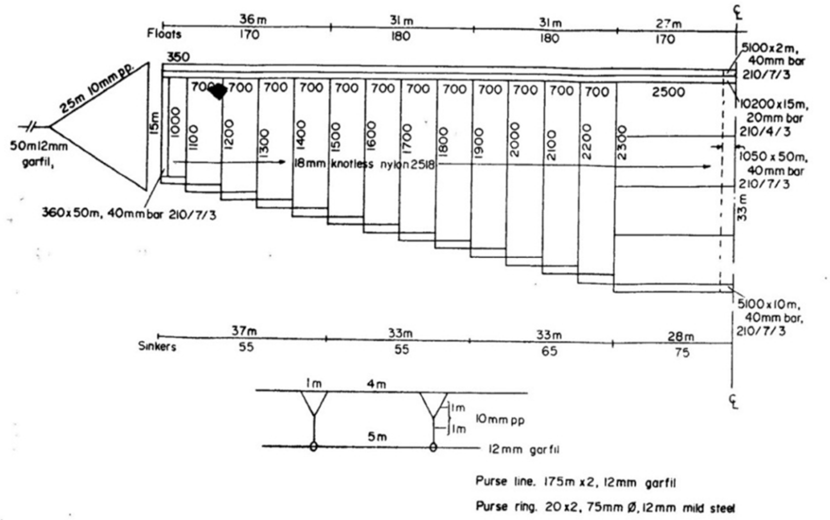


Fig 4.1 Typical design of Ring seine in 1985 (Source: Panicker *et al*., 1985)

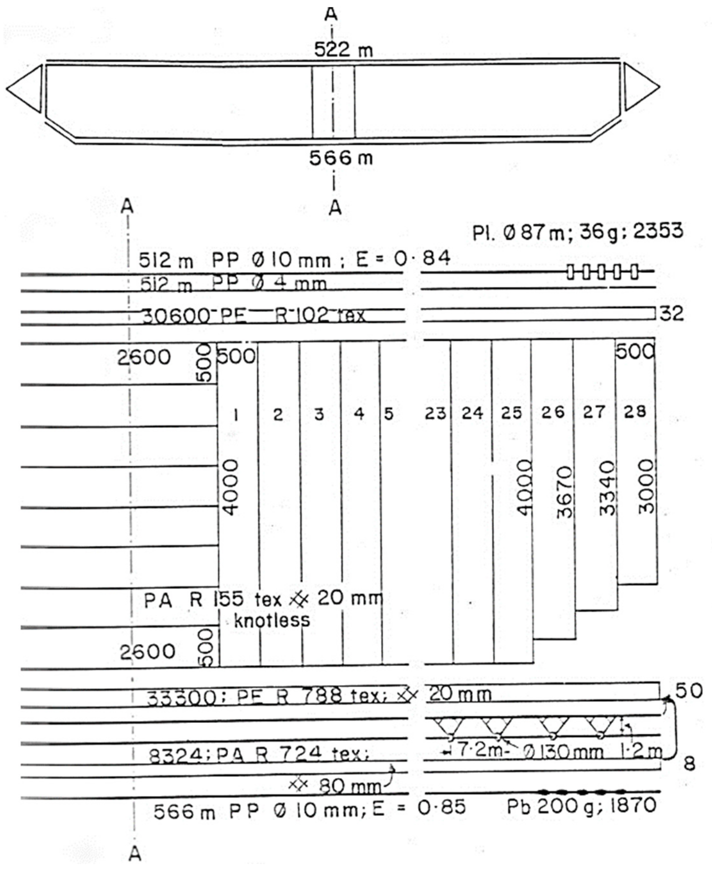


Fig 4.2 Typical design of Ring seine in 1996 (Source: Edwin & Hridayanathan 1996)

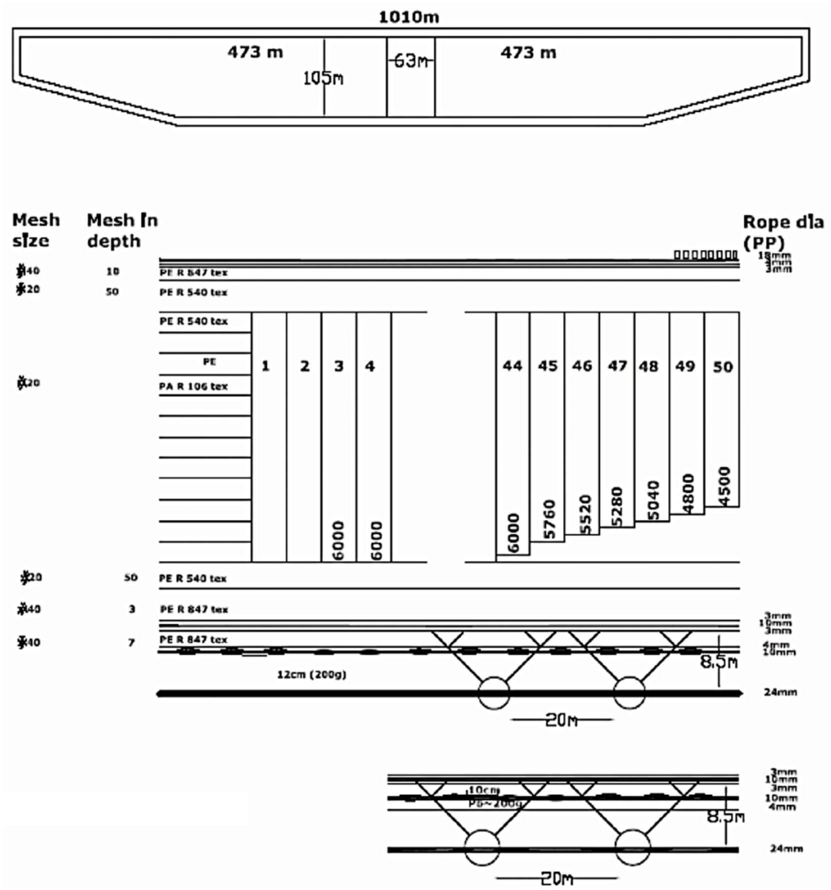


Fig 4.3 Typical design of Ring seine in 2010 (Source: Edwin *et al*., 2010)

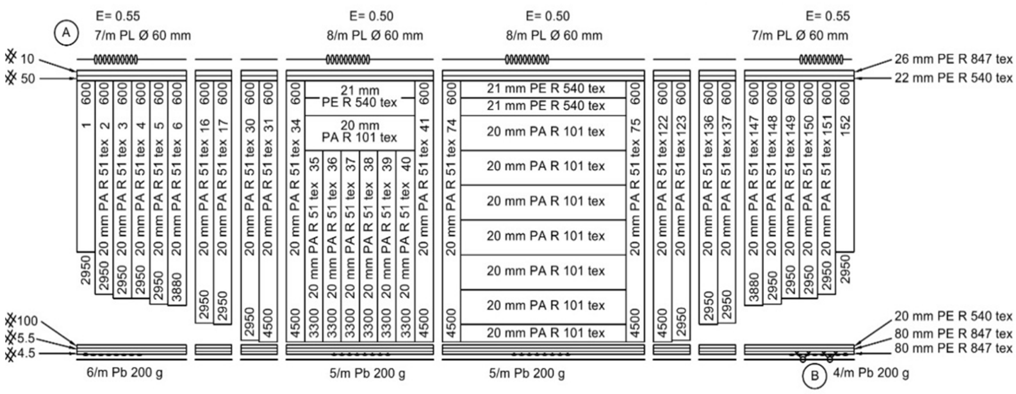


Fig 4.4 Typical design of Ring seine in 2014

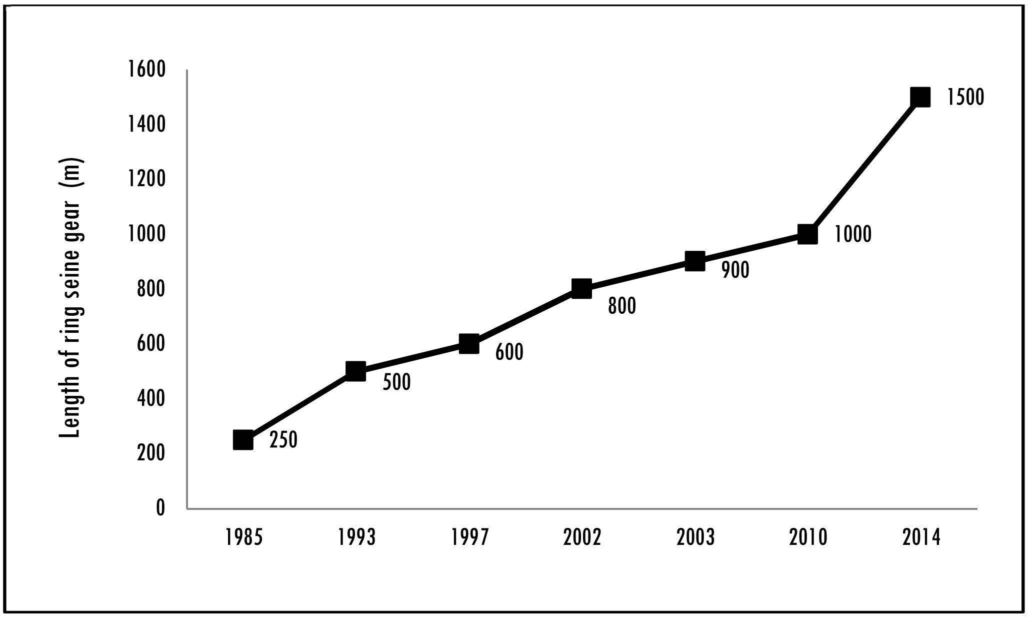


Fig 4.5 Increase in ring seine size of Kerala (1985-2014)

Table 4.1 Dimensions of the gear and targeted species

Source	Length (m)	Depth (m)	Mesh Size (mm)	Webbing Material	Targeted Species
Panicker *et al.*(1985)	250	33	18	Nylon	Sardine, Mackerel
D'Cruz (1998)	400-600	60- 70	20	Nylon	Sardine, Mackerel
Krishna *et al.* (2004)	900	90	20	Nylon	Sardine, Mackerel
Edwin *et al.* (2010)	250- 500	45- 75	8-10	Nylon	Anchovy, Sardine
Edwin *et al.* (2010)	600-1000	83-100	18-22	Nylon	Sardine, Mackerel
Edwin *et al.* (2014b)	600-1000	83-100	18-20	Nylon	Sardine, Mackerel

4.3.1.2 Size of Ring Seiner

The craft from which the erstwhile boat seine was operated and which later was used for the introduction of the mini-purse seine reported by Kuriyan *et al.* (1962) had an average length of 11.8 - 13.0 m and breadth of 0.9 - 3.3m.

These fishing craft are basically plank built, deckless canoes where fishermen sit and operate the gear. Studies conducted by the South Indian Federation of Fishermen Societies (SIFFS) indicate that between 1985 and 1988 the length of ring seine craft increased to 13.0 - 16.0m in the Aleppey region. The maximum breadth of the craft was 1.30m and depth of 1.25m - 1.40 m.

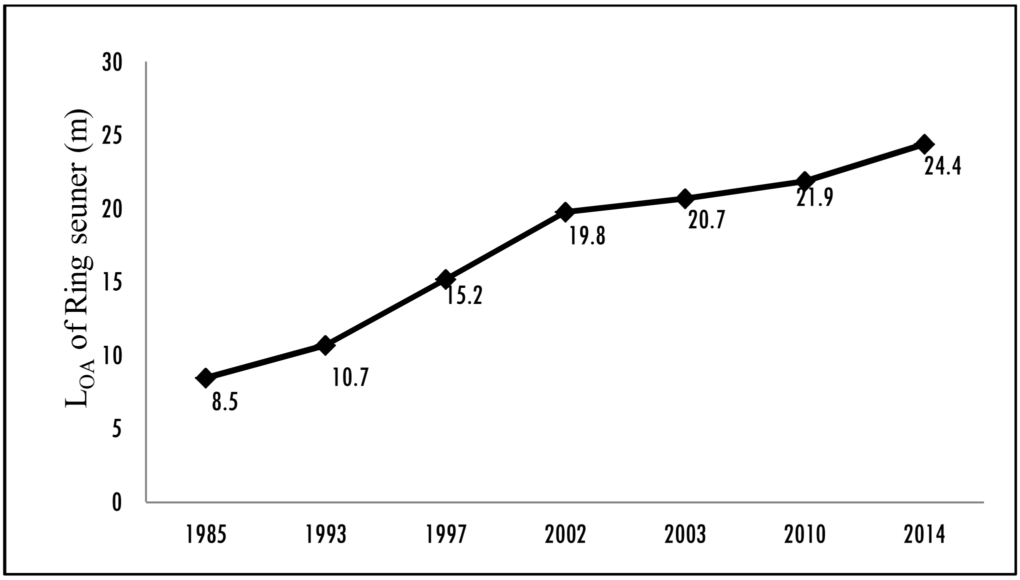


Fig 4.6 Increase in size of ring seiner (1985-2014)

The service life of the vessel is 2-6 years. Since majority of the vessels are in the size range of 18.3-25.9 m, they cannot be beach landed after operation as they used to with their smaller craft. The increase in size of the ring seiners during the last three decades is shown in Fig. 4.6. The vessels are left anchored at sea and the vulnerability to damage in rough weather has increased. The craft is exclusively designed for the ring seine operation and the fishing season of ring seine is restricted to six months in a year and large size of the canoes restricts its use for alternate types of fishing. Lifesaving, firefighting appliances, fish storage and crew accommodation facilities are also lacking on board these fishing vessels.

The increase in the size of fishing units which led to increase in fishing effort has been first manifested in the ring seine fishery of Kerala. In order to accommodate the huge gears, the size of craft also increased two fold in these areas and number of craft forming a unit increased four times.

4.3.1.3 Horsepower of the Fishing Units

The ring seiners used 8 to 15 hp engines for propulsion of the craft (D'Cruz, 1998). However, in certain cases, two engines are used in a single unit. These are necessitated because of large gear, 50-60 crew members and bulky catch. Currently such vessels use single inboard engines of 120-440 hp engines depending upon the size of the craft (Fig. 4.7). An all Kerala survey conducted by CIFT in 2013 shows that the fishermen are not satisfied with the power and performance of these engines and they are constantly on the lookout for more powerful marine engines (Edwin *et al.,* 2014a). Large scale entry of imported engines into the marine fishing industry with promises of delivering more power at a lesser price compared to the available branded marine engines in the market, attracts the fishermen. Shortage of experienced mechanics and scarcity of spare parts of imported engines are some of the problems faced by fishermen. The availability of powerful engines also fuelled the growth of the ring seine units.

The inboard engines used by ring seiners are often refurbished truck engines, resulting in high fuel consumption. The carrier vessel which accompanies the main vessel is fitted with either one engine of 25 hp or two engines of 25 or 40 hp or three engines of 9.9 hp. Small winches are used to facilitate hauling of the purse line.

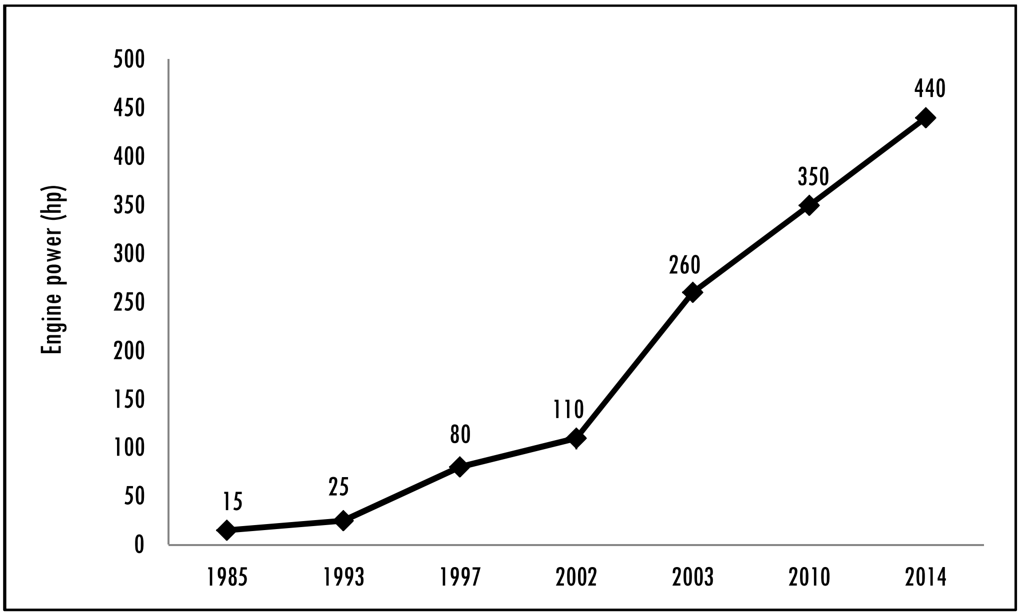


Fig 4.7 Increase in engine power (1985-2014)

4.4 Conclusion

The emergence of the ring seine caused two major artisanal gears of Kerala namely *koruvala* and *kollivala* to become obsolete (Rajan, 1993; Alagaraja *et al.,* 1994). With the ring seine replacing the traditional *koruvala*, the scale of operation has substantially increased. The size of the *thanguvallom* has been continuously increasing in order to accommodate larger gear. The ring seine belt between Quilon and Central Ernakulam districts has changed to two boat operation, one of which a smaller *thanguvallom* accompanies the larger one as a carrier boat engaged for transfer the catch to shore. Northern Ernakulam, Trichur and Malappuram districts have changed from dugout canoe *kollivala* fishing operation to plank built *thanguvallom* ring seine fishing and started to use small *thanguvallom* as carrier vessel. In Malappuram, boat seines are converted into single boat ring seine. Kasaragod fishermen started ring seine operation with four dugout canoes in 1986 and is called *ranivala*. Northern Calicut region and Kannur adopted the *ranivala* instead of *kollivala* and the southern part of Calicut has adopted *thanguvallom* ring seine. Finally the ring seine belt spread to entire Kerala with *ranivala* in northern part and *thanguvallom* ring seine in southern part.

Presently the Kerala ring seine belt extends from Muthalampozhi in Thiruvananthapuram district to Talapady in Kasaragode district (Edwin & Das, 2015). Each region has its own peculiarities in construction and operation of the gear. Gear with mesh size of 16-22 mm nylon knotless webbing is mainly used to catch sardines and mackerel. 10-14 mm mesh size ring seine (*choodavala*) is used to target small species like white baits, sardines and operate in shallow waters. The overall length of this gear ranges from 300 m to 1200 m with a depth range of 45 m to 110 m. *Thanguvalloms* of 70-76 feet long with a crew size of 35-45 operated with inboard engine are being currently used for ring seine operation (Edwin & Das, 2015). The ring seines of Kerala now contribute to 51% of the total marine fish landings of the state (CMFRI, 2015)

24 m steel ring seiner

1500 m ring seine

IBM ring seine engine

1200m ring seine under operation

Juvenile sardine landed in ring seine

Plate- 5 Large sized ring seine unit and juvenile landing

Chapter

5

DURABILITY OF RING SEINE GEAR

Contents

5.1 Introduction

Polyamide webbing are generally used for ring seine net construction. Polyamide multifilament webbings of size 210Dx1x2 or 210Dx1x3 or 210Dx2x2 or 210Dx2x3 contributes up to 90-100% of the total webbing weight of the gear and the remaining webbing with polyethylene. Polyamide (PA) is the first synthetic material used for replacing cotton/hemp in India for fishing gear in 1962 (Meenakumari *et al.,* 1993). One of the valid criteria for determining the strength and durability of materials is their resistance to photo-degradation and PA netting are highly sensitive to UV radiation (Molin, 1959). Weathering causes loss of strength, extensibility, general durability and appearance because of the modification or break down of molecular structure of polymers (Achhammer *et al.,* 1953; Winslow & Hawkins, 1967; Liu *et al.,* 1995). Loss in breaking strength is an index of degradation while assessing the durability of any gear (Egerton & Shah, 1968, Little & Parsons, 1967; Singleton *et al.,* 1965).

Many authors studied the effect of weathering and UV exposure in fishing net materials. Meenakumari and Ravindran (1985) studied the tensile strength properties of polyethylene netting twines exposed to UV radiation. Meenakumari and Radhalakshmi (1988) studied the photo-oxidative degradation of nylon twines. Effect of sunlight and UV radiation on mechanical strength properties of PA netting twines were studied by Meenakumari *et al.* (1985). Thomas & Hridayanathan (2006), compared the effect of sunlight on polyamide monofilament and multifilament netting twines. Studies by Klust (1983) showed that, damage of synthetic fibre due to weathering varied according to seasons and geographical regions.

The construction of a 1000m mechanized ring seine requires 2.5- 3.0 tonnes of webbing material. The chance of damage is comparatively very high compared to other fishing gears because of the material properties of nylon-PA multifilament and the operational procedure (shallow water operation). The major problem associated with the ring seine fishery is its periodic repair or replacement of webbings due to wear and tear and attack of marine cetaceans during the time of fish aggregation and brailing the catch. The cost of repair is high and the labour availability for repair is scarce. It was observed that an inboard ring seine unit replaces average 0.5 to 1.0 tonne of webbing every year during the study period. Polyamide multifilament webbing of 210Dx2x2 costs ₹ 4.8 lakhs per tonne and the mending is very labour intensive and skilled workers are required for this work. Repairing of the huge net will take one to three weeks depending up on the severity of damage and, the repairing charges varied between ₹ 1 to 2 lakh. Each ring seine unit usually need two to three major repairs in a year. Loss of revenue during the days of repair and the repairing charges are additional burden to fishermen.

Attack of dolphin during the fishing operation was identified as one of the major operational hurdles during the ring seine operation. There are mainly two methods for reducing the mammal fishery interactions viz, passive methods and active methods (Jefferson & Curry, 1996). The passive methods include net modifications and incorporation of add-on reflectors in the fishing gears. Active methods are mainly based on sound generators which includes shoot and kill of the offending animals (gunshots), use of explosives, biological sounds, mechanical sound generators and electronic sound generators. Besides this, there are several other methods like vessels chasses and the use of boat noises (Jefferson & Curry, 1996).

There were no reports available on the durability of ring seine webbing and damage due to marine animal attack. Ring seine fishermen of central Kerala fabricated a new wall net using locally available materials at a very low investment to prevent the damage caused by dolphins. This newly fabricated net is a passive method to reduce the cetacean interaction in ring seine fisheries. The structural and operational details of this wall net is presented in this chapter.

The chapter deals with the assessment of webbing durability under controlled conditions and assessment of areas most prone to damage during the operational life of the gear. An innovative management measure devised by ring seine fishermen of Kerala to prevent the dolphin attack to ring seine is also documented.

5.2 Materials and Methods

5.2.1 Assessment of Durability of Ring Seine Webbing

An 18 month durability study of most commonly used ring seine polyamide webbing of 210Dx2x3 with 20mm mesh size was conducted. Two types of exposure studies were conducted for accurate results. In the first method, the webbing panels were exposed to natural marine weather conditions and in the second method the webbing panels were exposed to simulated conditions in accelerated weathering equipment.

Natural weather exposure studies were conducted using long pieces of twenty five mesh wide polyamide webbings. The sample webbings were attached to plastic frames of 1 x 1 ft in size and placed in open study site near to coastal area at a 45^0 angle in north-south direction to get maximum sunlight. The subsamples were taken at every 30 day interval for testing. The study was conducted during the period Nov 2012 to April 2014.

PA webbing panel from the source was used for the second mode of exposure studies. In this method, webbing panels were exposed in ATLAS Xenotest Alpha+ accelerated weathering equipment under controlled conditions. Xenotest apparatus reduces the exposure time by $1/7^{th}$. Sub samples were collected from Xenotest apparatus in every 103 hrs (equaling to one month) for testing.

The exposed samples were tested for elongation at break and breaking strength using Shimadzu AG-1 Universal Testing Machine (UTM). IS 5815 (Part 5) was followed for mesh break load test (IS 5815-5, 2005). For UTM test, webbing samples of 3x3 meshes were used. A minimum of 10 samples were used for each type in the experiment.

Kruskal- wallis ANOVA with pairwise comparisons using Turky and Kramer (Nemenyi) test were used to compare the break load in different months and regression analysis is also applied.

5.2.2. Assessment of Damage of Ring Seine Gear

To study the strength reduction in ring seine webbing due to fishing operation, webbing samples were collected from five different locations of gear for testing. Samples were collected from a commercial ring seine of 1000m in length and 90m in depth having 20 mm mesh size (210Dx2x3) polyamide webbing. Webbing samples were collected during the time of gear repair or re-rigging. To get a clear idea about the life of ring seine gear, webbing strength studies were conducted in webbing samples collected from five different locations which play a critical role in operation (front panel of netting, end panel of netting, adjacent sides of bunt area, top panel of netting, bottom panel of netting) as shown in Fig 5.1, were collected from ring seine at the end of 3, 6, 9 and 10 months of continuous operation. The opinion from experienced fishermen were also sought while selecting the area more prone to damage. Collected samples were tested for elongation and breaking strength after conditioning in humidifier with a minimum period of 24 hours.

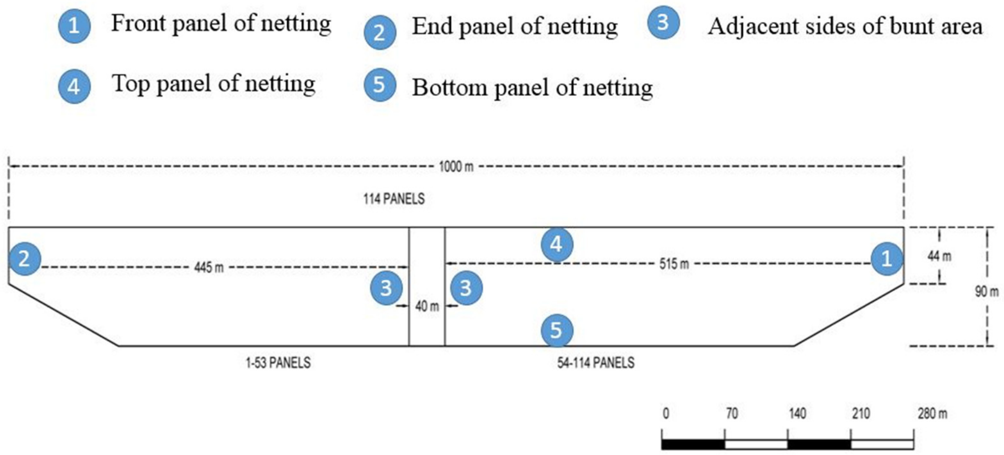


Fig.5.1 Diagrammatic representation of sample collected areas for ring seine gear strength studies

5.2.3 Fishermen Innovation to Protect Ring Seine Webbings from Marine Animal Attack

A field study which included extensive field survey and data collection for three months from July to September 2012 was conducted for collecting information from fishermen. This has resulted in documenting valuable information about reasons of webbing damage in fishing operation and its preventive measures. Ring seine fishermen of different age groups from varying socio-cultural background were interviewed using an unstructured questionnaire with open-ended questions. Each group consisted of 10 to 25 numbers of fishermen and minimum three such groups were interviewed form each station and the interaction lasted for 30 to 40 min. Questionnaires were prepared covering the technical aspects and operational details of ring seines. The discussions were held in the local language *Malayalam*. People who seemed comparatively more knowledgeable among the group were contacted individually and in-depth interviews were held with them. Data were validated through focused group discussions and interactions with group leaders of ring seiners and experienced fishermen. From the interaction, it is revealed that fishermen developed a new net Dolphin Wall Net (DWN) to overcome the problem. Structural details and operational procedures of DWN were recorded scientifically by direct field observations.

5.3 Result and Discussion

5.3.1 Assessment of Durability of Ring Seine Webbing

The ring seine webbing exposed to natural weather and accelerated weathering showed reduction in breaking strength (Fig.5.2.) and elongation at break after exposure. Specification and physical properties of webbing sample are given in Table- 5.1.

Table: 5.1 Specification of webbing sample studied

Type	PA Multifilament webbing
Specification	210x2x3
Mesh size	20mm
Color	Red
Diameter in mm	0.52
Strength (N)	178.6 ± 4.9 (three mesh)
Elongation at break (%)	20.0 ± 1.14 (three mesh)

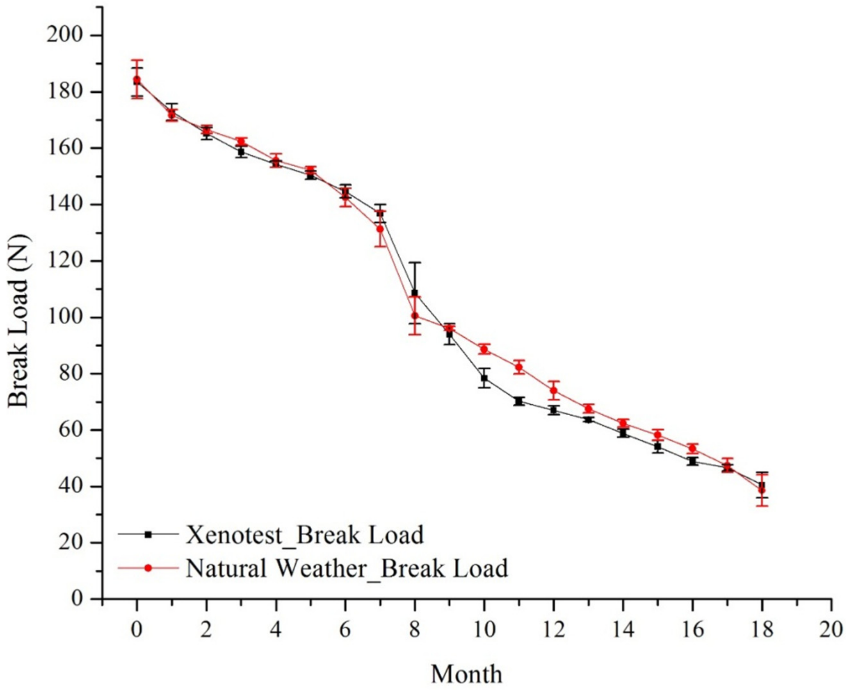


Fig. 5.2 Comparison of breaking strength reduction in Xenotest and Natural Weathering conditions (three mesh)

Results showed reduced breaking strength and elongation at break of samples exposed to sunlight and Xenotest. In case of break strength, no significant variations ($P < 0.01$) were observed between xenotest and natural weathering samples. An analysis of variance (ANOVA) showed significant reduction in breaking strength ($P < 0.01$) in the Xenotest and natural weathering samples. After 10 months of exposure there was a 50% reduction in breaking strength, which is considered unserviceable as per Brandt (1959). Variation in break strength with exposure time is given in Fig.5.3. The mean break load of ring seine webbing panel exposed in natural weathering and xenotest are shown in Table- 5.2 and the significantly different means are shown in bold.

Table-5.2 Kruskal-wallis ANOVA table of xenotest and natural weathering sample. The significantly different means (P<0.05) are shown in bold.

Month	Xenotest _break load	Natural_break load
0 Month	183.5	184.4
1 Month	172.9	171.6
2 Month	165.2	166.7
3 Month	158.6	162.4
4 Month	154.3	155.6
5 Month	150.4	152.2
6 Month	144.7	142.5
7 Month	136.8	131.3
8 Month	108.5	100.5
9 Month	94.0	96.1
10 Month	78.4	88.7
11 Month	**70.2**	**82.3**
12 Month	**67.1**	**74.0**
13 Month	**63.7**	**67.5**
14 Month	**58.9**	**62.4**
15 Month	**54.1**	**58.2**
16 Month	**48.9**	**53.4**
17 Month	**46.6**	**47.4**
18 Month	**40.5**	**38.5**

It was observed that breaking strength reduction is linear to exposure time in both the cases. Regression analysis showed a linear relationship (R^2= 0.959) between exposure time and breaking strength it can be used for predicting the durability of ring seine webbing. But in case of elongation at break, there is no linear relationship with exposure period. Regression analysis and probability plots are given in Table: 5.3 and Fig.5.4. The present study reveals that the polyamide multifilament webbings are susceptible to sunlight damage by exposure and this reduces the life of the gear.

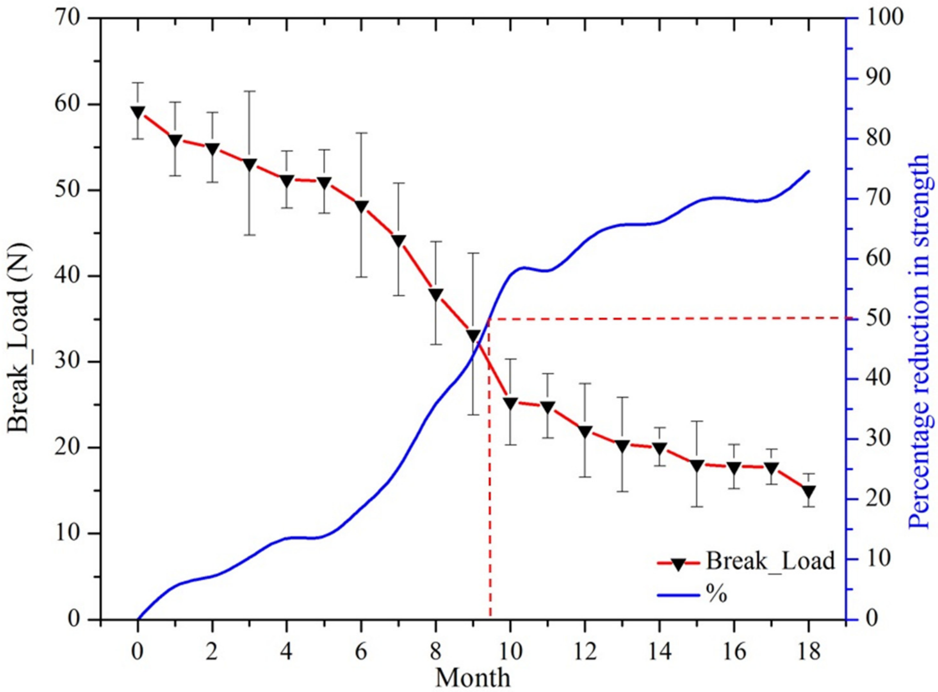
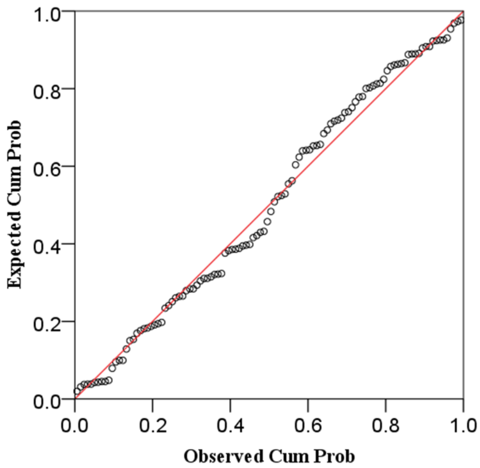


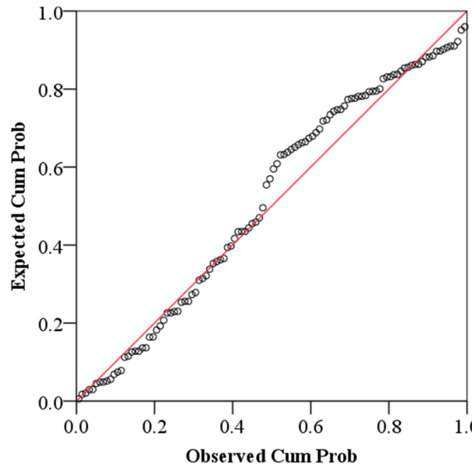
Fig. 5.3. Variation in break strength with time in polyamide webbing exposed to sunlight (single mesh).

Table: 5.3 Regression relationship between breaking strength and exposure time of experimental panels

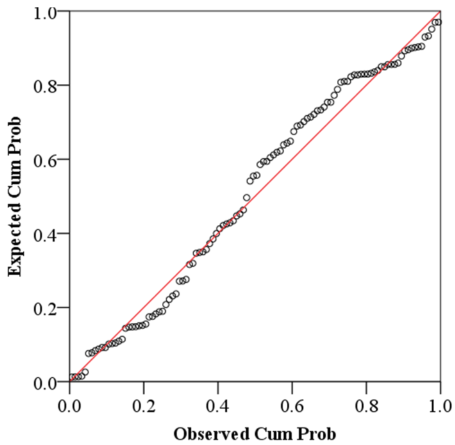
Xenotest Weather-o- meter sample		Natural weathering sample	
Breaking strength	**Elongation at break**	**Breaking strength**	**Elongation at break**
R^2=0.959	R^2= 0.689	R^2=0.970	R^2=0.593



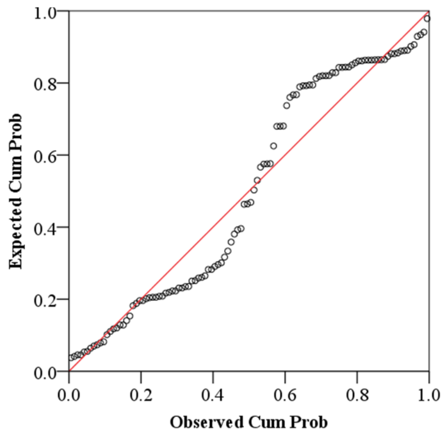
Xenotest Weather-o- meter sample breaking strength



Xenotest Weather-o- meter sample elongation at break



Natural weathering sample breaking strength



Natural weathering sample elongation at break

Fig. 5.4. Normal probability plot of breaking strength and elongation at break of webbing panel exposed in Xenotest and Natural weathering conditions

Study conducted by Thomas & Hridayanathan (2006) and Meenakumari & Radhalakshmi (1988) in polyamide multifilament twines, observed reduction in break strength with exposure time. Thomas & Hridayanathan (2006) observed lack of linear relationship between reduction in elongation at break and exposure time. In the same study, it is observed that twine thickness is inversely proportional to the breaking strength and elongation at break. Ring seines are commonly made up of thinner twined polyamide webbings which can be one of the reason for its comparatively low life.

5.3.2 Assessment of Damage of Ring Seine Gear

Results of breaking strength experiments showed variation in reduction of breaking strength in different parts of ring seine webbing with period of operation. Breaking strength measurement on webbing conducted in laboratory condition is considered as control and the webbing panels collected from selected ring seines from nearby fishing areas are taken as the experimental samples. In comparison it is clearly evident that the strength reduction in ring seine webbing panels are not uniform in all parts. Panels near to the bunt showed maximum strength reduction and least in webbing nearer to the extreme end panels during fishing operation (Table 5.4).

Table: 5.4 Percentage reduction in strength of ring seine webbing panels. 50% break load reduction points are given in bold

Month	Control	Top panel	Bottom panel	Bunt panel	First panel	Last panel
0	100.0	100.0	100.0	100.0	100.0	100.0
3	11.9	18.8	21.7	23.7	15.9	6.3
6	22.7	35.5	42.2	46.8	25.5	19.1
9	47.9	**54.1**	**56.8**	**64.5**	**53.4**	31.5
10	**51.9**	58.9	65.6	70.3	59.7	36.9
12	59.9	-	-	-	-	45.4
15	68.4	-	-	-	-	48.9
18	79.1	-	-	-	-	**59.9**

The webbing near to bunt portion showed a reduction of 64.5% breaking strength after nine months of fishing operation followed by bottom panels (56.8%), top panels (54.1), first panels (53.4%) and end panels (31.5%). All webbing panels in ring seine gear except end panels lost more than 50% breaking strength after nine month of operation where as the last panel showed only 31.5% strength reduction when compared to other panels. Table 5.5 showing the means of different portions of the ring seine. The significantly different means ($P<0.05$) are shown in bold.

Table: 5.5 Kruskal-wallis ANOVA means of different portions of the ring seine and the significantly different means ($P<0.05$) are shown in bold

	3 months	6 months	9 months	10 months
Near to top panel	149.8	**119.0**	**84.6**	**75.7**
Near to bottom panel	144.4	106.6	**79.6**	63.5
Near to bunt panel	140.8	98.2	**65.5**	54.8
Near to first panel	155.1	137.3	**85.8**	74.3
Near to last panel	172.8	149.1	**126.3**	116.4

Depending upon the shoal size, direction of shoal movement and area to be encircled, the quantity of webbing released from the fishing craft varied. In an effective fishing operation, fishermen surround the fish shoal with minimum length of webbing to reduce the labour and fishing time. Considering the case of a fishing operation with 1000m gear, more than 95% of the total fishing will be carried out with a gear length of 700 to 800 m while the rest of the webbing remain onboard undisturbed. While the wet webbing is stacked on top of the unused part, water from the top portions drains downwards and tends to keep the unused below part in a wet condition. Also this portion of webbing is least exposed to sunlight. Low sunlight exposure will extend the life of polyamide multifilament netting material (Meenakumari & Radhalakshmi, 1988; Dahm, 1992; Al-Oufi *et al.,* 2004; Thomas & Hridayanathan, 2006). This may be the reason for higher strength showed by this part of webbing.

The panels which were released first showed high break strength followed by end panels. In every fishing operation, these panels are immediately taken onboard after pursing and hence, the wear and tear during operation is very less. This may be the reason for high break strength. First panel and control panel break strength showed nearer values because, while gear is stored onboard, the first panels comes in the top side and it increases the chance of direct sunlight exposure same as control panel. Al-Oufi *et al.* (2004) and Thomas & Hridayanathan (2006) observed exposure to sunlight after fishing leads to strength reduction. Strength reduction in webbing panels collected from different locations of ring seine gear are compared with control and is given in Fig.5.5. Major repairs and webbing replacement during study period and reasons are given in Table 5.6.

Heavy wear and tear happens near to bunt area due to daily fishing operation. During ring seine operation, the catch is concentrated in the bunt made of HDPE webbing (Edwin & Das, 2015). The weight of the catch in the bunt webbing and nearby polyamide area increases the tear and wear of this portion. While hauling the net volume reduces resulting in overcrowding of fish and if the fish size is smaller than the webbing it gets gilled in the webbing and cause damage to the net. In the bunt area, fishes try to escape from the net by vigorous activity and this force also tends to damage the webbing.

While conducting ring seine operation in the shallow waters of near shore areas, lower part of the gear touches the sea bottom and sweep the bottom while pursing the gear. To protect the webbing panels from bottom contact and reduce the effect of lead weight load, the bottom portion of the ring seine gear is provided with bottom selvedge. But in muddy and rocky area operation the bottom selvedge is not sufficient to protect the gear portion adjacent to the bottom. The load exerted on the purse line while pursing the gear also affect the bottom webbing panels. These effects also contribute to the reduction in the service life of webbing.

In the case of top panels, damage is mainly due to the attack of puffer fish and other cetaceans. Paul *et al.* (2005); Pillai (2009) and Mohamed *et al.* (2013) reported the high occurrence of puffer fish in post monsoon period in Kerala waters and cause extensive damage to the fishing gear and catch. During fishing operation immediately after encircling, both ends of gear were tied in the forward and aft side of fishing vessel. If the water current is high, the gear stretches towards the direction of the current and such heavy currents also increase the chances of webbing damage.

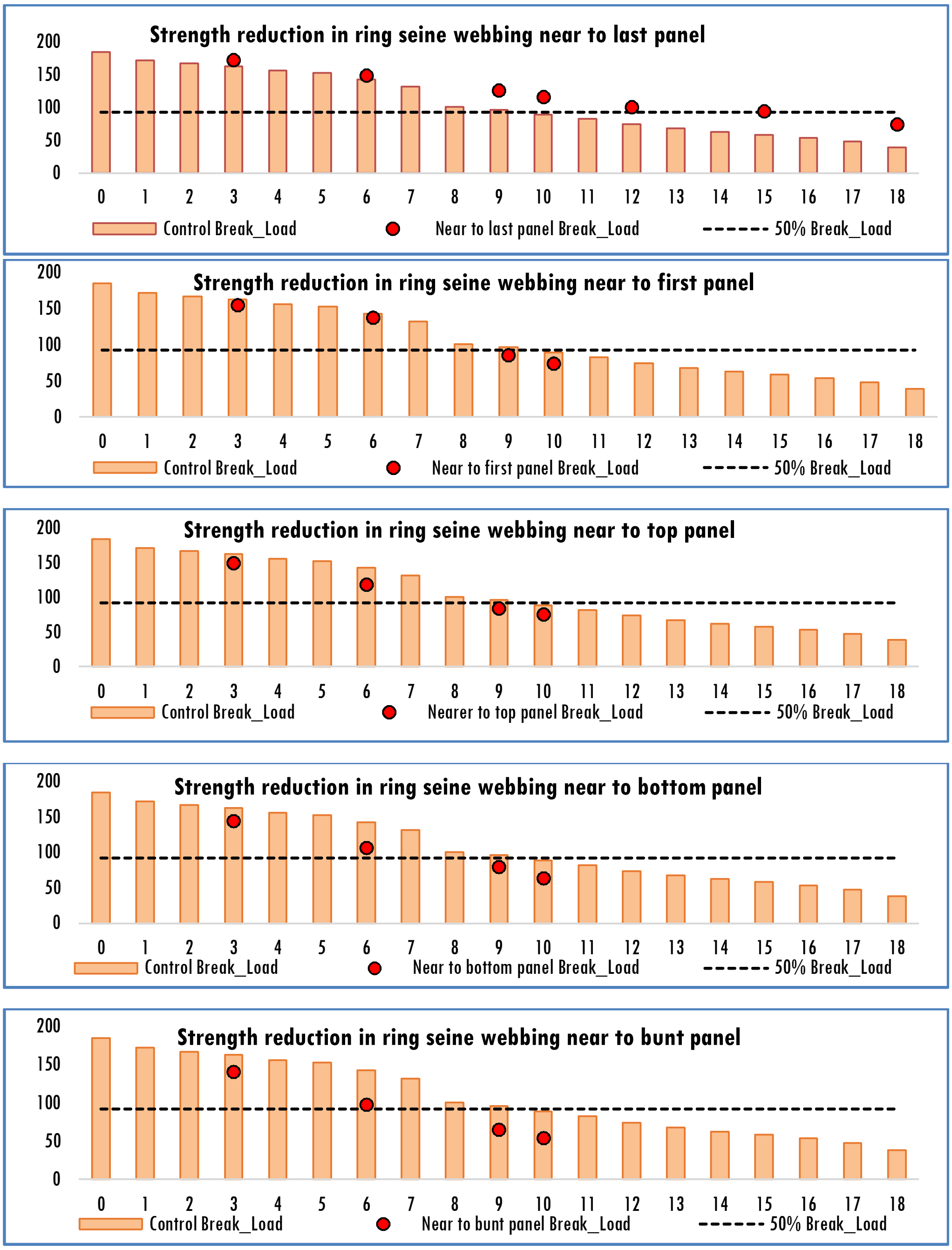


Fig.5.5. Strength reduction in different webbing panels of ring seine gear

Table: 5.6. Major repairs and webbing replacement during study period and reasons

Months	Top panel	Bottom panel	Near Bunt panel	First panel	Last panel
1					
2	Repaired_ damage due to dolphin attack				
3					
4		Repaired _damage due to operation in rocky bottom			
5			Repaired _damage due to dolphin attack		
6					
7					
8					
9		Repaired _damage due to operation in rocky bottom			
10	Repaired_ damage due to dolphin attack		Replaced_ unserviceable		
11					
12	Replaced_ unserviceable	Replaced_ unserviceable		Interchange with last panel	Interchange with first panel

5.3.3 Fishermen Innovation to Protect Ring Seine Webbings from Marine Animal Attack

In India, interaction between humpbacked dolphin and trawl/ purse seine fisheries is common (CMFRI, 2010). During ring seine operation, it was observed that groups consisting of about thirty animals congregate in the fishing area and surround ring seine net and cause disturbance to fishing by taking away fishes from the net. In order to prevent this disturbance, two types of measures are practiced by the fishermen. Some fishermen use crackers to drive away the dolphins from their fishing area. However, fishermen are cautious to avoid causing physical injury to dolphins. Some fishermen patrol the fishing area in a small boat. Boat anchors, tyres or any hard objects covered with plastic operated from carrier vessels are some of the indigenous objects used by fishermen to drive away the dolphins from fishing grounds. Attack of dolphin during fishing was identified as one of the major operational hurdles. From the interaction, it is revealed that fishermen developed a new net-Dolphin Wall Net (DWN) to overcome this problem.

Dolphin wall net is a 1000 - 1500 m long wall of netting framed with float line and steel rings hanging from the lower edge. The wall net is made up of 300-400 mm high density polyethylene (HDPE) webbing of 1.5 mm diameter with 25 mesh depth (Fig.5.6). Two types of dolphin wall nets are commonly seen in Kerala, one with conventional plastic float with selvedge and the other without selvedge (Fig. 5.7 and 5.8) with locally available materials like thermocole blocks and empty oil cans as floats. Selvedges are used for reducing the entangling of floats to the webbing. 80 mm HDPE webbing of 1.25 mm diameter and 11 meshes in depth are used as selvedge having apple floats of 90 mm diameter. Dolphin wall net without selvedge uses large 5 liter empty plastic cans or large thermocole blocks as floats (Fig. 5.9A). The floats and rings are attached to 6 mm polyethylene ropes. Apple floats are attached to the float rope at an interval of 3.66 m in Dolphin wall net with selvedge where as empty cans are attached at 15 m interval in dolphin wall net without selvedge.

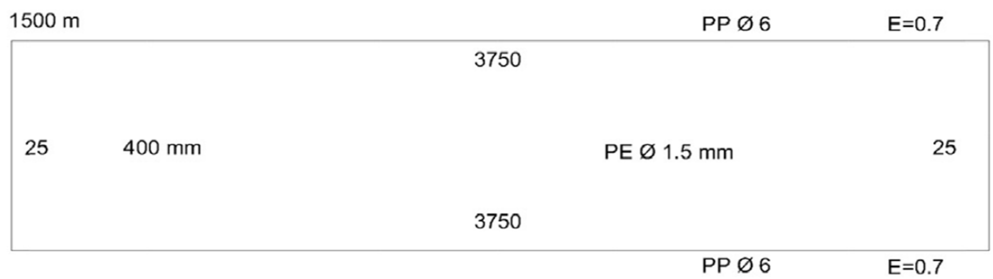


Fig.5.6. Diagrammatic representation of Dolphin Wall Net without selvedge & indigenously developed float

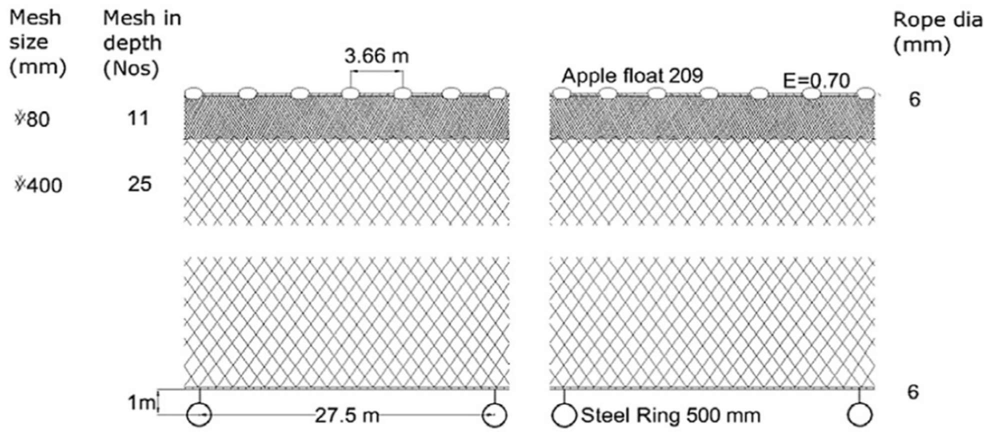


Fig. 5.7. Structural details of Dolphin Wall Net with selvedge & Conventional float

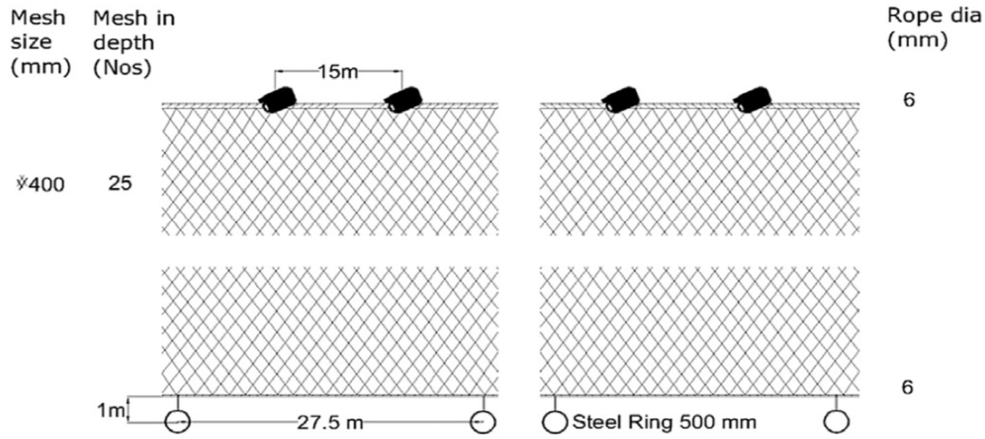


Fig. 5.8. Structural details of Dolphin Wall Net without selvedge & indigenously developed float

Fishermen from Kozhikode region in northern part of Kerala prefer thermocole block as floats. These are used to prevent entangling of net caused by sharp and irregular edges of the cans. Rings are attached to the foot rope with one meter length polyethylene rope at an interval of 27.5 m. Circular steel rings having diameter 500 mm and weighing 1-2 kg are commonly used as sinkers (Fig. 5.9B). Fibre-reinforced plastic or wooden fishing vessels of 15-20 ft with 9.9 hp outboard engines are used for operation.

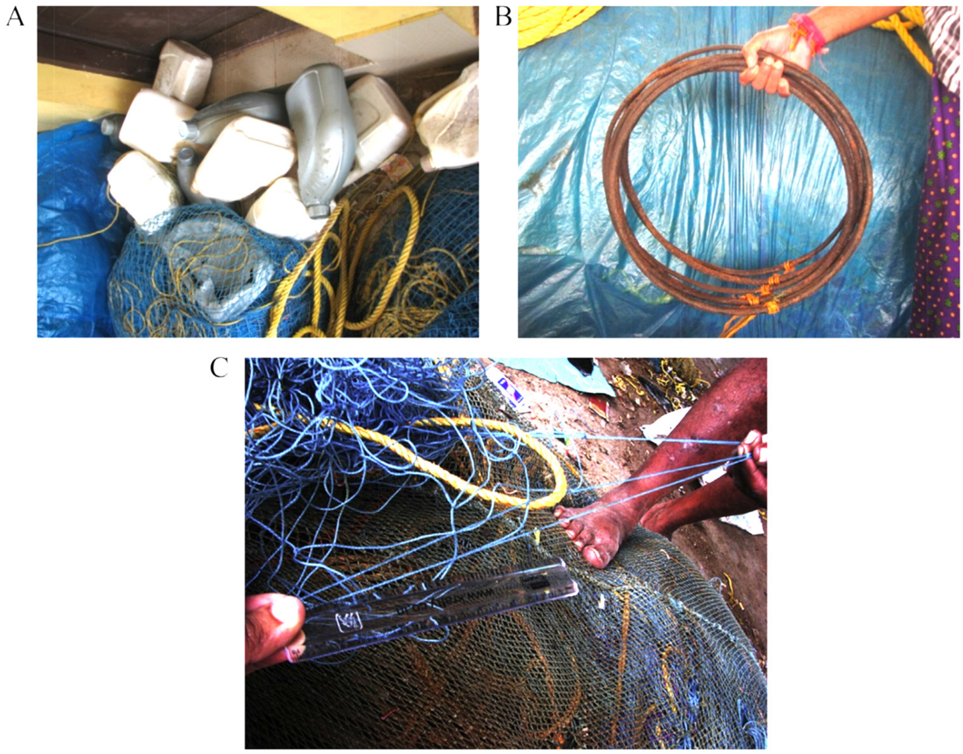


Fig. 5.9. A. Float of Dolphin Wall Net, B. Sinker rings of Dolphin Wall Net, C. Measurement of single mesh.

Once a school of appropriate size and desirable species is detected, the craft is taken sufficiently close to the school and ring seine net is encircled quickly. Simultaneously, DWN is operated from the carrier vessel with an L_{OA} 9-13 m. After the pursing operation, the catch is concentrated close to the craft in the bunt portion, by hauling up the main body of the seine from either end. Normally this net is used by fishermen during summer season only (March to May). According to fishermen, dolphin menace is more during summer due to clear and transparent water.

Interactions between dolphins and fishing nets have been reported for more than a century (Backhouse, 1843), but such events have been described sometimes as cooperative (Busnel, 1973; Pryor *et al.,* 1990; Neil, 2002). Currently, however, within the context of fish stock collapse (Jackson *et al.,* 2001; Myers & Worm, 2003), these interactions are considered by the fishing industry as conflicting (Yodzis, 1998). The marine mammal fishery interactions cause a loss in revenue to small and large scale fishermen by way of mechanical damage to the gear and to a certain extent loss of captured fish. Among several gears, gill nets and purse seines have been identified as the main cause for marine mammal mortality at the global scale (Cockcroft & Krohn, 1994; Perrin *et al.,* 1994; Archer *et al.,* 2001; Wise *et al.,* 2001; Read *et al.,* 2006). In Kerala, non motorized traditional fishing vessels play a major role in ensuring livelihood of the fisher folk (GoK, 2010). In the traditional sector, most important fishing gear in Kerala is ring seines (Boopendranath & Hameed, 2012). Fishermen report that the problem due to attack of dolphins during ring seine operation is more challenging during March to May. The approximate cost for a dolphin wall net is estimated as 1200 $. DWN is operating from the existing small carrier vessels. According to fishermen, compared to the economic loss due to the dolphin attack the expenditure for the continuous repairing of the ring seines, the amount spent for the fabrication of DWN is negligible. Recent reports also showed that dolphins have now learned to consider catches of fishing operations as a new food resource (Reeves *et al.,* 2001); they remove fish directly from nets, resulting in a loss of fish for fishers and damage to nets. Sometimes dolphins may act as indicators of fish availability. In Kerala, Dolphin-assisted cast net fishery in the Ashtamudi estuary, is an excellent example for this (Kumar *et al.,* 2012).

Sivadas and Kumar (2009) have described the dolphin attack preventing nets along Kozhikode coast, Kerala as dolphin excluder nets. Being a surrounding type of net, more than excluding, it creates a barrier to the ring seine and keeps away the mammals in a safe distance. Hence the name Dolphin Wall Net is more suitable for this type of net. Interactions between marine mammals and fisheries take several forms. Some are operational, in which marine mammals come into physical contact with fishing gear

(Beverton, 1985). Operational interactions can result in the mortality or serious injury of marine mammals that are "captured" but discarded, a process known as bycatch (Alverson *et al.,* 1994). In some areas of the world, marine mammals are captured unintentionally but retained for consumption or sale (Read *et al.,* 2006). In India, dolphins are caught in good numbers at Cochin, Malpe, Karvar, Goa and Bombay areas (Jayaprakash *et al.,* 1995). About 9000 to 10000 dolphins are estimated to be caught by gill net annually along the Indian coast (Mohan, 1985; Kasim *et al.,* 1993; Rao & Chandrasekar, 1994; Thiagarajan and Pillai., 2000; Yousuf *et al.,* 2008).

Gill net contributed 68.9% to the incidental catch. Two species commonly involved in the gill net fishery are the spinner dolphin *Stenella longirostris* and the bottlenose dolphin *Tursiops aduncus*. In addition, other species such as Risso's dolphin *Grampus griseus*, long-beaked common dolphin *Delphinus capensis* and Indo-Pacific humpbacked dolphin *Sousa chinensis* are also reported. Maximum number of dolphin entanglements in gill net was encountered in fishery for large pelagics such as tuna and seerfish. The length of gill net operated along the Indian coast ranged from 0.5 to 2 km with varying mesh size. A study by CMFRI showed that, the length of mechanized boats that incidentally caught dolphins and porpoise ranged from 9 to 15 m with 20-108 hp engine. The fishing operations were carried out 4-70 km from the shore. Off Mangalore, a large number of finless porpoise, *Neophocaena phocaenoides* are incidentally caught in purse seines. Stray numbers are caught in the Gulf of Mannar region (Jayaprakash *et al.,* 1995). At the Fisheries Harbour, Cochin, the drift gillnetters operating to exploit a variety of larger pelagic fishes also have been found dolphins to entangle incidentally (Silas *et al.,* 1984). Instance of dolphins 'caught' in large numbers by a purse-seiner operating at this centre is also reported from the same location in India. Reports on the incidental by-catch of dolphins have been reported by many workers (Rajagopalan *et al.,* 1984;

Mohan, 1985; James & Mohan, 1987; Pillai and Kasinathan, 1987; Santha *et al.,* 1987; Pillai & Chandrangathan, 1990; Pillai and Lipton, 1991; Pillai *et al.,* 1991). Silas *et al.* (1984) reported that 1% of the total landings by fishing gear at Cochin were dolphins. Marine mammals face a wide range of threats. The greatest threat to coastal populations of dolphins is the intense fishing activities which results in the incidental killing as a result of entanglement in fishing gear. With continued proliferation of synthetic gill nets throughout the world, bycatch has emerged as an extremely serious threat to marine mammals, as well as to sea birds, turtles, fishes and other non-target organisms (Northridge, 1991). In addition, reduction of prey due to overfishing affects the abundance of dolphins.

The DWN is known in the local parlance as *"Pannivala"* in south and central Kerala and it is known as *Edivala* in North Kerala. Among the passive methods for reducing fish mammal interaction, the main aspect is the modifications to detectability of nets to odontocete cetaceans, which have echolocation capabilities. Since major part of the mammal bycatch was reported from gill nets, several studies were done throughout the world for the structural modification in the gill net. The wall net fabricated by the Kerala ring seine fishermen is just like a panel of netting which resembles a gill net. Studies showed that the lead and float line of the gill net is more detectable to the mammals (Pence, 1988). The lead line and float line of the DWN is composed of bigger iron rings and plastic cans. So definitely it will prevent the entry of the animal to the ring seine operating area. As the net is made of thicker twine size (1.5 mm), wide webbing (400 mm) and large float and sinker attached to, it may increase the acoustic reflectivity (Jefferson & Curry, 1996) and this may be the reason for the non-entangling of the dolphins in the presently discussed net. Besides this, the cetaceans have natural tendency to avoid noval objects (Pryor, 1973) or they will be more cautious when they are aware of a potential barrier in the area.

5.4 Conclusion

Present study revealed that exposure to sunlight will expedite the deterioration in net breaking strength of polyamide webbing panels. Previous studies show that (Al-Oufi *et al.,* 2004) compared to natural fibres, the synthetic fibres do not rot, therefore there is no need to dry the webbing and can be stored in wet condition itself. In ring seine fishing the large volume of fishing gear is stored on board without any protection. Polyamide webbing should always be protected from direct sunlight as it ensures longer life span of net and low maintenance and repair. If it is possible to provide a shade over the net storage area in ring seiner it will help to increase the life of the gear.

Fishing gear strength studies conducted with samples collected from different areas of fishing gear revealed that the strength reduction in ring seine is not uniform and it varied from part to part and the parameters causing deterioration are also different in different gear locations. To attain better service life of gear there is an urgent need of area specific improvisations and use of alternative materials with high strength, high abrasion resistance and high resistance to UV radiation.

The Dolphin Wall Net (DWN) is framed to avoid the disturbance of dolphins during operation of net, it is an eco-friendly conservation aspect indigenously developed and followed by fishermen, which indirectly helps to protect the scheduled marine species. As most of the cetaceans in India are coming under protected category, the new initiative from fishermen to avoid incidental catch of marine mammals should be popularised. Purse seine fishermen all over the globe can also adopt this innovation to reduce mammal-fisheries interaction. Before implementing this technology, proper scientific study is needed to assess the merits and demerits of this net as well as the behaviour and response of cetaceans to new gear system. This will help to improvise the efficiency of the DWN developed by the fishermen.

Experimental set up for Xenotest weather-o-meter study

Experimental set up for natural weatering study

Plate-6. Experimental set up for natural and weather-o-meter studies

Plate-7. UTM Breakload experiment

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Chapter

6

SINKING SPEED AND OPERATIONAL EFFICIENCY

Contents

6.1 Introduction

Ring seine with its similarities in structure and operation with purse seine, differs from purse seine in its depth of operation. The peculiarity of ring seines, which are mostly operated in depths of 10-30m, is that the bottom of the net touches the seabed, unlike deep sea oceanic purse seine operations. In ring seine, the depth of the gear (which is mostly 80-100m) is more than three times the depth of the water column, the excess webbing create a shallow bag like structure after shooting the net. It helps to prevent fish escapement through jumping over the float line. Modern ring seine net is a combination of webbing panels with different mesh depth and hanging ratios.

After shooting, like in a purse seine, in ring seine also there is a high chance of fish escapement under the lead line and the open ends of the net. Hence, the efficiency of the fishing operation is mainly dependent up on the sinking speed of the gear, water current and speed of effective closing of open ends. Purse seine is considered as the one of the bulk catching mode of fishing and any of the above parameter affect the efficiency of this gear. In the initial stages, suggestions derived from mechanical properties of webbing material were used as tool for fishing gear efficiency studies (Konagaya, 1971; Kim and Park, 1995, 1998; Shin *et al.,* 1998; Kim, 2004). The use of underwater acoustic sensors were reported by Misund *et al.* (1992); Tenningen *et al.* (2015). In the recent past, numerical simulation approach has been used in application for understanding the underwater behavior of fishing nets (Lee *et al.,* 2005; Kim *et al.,* 2007; Hosseini *et al.,* 2011). Numerical hydroelastic behavior of purse seine nets and towing tank experiment (Riziotis *et al.,* 2012), numerical sinking resistance studies with different webbing twine diameter and leg length (Kim and Park, 1998), studies on shape of float line and lead line after the purse seine shooting (Kim and Park, 2009), computer aided simulation studies used for purse seine fishing gear performance (Kim *et al.,* 2007) and studies on purse seine volume and purse line tension during pursing in flume tank experiments (Kim, 1999) are some of the important studies in this field.

Effective encircling of a fish shoal with ring seine normally takes 8 to 12 minutes. Faster sinking speed prevents the escapement of fish shoal which move in a direction opposite to fishing operation and escape through the open ends and bottom portions of the gear. Fishermen are also aware about the importance of sinking speed in ring seine fishing and they tend to increase the weight of the sinker line for faster sinking of the net. The extra weight due to the addition of sinkers may tear the webbing when operation is carried out in muddy waters. The excess lead line weight increase the pursing time, the total weight and cost of the gear and makes handing/ operation more cumbersome. Typical mechanised ring seine operation is given in Fig.6.1.

Fig. 6.1 Ring seine under operation

Relationship between sinking speed and purse seine models of different hanging ratios were studied by Katiandagho and Imai (1985). Underwater camera aided purse seine fishing operation is not yet conducted (Zhou *et al.,* 2015).

Studies on the underwater behaviour and sinking speed of fishing nets are being carried out all over the world. Misund *et al.,*(1992) studied the variation of sinking speed in oceanic purse seine with varied mesh sizes and lead line weights and observed that the catch efficiency of purse seine depends on its length, depth, sinking speed, net type, hanging ratio, and the skill in operation among which, the sinking speed is one of the most important factor.

With the help of theoretical sinking speed studies, it is possible to calculate the time required for the gear to touch the bottom of the sea bed and the parameters influencing the sinking. Knowledge of sinking speed coupled with gear influencing parameters will help in adjusting the operational parameters. This will increase the efficiency of operation and reduce the production cost of ring seines. In ring seine, sinking speed and gear efficiency studies are limited. Edwin (1997) studied the material requirement for different ring seine gear in detail and regional design details were described by (Edwin & Das, 2015).

This chapter aims, primarily to develop a formula exclusively to calculate the sinking speed of ring seine and standardize the formula with acoustic sensor aided analysis and *in-situ* physical measurements. The study also aims at analysing the sinking pattern of ring seine webbing and parameters affecting sinking pattern of the gear and methods to increase its operational efficiency.

6.2 Materials and Methods

6.2.1 Derivation of the Modified Formula for Calculation of Sinking Speed

A modified formula was derived based on Dickson, (1980); FAO, (1990); Misund *et al.,* (1992) for seine nets operated along the shallow waters.

6.2.2 Sinking Speed Studies in Sea Conditions

To study the sinking speed in actual sea conditions, under water experiments were conducted in the clear waters of the Lakshadweep Sea, India. Three different mesh sizes of experimental panels of 10 meter in length and 50 meters in depth were used for the study. Sinking speed measurements were carried out in two ways. Simrad PI depth sensor were used for telemetric depth measurements and experienced scuba divers were engaged for physical monitoring of sinking speed at regular intervals (5, 10, 20, 30 m). Physical and sensor aided measurements were used to compare the results obtained from newly developed formula.

Two fishing vessels were used for a single experimental operation, one for webbing panel operation and one for sensor operation. Three skin divers were engaged one in the middle and two at the ends of netting panels to straighten the lead line in water surface for operation.

Scuba Pro dive computers and under water digital timers were used for physical measurement of sinking speed. Five digital timers and four digital dive computers were used for the study. All the five digital timers were set to uniform timing before starting the experiment. One timer was placed onboard to note the starting time and the remaining timers were with scuba divers positioned at 5m, 10m, 20m and 30m depth respectively. Dive computers were used by scuba divers for accurate depth monitoring under water. Each scuba diver noted the time taken for webbing panel to reach different depth intervals and recorded using an underwater slate. These readings were later used for calculating sinking speed at different depth classes.

For sensor aided reading, wireless telemetric sensors were attached to the centre portion of the webbing panel and the remote receiver placed at water surface. The receiver is connected to the monitor placed onboard and powered with 12V battery. The experimental sensors were made neutral buoyant with sufficient floats before operation. While operation, reading shown in the monitor was recorded continuously for future reference. Ten trials for each experimental panels were conducted with three different lead line weights. To avoid the heavy current near the shore, experiments were conducted in the deep sea area near to lagoons of Kavarathi Island, Lakshadweep.

6.2.3 Sinking Pattern Studies in Sea Conditions

Sinking pattern studies were conducted through personal underwater observation and documentation was with Hero GoPro under water cameras placed at different depth intervals (5, 10, 20, 30 m) in different angles. Sinking pattern studies of ring seine webbing panels are conducted in the clear waters of Lakshadweep Sea with the help of professional scuba divers and under water cameras. Six under water cameras were engaged for the study. Due to the absence of means communication with scuba divers while they are under water, no change could be made depending on the location of measurement and had to be set carefully prior to start experiment plan. The safe period for a scuba diver at 30m depth is less than 30 min and need to take a time break, experiment plan was prepared accordingly. The experimental operation including hauling of the wet webbing panels and underwater monitoring require trained professionals and for a single operation, minimum 5 scuba divers, 3 skin divers, 5 assistants for hauling and setting of the webbing, 2 for sensor operation and 2 in boat are required.

6.3 Result and Discussion

6.3.1 Derivation of the Modified Formula for Calculation of Sinking Speed

Although sinking speed has been worked out for purse seines that do not touch the sea bottom it is for the first time that a method was derived for calculation of sinking speed of a seine that layers towards the bottom portion. In case of purse seine operated in deeper waters, as described by Misund *et al.* (1992) the net during sinking has a snake part at the top, a twisted part and a straight part at bottom, whereas in the case of ring seine which is operated in shallow waters, the net sinks straight, due to excess weight of webbing, until the sinkers line touches the bottom.

This method for theoretical calculation of sinking speed was based on the methods of Dickson (1980); FAO (1990); Misund *et al.,* (1992) to suit the method of operation followed by ring seines used in shallow waters. The following parameters were taken for calculation of sinking speed viz. Specific weight of seawater (ρ), Acceleration of gravity (g), Twine drag coefficient (C_d), Skin friction drag (C_f), Hanging coefficient at float line (u_1), Hanging coefficient vertical direction (u_2), Knot dia.(d_k), Normal area of twine per unit length of headline (A_{ci}), Twine dia.(d), Bar length (a), Drag coefficent of sphere (C_k), Shadow drag coeffent (C_s), Area of webbing (As), Lead line sinking speed at depth z (v_z) and Lead line sinking speed at depth i (v_i). For the analysis, an assumption was made that the ring seine when sinking makes a straight path at all depths.

Weight of the webbing in air (g) W = H x L x Rtex/1000 x K (FAO,1990)

H	=	Number of rows of knots in the height of the netting 2 x number of meshes
L	=	Stretched length (m) of netting in operation
Rtex	=	The size of twine in the netting
K	=	Knot correction factor to take into account the weight of the knots (single knot)

Weight of the webbing in water (Kg) P = A x {1 - DW/DM} (FAO,1990)

A	=	Weight (kg) in air
DW	=	Density (g/cc) of water
DM	=	Density (g/cc) of material

Webbing surface area (m^2) $S = \frac{\left(\frac{N+n}{2}H\right)2a\phi}{1000000}(FAO,1990)$

N	=	Number of meshes at the top of the panel
n	=	Number of meshes at the bottom of the panel
H	=	Number of meshes in the height of the panel
a	=	Stretched mesh (mm)
ϕ	=	Diameter of twine (mm)

Drag coefficient of knotted mesh (Dickson, 1980)

$$C_{do} = \left\{ \left(C_d u_1^3 + C_f u_2^2 \right) \left[1 - \left(\frac{d_k}{d} \right) \left(\frac{d}{a} \right) \right] + \left[C_k \left(\frac{\pi}{8} \right) \left(\frac{d_k}{d} \right)^2 \left(\frac{d}{a} \right) \right] \left[1 - C_s \left(\frac{d}{a \times u_2} \right) \right]^{0.5} \right\}^2$$

C_d = Twine drag coefficient at 90^0 to current

C_f = Skin friction drag

u_1 = Hanging ratio along float line

u_2 = Hanging ratio in vertical direction

d_k = Knot diameter

d = Twine diameter

a = Bar length

C_k = Drag coefficient of a sphere

C_s = Shadow coefficient of a sphere

Sinking Speed (m/min^{-1}) (Z) = $\sqrt{\dfrac{G \times 2g}{\rho \times C_{d0} \times s}}$

G = Weight of purse seine material in water

g = Acceleration of gravity (m/s^2)

ρ = Density (g/cc) of sea water

C_{d0} = Drag coefficient of knotted meshes

S = Webbing surface area

Sinking speed =

$$\frac{\rho}{2g}\left\{(C_d u_1^3 + C_f u_2^2)\left[1-\left(\frac{d_k}{d}\right)\left(\frac{d}{a}\right)\right]+\left[C_k\left(\frac{\tau}{8}\right)\left(\frac{d_k}{d}\right)^2\left(\frac{d}{a}\right)\right]\left[1-C_s\left(\frac{d}{a\times u_2}\right)\right]^{0.5}\right\}^2\left[\left\{A_s v_Z^2+\sum_{i=1}^{5}\left(A_{ci}v_i^2\right)\right\}v_z^2\right]$$

Sinking speed calculation of a traditional ring seine with 20mm mesh size operated in 30m depth is described in Table 6.1.

Table 6.1 Characteristics of a one meter webbing panel operated at 30m depth and its sinking speed calculation

Twine drag coefficent (C_d)	:	1.00
Skin friction drag (C_f)	:	0.07
Hanging Coefficent Floatline (U_1)	:	0.53
Hanging Coefficent Vertical direction (U_2)	:	0.85
Knot dia./twine dia.(dk/d)	:	3.16
Twine Dia in mm (d)	:	0.50
Bar length in mm (a)	:	10.00
Drag coefficent of Sphere (C_k)	:	0.47
Shadow drag coeffent (C_s)	:	1.00
Pi	:	3.14
Mesh Size (mm)	:	20.00
Stretched depth (m) of netting (L)	:	30.00
Number of rows of knots in the height (H)	:	3000
Stretched length (m) of netting float line (L)	:	1.87
Stretched length (m) of netting lead line (L)	:	1.18
No. of meshes top panel	:	94.34
No. of meshes bottom panel	:	58.96
No. of meshes in height	:	1500.00
Rtex and m/kg	:	106.40
Knot correction factor(K)	:	1.40
Total PP Rope wt. (g) in meter	:	409.12
Total Pb Sinkers wt. (g) in meter	:	1318.68
Total Brass rings wt. (g) in meter	:	138.00
Density (g/cc) of sea water	:	1.026
Density (g/cc) of PA	:	1.14

Density (g/cc) of PP	:	0.91
Density (g/cc) of Pb	:	11.34
Density (g/cc) of Brass	:	8.60
Acceleration of gravity (m/s^2) (g)		9.81
Weight of Knotted netting in air (g)	=	843.17
Weight of PP rope in air (g)	=	409.12
Weight of Pb Sinkers in air (g)	=	1318.68
Weight of Brass rings in air (g)	=	138.00
Weight of Knotted netting in water (g)	=	84.32
Weight of PP rope in water (g)	=	-52.15
Weight of Pb Sinkers in water (g)	=	1199.37
Weight of Brass rings in water (g)	=	121.54
Total wt. of gear in kg	=	1.35
Drag coefficient knotted mesh	=	0.07
Area of webbing (As)	=	2.30
Sinking Speed m/min	=	**13.01**

The formula was applied for change in twine diameter, mesh size, lead weight and depth of operation for the above mentioned traditional ring seine with 20mm mesh size, 0.5 mm twine diameter and 1.32kg lead weight operating at 30 meter in depth

Among the parameters like mesh size, twine size, lead weight and depth of operation, mesh size and lead weight are directly proportional to sinking speed whereas twine diameter and operational depth are inversely proportional to sinking speed (Table 6.2 & Fig. 6.2). Increase of mesh size to 100%, 200% and 300% increased the sinking speed upto 66%, 117% and 161% respectively. On the contrary, reduction of 25%, 50% and 75% twine size increase the sinking speed upto 25%, 67% and 161% respectively. As the lead weight is increased, the change in sinking speed is limited compared to mesh size. If the lead weight is increased to 100%, 200% and 300%, the sinking speed increase to 32%, 58% and

80% only. Considering the depth of operation, 25%, 50% and 75% reduction increases the sinking speed upto 14%, 38% and 94% respectively.

Table: 6. 2. Change in sinking speed with variation in parameters

Sl. No.	Mesh size (mm)	Sinking Speed (m/min)	Twine Dia. (mm)	Sinking Speed (m/min)	Lead wt. (g/m)	Sinking Speed (m/min)	Depth (m)	Sinking Speed (m/min)
1	10	7.82	0.20	23.77	500	8.72	10	22.05
2	12	8.99	0.24	21.25	600	9.35	12	20.18
3	14	10.09	0.28	19.27	700	9.94	14	18.72
4	16	11.12	0.32	17.67	800	10.50	16	17.55
5	18	12.09	0.36	16.34	900	11.02	18	16.58
6	20	13.01	0.40	15.21	1000	11.53	20	15.76
7	22	13.88	0.44	14.24	1100	12.01	22	15.06
8	24	14.72	0.48	13.39	1200	12.48	24	14.45
9	26	15.52	0.52	12.64	1300	12.92	26	13.91
10	28	16.28	0.56	11.97	1400	13.36	28	13.43
11	30	17.03	0.60	11.38	1500	13.78	30	13.01
12	32	17.74	0.64	10.84	1600	14.18	32	12.62
13	34	18.43	0.68	10.34	1700	14.58	34	12.27
14	36	19.10	0.72	9.90	1800	14.96	36	11.95
15	38	19.75	0.76	9.48	1900	15.34	38	11.65
16	40	20.38	0.80	9.11	2000	15.70	40	11.38

This method shows that mesh size, twine size and sinker weight are the main factors influencing the sinking speed of ring seines. Among this, mesh size and twine size are contributing more to sinking speed. Increase of mesh size to 100% or reduction in twine size to 50% will increase the sinking speed up to 66%, but in case of lead weight, it required more than 240 % increase to get the same speed. Earlier studies of Iitaka (1971) reported that the sinking speed and lead line weight exhibit a linear relationship, where in sinking speed is related to square root of lead weight. Results obtained by Misund *et al.,* (1992) commensurate with the present study.

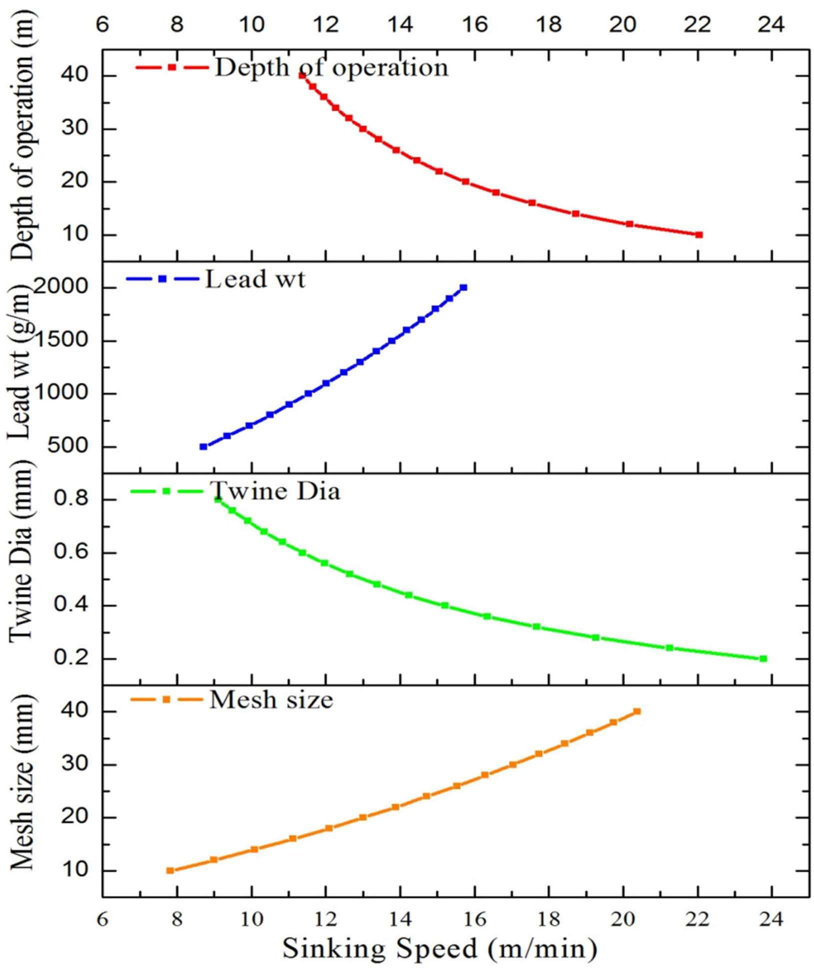

Fig. 6.2 Change in sinking speed with varying parameters like depth of operation, lead line weight, twine diameter and mesh size

6.3.2 Sinking Speed Studies in Sea Conditions

Sinking speed studies of ring seine panels were conducted in the open waters of Lakshadweep Sea with three most common mesh sizes used in Kerala. The design and dimensions of webbing panels used for the study are given in Fig.6.3 to 6.5.

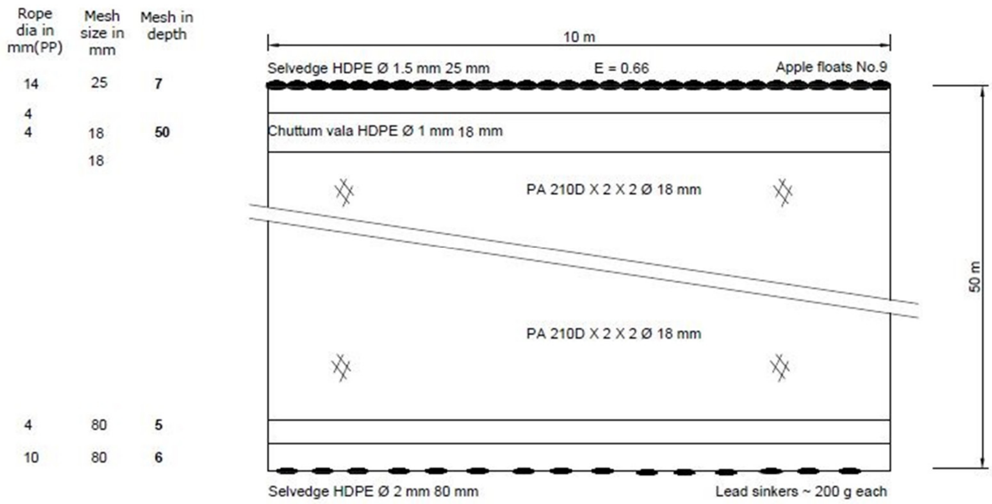

Fig. 6.3. Ring seine experimental panel design-RS 1, 18mm

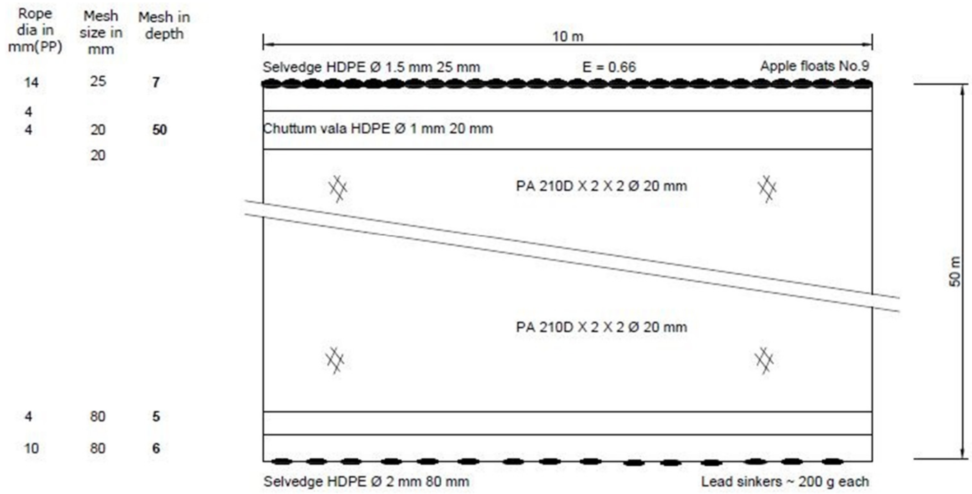

Fig. 6.4. Ring seine experimental panel design-RS 2, 20mm

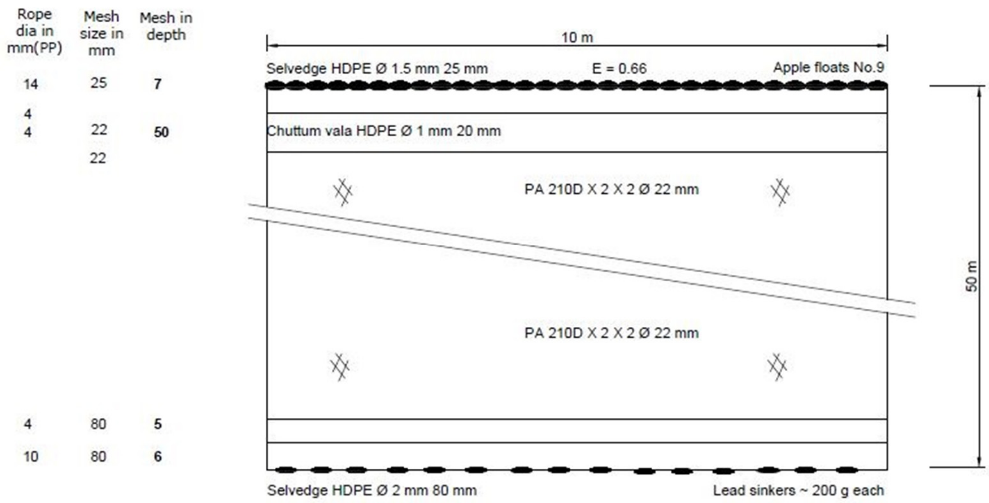

Fig. 6.5. Ring seine experimental panel design-RS 3, 22 mm

Each design was tested with three different lead line weight at five different depths. The study is limited to compare the sinking speed with varying mesh size and lead weight due to the commercial unavailability of same mesh size webbing with different twine size and material. Among the three experimental panels design, RS 3 showed maximum sinking speed in all the depths with different lead line weight. Change in sinking speed with change in depth, lead and mesh size showed significant variations ($P<0.05$) and the result obtained from direct scuba observation and sensor readings are not significantly varied ($P<0.01$). Lead weight and depth shows visible changes in sinking speed during operation and the influence of mesh size change is limited, because the change in mesh size is limited to 10-20% where as in lead weight and depth the change was 100-200% (Table 6.2 & 6.3). There are no reports on ring seine webbing (20mm) sinking speed studies and study conducted in purse seine webbing with depth sensors confirmed that the sinking speed varied with mesh size and lead weight (Misund *et al.,*1992).

Table 6.3 Average sinking speed to different depth for webbing panels with different mesh size (observation by scuba divers)

		Design RS 1 (18mm)				Design RS 2 (20mm)				Design RS 3 (22mm)			
	Depth (m)	**5 m**	**10 m**	**20 m**	**30 m**	**5 m**	**10 m**	**20 m**	**30 m**	**5 m**	**10 m**	**20 m**	**30 m**
Lead line wt. 1kg/m	Time taken (sec)	13.0	35.0	96.0	174.0	12.0	32.0	90.0	162.0	11.0	31.0	85.0	152.0
	Sinking speed calculated (m/min)	23.1	17.1	12.5	10.3	25.0	18.8	13.3	11.1	27.3	19.4	14.1	11.8
Lead line wt. 2kg/m	Time taken (sec)	10.0	26.0	72.0	129.0	9.0	25.0	67.0	121.0	8.0	23.0	62.0	113.0
	Sinking speed calculated (m/min)	30.0	23.1	16.7	14.0	33.3	24.0	17.9	14.9	37.5	26.1	19.4	15.9
Lead line wt. 3kg/m	Time taken (sec)	8.0	22.0	60.0	108.0	8.0	20.0	56.0	101.0	7.0	19.0	53.0	95.0
	Sinking speed calculated (m/min)	37.5	27.3	20.0	16.7	37.5	30.0	21.4	17.8	42.9	31.6	22.6	18.9

Table 6.4 Sinking speed of different webbing panels in varied webbing panel parameters (sensor reading)

	Design RS 1 (18mm)				Design RS 2 (20mm)				Design RS 3 (22mm)			
Depth (m)	**5 m**	**10 m**	**20 m**	**30 m**	**5 m**	**10 m**	**20 m**	**30 m**	**5 m**	**10 m**	**20 m**	**30 m**
Sinking speed (m/min) with 1kg lead wt./m	24.75	19.91	14.27	13.08	27.09	20.84	15.60	14.21	29.13	21.41	16.20	15.19
Sinking speed (m/min) with 2kg lead wt./m	32.01	25.60	18.68	15.99	35.38	26.58	19.63	18.31	39.36	28.61	21.40	18.84
Sinking speed (m/min) with 3kg lead wt./m	39.16	29.27	21.66	18.73	39.29	32.08	23.47	20.61	44.50	34.05	25.00	21.88

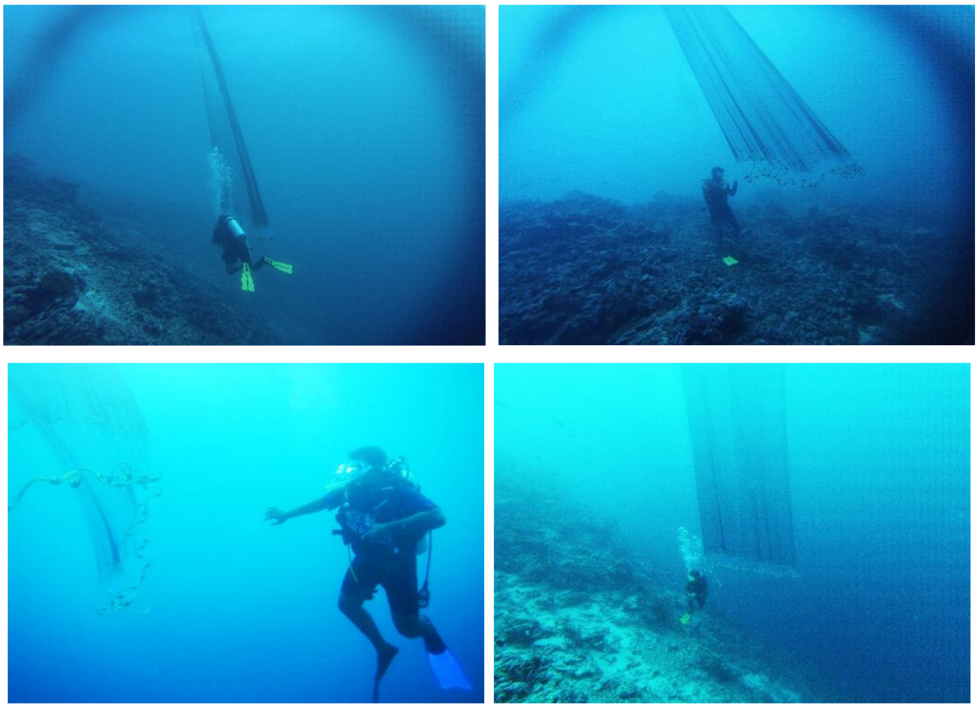

Fig. 6.6 Different stages of physical observation of sinking speed with scuba divers

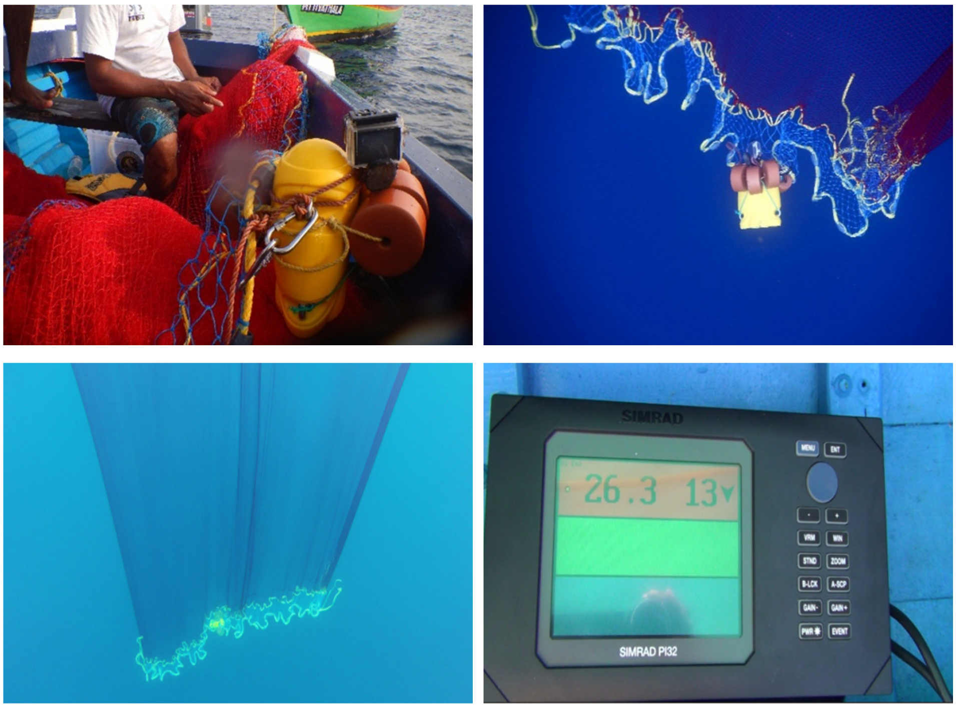

Fig.6.7 Different stages of depth sensor experiment

6.3.3 Sinking pattern studies in sea conditions

Sinking pattern studies are very important for analysis of the efficiency of the gear. Damage of fishing gear in monsoon season is the most common phenomenon in ring seine fishery. One of the reasons for gear damage and tearing of webbing is because of rough sea. The influence of water current on sinking pattern of webbing while operation are unknown. In real time, sinking pattern study of ring seine gear in fishing operation is very difficult due to the low visibility and high turbidity in near shore areas.

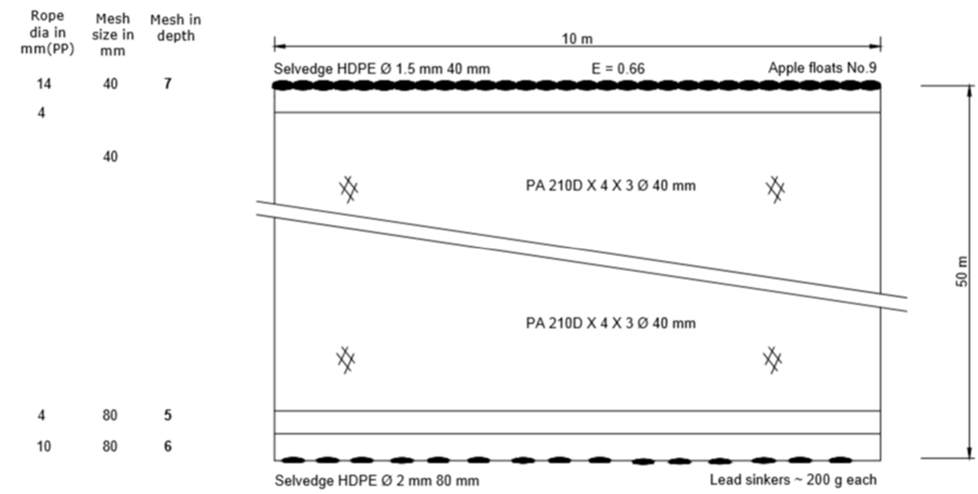

Fig.6.8 Experimental panel design-RS 4, 40mm

Influence of water current on the webbing panels were studied in the high wave action areas of Kavarathi Island in Lakshadweep Sea. Four different mesh sizes of webbing panels were used for the operation with 18mm, 20mm, 22mm, and 40mm respectively (Fig.6.3, 6.4, 6.5 and 6.8). In the present study it is observed that design RS 1 is more sensitive to water current and the design number RS 3 is less sensitive towards current. To confirm influence of mesh size to water current one large mesh sized (40mm) panel (Fig.6.10) was used simultaneously. Compared to large mesh panel the deviation of the small mesh panel in the direction of water current is very high. This was observed only in the first five meter depth, rest of the panel moved in a straight path in water column. After the lead line touches the bottom webbing panels keep in sinking until tight the float line at water surface, with a sinking speed less than 3 m/min. The excess webbing move freely along with the water current.

Fig. 6.9 Influence of water current on 20mm webbing panel

Fig.6.10 Influence of water current on 40mm webbing panel

Fishing efficiency of ring seine depends not only on the sinking process, but also the spatial arrangement, net volume and movement of gear. The factors influencing fishing efficiency have close relationship between water current and direction. This study helped to determine the effect of different mesh sizes relative to current direction on the movement and sinking pattern of the ring seine net. The shape of webbing and position of lead line and float line represent the net geometry. Water current influence the geometry and cause deformation of fishing net and reduction of net volume, which may lead to overcrowding, high mortality and escapement of fish (Tenningen *et al.,* 2015). The results proved that the current direction affect the sinking behavior of lead line. Depending upon the shooting direction in tandem to the water current, helps to improve the fishing efficiency of ring seine. Results revealed that when there is change in water current, pattern of deformation is high in small meshed (18mm) webbings than the large meshed one (40mm). Model experiments conducted on shooting patterns by Zhou *et al.* (2015) observed that shooting against water current is the optimal strategy for purse seine operation.

6.4 Conclusion

The major factors influencing the sinking speed were twine size and mesh size. Experimental ring seine panels of 22mm mesh size were having maximum sinking speed. Instead of increasing the lead weight, use of species specific optimum mesh sizes and appropriate twine sizes will give good results for enhanced sinking speed. Material substitution of polyamide webbing with Ultra High Molecular Weight Polyethylene (UHMWPE) can reduce the twine size by half and will also enhance the sinking speed up to 100%.

Sinking pattern studies brought to light the problems faced by the ring seine fishermen in monsoon season. In the recent past, to capture small size pelagic species and shrimps, ring seine fishers of Kerala have reduced the mesh size up to 5mm with the same twine size. The reduced mesh size increases the drag and the comparatively low strength of polyamide webbings fail to tolerate the high drag and leads to damage of webbing.

Rigging of webbing panels

Transportation of webbing panels

Loading to the vessel

Site selection for experimental operation

Preparation for experimental operation

Webbing panel under observation

Plate-8 Different preparatory stages of underwater sinking speed studies

Chapter

7

SPATIAL AND SEASONAL DISTRIBUTION OF FISHING GROUNDS

Contents

7.1 Introduction

The pelagic fishery resources play a significant role in Indian marine fish production (CMFRI, 2015). This group exhibits rich species diversity and abundance in the Indian EEZ with 240 species (Pillai & Ganga, 2008) and it contributes about 55% of the marine landings. Small pelagics such as the Indian oil sardine and Indian mackerel together contribute 21% of the catch (CMFRI, 2011). In Kerala, these two species together contribute 67% of the total landings and the artisanal ring seine fishery is the major contributor with 98.8% of oil sardine and 56% of mackerel landings (CMFRI, 2011). Ring seines are classified under surrounding nets or encircling nets and come under the group of active fishing gear (Nedlec, 1982; Brandt, 1984; Ben-yami, 1994; Edwin & Hridayanathan, 1996; Sainsbury, 1996; Hameed & Boopendranath, 2000). The dependence of a large number of artisanal fishers on pelagic fisheries underlines the socio-economic importance of this fishery. The most prominent feature of the pelagic fisheries is their seasonal migration and extreme annual fluctuations (Pillai & Ganga 2008; Pillai & Nair 2010). The effort expended in locating these pelagic shoals leads to wastage of fuel and time which makes fishing operation uneconomical. Spatial information and mapping tools throw light on the distribution and abundance of pelagic fishes (Watson *et al.*, 2006). The spatial distribution knowledge of the fishing grounds and the ability to analyze the variability of species composition in the resulting regions leads to its sustainable management and helps us in protecting the marine ecosystem from stress (Botsford *et al.,* 1997; Babcock *et al.,* 2005).

Many researchers have studied the spatial analysis and seasonal variation of the fisheries worldwide. Silvano & Begossi (2001) studied the small-scale fishery in the Piracicaba River in southeastern Brazil, with regard to the diversity, quantity and composition of fish catches by different seasons. Axenrot & Hansson (2004) quantified pelagic fish abundance in coastal area of Baltic Sea using hydroacoustics method and the variation, expressed with the help of geostatistical coefficient of variation and observed intra-annual dynamics in acoustic fish abundance, densities and size composition. Wilde & Paulson (1989) studied the spatial and temporal patterns in fish abundance in Lake Mead, Arizona-Nevada with non-parametric statistical methods. The spatial and temporal distribution patterns of cuttlefish abundance and its relationships with environmental variables in the French Atlantic coast, the English Channel using geographical information system and statistical methods was studied by Wang *et al.* (2003).

The geostatistics application to study spatial distribution started in 1950s and 1960s as autocorrelation model and has been extensively used for ecological studies in 1970s and 1980s (Berry & Marble, 1968). In 1990s, it became the main statistical method used for spatial application (Deutsch, 2002). Geostatistics application on demersal fishery resources was widely used few decades ago (Petitgas & Poulard, 1989; Sullivan, 1991; Freire *et al.,* 1992; Simard *et al.,* 1992; Gurriarán *et al.,* 1993; Pelletier and Parma, 1994; Maynou *et al.,* 1998; Maynou, 1998). Petitgas (1993) studied the geostatistical application on the stock assessment of pelagic fishes. Small pelagic fishes have extensive variations in both, their distribution and abundance over time (Kawasaki 1984., Lluch-Belda *et al.,* 1989) influenced by seasonal, inter-annual and decadal marine climate variations (Lluch-Belda *et al.,* 1989; Bakun & Broad 2003; de Young *et al.,* 2004).

Generalized Additive Models (GAM) are used for stating the relationship between response and predictor variables with the help of nonparametric and semi parametric techniques. The peculiarity of GAM is that there is no need to make any prior assumption on the functional form linking the two set of variables, as these relationships are modelled with smooth functions. The applications of GAM in marine ecology and fisheries spatial data are numerous (Rossi *et al.,* 1992; Maravelias *et al.,* 2000; Guisan *et al.,* 2002). The main application of the GAM is modelling different functional responses between the species and the co-located environmental variables (Ciannelli *et al.,* 2008). Mapping global landings is an important prerequisite for examining causal relationships between fishing and ecological change. The west coast of India experiences intense rainfall activity during the summer monsoon season, and is also influenced by large cloud cover (Suprit & Shankar, 2008) which adversely affects the satellite aided fishing and fishery forecasting (Ravichandran *et al.,* 2012). In these circumstances, time series catch data aided models will help to predict the fishing zones more accurately.

The primary objective of the present study is to identify and characterize abundance and spatial distribution of small pelagic fish of South Eastern coastal Arabian Sea with respect to different seasons. The secondary objective is to develop an algorithm to predict the major pelagic fishing grounds for traditional fishers to reduce fuel and time spent for searching the fishing ground.

7.2 Materials and Methods

The study was carried out in southern Kerala coast, part of south eastern Arabian Sea. The ring seine fishing is said to have been first introduced in this stretch of the coast (Panicker *et al.*, 1985). The present study was conducted during June 2012 to May 2014. Detailed species wise daily landing information and fishing area (GPS locations) were collected from ring seine vessels operating in this region. The data for 1162 fishing trips of 36 fishing vessels were collected. Details of units selected are given in Table 7.1. Fishing area, GPS data on latitude and longitude expressed in degree were collected with the help of Marine GPS/WAAS Navigator fixed on board. Catch and species wise information were collected from log books maintained in the vessel. Non-target fishes and the accidental occurrence of high value fishes, which comprises a negligible fraction of the total catch, were excluded from the study. For analytical purpose, months were grouped in seasons: pre monsoon (February-May), monsoon (June-September) and post monsoon (October-January). The analyses comprises of characterization and illustration of fish yield (abundance) distribution using geostatistical analysis and estimation of yield abundance in terms of spatial parameters using statistical modeling techniques.

Table 7.1 Details of the ring seiner selected for the study

Sl.No	Craft Name	Year of construction	Category	Construction Material	L_{OA} (m)	Gear	Length (m)
1	Air India	2008	IBM	Steel	23.3	Thanguvala	910
2	Aquilas	2009	IBM	Steel	19.7	Choodavala	728
3	Arakkal	2007	IBM	Steel	19.7	Thanguvala	819
4	Arrow/Penuvel	2007	IBM	Wood	21.2	Thanguvala	819
5	Avemarry	2009	OBM	Wood	13.3	Choodavala	273
6	Beselial	2010	IBM	Steel	23.3	Thanguvala	1000
7	Beyoola	2010	IBM	Steel	22.7	Thanguvala	910
8	Commrade	2007	IBM	Steel	22.4	Thanguvala	819
9	Deiva kripa	2005	IBM	Steel	21.2	Choodavala	273
10	Ealiya	2007	IBM	Wood	21.2	Choodavala	273
11	Emmanual	2010	IBM	FRP	22.4	Thanguvala	1000
12	Fortune	2009	OBM	Wood	13.3	Choodavala	273
13	Freedom	2007	IBM	Wood	21.2	Thanguvala	819
14	Israyel	2009	IBM	Steel	23.3	Thanguvala	910
15	Japamala	2008	OBM	Wood	22.4	Choodavala	273
16	Joshya	2008	IBM	FRP	22.4	Thanguvala	910
17	Joyal	2007	OBM	Wood	12.1	Choodavala	273
18	Kripa	2007	OBM	Wood	13.3	Choodavala	273
19	Kripasanam	2007	IBM	Steel	22.7	Thanguvala	910
20	Madapravu	2008	IBM	Steel	22.4	Thanguvala	910
21	Marrymatha	2008	OBM	Wood	13.3	Choodavala	273
22	Nallidayan	2007	OBM	Wood	13.3	Choodavala	273
23	Nauma	2007	IBM	Wood	20.6	Thanguvala	819
24	Pishone	2010	IBM	Steel	22.4	Thanguvala	910
25	Ponnonam	2007	IBM	Steel	21.2	Thanguvala	728
26	Prapancham	2007	IBM	Wood	22.7	Thanguvala	910
27	Rose mary	2004	IBM	FRP	18.2	Choodavala	637
28	Rubel	2008	IBM	Steel	22.7	Thanguvala	910
29	Sammuval	2005	IBM	Steel	19.7	Choodavala	728
30	Samudra	2007	IBM	Steel	21.2	Thanguvala	910
31	St: Joseph	2009	OBM	Wood	13.3	Choodavala	300
32	St: Mary	2008	IBM	Steel	19.7	Choodavala	728
33	Udhanam	2007	IBM	Steel	18.2	Thanguvala	546
34	Yahovaneesi	2008	OBM	FRP	14.8	Choodavala	282
35	Yona/Bencristy	2007	IBM	Wood	21.2	Thanguvala	819
36	Zion	2004	IBM	Steel	23.3	Thanguvala	910

To identify the spatial distribution of the two dominant pelagic fish species (*Sardinella longiceps* and *Rastrelliger kanagurta*), one way analysis of variance was used to test the effect of season as an independent factor on catch abundance. The average successful fishing days during different seasons were compared by using Tukey test. The Catch Per Unit Effort (CPUE) has been estimated as kg/day/boat (El-Haweet *et al.*, 2004). The spatial distribution of abundance of pelagic fish in relation to the shooting area was mapped using ODV (Ocean Data View) freeware package for the oceanographic visualization software (Schlitzer, 2011) with respect to latitude and longitude. A two dimensional contour map of fish yield was also drawn to get an idea of variability in the yield.

The spatial dependence/characterization of fish yield was quantified using variogram. Standardized semi variogram on season wise sardine and mackerel catch was computed and plotted for analyzing the spatial distribution of fish abundance. Euclidean distance on fish yield of each species during different seasons was computed for each pair of observation $|N(\theta_k, L)|$ on response variable at Yi several fishing location (Latitude and longitude). The sample standardized semivariogram at a specific lag-distance h, is estimated on all pair of points separated by the distance 'h' is given by

$$\hat{\gamma}(h_k) = \frac{1}{2|N(\theta_k, L)|} \sum p_i p_j \in N(\theta_k, L) \left[V(s_i) - V(s_j) \right]^2$$

Where h_k in the average distance in class (θ_k, L)

i.e, $h_k = \frac{1}{|N(\theta_k, L)|} \sum p_i p_j \in N(\theta_k, L) \left| p_i p_j \right|$

$\left(p_i p_j \right)$ is (I, j)th pair of observation.

Then, from each sampling point Si, the distance to each location is computed and arranged according to the specified distance classes. The squared difference of density values for each pair of samples pertaining to a given lag is then computed. Finally the estimated variogram value for a given lag is obtained, dividing the sum of squared differences by the number of pairs of sampling points pertaining to this lag. The semivariogram estimates was used to illustrate the spatial data as a function of correlation structure of dependent variable (fish yield) and the location parameters (latitude and longitude) (Matheron, 1963; Schabenberger & Gotway, 2005).

The next step was to develop the algorithm for predicting spatial occurrence. The statistical modelling techniques of spatial data considered here is an extension of the regression analysis when the linearity assumption do not assume and thus use multiple penalized regression splines, known as Generalized Additive Model (Hastie & Tibshirani, 1990; Wood, 2004). Generalized Additive Model (GAM) with usual regression parameters and smoothing parameters for latitude and longitude was used to estimate the fish abundance with respect to location parameters and it was done separately for sardine and mackerel catch/yield. GAM, function of additive explanatory variable was used to establish a relationship between the mean of the response variable and a 'smoothed' function of the explanatory variable(s) (Hastie and Tibshirani, 1986).

i.e.

$$\left(Yi/X \right) = \beta_0 + \beta_1 (X_1) + \beta_2 (X_2) + S_1 (X_1) + S_2 (X_2) + \varepsilon_i$$

Where

Y_i= Fish yield

X_1= Latitude q

X_2= Longitude

$\beta_1 + \beta_2$ are linear regression coefficient q

S_1 = Smoothing function of latitude

S_2 = Smoothing function of longitude

ε_i = Error term

The usual regression parameters were estimated by ordinary least square method and the smoothing parameters were estimated by using Back fitting algorithm. All the statistical analysis was carried out using SAS 9.3. (SAS, 2012)

7.3 Result and Discussion

7.3.1 Abundance and Spatial Distribution

The total quantity of the fish caught during the study period was 3635.25 tonnes from the selected ring seines. According to CMFRI (2012c), pelagic fish resource contribute 73% of the total Kerala landings, in this 73.5% were contributed by sardine and mackerel and ring seine contribute 97.9 % of sardine and 68.3% of mackerel landings of Kerala state. The total successful fishing days during the period of study in pre-monsoon, monsoon and post-monsoon seasons were 184, 230 and 165 days respectively and CPUE were 3335.21±1836.19 kg day^{-1}, 5799.36±2159.33 kg day^{-1} and 3366.97±2104.59 kg day^{-1} respectively. Das *et al.* (2012) observed large number of ring seine operation in the same region during monsoon season. Boopendranath and Hameed (2012) reports that monsoon period showed high landings in ring seines.

The contour plot of sardine and mackerel yield during different seasons is given in Fig. 7.1. and it is noticed that the data expressed spatial variability in the fish abundance for both sardine and mackerel. The fish yield data incurred lots of scattered patterns in all seasons because of the catch variability in the ring seine fishery in different seasons. Sardine and mackerel showed a variability of 1-12 and 1-14 ton respectively. The catch obtained in the individual ring seines is not directly proportional to the fish abundance because success of ring seine fishing is influenced by many factors like water current, wind direction, experience of the crew, skill of the master, etc. (Das *et al.*, 2012). Only an experienced master fisherman can predict the fish shoal movement and decide the direction of encircling. Minor mistakes in the prediction causes a failure of the operation or leads to loss of a major portion of the fish shoal. In monsoon season, the prediction of fish shoal and the operation of the gear becomes difficult due to the rough sea. The chances of escapement of fish shoal is also high during this period and may be because of this reason, variogram of monsoon season showed a large scale variability than other seasons.

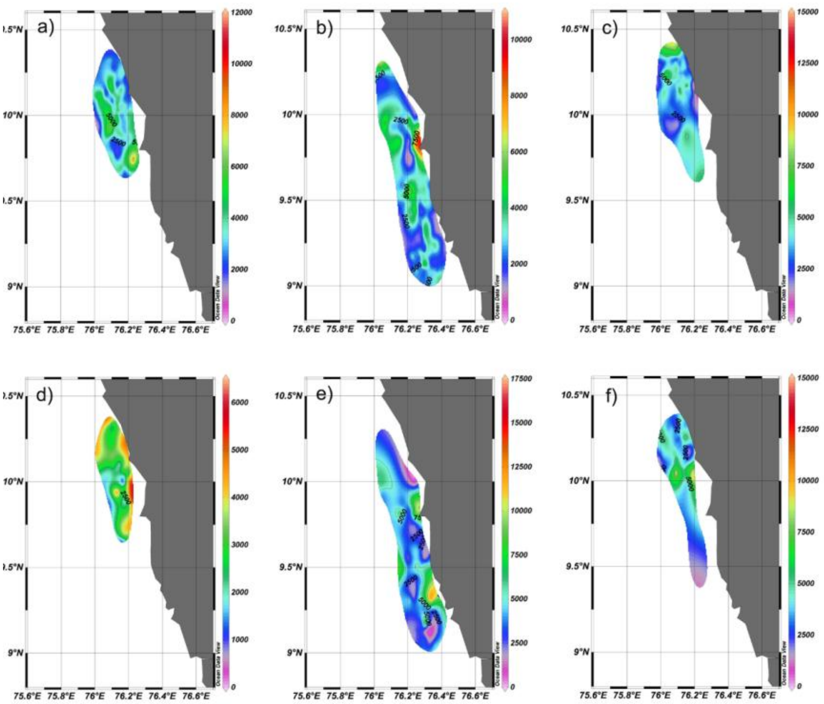

Fig.7.1 Contour plot of yield of ring seine yield, plots a, b and c represents sardine yield and plots d, e and f represents mackerel yield for the seasons pre monsoon, monsoon and post monsoon respectively.

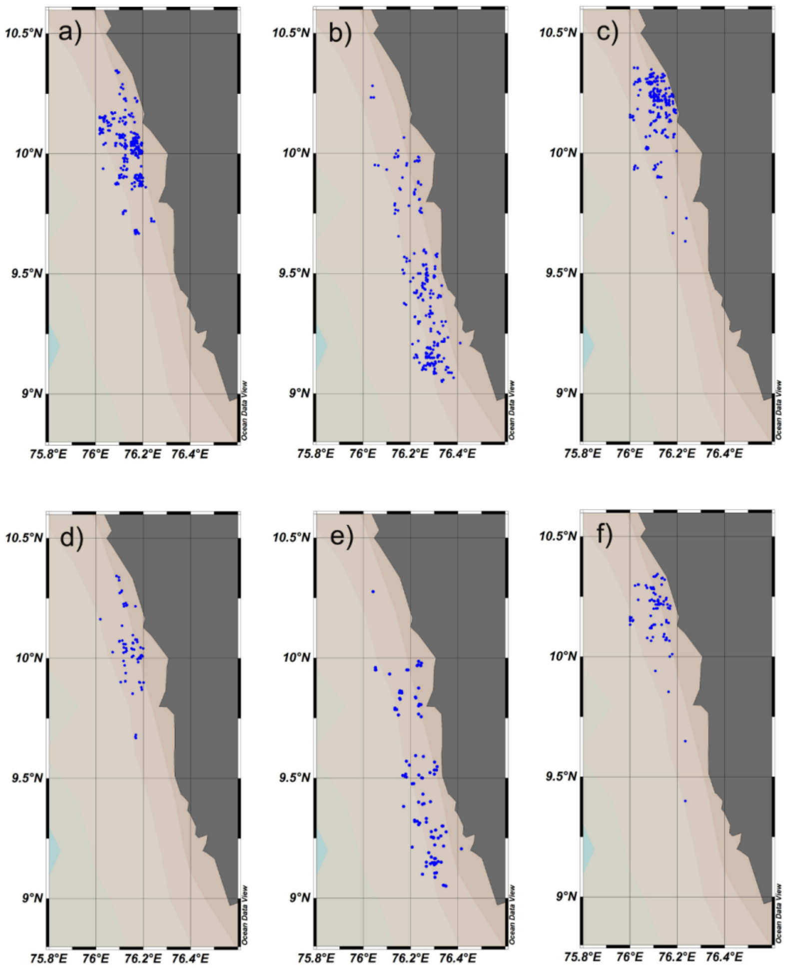

Fig. 7.2 Seasonal distribution of pelagic fish abundance, plots a, b and c represents sardine yield and plots d, e and f represents mackerel yield for the seasons pre monsoon, monsoon and post monsoon respectively.

The pelagic fish was mainly distributed spatially over the three seasons viz. pre-monsoon, monsoon and post-monsoon. The range of fish distribution varied from 9.050-10.355N to 76.00-76.415E and the spatial distribution variability of sardine and mackerel abundance is depicted in figure 7.2. There exists no significant difference between the variability of sardine and mackerel yield during different seasons. But it exhibited a significant difference ($P<0.05$) of seasonal shift of fishing ground and it showed a clear sign of spatial displacement. During monsoon season, fishing ground shifted below 9.5^0 N, exhibiting a southward shift of fishing ground during the period.

The spatial dependence of sardine and mackerel yield abundance was also computed by standardized semi variance and plotted against the distance (Fig.7.3). The standardized semivariogram of pre monsoon sardine yield showed a maximum displacement up to 0.5° lag distance and the maximum fishing activity were concentrated at the lag distance between 0^0 to 0.3^0 (Fig 7.3.a). The standardized semivariogram of sardine yield at pre monsoon season produced a sill and nugget approximately at 1^0 and the variability showed a uniform pattern of fish catch in the entire season and this is well supported in the contour plot of pre monsoon sardine catch. The standardized semivariogram of sardine yield during monsoon noticed wide range of spatial variability ranging between 0^0 to 0.8° lag distance (Fig 7.3.b) as compared to other seasons and showed a scattered pattern in the season because of the high rate of variability in the catch and fishing area and the variability of yield which is plotted in Fig 7.1.b. The standardized semivariogram (Fig 7.3.c) of sardine yield during post monsoon period ranged between 0^0 to 0.4° and the displacement of points in the semivariogram showed non-uniformity which had much variability than pre monsoon yield.

The standardized semivariogram of mackerel yield during pre monsoon showed slight increasing trend and the range was between 0° to 0.6° lag distance and had a comparatively higher sill than sardine yield. The area of fish distribution was concentrated between 0° to 0.4° lag distance (Fig.7.3 d). The standardized semivariogram of mackerel yield during monsoon showed a uniform distribution of data points as compared to the sardine yield and the range of fishing area distribution observed between 0° to 0.8° lag distance is same as sardine yield (Fig.7.3 e). The standardized semivariogram of mackerel yield during post monsoon showed a slight increase up to 0.3° lag distance and started decreasing afterwards. The sill of the semivariogram was nearly 2. The fishing area distribution during the season varied between 0° to 0.4° lag distance and maximum concentration was between 0° to 0.2° (Fig.7.3 f).

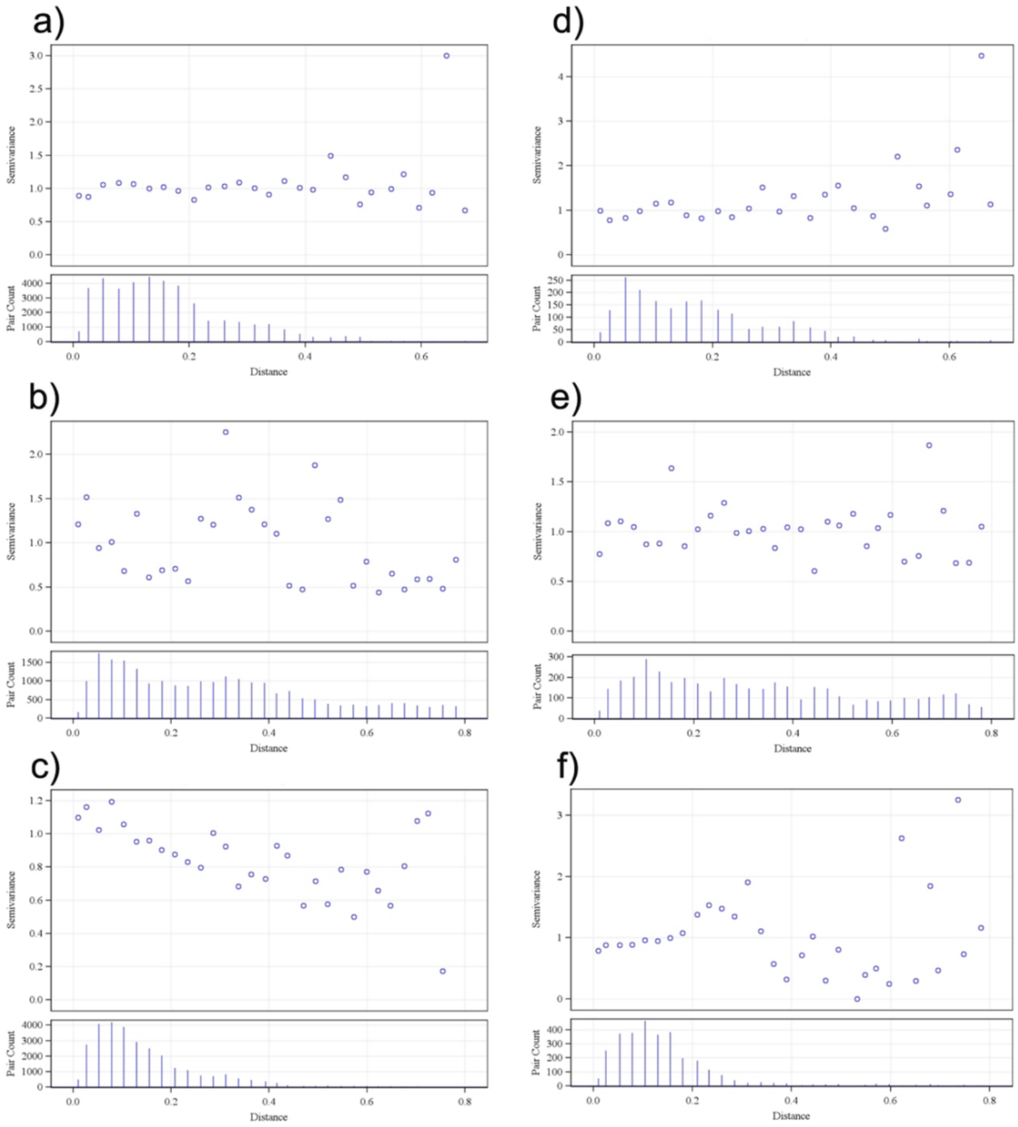

Fig 7.3 Empirical Semivariogram for ring seine yield. Plots a, b, c represents sardine yield and plots d, e and f represents mackerel yield for the season's pre monsoon, monsoon and post monsoon respectively. The longitudinal distance of fishing area is plotted in X axis against standardized variance of fish yield and pair count frequency in Y axis.

The semivariogram shows that pre monsoon and post monsoon seasons have less variability with respect to fishing areas than the monsoon season. In the monsoon season, the fish availability is widely spread across the entire coastal area due to the monsoonal upwelling in the west coast side of India. The result of the present study is in conformity with the observations of Pillai *et al.,* (2000) which states that topographical features and meteorological condition influence the distribution pattern and seasonal abundance of fishes in India.

The standardized semivariogram showed nearly similar pattern in sardine and mackerel yield for pre and post monsoon period, but a southward movement of fishing ground was observed in monsoon season. Based on these characteristics, it was inferred that sardine and mackerel yield abundance was depending on spatial parameters viz. latitude and longitude during different seasons and it is evident from the Fig.7.2. The Arabian sea is considered as one of the highest productive regions of the world ocean (Madhupratap *et al.,* 1996) and shows distinct seasonal variabilites (Madhupratap *et al.,* 1996; Murtugudde *et al.,* 1999; Kumar *et al.,* 2001a, 2001b; Paul & Kumar, 2005; Wiggert *et al.,* 2005; Levy *et al.,* 2007). During the monsoon, strong coastal upwelling leads to high productive region along the Somalia, Arabia, and the southwest coast of India (Kumar *et al.,* 2001a; Wiggert *et al.,* 2005; Levy *et al.,* 2007). This coincides with the fact that during the south west monsoon season, the southern side of Kerala coastal area shows a unique nature of fish aggregation phenomenon known as *chakara* (mud bank formation) (Damodaran 1972; Mathew & Gopinathan 2000). This area is an active feeding and breeding site for many of the pelagic fishes and crustaceans and this may be the reason for the shift of fishery towards the south region in monsoon season. According to Pillai & Nair (2010), pelagic fish exhibited vertical migration in post monsoon and pre monsoon seasons for avoiding the comparatively warmer surface water and this tendency is found more or less during all the months except during the monsoon season. This type of migration influences the occurrence of surface fish shoal.

Season wise revenue obtained showed slight increase in monsoon season with 26.31 million Indian rupees and 18.56 and 19.45 million Indian Rupees (₹) in post and pre monsoon season respectively. All these factors point out to the high abundance of pelagic catch during monsoon. Compared to pre monsoon and post monsoon (15183.48 ± 6126 and 18239.94± 9406 ₹/day) the monsoon season showed high operational expense (22088.54± 9223 ₹/day) because of the shift of fishing ground towards south and the fishermen travel more distance (58.3880 ± 29.84 km) to reach fishing ground in monsoon season than the other seasons (pre monsoon 21.8259 ± 17.19 km; post monsoon 31.2988 ± 8.58 km). The average operational expense for one ring seine fishing trip was 18331.58 ± 8730.60 ₹/day and the 87% of the total expense is spent as fuel cost. An average fishing trip takes 12.28 ± 2.06 hours of operation. The cruising time to the fishing ground and the fishing operation takes less than 45% of the total fishing time and major time was spent for searching for shoals for which maximum fuel is consumed.

7.3.2 GAM of Ring Seine Fishing Grounds

The spatial distribution of sardine and mackerel abundance was highly volatile over a range of spatial variables viz; latitude and longitude. The fit summary of the estimated spline parameter and corresponding degrees of freedom of the resultant model for sardine and mackerel yield is plotted. An attempt is made to estimate the sardine and mackerel yield during different seasons in terms of latitude and longitude using GAM in Fig.7.4. In pre monsoon season, sardine fishing ground showed a strong positive relationship between 10.1°N to 9.9°N latitude after 10.1°N exhibited a sharp break. In monsoon season, the fishing ground exhibited a positive relation between

9.8°N to 9.25°N and in post monsoon season, it showed in between 10.3°N to 10.1°N. It is clearly evident that the ring seine fishing ground shows a displacement with seasons and the sardine fishery showed a monsoonal south and post monsoonal reverse movement. In post monsoon season, the sardine fishery concentrated on the 10.3°N to 10.1°N latitude after that it moves towards south between 10.1°N to 9.9°N and in monsoon season it spread south from 9.8°N to 9.25°N and again move to North in post monsoon season.

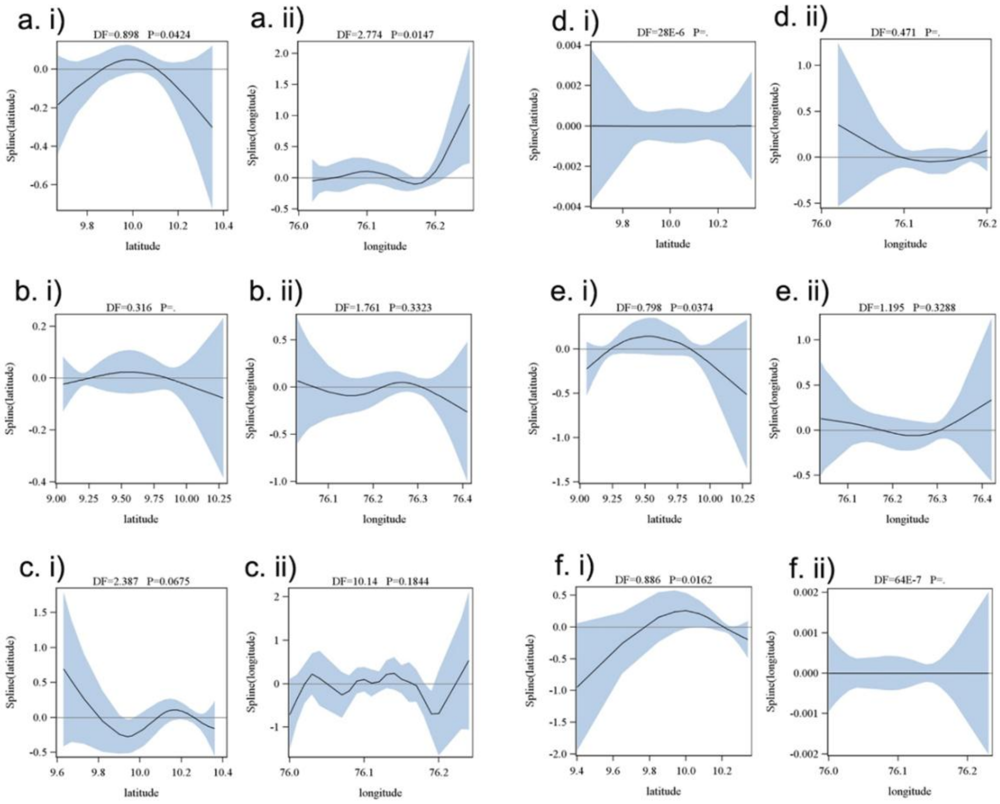

Fig.7. 4 Smoothing component of ring seine yield. plots a, b and c represents sardine yield and plots d, e and f represents mackerel yield for the seasons pre monsoon, monsoon and post monsoon respectively. The latitude and longitude plots in i and ii respectively in X axis against spline function in the Y axis.

Pre monsoon season longitudinal distribution shows a positive relationship in 76.1°E longitude and monsoon season exhibited a positive relationship in 76.3°E longitude. Post monsoon season shows a non-linear response pattern towards longitude and it shows positive relationship after 76.1°E. Like sardine, mackerel fishing ground exhibited a positive relationship between 9.8°N to 9.25°N in monsoon season. In post monsoon season mackerel fishing ground showed a strong positive relationship to the site in between 9.8°N to 10.2°N latitude. Longitudinally mackerel pre monsoon displayed a negative relationship in 76.1°E and in monsoon season it showed in between 76.2°E to 76.3°E. A comparison of seasonal distribution of the ring seine fishery shows a reliable pattern of fishing ground displacement. Between the sardine and mackerel fishing grounds latitudinal fishing positions are similar but longitudinally it shows a negative relationship.

The spatial distribution of sardine and mackerel abundance changed with latitude and longitude. The spatial data of sardine and mackerel yield was modeled as a normal and spline functions of latitude and longitude. The resultant model is given below

$\text{Yield}_{\text{Sardine pre monsoon}}$ = 196.92930 - 0.69364 latitude - 2.49522 longitude* + spline (latitude) + spline (longitude)

$\text{Yield}_{\text{Sardine monsoon}}$ = -51.79577 + 0.46296 latitude + 0.62201 longitude + spline (latitude) + spline (longitude)

$\text{Yield}_{\text{Sardine post monsoon}}$ = 133.13634 + 0.29721 latitude - 1.78896 longitude + spline (latitude) + spline (longitude)

$\text{Yield}_{\text{Mackerel pre monsoon}}$ = -341.44618 + 1.21786 latitude + 4.32355 longitude + spline (latitude) + spline (longitude)

$\text{Yield}_{\text{Mackerel monsoon}}$ = 30.74675 + 0.08814 latitude - 0.41426 longitude + spline (latitude) + spline (longitude)

$\text{Yield}_{\text{Mackerel post monsoon}}$ = -39.15303 - 0.11073 latitude + 0.52924 longitude + spline (latitude) + spline (longitude)

The fit summary of the estimated spline parameter and corresponding degrees of freedom of the resultant model for sardine and mackerel yield for different seasons is given in table 7. 2.

The linear component of latitude of sardine yield produced a significant effect at 5% level of significance. The other linear parameters of sardine and mackerel yield was found non significant. The parametric and non parametric parameters of back fitting algorithm of sardine and mackerel yield converged satisfactorily.

The smoothing component of sardine yield with respect to the latitude and longitude was a quadratic and complex function respectively. The spline smoothing function of latitude and longitude with 95% confidential limits is given in Table.7.2. The spline smoothing parameter for both the covariates was significant at 5% level of significance.

Table-7.2 Fit summary for smoothing components of yield

Component	Smoothing Parameter	DF	GCV	Sum of Squares	Chi-Square	Pr > ChiSq
Sardine Pre monsoon Spline (latitude)	0.999960	0.897788	0.481521	3.718397	3.8531	0.0424
Sardine Pre monsoon Spline (longitude)	0.991434	2.773829	0.525119	9.707856	10.0594	0.0147
Sardine Monsoon Spline (latitude)	0.999998	0.316158	0.484048	0.550628	0.5531	
Sardine Monsoon Spline (longitude)	0.999064	1.760518	0.277996	1.897982	1.9065	0.3323
Sardine Post monsoon Spline (latitude)	0.998702	2.386726	0.465149	5.923960	6.0916	0.0675
Sardine Post monsoon Spline (longitude)	0.466225	10.137786	0.194490	13.540201	13.9233	0.1844
Mackerel Pre monsoon Spline (latitude)	1.000000	0.00002843	0.861474	0.0000114	0.0000	
Mackerel Pre monsoon Spline (longitude)	0.996138	0.471400	0.553136	1.090264	1.0992	
Mackerel Monsoon Spline (latitude)	0.999925	0.798440	1.040144	3.749275	3.7832	0.0374
Mackerel Monsoon Spline (longitude)	0.998703	1.194550	0.184060	1.195587	1.2064	0.3288
Mackerel Post monsoon Spline (latitude)	0.999252	0.885838	1.235833	5.272304	5.4478	0.0162
Mackerel Post monsoon Spline (longitude)	1.000000	0.0000063	0.669427	0.0000067	0.0000	

The smoothing parameters of sardine yield for latitude were nearly 0.999 in all the seasons and for longitude were 0.991, 0.999, and 0.466 during pre monsoon, monsoon and post monsoon respectively. The smoothing parameter of mackerel yield for latitude was 1 in pre monsoon and 0.999 for both monsoon and post monsoon seasons. The corresponding longitudinal parameters were 0.996, 0.998 and 1 during pre monsoon, monsoon and post monsoon respectively. The spline parameter of sardine for latitude and longitude were significant at 5% level during pre monsoon period. The spline parameter of mackerel for latitudes were significant during monsoon and post monsoon seasons (<0.05). The spline parameters of sardine and mackerel yield with respect to latitude and longitude was close to 1, which indicates a smother curve for approximating the expected value of the dependent variable. It could be inferred from the figure 7.4, that the smoothing component of sardine and mackerel yield with respect to the spatial parameters was exhibited as a quadratic function in different seasons.

These analyses were expected to reveal strong geographic effects on small pelagic fishery catch rates, with latitude predominant. The pelagic fish vertical migration in post monsoon and pre monsoon seasons for avoiding the warmer surface water (Pillai & Nair, 2010) and the unique nature of fish aggregation phenomenon during the south west monsoon season in the southern side of Kerala coastal area (Damodaran, 1972; Mathew & Gopinathan 2000) influences distribution of pelagic fish in these areas.

Bigelow *et al.* (1999) developed a GAM for Blue Shark catch rates from logbook data and found that latitude, longitude and sea surface temperature were the most important predictor variables. Walsh & Kleiber (2001) studied the GAM including nine spatio- temporal, environmental and operational variables and explained 72.1% of the deviances of the blue shark catch rates and the author reported latitude exerted the strongest effects of any individual variable. Present study generated similar longitudinal effect on fish abundance and in addition to that, years are grouped in to three distinguished seasons and concentrated on the two major small pelagic fish abundance study.

7.4 Conclusion

The ring seine fishing grounds in the south eastern Arabian sea exhibited a seasonal variability in distribution. During the period of this study, the fishing area was varying significantly from 9.050-10.355N to 76.00-76.415E and total yield showed significant variation during different seasons. Until now spatial distributions of sardine and mackerel abundance have been based mainly on the fishers assumption of locations that maximize their expected profit from a fishing trip. Spatial models of catch dynamics with spatial data allow more accurate prediction of fisheries management measures. The catch data modelling is able to predict the consequences for future management actions. The regional model developed in the study will help in predicting abundance and spatial distribution with reference to latitude and longitude. Development of this predictive model can help in formulating regional algorithms for pelagic fisheries in other parts of the world.

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Chapter

8

LIFE CYCLE ASSESSMENT OF RING SEINE AND CARBON FOOTPRINT STUDIES

Contents

8.1 Introduction

The pelagic fishery resources play a significant role in Indian fish production. Small pelagics such as Indian oil sardine (*Sardinella longiceps*) and Indian mackerel (*Rastrelliger kanagurta*) together contribute 21% of the total marine landings. The state of Kerala is situated in the west coast of India with a coast line of 590 km finds a position in the first three ranks in marine fish production in the country.

Oil sardine is a fish relished by Kerala population. Major portion of the oil sardine landings are sold in the local market and remaining are used for fish meal production and export as pet feed. In Kerala, oil sardine contribute 57.4% of the total marine landings (CMFRI, 2015) and the ring seine fishery is the major contributor with 98.8% of sardine landings and ring seines also contribute 55.7% of the total state production (CMFRI, 2013).

Ring seining is one of the most efficient fishing methods of Kerala. This surrounding gear is mainly used for catching dense, mobile schools of pelagic fishes like sardine, mackerel, anchovy etc. The fish shoal are surrounded and trapped by means of a large wall of netting with floats at the top and sinkers at the bottom, coming under the category of surrounding nets.

According to SER Kerala, (2005) total 2800 units of ring seine are operating in Kerala with 2100 motorised units and 700 mechanised units. 12-24 m wooden/ steel/ FRP (Fiberglass Reinforced Plastic) vessels with 120-440 hp engines are used for mechanized ring seine operation and 7- 16 m FRP or wooden vessels with one or two 9.9/ 25 and/or 40hp engines are used for motorized ring seine operation. The ring seine use small motorized vessel as skiff for assistance in fishing operation and transfer of catch to the landing centre.

This chapter is an attempt to collect all the inventory data associated with the Indian oil sardine, the most important marine species of Kerala.

8.1.1 Environmental Impact on Fishing

Fishing has a major role in supply of cheap source of proteins and fishing is the only food producing method to harvest organisms from ecosystem (Christensen *et al.,* 2003). The rise of sea food demand in the last century and the technological changes in fishing industry has increased the world marine landings. Currently world marine landing reached at 79.7 million tonne in 2012 with many ups and downs in last two decades (FAO, 2014). Fluctuations in the marine fishery data is mainly due to the over exploitation of marine species (Pauly *et al.,* 2002). According to FAO (2014), 28.8% of the fish stocks are over exploited and 61.3% are fully exploited remaining 9.9% are only coming under the category under exploited.

Studies are conducted worldwide to improve the fishery management for sustainability and factors affecting fishery environment, including studies towards the direct environmental impact of fishing activity like impact towards harvested organism, discards, sea bottom damage, etc. (Alverson *et al.,*1994; Glass, 2000;

Johnson, 2002; Pauly *et al.,* 2002; Christensen *et al.,* 2003; Chuenpagdee *et al.,* 2003; Myers & Worm, 2003). Other than the direct impact, impact of fishing gear, craft, fuel usage, antifouling paint, production of ice, transportation, discharge of wastes and loss of fishing gear at sea were also studied (Watanabe and Okubo, 1989; Hayman *et al.,* 2000; Karlsen & Angelfoos, 2000; Andersen, 2002; Derraik, 2002; Ziegler & Hansson, 2003; Ziegler *et al.,* 2003; Thrane, 2004; Tyedmers, 2004; Hospido & Tyedmers 2005).

Life Cycle Assessment (LCA) useful impact assessment methodology and its suitability for quantifying the impact associated with fisheries are proven (Pelletier *et al.,* 2007). Many authors have studied the impact associated with capture fisheries using LCA methodology.

LCA was applied to the food system and agricultural production in 1990s and was initiated in fisheries and aquaculture in 2000s. Fisheries LCA studies were conducted worldwide, Tyedmers (2001), Ziegler *et al.* (2003), Thrane (2004), Ellingsen & Aanondsen (2006), Thrane (2006), Ziegler & Valentinsson (2008), Vázquez-Rowe *et al.* (2010a and 2010b), Ramos *et al.* (2011) and Svanes *et al.* (2011) conducted the LCA studies on different fishing systems of Northeast Atlantic fishing region. Hospido and Tyedmers (2005) studied the purse seine tuna fishery of Atlantic, Pacific and Indian oceans; Emanuelsson *et al.* (2008) studied the trawl fishery of Eastern Central Atlantic; Iribarren *et al.* (2010) studied the trawl, purse seine and line fisheries of Atlantic, Pacific and Indian oceans and Vázquez-Rowe *et al.* (2012) studied the trawl octopus fishery of Eastern Central Atlantic. Very few studies have been reported in energy analysis of fish harvesting systems operating in Indian waters (Edwin & Hridayanathan, 1997; Boopendranath, 2000; Boopendranath & Hameed, 2009; Boopendranath & Hameed, 2010; Vivekanandan, 2013; Ghosh *et al.,* 2014)

Mechanized and motorized fish harvesting systems are dependent on fossil fuels which are non-renewable and releases high levels of carbon dioxide to the atmosphere contributing to greenhouse effect. In this scenario, energy analysis are relevant in relation to fisheries LCA due to the accepted importance of fuel consumption for fleet operations (Tyedmers, 2001) and associated environmental impacts (Thrane, 2004; Schau *et al.,* 2009; Driscoll and Tyedmers, 2010). According to Vivekanandan, (2013) Indian capture fisheries annually consumes 1378.8 million litres of fuel and releases about 3.13 million tonne of CO_2 into the atmosphere. In India marine fish landed release 1.02 tonne of CO_2 per tonne of live-weight of fish (Vivekanandan, 2013). Environmental analysis of Indian capture fisheries are limited to greenhouse gas emission and mainly related to fuel consumption per kilogram of landed fish and it will mask the other factors like materials used for vessel and gear construction, maintenance, life span etc.

In this chapter an attempt is made to conduct a LCA analysis on oil sardine fishery of Kerala including craft, gear and operation individually. Moreover, a comparison is established between three different type of ring seine fishery (mechanized (MeRS), motorized (MoRS) and motorized traditional ring seine (TrRS)) operated in the same geographical position at the same period to determine the environmental burden associated between the same species extracted in three different ways.

8.2 Materials and Method

8.2.1 Study Area

Ring seines operating along the Kerala coast can be classified based on the mode of propulsion in to two types, mechanized craft using an inboard motor and motorized craft using outboard motor (Edwin & Das 2015), henceforth referred to as mechanized ring seine and motorized ring seine respectively. A very small sized motorized ring seine unit category operated by the traditional fishermen is also studied and is denoted as traditional ring seine.

Kalamukku, a landing center in Kerala, south west coast of India, situated in 9°58'55.48"N latitude and 76°14'34.27"E longitude was selected as the study area and is an important landing center of central Kerala (both MeRS and MoRS). Motorized traditional ring seines (TrRS) are usually landed in beaches. TrRS landings were collected from *Chellanam* beach landing center, Cochin.

Fishing operation of ring seines are restricted to single day, the operation starting early in the morning and ends late at night. Unlike other fishing systems, ring seiners lack proper wheel house and fish storage facility. The operations are similar to purse seine, pursing is done by means of both mechanized and manual mode and net hauling is done manually by fishermen. Catch is transported to the landing center by skiff. One or two numbers of such skiff vessels are common in a unit.

In the race for more fish, the fleet size and capacity has increased drastically and presently investment in a single mechanized ring seine unit has reached upto 80 lakh rupees. The labour required for operation and the operational expenses have also increased (Das *et al.,* 2012). In this context, some innovative fishermen of Kerala have come up with a cost effective motorized ring seine unit and within a short time it got wide acceptance. This recently introduced ring seine is also included in the present study as motorized traditional ring seine (TrRS).

The daily fish production data for 36 ring seiners (20 mechanized, 10 motorized, 6 traditional) were collected. These vessels represent the different categories of ring seine fishing fleet of the state. This study was conducted during January 2012 - December 2014. The three types of fishing systems were designated as MoRS, MeRS and TrRS. This classification is based on an all India study conducted by the Central Institute of Fisheries Technology (Edwin *et al.,* 2014a).

8.2.2 Life Cycle Assessment (LCA)

LCA is generally organized into a four step process viz. goal and scope definition, inventory analysis, impact assessment and interpretation of results. The functional unit taken for the study is one tonne of oil sardine (*Sardinella longiceps*) landed. The functional unit (FU) is a quantified definition of the function of a studied system and it provides a reference to which the inputs and outputs can be related (ISO: 14040, 2006). The major operational inputs and outputs associated with fishing activity of MoRS, MeRS and TrRS fishing in the south east Arabian Sea was collected and analyzed. Under MoRS, MeRS and TrRS six categories of fishing systems were identified based on the material of construction (Table-8.1). Ring seine gear were classified into three types based on the size of the gear and mesh size (Table-8.2).

The following types of fishing systems (FS) were identified based on the craft-gear combinations:

Category-1:Mechanised fishing system

FS-1 Steel vessel MeRS with skiff-1 operating RS-1

FS-2 FRP vessel MeRS with skiff-1 operating RS-1

FS-3 Wooden vessel MeRS with skiff-1 operating RS-1

Category-2:Motorised fishing system

FS-4 FRP vessel MoRS with skiff-2 operating RS-2

FS-5 Wooden vessel MoRS with skiff(s)-2 operating RS-2

Category-3:Traditional fishing system

FS-6 FRP vessel MoRS operating RS-3

The above fishing systems were selected for LCA analysis to be conducted on each of the systems separately. The analysis also included all activities pertaining to vessel construction, onboard equipment like purse winch, purse line reel, fishing gear construction, fuel production and consumption and all activities related to the manufacture of fishing accessories.

Table-8.1 Fishing vessel characteristics

	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6	Skiff-1	Skiff-2
Number of vessels sampled (No.)	8	7	5	5	5	6	10	10
Average length (m)	18-22	18-21	16-18	14-16	12-14	7-9	16-18	14-16
Average Main engine power (hp)	250-350	180-250	120-200	25 and/ or 40	25 and/ or 40	9.9	2x25	2x25
Avg. Number of crew	50	50	50	30	30	10		
Mode of pursing the gear	Mechanized	Mechanized	Mechanized	Mechanized / manual	Mechanized / manual	Manual		
Mode of hauling	Manual	Manual	Manual	Manual	Manual	Manual		
Estimated life (year)	15	10	10	8	8	6	8	8

Table-8.2 Fishing gear characteristics

	RS-1	RS-2	RS-3
Number of gear sampled	15	10	5
Mesh size (mm)	18-22	10-14	8-12
Length (m)	800-1000	500-799	200
Estimated life (year)	1	1	1

All major activities associated with the inputs for assessment of LCA are depicted in the system boundary chart comprising of three sub systems are given in (Fig.8.1). The system boundary defines which processes will be included in, or excluded from, the system and describes the processes and their relationships. In this study, LCA analysis for individual fishing unit (vessel and gear) and its operation was conducted using a cradle to gate approach. The post-harvest processes have been excluded from the system boundary as the use of catch varied with the different fishing units. So in this study system, boundary has been limited to the point at which the catch reaches the harbour.

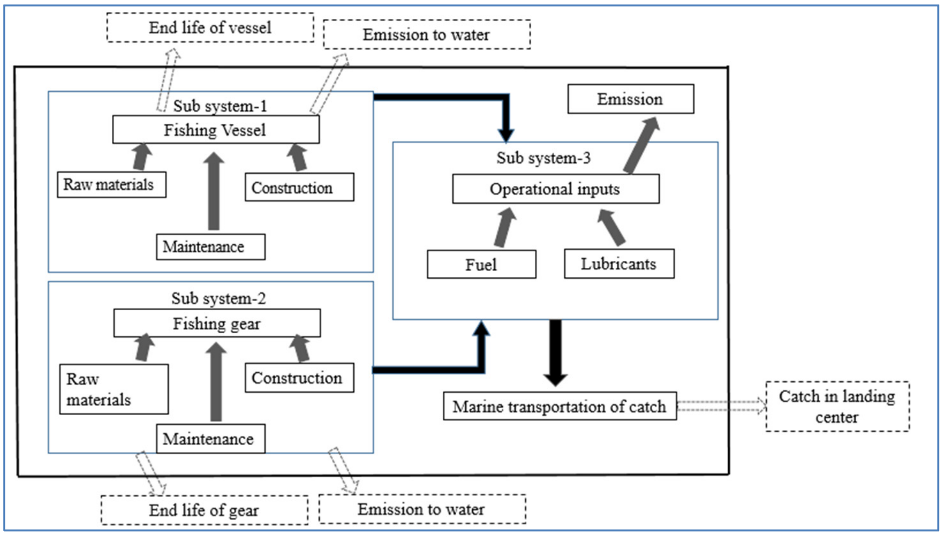


Fig 8.1 Block diagram of the studied system. Dotted line represent the factors excluded from system boundary

Collecting quantitative and qualitative data for every unit process in the system was the most cumbersome part of LCA analysis. Gabi 6 LCA software was used for analysis of the data. As per the requirements of this software the data for each unit process can be classified as energy inputs, raw material inputs, ancillary inputs, other physical inputs, products, co-products, wastes etc. Details of the data collection is given in the next section.

CML 2001 methodology which includes classification, characterization and normalization of the environmental impacts resource inputs and emissions is adopted by Gabi 6. As per the recommendations of Guinee *et al.* (2001), ten environmental impact categories, namely abiotic depletion potential elements (ADP elements), abiotic depletion potential fossil (ADP fossil) acidification potential (AP), eutrophication potential (EP), global warming potential (GWP), human toxicity potentials (HTP), marine aquatic eco-toxicity potentials (MAETP), stratospheric ozone depletion potential (ODP) and finally photo-oxidant formation potential and terrestrial eco toxicity potential (POFP and TETP) were chosen to quantify the environmental impacts associated with the activities.

8.2.3 Data acquisition

8.2.3.1 Fishing vessels

The three categories of vessels differ mainly with respect to the type of engine, fuel used, material used for construction and size of fishing craft and gear. Details of materials used for construction of fishing vessel were collected from local boat building yards by interviews with boat builders, skippers and log books maintained at boat yards and vessels. Quantity wise data on materials like steel (for hull, engine, propeller shaft etc.) welding rod, electricity for welding, grinding, light (unit kwh) plywood for deck, wooden material, alloy for propeller, fiber glass mat, resin, other ingredients (accelerator, catalyst, etc.) material, details of primer, paint, antifouling paint etc. and transportation were collected. Collected quantitative vessel characteristics were amortized with the life span of the fishing vessel and calculated for one tonne landings. Inventory data for subsystem-1 fishing vessel is given in Table-8.3.

Table-8.3 Inventory for fishing sub system-I (data for one tonne of landed Indian oil sardine)

Particulars	FS-1 Steel	FS-2 FRP	FS-3 Wood	FS-4 FRP	FS-5 Wood	FS-6 FRP	Skiff-1 FRP	Skiff-2 Wood
Paints (surface primer, paint, antifouling paint, etc.)	1.79E-01	3.32E-01	2.69E-01	1.31E-01	1.73E-01	2.87E-02	1.44E-01	1.20E-01
Copper	-	-	1.02E-01	-	3.09E-02	-	-	2.14E-02
Cotton fibers packed	-	-	7.68E-02	-	1.03E-01	-	-	7.13E-02
Electricity	1.43E-01	8.69E-02	1.13E-01	1.92E-02	2.97E-02	9.38E-02	2.11E-02	2.06E-02
Welding Electrodes	8.82E-02	5.21E-03	4.23E-03	6.42E-04	5.66E-04	2.35E-03	7.02E-04	3.92E-04
Fiber reinforced plastic material (Resin, gel and glass mat)	4.48E-02	2.93E+00	1.44E-01	8.03E-01	1.00E-01	3.76E+00	8.79E-01	6.94E-02
Gunmetal	2.56E-02	5.05E-02	4.10E-02	-	-	-	-	-
Hard wood log mix	8.82E-02	5.21E-02	2.68E+00	4.81E-01	1.41E+00	7.51E-01	3.51E-01	8.82E-01
Limestone	1.92E-02	7.58E-02	-	1.05E-02	-	3.84E-02	1.15E-02	-
Plywood board	9.62E-03	1.90E-02	1.54E-02	1.40E-01	-	5.12E-01	1.53E-01	-
Steel	2.03E+00	5.21E-01	3.80E-01	2.57E-01	2.26E-01	9.38E-02	3.51E-02	2.94E-02

8.2.3.2 Fishing gear

Quantity of polyamide multifilament webbing, high density polyethylene webbing, polypropylene rope, plastic floats, lead sinkers and brass rings were collected from net fabrication sites and net making factory. Maintenance of the fishing vessel and gear also come under the purview of the data collected. In fishing gear, life span is considered as one year and the quantitative inputs were expressed in terms of per tonne sardine landings. Inventory data for subsystem-2 fishing gear is given in Table-8.4

Table-8.4 Inventory for fishing sub system-II (data for one tonne of landed Indian oil sardine)

	FS-1	FS-2	FS-3	FS-4	FS-5	FS-6
Polyamide Webbing Material	1.42E+00	1.53E+00	1.59E+00	9.16E-01	1.08E+00	9.40E-01
HDPE Webbing Material	3.16E-01	3.40E-01	3.54E-01	2.62E-01	3.09E-01	2.35E-01
Polypropylene Rope	4.34E-01	4.68E-01	4.87E-01	3.40E-01	4.02E-01	3.29E-01
Lead Sinker	9.87E-01	1.06E+00	1.11E+00	5.24E-01	6.19E-01	4.70E-01
Brass	1.03E-01	1.11E-01	1.15E-01	1.05E-01	1.24E-01	1.41E-01
Plastic float	3.16E-01	3.40E-01	3.54E-01	2.88E-01	3.40E-01	1.88E-01

8.2.3.3 Operational inputs

Details of engine and its horsepower, number, types and size of fishing gear, details of fishing operations including the number of fishing days in an year, time of shooting the net, time of hauling, number of hauls, fuel used (diesel, petrol, kerosene and lubrication oil) were collected from skippers and fishing vessel owners and species wise catch details were collected from the daily landing log books of fishermen cooperative societies. Compared to any other fishing systems, ring seine show more number of days without catch even after search because of non-availability of shoals/ unsuitable condition for shooting the net like rough sea condition, distracted shoals, fast moving shoal, small shoals etc.). This study has taken into consideration such days also. This data were validated with secondary data obtained from Central Marine Fisheries Research Institute (CMFRI), Cochin. Inventory data for Indian oil sardine harvesting sub systems is per tonne of oil sardine landed. Inventory data for subsystem-3 fishing operation is given in Table-8.6

Table-8.5 Details of species wise fish landing days per year

Species	FS-1 Steel	FS-2 FRP	FS-3 Wood	FS-4 Wood	FS-5 FRP	FS-6 FRP
Sardine	139.7	137.5	143.0	156.2	159.5	57.2
Mackerel	43.9	39.3	40.9	10.9	11.0	3.4
Anchovy	9.558	8.25	3.02	33.26	20.25	42.3
Others	19.558	19.25	20.02	14.42	19.75	52.87
Total	212.7	204.3	206.9	214.7	210.5	155.8

Table-8.6 Inventory for fishing sub system-III (data for one tonne of landed Indian oil sardine)

	FS-1 Steel	FS-2 FRP	FS-3 Wood	FS-4 FRP	FS-5 Wood	FS-6 FRP
Diesel	89.50684	85.56297	87.85965			
Petrol	4. 945890	4.890945	5. 094589	8.114803	8.899482	9.341826
Kerosene	32.44179	31.94401	33. 02941	141.9945	141.0218	74.73461
Lub oil	1.316277	1.383796	1.402016			

8.2.3.4 Inputs Excluded from System Boundary

Harvest loses during transfer of catch at the landing centes, solid and liquid waste generated in the fishing vessel and discharges of such matter into the sea were not taken into account of the study due to insignificant quantity and lack of data. Quantitative data on electric wiring circuits, navigational equipment also do not come under the purview of this study.

8.3 Result and Discussion

Ring seine fishery started mid-1980s in the study area and right from the time of introduction, it contributed a major role in the capture fisheries of the state. The total landings from the study area was 4127.89 tonne and 4146.46 tonne in 2013 and 2014 respectively. The percentage share of mechanized ring seine which was 51.30% during 2002 has been increasing ever since (Fig.8.2). In 2014, 96% of ring seine production in the area was by the mechanized ring seine fishing craft. The contribution of motorized fishery to the total ring seine landings reduced during the period from 49% in 2002 to 4% in 2014. This was because, the number of mechanized ring seiners increased by 83% during the period whereas, the number of motorized ring seiners increased only by 25% and the size and power of the craft, gear and engine increased two to three times with respect to mechanized ring seine units. By virtue of their increased horse power and large gear size, the mechanized fishing fleets exploit more areas and the high landing of this fishery attract more investors to this fishery. The size of the gear has increased gradually from 250m length and 30m (max.) depth to a length of more than 1000m and a depth of 100m (Edwin *et al.,* 2014b).

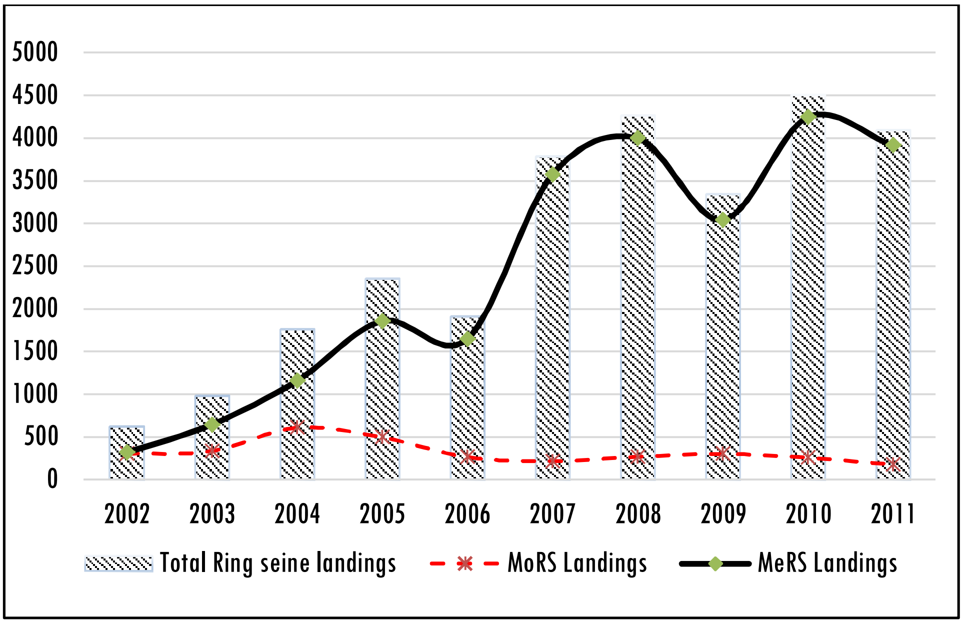


Fig-8.2 Ring seine fish landing of the study area (in tonne)

8.3.1 Environmental Performance of Ring Seine Fishery

8.3.1.1 Sub system-1 Fishing Vessel

With reference to subsystem-1, the environmental impact of material used for the construction procedure and the repair and maintenance of the vessel during its life time have been assessed (Fig.8.3). In case of steel fishing vessel under FS-1 and out of 10 environmental factors studied eight showed more than 74% contribution toward the construction material steel (HTP 86.58%, MAETP, 82.85%, EP 82.85%, GWP 82.80%, POPC 80.66%, TETP 79.67%, ADP fossil 76.44% and AP 74.65%). In FRP fishing vessel FS-2, FRP materials contribute major share of ADP element (86.47%), ADP fossil (82.12%), EP (80.47%), ODP (79.24%), GWP (75.65%) and AP (56.64%). In wooden fishing vessel under FS-3, Copper nails used for the hull construction contributed maximum to 97.67% of ADP elements, 54.62% of HTP, 40.41% of ODP; paints including antifouling paints contributed to 51.24% of TETP, 44.44% of AP, 40.27% of ADP fossil; steel contributed 40.68% of MAETP and cotton used for caulking contributed 45.51% of EP. Wood contributed maximum to the biomass for construction but contribution to the environmental factors were comparatively less (POCP contributed 37.34 %), GWP contribution shown negative value (-64.52%).

In motorized FRP fishing vessel under FS-4, FRP material contributed maximum to the ADP element 98.63% followed by ADP fossil 74.58%, ODP 73.33%, EP 69.68%, GWP 50.53% and steel contributed 48.08% to HTP, MAETP 47.62% and TETP 43.39%. Contribution of wood is negligible to all environmental factors and in GWP it showed negative value (-21.26%). In wooden fishing vessel under FS-5, copper nails used for the hull construction contributed maximum of 98.25% to ADP elements and 42.92% to HTP cotton used for caulking contributed 68.68% of EP. Steel contributed 56.03% of MAETP and paints including antifouling paints contributed to 50.43% of AP, 50.21% of TETP and wood contribute 35% of POCP and -63.30% of GWP. In motorized traditional FRP fishing vessel under FS-6, FRP material contributed maximum to all the environmental factors (ADP element 99.87% followed by ADP fossil 96.12%, ODP 95.39%, EP 90.71%, AP 86.66%, GWP 79.97%, HTP 73.25%, POCP 68.24%, TETP 61.04% and MAETP 41.15%).

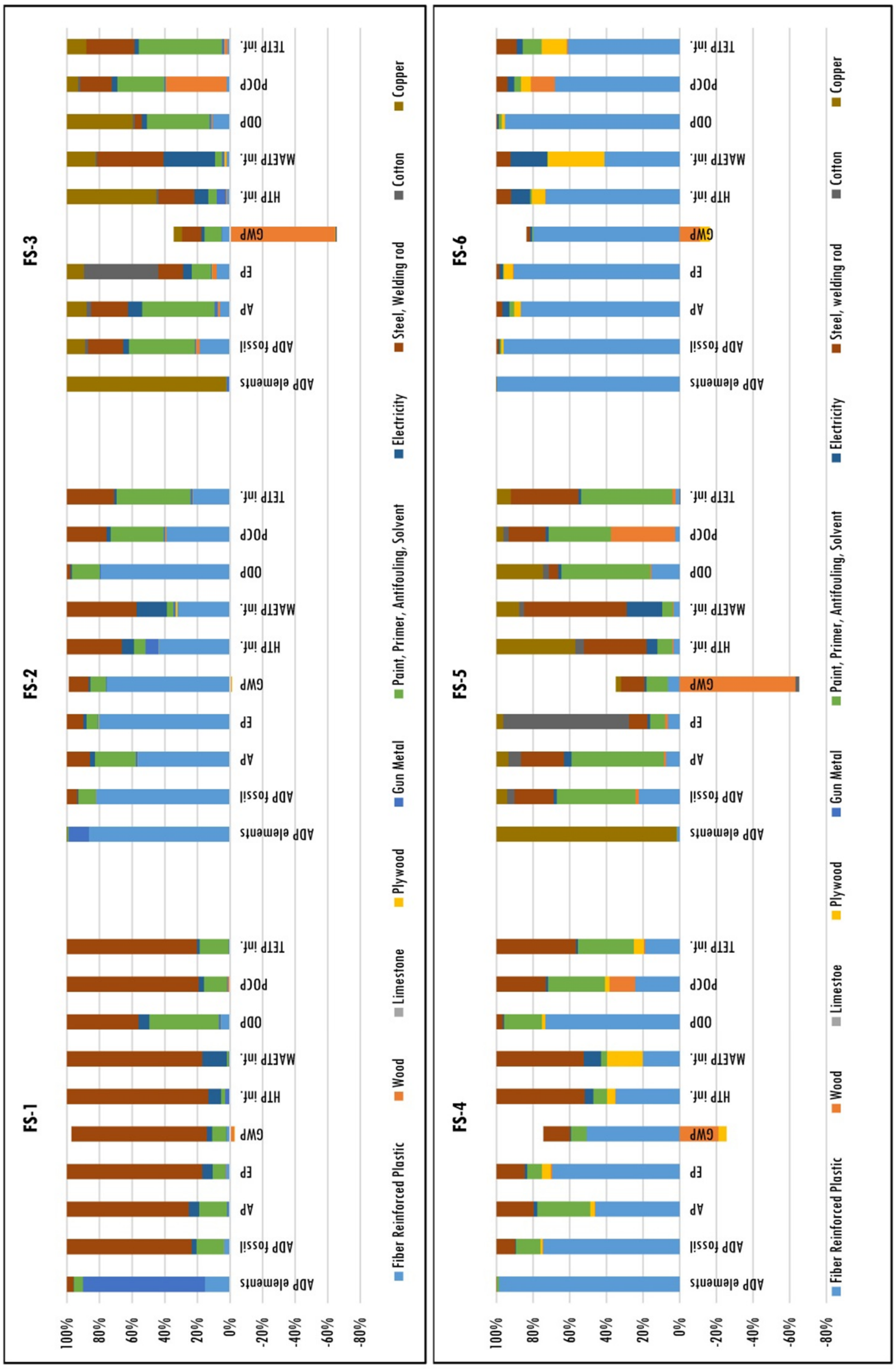


Fig.8.3 Relative contribution to environmental impact associated with the subsystem-1 fishing craft

8.3.1.2 Sub System-2 Fishing Gear

In the case of subsystem-2 fishing gear under RS-1, RS-2 and RS-3, the synthetic materials used, construction, maintenance and repair were taken into consideration while assessing the contribution to environmental factors. In case of fishing gear coming under the subsystem-2, polyamide webbing contributed maximum to ODP, EP, GWP, ADP fossil, POCP, AP and TETP inf. with an average of 83.94%, 81.43%, 77.94%, 69.49%, 57.69%, 44.57% and 44.96% respectively. Lead was the second most important factor that contributed to environmental impact accounting for 94.63% of ADP elements; 45.18% of HTP inf. and 40.46% of AP. HDPE webbing contributed 62.23% of MAETP inf. Environmental impact associated with the subsystem-2 ring seine gear is given in Fig.8.4.

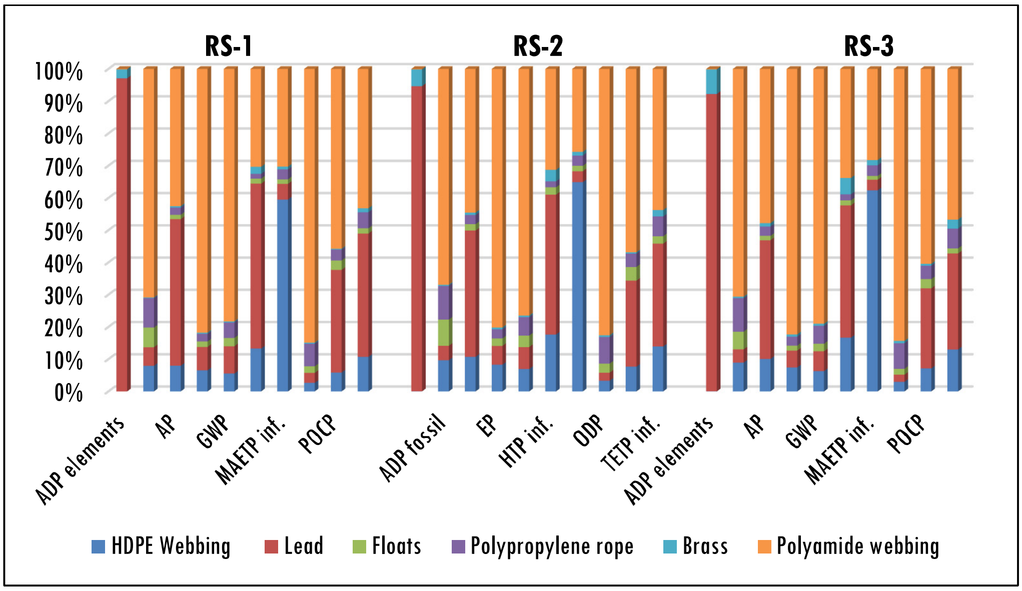


Fig.8.4 Relative contribution to environmental impact associated with the subsystem-2 Fishing gear RS-1, RS-2, RS-3

8.3.1.3 Sub system-3 Fishing Operation

In case of subsystem-3 fishing operation under FS-1, FS-2 and FS-3, the fuel used by the main vessel, skiff vessel and lubricant oil were taken into consideration while assessing the contribution to environmental factors. In case of fishing operation coming under the subsystem-3 diesel contributed 74.26% to 78.75% of all the environmental parameters and kerosene contributed 19.92% to 18.66% to the environmental parameters (Fig.8.5). Contribution of lubricant and petrol were less than 4%.

In fishing operation under FS-4 and FS-5 the contribution of kerosene to the environmental factors were 93.61% to 98.69% where as in FS-6 it contributed 88.81% to 97.39%. The petrol contributed 1.31% to 6.39% in FS-4 and FS-5 where as in FS-6 it contributed 2.61% to11.18% (Fig.8.6)

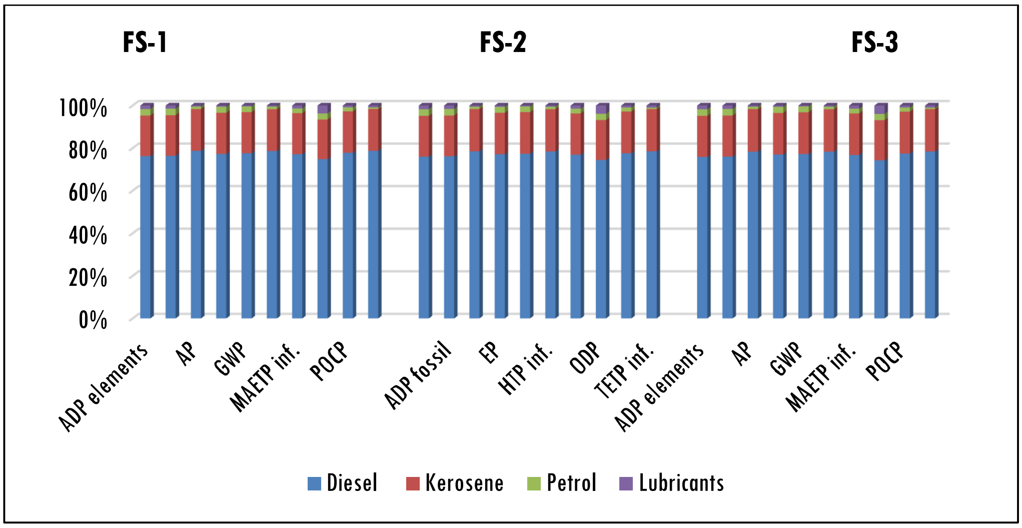


Fig.8.5 Relative contribution to environmental impact associated with the subsystem-3 Fishing operation FS-1, FS-2 and FS-3

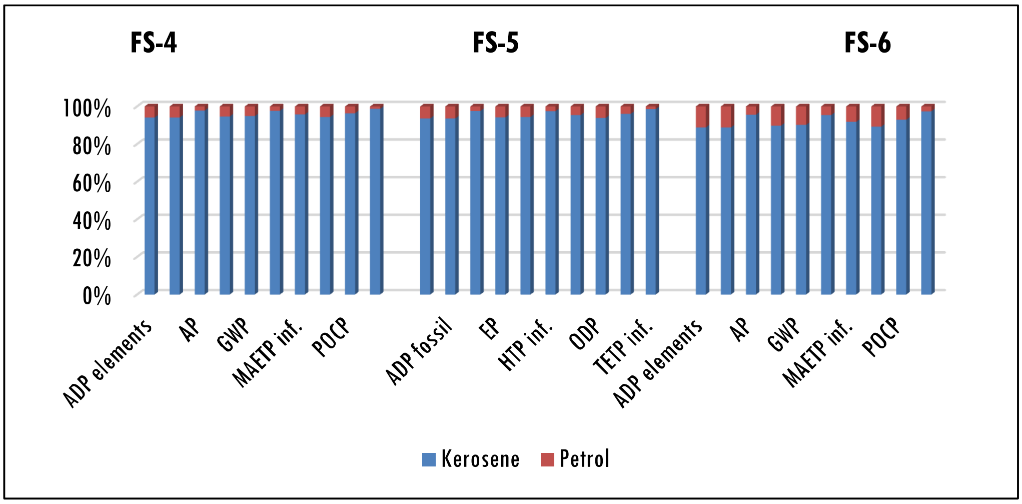


Fig.8.6 Relative contribution to environmental impact associated with the subsystem-3 Fishing operation FS-4, FS-5 and FS-6

8.3.2 Environmental Performance of Indian Oil Sardine Landing by Ring Seine Fishery

While considering the environmental performance of oil sardine fishery of Kerala landed by ring seines, gear contributes maximum to ADP element and ODP and fishing operation contributed maximum to all other environmental factors considered in this study.

Maximum contribution to ADP elements was by the fishing gear due to the presence of lead used in the sinker line and the gear used in the mechanized fishing systems contributed maximum to ADP and the minimum contribution was by the traditional gear. Similar pattern was observed in the case of ODP where the environmental impact is due to the polyamide webbing used studied by Vázquez-Rowe *et al.*, (2010b) while assessing the LCA of horse mackerel in Galicia.

Maximum contribution to ADP fossil was through fishing operation which is due to the presence of fossil fuel used for the vessel operation (Table-8.7). Among the fishing systems, motorized fishing vessel operation contribute more to the ADP fossil which is due to the heavy fossil fuel used by the outboard engines. The minimum contribution was by traditional fishing vessels. Second highest contributor to the ADP fossil was fishing vessel followed by fishing gear. In steel mechanized fishing vessel, steel metal contributed maximum, in FRP mechanized fishing vessel, FRP material contributed maximum and in wooden mechanized fishing vessel paint including surface primer, base coat and antifouling paint contributed maximum followed by FRP constituents and steel. In fishing gear, polyamide webbing contributed maximum to ADP fossil.

Maximum contribution to ADP fossil, AP, EP, GWP, HTP, MAETP, POCP and TETP was by fishing operation due to the presence of fossil fuel used for the vessel operation. Observations was reported in previous works done by Edwardson, (1976); Watanabe & Okubo, (1989); Tyedmers, (2001); Ziegler *et al.,* (2003); Tyedmers *et al.,* (2005); Thrane, (2004); Hospido and Tyedmers, (2005); Schau *et al.,* (2009) and Vázquez-Rowe *et al.,* (2010b). Nonetheless, it is interesting to point out that among the fishing systems studied, motorized fishing vessel operations contribute more to the above environmental factors, except MAETP. Fishing system-2 mechanized FRP craft has higher MAETP contribution than motorized fishing system which is due to the FRP material used for construction.

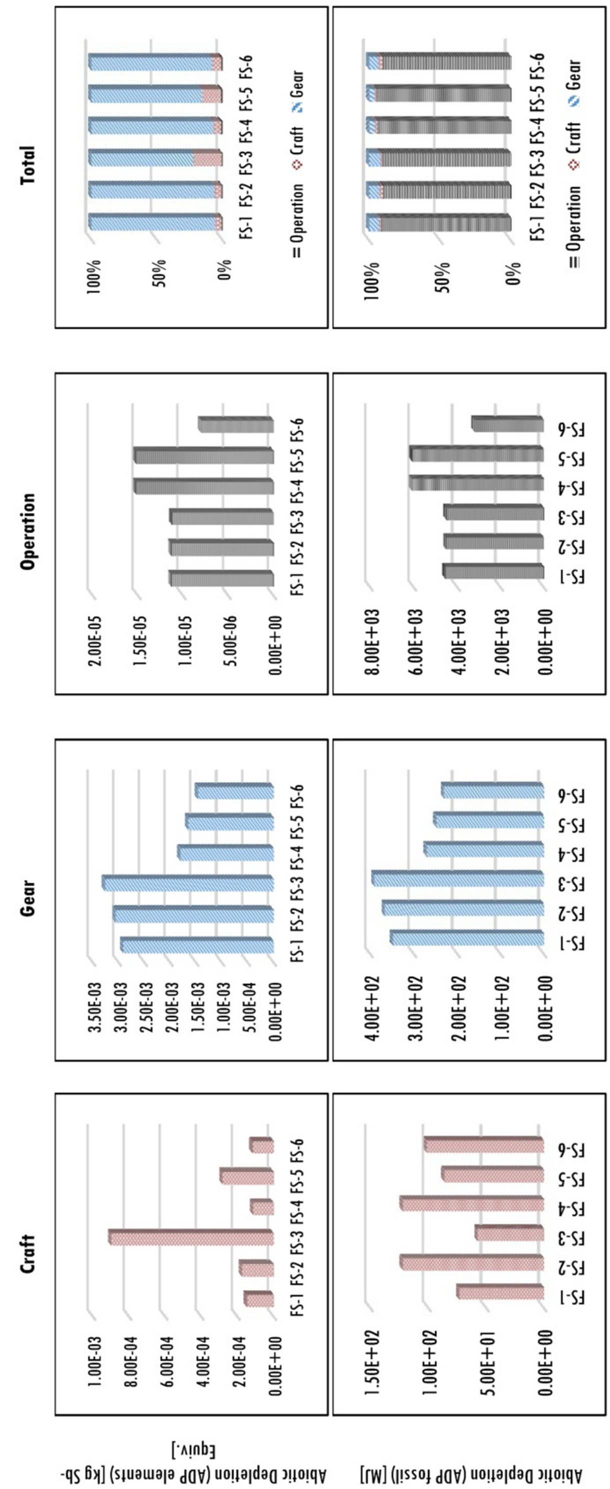
Table-8.7 Environmental performance of different ring seine fishing systems operated along the Kerala coast (data for one ton of landed Indian oil sardine)

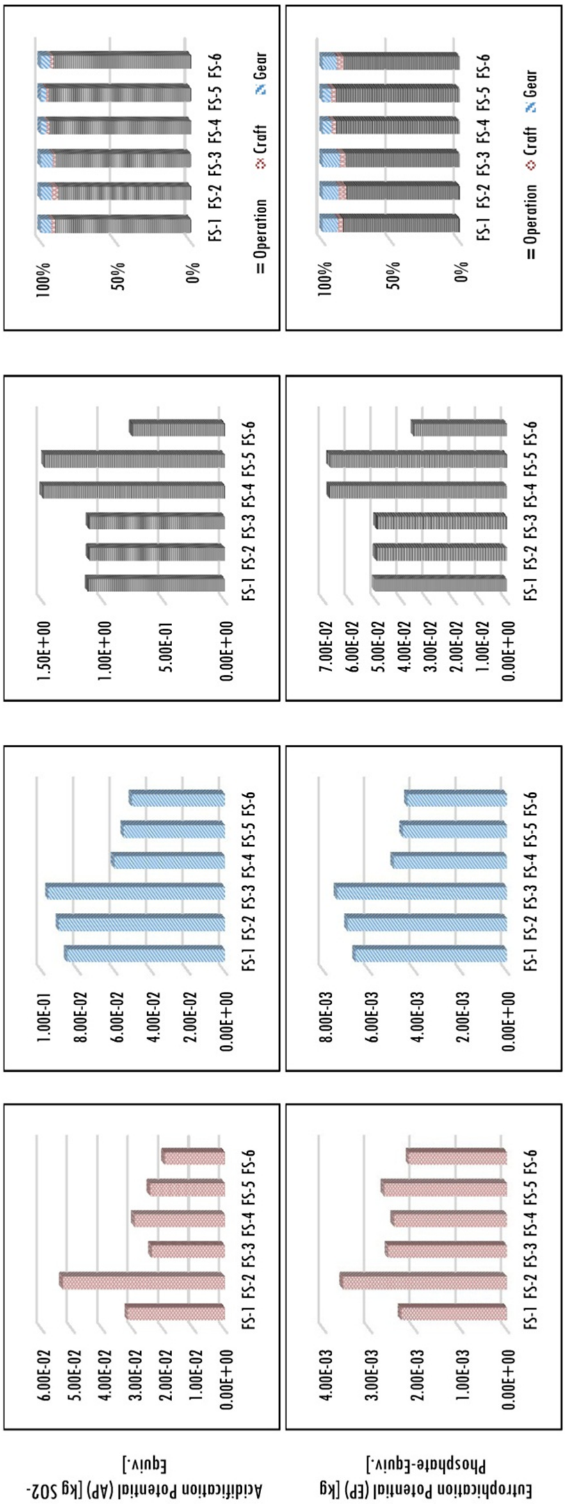
	Fishing System 1			Fishing System 2			Fishing System 3		
	Operation	Craft	Gear	Operation	Craft	Gear	Operation	Craft	Gear
ADP elements	1.13E-05	1.45E-04	2.91E-03	1.13E-05	1.75E-04	3.06E-03	1.12E-05	8.98E-04	3.26E-03
ADP fossil	4.55E+03	7.33E+01	3.48E+02	4.51E+03	1.22E+02	3.67E+02	4.49E+03	5.76E+01	3.91E+02
AP	1.12E+00	3.18E-02	8.61E-02	1.11E+00	5.32E-02	9.07E-02	1.11E+00	2.39E-02	9.65E-02
EP	5.03E-02	2.30E-03	6.61E-03	4.99E-02	3.58E-03	6.96E-03	4.96E-02	2.59E-03	7.41E-03
GWP	3.74E+02	4.15E+00	1.96E+01	3.71E+02	7.83E+00	2.06E+01	3.69E+02	-3.21E+00	2.19E+01
HTP inf.	2.57E+01	8.51E-01	1.68E+00	2.55E+01	1.44E+00	1.77E+00	2.53E+01	7.38E-01	1.89E+00
MAETP inf.	6.87E+03	1.94E+03	1.59E+03	6.82E+03	3.36E+03	1.70E+03	6.78E+03	9.18E+02	1.79E+03
ODP	3.45E-10	9.29E-11	2.58E-09	3.43E-10	1.45E-10	2.72E-09	3.41E-10	1.49E-10	2.89E-09
POCP	7.49E-02	3.47E-03	1.00E-02	7.44E-02	5.66E-03	1.05E-02	7.39E-02	3.53E-03	1.12E-02
TETP inf.	1.63E-01	3.08E-02	1.68E-02	1.62E-01	5.25E-02	1.77E-02	1.61E-01	1.95E-02	1.88E-02
	Fishing System 4			Fishing System 5			Fishing System 6		
	Operation	Craft	Gear	Operation	Craft	Gear	Operation	Craft	Gear
ADP elements	1.52E-05	1.13E-04	1.80E-03	1.52E-05	2.82E-04	1.65E-03	7.98E-06	1.14E-04	1.46E-03
ADP fossil	6.09E+03	1.22E+02	2.70E+02	6.08E+03	8.61E+01	2.48E+02	3.20E+03	1.01E+02	2.31E+02
AP	1.49E+00	2.95E-02	6.02E-02	1.48E+00	2.44E-02	5.52E-02	7.56E-01	1.96E-02	5.06E-02
EP	6.78E-02	2.46E-03	4.93E-03	6.77E-02	2.68E-03	4.53E-03	3.55E-02	2.14E-03	4.34E-03
GWP	5.05E+02	4.85E+00	1.46E+01	5.04E+02	1.23E+00	1.34E+01	2.63E+02	4.64E+00	1.28E+01
HTP inf.	3.42E+01	3.20E-01	1.19E+00	3.40E+01	3.62E-01	1.10E+00	1.73E+01	2.02E-01	9.98E-01
MAETP inf.	9.14E+03	7.41E+02	1.37E+03	9.12E+03	6.28E+02	1.26E+03	4.73E+03	4.73E+02	1.13E+03
ODP	4.52E-10	1.67E-10	1.94E-09	4.51E-10	1.40E-10	1.78E-09	2.37E-10	1.25E-10	1.72E-09
POCP	9.99E-02	6.76E-03	7.18E-03	9.96E-02	4.92E-03	6.59E-03	5.14E-02	5.73E-03	6.10E-03
TETP inf.	2.14E-01	1.24E-02	1.21E-02	2.13E-01	1.25E-02	1.11E-02	1.08E-01	5.01E-03	1.03E-02

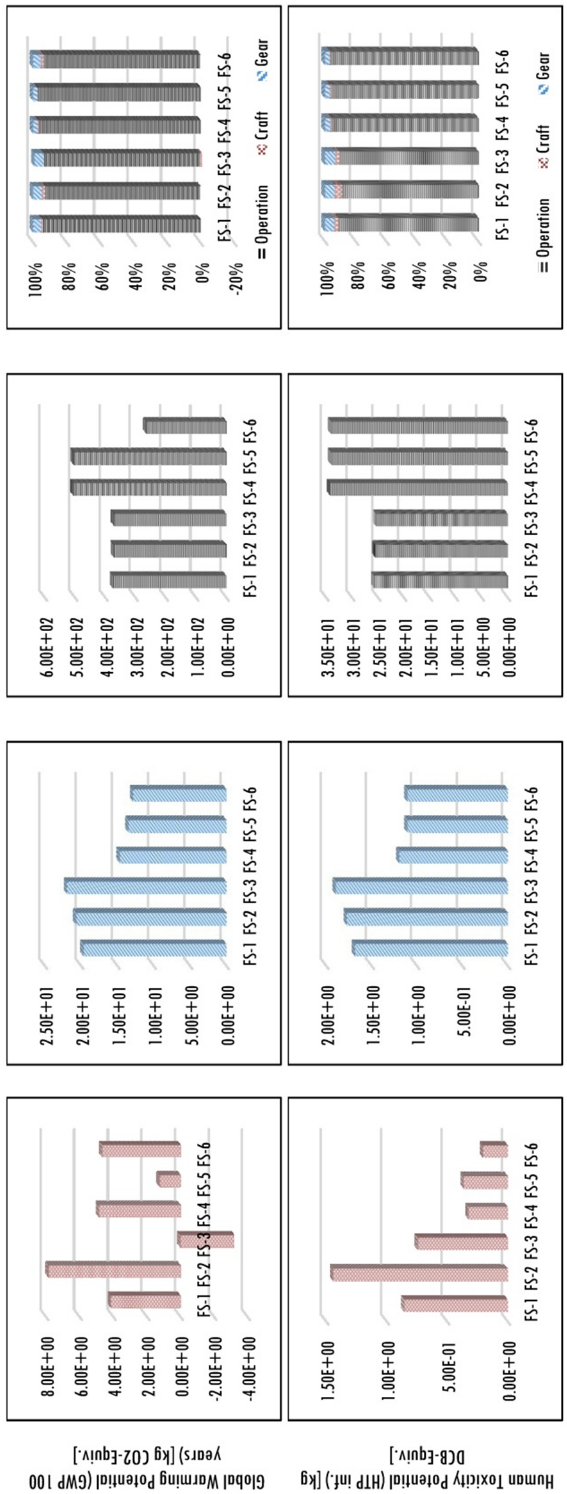
Table-8.8 Combined environmental performance of different ring seine fishing systems operated along the Kerala coast (data for one tonne of landed Indian oil sardine)

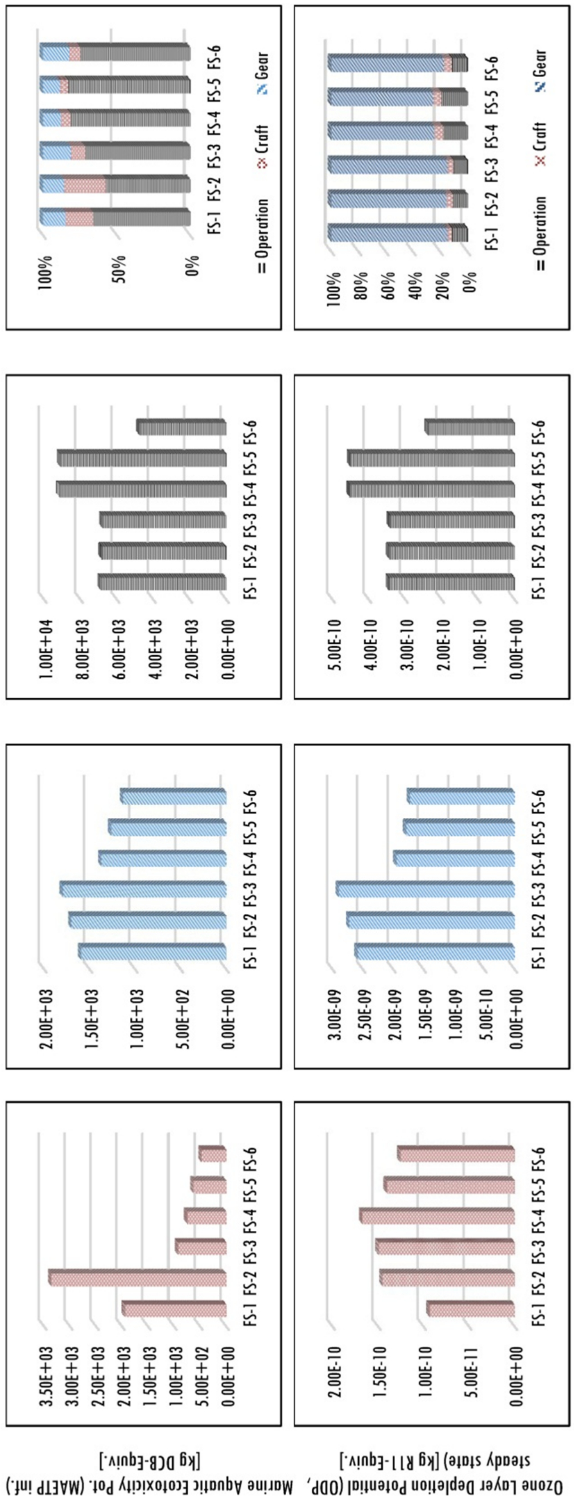
	FS-1	FS-2	FS-3	FS-4	FS-5	FS-6
ADP elements	3.07E-03	3.25E-03	4.17E-03	1.93E-03	1.95E-03	1.58E-03
ADP fossil	4.97E+03	5.00E+03	4.94E+03	6.48E+03	6.41E+03	3.53E+03
AP	1.24E+00	1.25E+00	1.23E+00	1.58E+00	1.56E+00	8.26E-01
EP	5.92E-02	6.04E-02	5.96E-02	7.52E-02	7.49E-02	4.20E-02
GWP	3.98E+02	3.99E+02	3.88E+02	5.24E+02	5.19E+02	2.80E+02
HTP inf.	2.82E+01	2.87E+01	2.79E+01	3.57E+01	3.55E+01	1.85E+01
MAETP inf.	1.04E+04	1.19E+04	9.49E+03	1.13E+04	1.10E+04	6.33E+03
ODP	3.02E-09	3.21E-09	3.38E-09	2.56E-09	2.37E-09	2.08E-09
POCP	8.84E-02	9.06E-02	8.86E-02	1.14E-01	1.11E-01	6.32E-02
TETP inf.	2.11E-01	2.32E-01	1.99E-01	2.39E-01	2.37E-01	1.23E-01

The high environmental impact of the motorized fleets (Table-8.8) are mainly due to the, operational issues like the intensive use of kerosene as fuel by highly inefficient outboard engines, where as mechanized ring seines are propelled by inboard engines run by diesel. The motorized unit uses 150 liters of fuel for production of one tonne of oil sardine landing whereas mechanized and traditional vessels consume 112 and 84 liters respectively per tonne of fish landed. A study conducted by Schau *et al.* (2009) in Norwegian fleet shows that 90 kg fuel was consumed per tonne of mackerel landed. Similar study by Vázquez-Rowe *et al.* (2010b) in Galicia on the horse mackerel fishery reports that 176 kg of fuel has been used for the production of one tonne of fish. Studies by Hospido and Tyedmers (2005) on Spanish tuna fishery shows 420 kg of fuel usage per tonne of production. To our knowledge there are no environmental impact studies for motorized and mechanized fishing fleet for oil sardine fishery in India.


Craft
Gear
Operation
Total
Abiotic Depletion (ADP elements) [kg Sb-Equiv.]
Abiotic Depletion (ADP fossil) [MJ]
FS-1 FS-2 FS-3 FS-4 FS-5 FS-6
Operation
Craft
Gear
100%
50%
0%


Acidification Potential (AP) [kg SO2-Equiv.]
Eutrophication Potential (EP) [kg Phosphate-Equiv.]
FS-1 FS-2 FS-3 FS-4 FS-5 FS-6
Operation
Craft
Gear
100%
50%
0%


Global Warming Potential (GWP 100 years) [kg CO2-Equiv.]
Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]
FS-1 FS-2 FS-3 FS-4 FS-5 FS-6
Operation
Craft
Gear


Marine Aquatic Ecotoxicity Pot. (MAETP inf.) [kg DCB-Equiv.]
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]
FS-1 FS-2 FS-3 FS-4 FS-5 FS-6
Operation
Craft
Gear

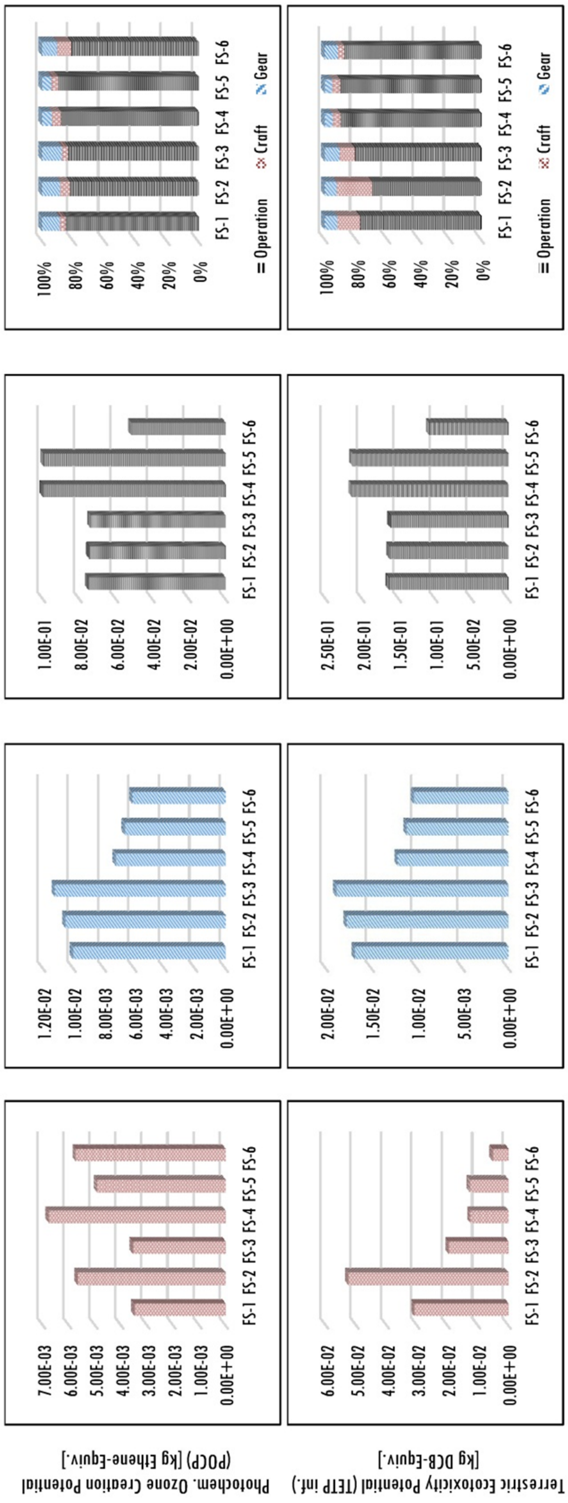


Fig. 8.7 Graphical representation of environmental performance of different ring seine fishing systems operated along the Kerala coast (data for one ton of landed Indian oil sardine)

Table- 8.9 Mass allocation of impact categories in terms of one tonne sardine landed

Impact Category	Mechanised	Motorised	% difference motorized / mechanized landings
ADP elements	3.50E-03	1.94E-03	-80.24%
ADP fossil	4.97E+03	6.45E+03	22.89%
AP	1.24E+00	1.57E+00	21.02%
EP	5.97E-02	7.51E-02	20.41%
GWP	3.95E+02	5.22E+02	24.26%
HTP	2.83E+01	3.56E+01	20.60%
MAETP	1.06E+04	1.12E+04	4.96%
ODP	3.20E-09	2.47E-09	-29.95%
POCP	8.92E-02	1.13E-01	20.71%
TETP	2.14E-01	2.38E-01	10.08%

Results show that oil sardine landed by motorized ring seine fleet is having higher impact when compared to mechanized ring seine fleet except ADP element and ODP it due to the high use of lead weight and polyamide webbing in mechanized fleets. While comparing motorized fleets (Table-8.9), impact of ADP fossil, AP, EP, GWP, HTP and POCP shows more than 20% higher impact than mechanized fleet with a higher value of 24% in GWP.

Different hot spots have been identified in the study of oil sardine fishery through motorized and mechanized ring seine activities. Through this study some important interventions can be proposed for the improved efficiency of the fishery. The reduction of fuel through reduction of speed can bring about a major change. Gulbrandsen (2012) has opined that 10% reduction of engine rpm will reduce 20% fuel consumption and 20% reduction in rpm will reduce 40% fuel consumption. Proper maintenance of vessel hull also contributes a major role in fuel use. In tropical conditions hull fouling increases fuel consumption at 7% in first month of operation and up to 44% after six month of operation if antifouling paint is not used (Gulbrandsen, 2012). Vessel drag reduction through improvised hull shape will help in energy efficiency up to 20% (Schau *et al.,* 2009). In motorized fleets, replacement of high energy consuming 2-stroke out board engine to inboard engines will reduce the fuel usage. According to Gulbrandsen (2012) when compared with 2-stroke out board petrol engines inboard diesel engine consume 62% less fuel at same speed.

Ring seine operations are conducted based on the occurrence of small pelagic fish shoals. The chance of occurrence of fish as small pelagic shoals mainly depends on the sea surface temperature and chlorophyll concentration (Pillai and Nair, 2010). Boopendranath and Hameed (2012) observed that Kerala ring seine fuel consumption per kg fish landed varied with lower fuel consumption during the month of May to December and higher in January to April. The high fuel consumption during this period is due to the movement of oil sardine shoals towards deeper depth, because of distortion caused by direct sunlight (Pillai and Nair, 2010) which make the fishing more difficult and increase the total fish shoal searching time and leads to the wastage of fuel. During the study period it is observed that an average ring seine fishing trip takes 12.28 ± 2.06 hours of operation, including the cruising time to the fishing ground and the fishing operation takes less than 45% of the total fishing time and major time was spent for searching the fish shoals for which maximum fuel is consumed. Knowledge about the spatial distribution of fish over the time and the effective use of Potential Fishing Zone (PFZ) forecast based on sea surface temperature and or surface chlorophyll concentrations can help to reduce the searching time and environmental impact.

Replacement of low durable polyamide webbing with highly durable Ultra-High Molecular Weight Polyethylene (UHMWPE) will help to increase the life span of webbing which will lead to reduction in detrimental effect on environmental impact factors. Appropriate use of lead sinkers will reduce the number of sinker per meter of sinker line which will also reflect in environmental factors like ODP. Compared to mechanized and motorized ring seine units, traditional ring seine units are least contributing to the environmental factors. L_{OA} of motorized ring seine units restricted to 15m for near shore operation with smaller size of ring seine gear and mechanized ring seine units with optimized gear for off shore operation will help to reduce the environmental impacts.

8.4 Conclusion

In Kerala, ring seines contribute about 98.8% of oil sardine fishery, as far as we have been able to ascertain, it is the first life cycle assessment performed on the Indian oil sardine fishing fleet. The two hot spots identified in the Indian oil sardine fishery (mechanized and motorized ring seine) were fuel usage for fishing operation and material for fishing craft and gear. Compared to mechanized fleet the environmental impacts of motorized fleet are high. Fishing vessel hull optimization, reduction of engine rpm, periodic maintenance of hull and replacement of two stroke petrol engine to inboard diesel engine is recommended in order to reduce environmental impact related to fishing operation and knowledge about pelagic fish spatial distribution reduce the environmental impact by reduced shoal searching time. Use of high durability alternative webbing materials and appropriate use of lead sinkers will increase the life of gear and reduce the environmental impact.

Chapter

9

CONCEPT AND DESIGN OF A NEW RING SEINE GEAR

Contents

9.1 Introduction

Unscientific increase in the dimensions of the gear in the ring seine sector has led to increase in fishing capacity. For greater exploitation of the fishery, fishermen themselves increased the size of fishing gear in an unplanned manner. In order to accommodate the huge gear, catch and crew onboard, the craft size was increased (D'Cruz, 1998). The shape and design of new gear is an enlarged version of the old one with regional variations in the wing panels. Lack of scientific approach in the enlargement of fishing gear caused major problems to the fishery like low sinking speed, frequent wear and tear and most importantly capture of juveniles. Low sinking speed results in the escapement of shoals from below the net. More successful commercial exploitation of active pelagic shoals require ring seine with high sinking speed. Low load bearing capacity near the bunt portion and attack by dolphin and puffer fish in the upper panels of the net are serious threats to ring seine operation resulting in loss of fishing days and increase in maintenance charges.

Use of small mesh size is a serious issue resulting in capture of juveniles. Najmudeen and Sathiadas (2008) reported that juveniles of fishes caught in ring seines are comprised of anchovies (40%), oil sardine (30%) and mackerel (15%) of the total catch along the Kerala coast. It is reported that the annual economic loss due to juvenile fishing in ring seiners with a fleet size of 2351 cause US$ 2037 million annum^{-1} to the economy (Najmudeen & Sathiadas, 2008). Pramod (2010) reported that the excess juvenile catch in ring seine fishery is due to small meshed ring seine operation and ring seines of Kerala catch 0 and 1 year class of sardine and mackerel in high quantity every year. During the peak season, excess landings of small pelagic fish like sardine result in decline of market prices and these excess fish is dumped in backwaters as discards (Van der Heijden 2007). Every year ring seine units discarded 1.8 -3 tonnes of oil sardine in Cochin backwater (Pramod, 2010). According to CMFRI (2012c), the year 2011 noticed a heavy exploitation of sardine juveniles and 78.5 % of the juveniles landings are contributed by seine net units.

In this chapter an attempt is made to propose a design of ring seine made of a combination of new generation materials like UHMWPE, sapphire and bite resistant polyethylene for sustainable exploitation of the small pelagic fishery based on the findings of the present study.

9.2 Results and Discussion

A new ring seine fabricated using a combination of new generation materials is designed for the exploitation of small pelagic fishery. Details of the proposed design is given in Fig.9.1. The dimensions of the ring seine gear has been optimized by rightsizing the gear (600 x 60 m with 22mm mesh size) as per Kurup et al. (2009). A new webbing material namely Ultra High Molecular Weight Polyethylene (UHMWPE) popularly known as Dyneema/ Plateena etc. was introduced in the ring seine fishery for improved sinking speed and greater break load.

UHMWPE fibre is a version of polyolefin manufactured by the gel spinning synthesis of monomer of ethylene. It exhibits a high degree of molecular orientation, very high tensile strength and monomer units per molecule (molecular weight) (3.1 to 5.7 million) when compared to HDPE (700 to 1800). The material is 15 times stronger than steel (on a w/w basis). The material has high strength, low density, no water absorption capacity, low elongation at break, high abrasion resistance, high resistance to UV radiation and high resistance to degradation by micro organisms (Thomas & Edwin, 2012). With UHMWPE we can make thinner twine than PA or HDPE with same strength. It is proven that due to this property and comparatively less weight of UHMWPE the drag and fuel in trawl fishing is reduced considerably (Anon, 2009; Sendlak, 2001; Sala *et al.,* 2008).

Application of UHMWPE in ring seine fishing will increase the sinking speed of ring seine through reduction in drag and increase in water filtration. According to Thomas and Edwin, (2012) replacement of polyamide webbing with UHMWPE will ensure the increase in life of purse seine by at least 2-3 times more.

From this study it is evident that operational depth of ring seine vary mainly between 10-30m. Considering this, in the proposed ring seine 33 % of the bottom portion of the vertical panels are replaced by UHMWPE for increased sinking speed. This also helps to optimally utilize UHMWPE which is much costlier than polyamide.

UHMWPE is three times stronger than polyamide with same diameter and higher abrasion resistance. The area on either side of bunt portion which is less durable due to maximum wear and tear caused by the heavy load of fish is replaced with UHMWPE will ensure more life. The thicker twine of the bunt is replaced by thinner twines of UHMWPE and this will reduce the net storage space, ensure improved sinking speed and more life.

Netting made of UHMWPE does not absorb water. This property reduces the drudgery while hauling due to its lesser weight of net. UHMWPE webbing are used in critical areas to increase the durability of webbing.

Webbing below the float lines up to six meters is replaced with bite resistant polyethylene as this area is found damaged by puffer fish and dolphins. Bite resistant polyethylene which is stiff in nature is made with a combination of synthetic fiber(s), metal wire(s) and stiffening cum waxy material like hot melt adhesive (GWR, 2013). Bite resistant polyethylene are mainly used for cage culture to protect the culture fish from predators like shark, sea lion etc. Northridge (2013) also reported the advantage of steel or copper cored bite resistant polyethylene for predator protection in cage culture.

To reduce weight, wear and tear, the webbings of the side panels are replaced using sapphire®. Sapphire is a modified form of HDPE and was reported to be used for fabrication of trawl nets and gillnets (Councilman *et al.,* 2011; Edwin *et al.,* 2014a; Muhammed *et al.* 2015). Use of sapphire gives advantages like better abrasion and knot stability than other gear materials (Councilman *et al.,* 2011). Muhammed *et al.* (2015) observed that Sapphire was more durable than PA and HDPE and that being lighter than PA, sapphire nets can be operated very easily. Nielsen *et al.* (1983) reported that braided twines of sapphire netting gave better durability and abrasion resistance than twisted twine of nylon in trawl nets.

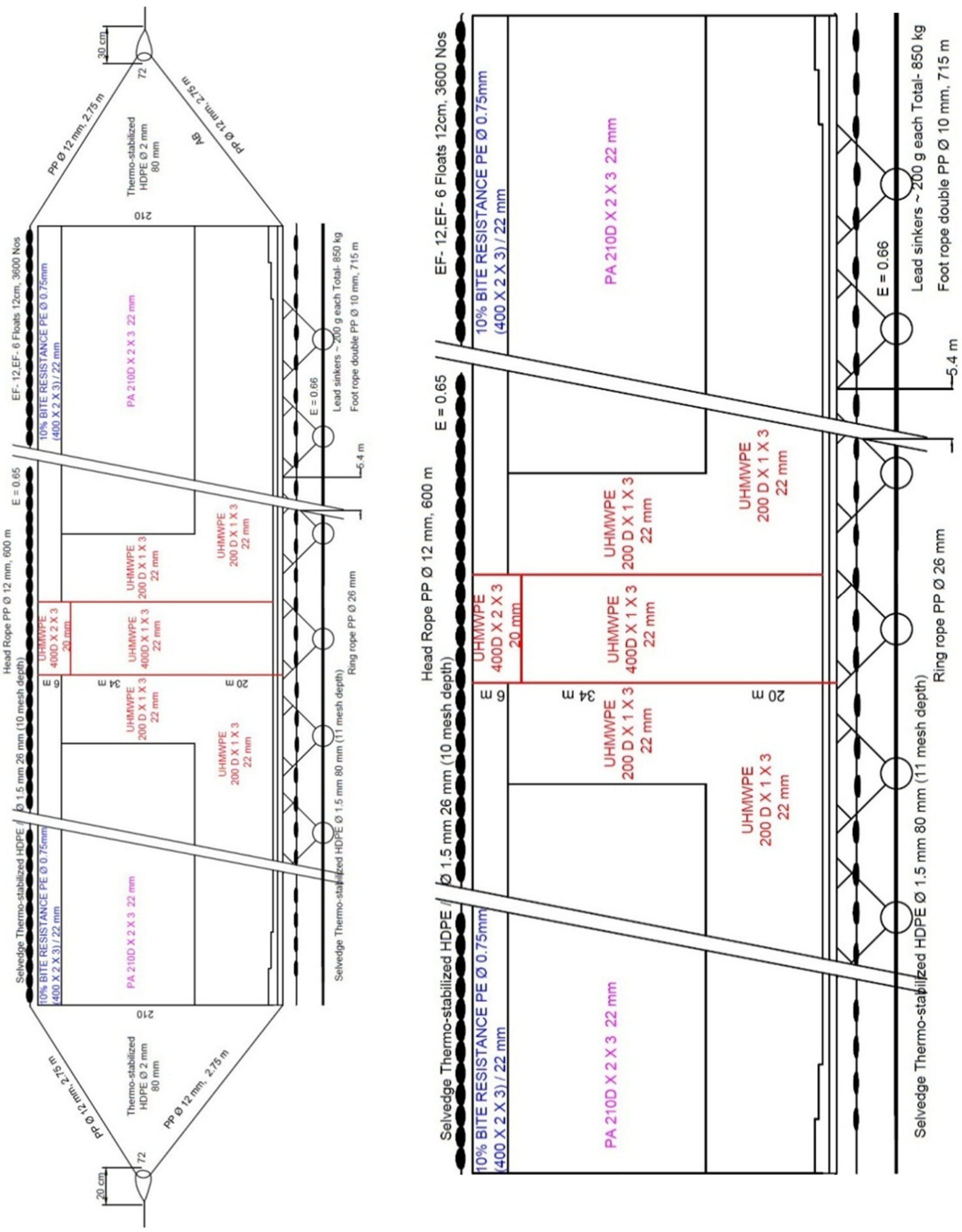


Fig.9.1 Design of proposed 600 m ring seine

9.3 Conclusion

With appropriate use of new generation fishing gear materials and right sizing the gear, the model ring seine design resulted in 45 % lesser weight than the conventional gear polyamide ring seine. As per the theoretical calculation of sinking speed using the new formula, conventional polyamide ring seine shows sinking speed of 13.88 m/min with 22mm mesh size where as in ring seine with UHMWPE shows 22.17 m/min with the same mesh size. Durability of the new gear is anticipated to be 2-3 times more than the conventional gear. Due to increased durability, service life ensure 60.43% lesser carbon emission than conventional polyamide ring seine in LCA analysis.

Chapter

10

SUMMARY AND RECOMMENDATIONS

Traditional fishermen welcomed the new fishing gear called ring seine, as it assured them a large quantity of catch compared to their conventional fishing methods. Widespread adoption of this technology resulted in substantial increase in the landings of small pelagic species like oil sardine, mackerel and anchovies by the traditional sector. By the end of the eighties, ring seine became the principal gear for the exploitation of pelagic fish resources along the coast of the state of Kerala and it later spread along the entire south west coast of the country. Under the doctoral programme, studies were conducted on the present status of ring seine and its regional growth, structural changes in the ring seine system, durability of ring seine gear, sinking speed and operational efficiency of gear, spatial and seasonal distribution of fishing ground, life cycle assessment and carbon foot print of fishery and concept of a new ring seine gear. The work done can be summarized as follows.

- The design of the ring seines varied with reference to the area and type of operation, species caught, type of vessel used for operation, etc. and the maximum size of gear is increased up to 1500m in length.
- The L_{OA} of motorised units ranged between 7.27m to 19.39m propelled by OBM of 9.9 to 80hp (40 x 2) and among the units sampled, 58% were wooden vessels. The L_{OA} of mechanised units ranged between 17.87m to 24.38m propelled by IBM of 104 to 440hp and among the units sampled, FRP units (59%) dominated followed by steel (41%).

- The operational procedures have changed with the increase in size of the ring seine system ranging from one boat in Alappuzha to four boats in Kasaragod.
- Break load studies of ring seine sections shows that the least durable part in webbing are the areas adjacent to the bunt followed by front panel of netting, bottom panel of netting, top panel of netting and end panel of netting and showed unsuitability for use after 10 months. The Dolphin Wall Net (DWN) used by fishermen was observed to be a suitable solution to reduce the damage caused by aquatic fish/ mammals.
- It was concluded from the sinking speed studies that instead of increasing the lead weight, use of species specific optimum mesh sizes and appropriate twine sizes will give enhanced sinking speed. Material substitution of polyamide webbing with Ultra High Molecular Weight Polyethylene (UHMWPE) can reduce the twine size by half and will also enhance the sinking speed up to 100%.
- Spatial analysis of species distribution showed that there is a significant seasonal shift of fishing ground which showed a clear sign of spatial displacement of fish shoals. During monsoon season, fishing ground shifted below 9.50 N from 10.1N, exhibiting a southward shift of fishing ground during the period.
- Among the inputs used for construction of an FRP vessel, the polymer contributed maximum to carbon emission, in the case of a steel vessel the steel plates contributed 82.80 %, in the case of a wooden vessel, the wood contributed -64.52 %, in the case of a plywood vessel, the FRP sheathing and polymer used contributed more. Polyamide webbing contributed to 78.21% of Global Warming Potential (GWP) in case of

gear. In motorised and mechanised ring seine fishing operation, kerosene contributes the maximum of CO_2 emission with 46% and 36 % respectively.

- A concept for design of a ring seine with new generation material is proposed with materials like UHMWPE, sapphire and bite resistant polyethylene. The theoretical weight of the model ring seine is 45 % lesser than the conventional gear, sinking speed is 62.6 % higher than PA gear and carbon foot print 60.43% lesser than the conventional gear. Durability of the new gear is anticipated to be 2-3 times more than the conventional gear.

Recommendations

- There has been an increase in size of ring seine unit and power of units which has to be reduced for sustainable exploitation and reduction of energy use.
- Information on season specific shift in fishing ground is observed in this study, if provided to fisherman will help in reducing fuel consumption. Further studies in this regard are needed.
- Optimal use of steel/ wood/ plywood for construction of craft reduces carbon foot print by 20-35% when compared to FRP and hence recommended for use.
- Use of appropriate material which will increase sinking speed, thereby increasing efficiency of the gear and use of bite resistant HDPE and highly durable UHMWPE are recommended for increased (2-3 times) life of the gear.

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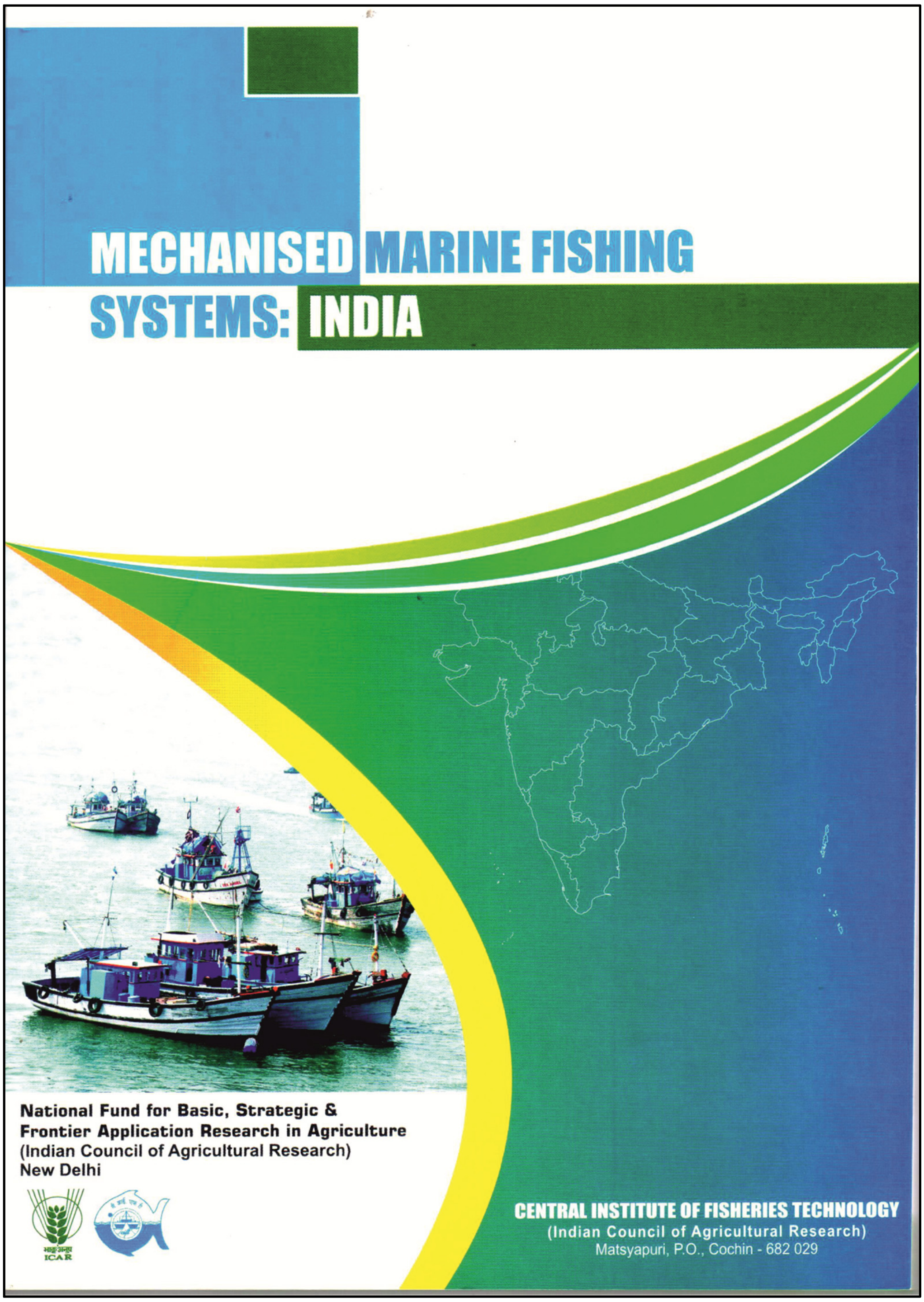
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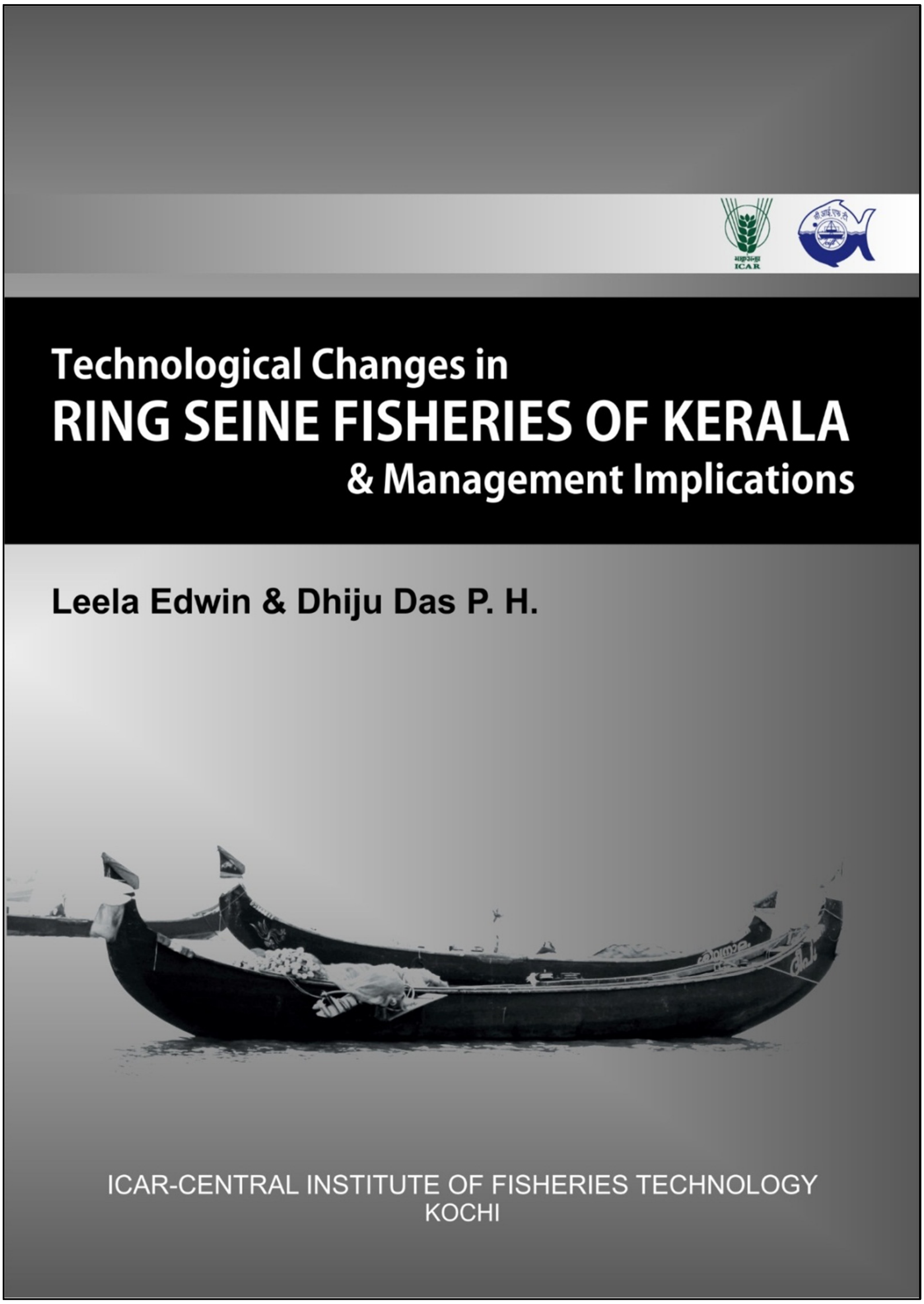
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Dolphin Wall Net (DWN) — An innovative management measure devised by ring seine fishermen of Kerala-India to reducing or eliminating marine mammal–fishery interactions

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ABSTRACT

One of the major problems associated with the operation of ring seines in Kerala coast is the attack of dolphins. In order to overcome this problem without harming marine cetaceans, fishermen developed a special type of net forms an outer protective wall to the ring seines. This paper discusses the structural and operational details of this net. This initiative of traditional fishermen to conserve marine cetaceans is documented in this communication.

1. Introduction

In India, ring seines were developed and introduced by the Central Institute of Fisheries Technology (Panicker et al., 1985). It was christened as a mini purse seine and was employed for the harvesting of small pelagic fisheries resources of south west coast of India particularly in the Kerala coast. About 71% of pelagic fish landing in Kerala are contributed by ring seine fishery with oil sardine (54%), mackerel (13%), carangids (9%), anchovies (6%), tunas (5%), ribbonfish (4%), seer fishes and lesser sardines (2% each). Out of this, 98.8% of oil sardine, 71% of lesser sardine, 56% of mackerel and 42.6% of white baits landings were contributed from ring seiners (CMFRI, 2011). This highly efficient artisanal gear is widely accepted by fishermen and over the years this gear increased in number phenomenally (Edwin et al., 2010).

The success of ring seine operation caused this gear to become hugely popular among traditional fishers and has spread to other coastal states of India. Ring seining involves surrounding schools or other accumulation of fish with a net, impounding the fish by pursing the net from below, and drying up the catch by hauling the net so that the fishes are crowded in the bunt and can then be brailed out. The major problem associated with the operation of the ring seine is the attack of dolphins and other cetaceans during the time of aggregation and brailing the catch. There are several reports on the incidental catch of dolphins from gill nets, purse seine, trawl nets and ring nets. Leatherwood and Reeves (1978) had reported the inadvertent destruction of large number of cetaceans by tuna purse-seiners. Jayaprakash et al. (1995) reported incidental catch of 42 numbers of common dolphin *Delphinus delphis* in 1984 associated with purse seine fishery. In recent years, with increasing fishing activity and extension of fishing to oceanic waters, the encounters between fishing gear and marine mammals are on the rise (CMFRI, 2010). Attack of ring seines by dolphins in Kerala causes huge financial burden to the ring seine fishermen every year. It is estimated that the average cost for repairing a damaged net will be approximately 1 700–3 400$.

There are currently 125 recognized species of marine mammals in the world. IUCN has listed 25% of these species as threatened (IUCN, 2009). Several species are in danger of extinction (Prideaux, 2003). In India, 26 species of cetaceans and one species of Sirenian have been recorded (CMFRI, 2010). All the species are placed under Wildlife (Protection) Act, 1972. Under the Act, three species, namely Gangetic dolphin (*Platanista gangetica*), Irrawaddy dolphin (*Orcaella brevirostris*) and dugong (*Dugong dugon*) are under Schedule I and others are under Schedule II. As per the act, Schedule I and Part II of Schedule provide absolute protection. Capture, use and trade of animals under this schedule prescribed the highest penalties. However, marine mammal–fisheries interaction is a major cause for concern (CMFRI, 2010). Worldwide, marine mammals have declined due to various reasons including increasingly sophisticated methods of hunting, pollution, degradation of habitasts and growing human populations (Leatherwood and Donovan, 1990). There are reports of incidental landing of smaller cetaceans

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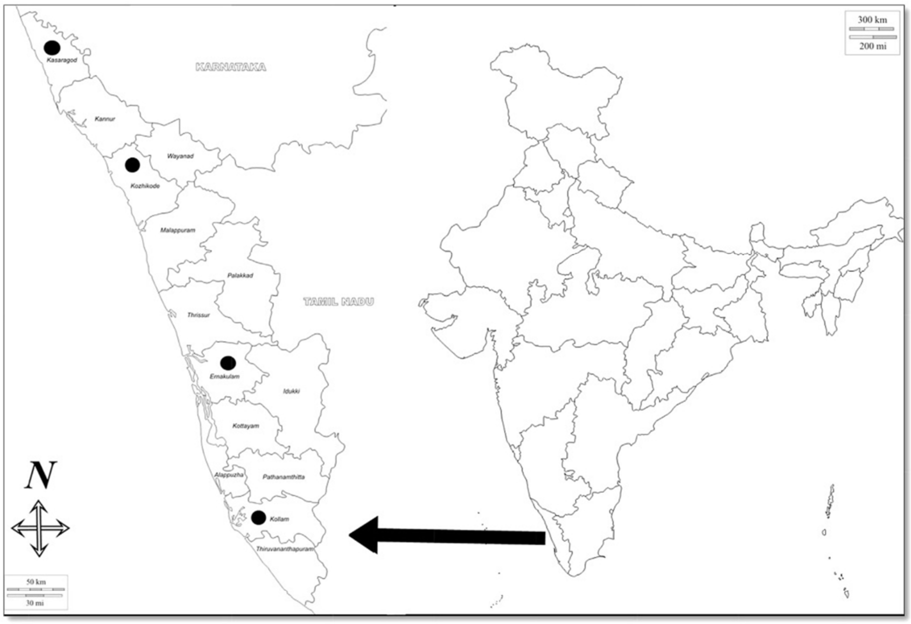

Fig. 1. Map of study site, Kerala, India.

in commercial fisheries as by catch (Anon, 2003). Interactions between marine mammals and commercial fisheries have occurred for centuries but are increasing in frequency and intensity, a trend that is likely to continue into the foreseeable future (DeMaster et al., 2001).

There are mainly two methods for reducing the mammal–fishery interactions viz, passive methods and active methods (Jefferson and Curry, 1996). The passive methods include net modifications, incorporation of add-on reflectors in the fishing gears. Active methods are mainly based on sound generators which includes shoot and kill the offending animals (*Gunshots*), use of explosives, biological sounds, mechanical sound generators and electronic sound generators. Besides this, there are several other methods like vessels chasses and the use of boat noises (Jefferson and Curry, 1996).

Most of the previous attempts to deter marine mammals from fishing activities were based upon trial and error with few controlled experiments (Jefferson and Curry, 1996). Often, the fishermen understandably unwilling to wait for the slow process of science to provide a solution, have 'taken matters into their own hands', experimenting on their own with various techniques (Jefferson and Curry, 1996). Ring seine fishermen of central Kerala have fabricated a new wall net using locally available materials with low investment to prevent the damage caused by dolphins. This newly fabricated net is a passive method to reduce the cetacean interaction in ring seine fisheries. The structural and operational detail of this wall net is presented in this text.

2. Materials and methods

The data for this study was collected from the selected centres of Kerala, India. Stations were identified and fixed by reviewing the literature and also by consulting the experts in this field. Four stations in the state were selected representing north, central and south coastal district of the state. viz, Kasargode, Kozhikode, Ernakulum and Kollam (Fig. 1). Sampling was done in minimum three major ring seine operating fishing harbours/landing centres of each district (Table 1). The field studies involved extensive field survey and data collection lasting for three months from July to September 2012. This has resulted in documenting valuable information about the operational and technical aspects of ring seine

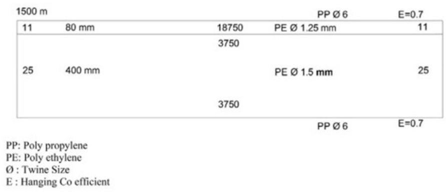

Fig: 2. Diagrammatic representation of Dolphin Wall Net with selvedge & conventional float.

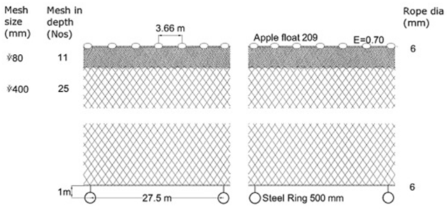

Fig: 3. Structural details of Dolphin Wall Net with selvedge & Conventional float.

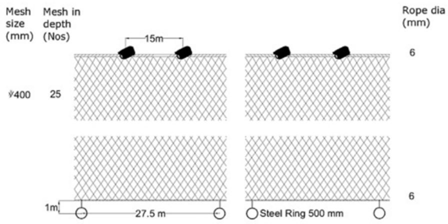

Fig: 5. Structural details of Dolphin Wall Net without selvedge & indigenously developed float.

operation. Ring seine operating fishermen of different age groups from varying socio-cultural background were interviewed using an unstructured questionnaire with open-ended questions. Each group consisted of 10–25 numbers of fishermen and minimum three such groups were interviewed form each station and the interaction lasted for 30–40 min. Questionnaires were prepared covering the technical aspects and operational details of ring seines. The discussions were held in the local language – *Malayalam*. People who seemed comparatively more knowledgeable among the group were contacted individually and in-depth interviews were held with them. Data were validated through focussed group discussions and interactions with group leaders of the ring seiners and experienced fishermen. The matrix ranking method was prepared to prioritise the primary operational problems during ring seining (Table: 2). Attack of dolphin during fishing was identified as one of the major operational hurdles. From the interaction, it is revealed that fishermen developed a new net-Dolphin Wall Net (DWN) to overcome this problem. Structural details of the DWN were recorded scientifically by direct field observations.

3. Results

3.1. Structural details of dolphin wall net

Dolphin wall net is a 1 000–1 500 m long wall of netting framed with float line and steel rings hanging from the lower edge. The wall net is made up of 300–400 mm high density polyethylene (HDPE) webbing of 1.5 mm diameter with 25 mesh depth (Fig. 6C). Two types of dolphin wall nets are commonly seen in Kerala, one with conventional plastic float with selvedge (Figs. 2 and 3) and the other is without selvedge (Figs. 4 and 5) with locally available materials like thermocole blocks and empty oil cans as floats. Selvedges are used for reducing the entangling of floats to the webbing. 80 mm HDPE webbing of 1.25 mm diameter and 11 meshes in depth are used as selvedge having apple floats of 90 mm diameter. Dolphin wall net without selvedge uses large 5 l empty plastic cans or large thermocole blocks as floats (Fig. 6A). The floats and rings are attached to 6 mm polyethylene ropes. Apple floats are attached to the float rope at an interval of 3.66 m in Dolphin wall net with selvedge where as empty cans are attached at 15 m interval in dolphin wall net without selvedge. Fishermen from Kozhikode region in northern part of Kerala prefer thermocole block as floats. These are used to prevent entangling of net caused by sharp and irregular edges of the cans. Rings are attached to the foot rope with one meter length polyethylene rope at an interval of 27.5 m. Circular steel rings having diameter 500 mm and weighing 1–2 kg are commonly used as sinkers (Fig. 6B). Fibre-reinforced plastic or wooden fishing vessels of 15–20 ft with 9.9 hp outboard engines are used for operation.

Fig: 4. Diagrammatic representation of Dolphin Wall Net without selvedge & indigenously developed float.

3.2. Operation of dolphin wall net

Once a school of appropriate size and desirable species is detected, the craft is taken sufficiently close to the school and ring seine net is encircled quickly. Simultaneously, DWN is operated from the carrier vessel with an LOA 9–13 m. After the pursing operation, the catch is concentrated close to the craft in the bunt portion, by hauling up the main body of the seine from either end. Normally this net is used by fishermen during summer season only (March to May). According to fishermen, dolphin menace is more during summer due to clear and transparent water.

3.3. Problems associated with ring seine operation

In India, interaction between humpbacked dolphin and trawl/purse seine fisheries is common (CMFRI, 2010). During ring seine operation, it was observed that groups consisting of about thirty animals congregate in the fishing area and surround ring seine net and cause disturbance to fishing by taking away fishes from the net. In order to prevent this disturbance, two types of measures are practised by the fishermen. Some fishermen use crackers to drive

Table: 1
List of Study area.

Sl No	Locations	Study site	Co ordinates
1	Kasargode	1.Kasaba beach	(12° 30′7″N 74° 58′27″E)
		2.Hos durg	(12° 20′9″N 75° 3′54″E)
		3.Bekal	(12° 24′58″N 75° 1′6″E)
		4.Neeleswaram	(12° 15′1″N 75° 6′3″E)
2	Kozhikode	1.Baypore	(11° 09′56″N 75° 48′23″E)
		2.Chaliyam	(11° 09′44″N 75° 48′30″E)
		3.Koyilandi	(11° 25′50″N 75° 41′38″E)
		4.Chombala	(11° 39′43″N 75° 33′04″E)
		5.Vellayil	(11° 15′51″N 75° 46′01″E)
3	Ernakulam	Chellanam	(9.8072° N, 76.2774° E)
		Munanmabm	(10° 10′59″N 76° 10′16″E)
		Toppumpadi	(9° 56′19″N 76° 15′46″E)
4	Kollam	Thankasery/Vaady	(8° 52′37″N 76° 35′02″E)
		Puthanthura	(8° 57′38″N 76° 31′51″E)
		Azheekal	(9° 7′53″N 76° 28′02″E)

Table: 2
Matrix ranking table for studying problems related with ring seine operation.

Interviewer's name:
Date:
District:
Harbour/landing centre:

Problem	Key Informer	Rank	Weightage
Puffer fish/dolphin attack	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			
Net damage due to entangling in rocky area or dragging in sea bottom	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			
Shortage of labour	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			
Increased fuel price	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			
Low durability/high price of webbings	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			
Over capacity (Number of fleets and size of fleet)	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			
On-board crew facility/safety	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			
Middleman influence on fish sale	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			
Conflicts with other fishermen	KI 1		
	KI 2		
	KI 3		
	KI 4		
	KI 5		
Total			

away the dolphins from their fishing area. However, fishermen are cautious to avoid causing physical injury to dolphins. Some fishermen patrol the fishing area in a small boat. Boat anchors, tyres or any hard objects covered with plastic operated from carrier vessels are some of the indigenous objects used fishermen to drive away the dolphins from fishing grounds.

4. Discussion

Interactions between dolphins and fishing nets have been reported for more than a century (Backhouse, 1843), but such events have been described sometimes as cooperative (Busnel, 1973; Pryor et al., 1990; Neil, 2002). Currently, however, within the context of fish stock collapse (Jackson et al., 2001; Myers and Worm, 2003), these interactions are considered by the fishing industry as conflicting (Yodzis, 1998). The marine mammal–fishery interactions cause a loss in revenue to small and large scale fishermen by way of mechanical damage to gear and to a certain extent loss of captured fish. Among several gears, gill nets and purse seines have been identified as the main cause for marine mammal mortality at the global scale (Cockcroft and Krohn, 1994; Perrin et al., 1994; Archer et al., 2001; Wise et al., 2001; Read et al., 2006). In Kerala, non-motorized traditional fishing vessels play a major role in ensuring livelihood of the fisher folk (GoK, 2010). In the traditional sector most important fishing gear in Kerala is ring seines (Boopendranath and Hameed, 2012). Fishermen report that the problem due to attack of dolphins during ring seine operation is more challenging during March to May. The approximate cost for a dolphin wall net is estimated as 1 200$. DWN is operating from the existing small carrier vessels. According to fishermen, compared to the economic loss due to the dolphin attack the expenditure for the continuous repairing of the ring seines, the amount spent for the fabrication of DWN is negligible. Recent reports also showed that dolphins have now learned to consider catches of fishing operations as a new food resource (Reeves et al., 2001); they remove fish directly from nets, resulting in a loss of fish for fishers and damage to nets. Sometimes dolphins may act as indicators of fish availability. In Kerala, Dolphin-assisted cast net fishery in the *Ashtamudi* estuary, is an excellent example for this (Kumar et al., 2012).

Sivadas and Kumar (2009) have described the dolphin attack preventing nets along Kozhikode coast, Kerala as dolphin excluder nets. Being a surrounding type of net, more than excluding, it creates a barrier to the ring seine and keeps away the mammals in a safe distance. Hence the name Dolphin Wall Net is more suitable for this type of net. Interactions between marine mammals and fisheries take several forms. Some are operational, in which marine mammals come into physical contact with fishing gear (Beverton, 1985). Operational interactions can result in the mortality or serious injury of marine mammals that are "captured" but discarded, a process known as by catch (Alverson et al., 1994). In some areas of the world, marine mammals are captured unintentionally but retained for consumption or sale (Read et al., 2006). In India, Dolphins are caught in good numbers at Cochin, Malpe, Karvar, Goa and Bombay areas (Jayaprakash et al., 1995). About 9 000 to 10 000 dolphins are estimated to be caught by gill net annually along the Indian coast (Yousuf et al., 2008; Mohan, 1985; Kasim et al., 1993; Satya Rao and Chandrasekar, 1994; Thiagarajan and Pillai., 2000). Gill net contributed 68.9% to the incidental catch. Two species commonly involved in the gill net fishery are the spinner dolphin *Stenella longirostris* and the bottlenose dolphin *Tursiops aduncus*. In addition, other species such as Risso's dolphin *Grampus griseus*, long-beaked common dolphin *Delphinus capensis* and Indo-Pacific humpbacked dolphin *Sousa chinensis* are also reported. Maximum number of dolphin entanglements in gill net was encountered in the fishery for large pelagics such as tuna and seerfish. The length of gill net operated along the Indian coast ranged from 0.5 to 2 km with varying mesh size. A study by CMFRI showed that, the length of mechanized boats that incidentally caught dolphins and porpoise ranged from 9 to 15 m with 20–108 hp engine. The fishing operations were carried out 4–70 km from the shore. Off Mangalore, a large number of finless porpoise, *Neophocaena phocaenoides* are incidentally caught in purse seines. Stray numbers are caught in the Gulf of Mannar region (Jayaprakash et al., 1995). At Fisheries Harbour, Cochin, the drift gillnetters operating to exploit a variety of larger pelagic fishes also have been found dolphins to entangle incidentally (Silas et al., 1984). Instance of dolphins

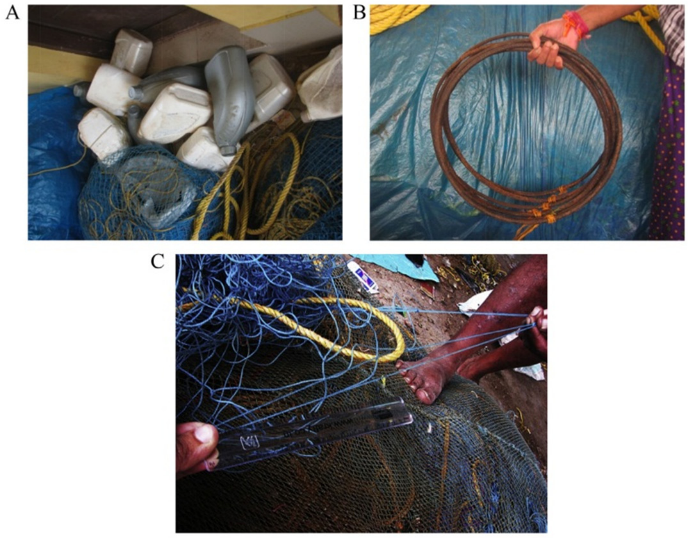

Fig. 6. A. Float of Dolphin Wall Net, B. Sinker rings of Dolphin Wall Net, C. Measurement of single mesh.

'caught' in large numbers by a purse-seiner operating at this centre is also reported from the same location in India. Reports on the incidental by-catch of dolphins have been reported by many workers (James and Mohan, 1987; Mohan, 1985; Pillai and Kasinathan, 1987, 1988; Pillai and Lipton, 1991; Pillai et al., 1991; Pillai and Chandrangathan, 1990; Rajagopalan et al., 1984; Santha et al., 1987). Silas et al. (1984) reported that 1% of the total landings by fishing gear at Cochin were dolphins. Marine mammals face a wide range of threats. The greatest threat to coastal populations of dolphins is the intense fishing activities which results in the incidental killing as a result of entanglement in fishing gear. With continued proliferation of synthetic gill nets throughout the world, by catch has emerged as an extremely serious threat to marine mammals, as well as to sea birds, turtles, fishes and other non-target organisms (Northridge, 1991). In addition, reduction of prey due to overfishing affects the abundance of dolphins.

The DWN is known in the local parlance as "*Panni vala*" in south and central Kerala and it is known as *Edi vala* in North Kerala. Among the passive methods for reducing fish–mammal interaction, the main aspect is the modifications to detectability of nets to odontocete cetaceans, which have echolocation capabilities. Since major part of the mammal by catch was reported from gill nets, several studies were done throughout the world for the structural modification in the gill net. The wall net fabricated by the Kerala ring seine fishermen is just like a panel of netting which resembles to a gill net. Studies showed that the lead and float line of the gill net is more detectable to the mammals (Pence, 1988). The lead line and float line of the DWN is composed of bigger iron rings and plastic cans. So definitely it will prevent the entry of the animal to the ring seine operating area. Being the net is made of thicker twine size (1.5 mm), wide webbing (400 mm) and large float and sink attached to, it may increase the acoustic reflectivity (Jeonfferson and Curry, 1996) and this may be the reason for the non-entangling of the dolphins in the presently discussed net. Besides this, the cetaceans have natural tendency to avoid noval objects (Pryor, 1973) or they will be more cautious when they are aware of a potential barrier in the area.

5. Conclusion

The dolphin wall net is an indigenously developed system associated with ring seine fishery of Kerala. Even though the DWN is framed to avoid the disturbance of dolphins during operation of net, it is an eco-friendly conservation aspect followed by fishermen, which indirectly helps to protect the scheduled marine species. Being most of the cetaceans in India are coming under protected category, the new initiative from fishermen to avoid incidental catch of marine mammals should be popularised. Proper legislation and management measures should be framed in this regards. Purse seine fishermen all over the globe can adopt this innovation to reduce mammal–fisheries interaction. Before implementing this technology, proper scientific study is needed to assess the merits and demerits of this net as well as the behaviour and response of cetaceans to new gear system. This will help to improvise the efficiency of the DWN developed by the fishermen. Future study is needed for the development of suitable technology for reducing mammal by catch in the gill net, which is one of the major concerns in India.

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Labour Deployment and Wage Distribution in Ring Seine Fishery of Central Kerala

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Abstract

The study is focused on the traditional ring seine fishery of Chellanam village in the Ernakulam district of Kerala. This fishery has a unique traditional system of managing the labour as well as fishing activities, an important tradition being the *karanila* system which regulates the work and wage sharing pattern of the fishery. Though the ring seine unit (craft and gear) is owned by more than one fishermen (shareholders), every fisherman who is capable of fishing has a right to work as well as a share in the wages. The crew: owner ratio of sharing the benefits is 60:40, with the returns to labour being proportional to the revenue generated. The impact of the work and wage share system has been that every healthy fisherman gets assured employment and a wage, even if he is not actually part of the fishing crew. Though it is a form of disguised unemployment, it has aided in reduction of abject poverty in the community in this area.

Key words: Ring seine, fishery, labour, work share, wage share, *karanila*

JEL Classification: J21, J31

Introduction

The coastline of Kerala accounts for only about 10 per cent of the country's coastline, but the state contributes about 20 per cent to the total marine fish production of India and about 40 per cent of its seafood exports. The state is blessed with a continental shelf of about 40,000 km^2 which is considered to be one of the most productive waters. The state has 223 fishing villages and an estimated 11.43 lakh persons depend on the marine resources for their livelihood, in which the number of active fishermen is about 2.63 lakh and the others are employed in allied fisheries activities like marketing, transportation, processing, etc. (DES, 2010).

The fishers of Kerala depend on various types fishing systems for their livelihood. These include the mechanized fishing fleet with trawlers, gill netters, long liners, hand liners and large mesh purse seiners and motorized traditional fleet with IBM (in board motor) ring seines, OBM (out board motor) ring seines, mini trawlers, gill netters, hooks and liners, encircling nets, boat seiners and shore seiners. Non-motorized traditional fishing vessels also play a major role in ensuring livelihood of the fisher folk of Kerala (GoK, 2010).

The labour requirements are comparatively higher in the ring seine sector than other classes of fishing vessels in the traditional sector. But, the special feature of the ring seine fishery in Kerala is that these units are operated entirely by the local fishermen. The state has a unique traditional system of managing the fishing activity, which regulates the work and wage sharing, and this has been discussed in this paper.

Materials and Methods

The study was carried out in Chellanam village in the Ernakulam district of Kerala. The ring seine fishing is believed to have been introduced first in this stretch

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of the coast (Panicker *et al.,* 1985). Even today, the fishers of this area mainly depend on ring seine fishery for their livelihood. In Chellanam, there are 455 fishing crafts of which only 33 are ring seiners and the rest are gillnetters. Out of 3000 fishermen in Chellanam fishing village, 62.5 per cent work on board ring seiners as the labour requirement for each ring seine ranges between 55 and 65 compared to gillnetters where only 2-4 fishermen are engaged in operation. For the present study, detailed information was collected from 27 ring seiners operating in this region, during the period January 2010-March 2011. The data were validated through focussed group discussions and interactions with group leaders of the fishing craft and experienced fishermen. For clarity in discussion, the work and wage share calculations have been presented and discussed. The disguised unemployment rate was calculated using the formula (Nayak and Chatterjee, 1986) given below, which is based on the time criteria where the number of days of employment is also a factor:

$$DU = [(L-L^*)/L] \times 100$$

where,

DU = Disguised unemployment,

L = Full employment days of work (in this case taken as 180 days as this is the maximum number of days of fishing possible for a ring seine unit on an average annually), and

L* = Number of days worked by a fisherman.

Results and Discussion

Ring Seine Fishery

The traditional ring seine fishery is seen along in the entire coast of Kerala, except for the southern tip (D'Cruz, 1998), with regional variations in the fishing gear and method followed at different places (Edwin and Hridayanathan, 1996; D'Cruz, 1998; SIFFS, 1999; Vijayan *et al.,* 2000). The fishing craft is called the *thanguvallam* and the fishing gear is known as *thanguvala*. Since its introduction, the ring seine has played a significant role in the marine landings in Kerala, contributing 51.6 per cent to it (CMFRI, 2011). The pelagic resources contribute 71 per cent to the total state marine production (CMFRI, 2011) with oil sardine (54%), mackerel (13%), carangids (9%), anchovies (6%), tunas (5%), ribbonfish (4%), and seer fishes and lesser sardines (2% each). Out of this, 98.8 per cent of oil sardine, 71 per cent of lesser sardine, 56.0 per cent of mackerel and 42.6 per cent of white baits landings are contributed from ring seiners (CMFRI, 2010).

The ring seine is an encircling net used to capture pelagic fishes. A number of modifications have been introduced in the design of the gear as innovations by the traditional fishermen (Edwin and Hridayanathan, 1996; D'Cruz, 1998; SIFFS, 1999). In the study area Chellanam, ring seines with a mesh size of 20 mm with a length and depth of 600-1000 m and 83-100 m, respectively and having a weight of 1500 to 2500 kg was targeted to catch the pelagic shoaling fishes like the sardines and mackerel (Edwin *et al.,* 2010). The net is operated from steel / wooden fishing vessels of 65-80 ft in length propelled by an inboard motor and smaller (skiff) vessels of 40-55 ft are used for assistance in fishing operation and transportation of the catch.

The average investment for craft and gear in a steel IBM ring seiner was between ₹ 50 lakh and ₹ 80 lakh; the vessel, including engine, costing upto ₹ 60 lakh and the gear ₹ 15- 20 lakh. Kurup and Radhika (2003) have observed that the cost of production of one IBM wooden ring seiner unit was about ₹ 11.40 lakh. A sudden increase in the capital investment of ring seine units had occurred after 2003. The uncontrolled growth in size of craft and gear size are the main reasons for the huge investment (Edwin *et al.,* 2010). The new engines and change of wooden craft to steel craft have also increased the capital investment. The carrier skiffs are, however, even now made of wood.

The main fishing season for the ring seiners in Chellanam is from June to November. From November onwards the catch declines and some craft are withdrawn. During 2010, the number of craft that operated ranged from 8 to 24 during various months, the least being in January and maximum during July (Figure 1) The number of ring seine fishing days in a month varied from 6 to 20. The fishing trips are carried out during the day, if the conditions are favourable.

Ownership Pattern

In the ring seine fisheries sector, there are two types of ownership of the fishing units, individual and collective. The concept of individual ownership is restricted to smaller crafts of up to 40 feet LOA which are generally non-motorized or craft fitted with outboard motors (OBM). The ownership of a unit by

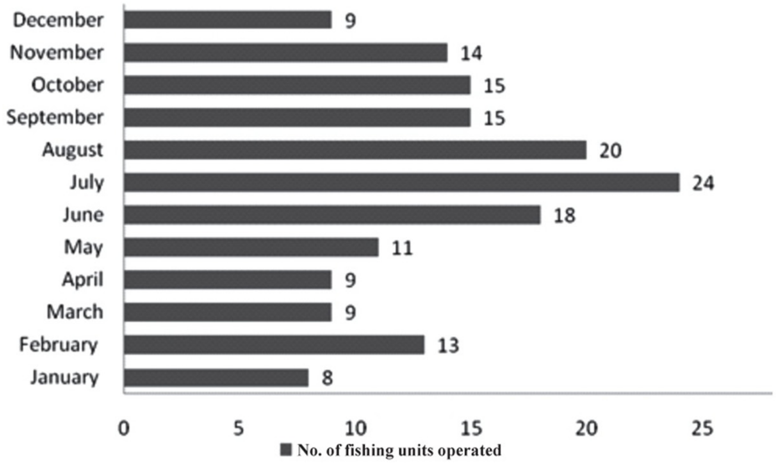

Figure 1. Monthly variation of ring seine fleet operations in study area

family may also be treated as individual ownership. In individual-owned craft, the crew members are usually, though not exclusively, the kith and kin of the owner. In larger units, where the size of craft and gear are bigger, the ownership is collective, with the unit being owned by a group of fishermen (share holders). The investment by individual members of the group to the unit needs not be equal. In both the types of ownership, the distribution of earnings to the owner (returns to capital) from the catch is in the form of 'share' of the production, and owner gets 30-40 per cent of the net income, beside a percentage for the craft, gear and engine. The owner(s) are also generally active fishermen and go onboard.

The shift from single ownership to collective ownership occurred mainly because of requirement of huge capital investment on the ring seine unit (Antonyto, 2002). The risk was thus shared by a group of fishermen. Antonyto (2002) has also reported that the fishermen co-operative societies finance the ring seine units on the basis of share system of ownership. In the present study area, apart from institutional lenders like the Fishermen Cooperative Society which provided credit to fishermen groups, private financers were also common. Private moneylenders are generally auctioneers and they collect the interest on capital as a percentage of the day's catch during the auction itself. The ease of credit availability and absence of formal procedural difficulties are the reasons behind the dominance of informal sources of credit in the fisheries sector.

Work Sharing Pattern

The ring seine unit has a well-structured labour distribution pattern. Each ring seine unit is controlled by a group leader, locally known as *aryakaaran*, who decides about the number of crew on a particular day and is assisted by two or more helpers. Owner(s) always offer huge amounts to hire an experienced *aryakaaran* for their craft. Usually, the crew also gives more value to a good *aryakaaran's* experience and skill rather than the reputation of the boat owner(s).

Fishing area and fish shoal detection is the most challenging task of an *aryakaaran* in the ring seine operation. After sighting the shoal, the other crew members wait for the instructions of *aryakaaran* to shoot the net. He divides and allots the onboard work based on the experience and efficiency of the crew members. The other crew members include skipper, engine mechanic, cook (usually a fisherman) and *chattakaaran* who jumps into the sea for scaring the fish and preventing the escape of fish. The other crew members number around 50-55, and they carry out all

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the activities as per instructions of the *aryakaaran*. The crew strength depends on the size of craft as well as gear because the main effort is for hauling the net after the fish shoal is caught.

The fishermen forming the crew fall in two categories in the ring seine fisheries sector. The first category actually goes on-board the craft for fishing and the second category that stays ashore but is considered crew for all practical purposes. The actual labour requirement for the operation of ring seine units of Chellanam was around 1500. However, the number of active fishermen in the region was higher. Traditionally, every healthy fisherman in a village can join a fishing unit, irrespective of the actual or maximum number of crew a fishing craft can accommodate. The surplus labour that cannot find a place in the craft that goes for fishing on a particular day is called the *karanila* fishermen (Kurien and Vijayan, 1995). *Karanila* literally means 'status on shore'. As all the fishermen, going onboard or staying ashore, are physically capable of taking up the fishing activity, the work is rotated and fishermen going for one fishing trip may be replaced by others on the next trip. This way there is an almost equal sharing of work among the available labour in the community. The number of *karanila* fishermen was not uniform every day; it depended on the fishing season and was more during June to September (south-west monsoon season), which incidentally is also the peak season for ring seine fishing (Figure 2).

Usually, during the south-west monsoon season, a unique fish aggregation phenomenon occurs in the near-shore area of Kerala, known as *chakara* (mud bank formation) (Mathew and Gopinathan, 2000). During the *chakara* period, there are more number of fishing operations per day. These monsoon fishing operations are highly labour-intensive and hauling the gear is tedious due to the strong currents and heavy winds. Each fishing trip takes more than sixteen hours. In such situations, there is a need for rotation of fishermen employed onboard for fishing operation. This *karanila* system ensures work rotation optimizing the maximum catch. This system also provides an alternative livelihood option for the trawl boat fishermen rendered jobless during the 45-day monsoon trawl ban period, when trawlers are not operated (Srinath, 2003). The general fishermen cannot become *karnaila* fishermen unconditionally. He should be a regular crew member. The only exception being the trawl boat workers during the trawl ban period even though trawlers pose stiff competition to ring seines during marketing of the catch. The second condition they need to fulfill is that they should be willing to go onboard for fishing. Only in case of genuine reasons like illness, funeral, marriage, etc. labourers are allowed to stay on shore as *karanila*.

In some regions, the *karanila* group is required to be present to help in the departure of boat in the morning and also when the craft lands on the shore (Berg and Lensing, 2006). However, it was practical

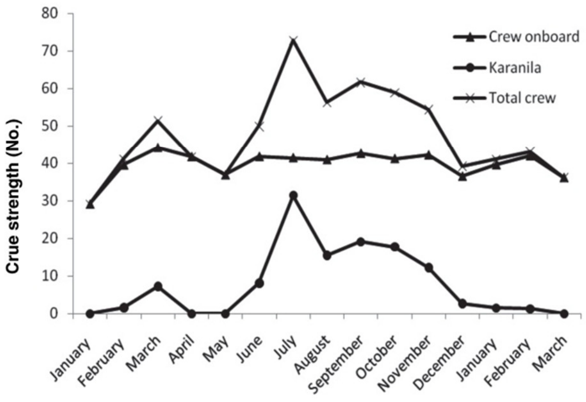

Figure 2. Changing pattern of *karanila* strength in ring seine fishery: 2010-11

only when the craft operated from beach landing centres. Nowadays, ring seiners also operate from fishing harbours and *karanila* fishermen are no longer needed for pushing the craft into the sea or pulling it towards the shore on returns. Besides, the crew have to be transported from the village to the harbour for which the cost has to be borne by the owner. The *karanila* system in ring seine fisheries sector works as a buffer against unemployment in the traditional fisheries sector.

Wage Sharing Pattern

The crew (including *karanila* fishermen) of a fishing unit have the traditional rights on the landed fish. They take enough fish to meet their household requirements. A share for household consumption is also given to persons such as widows, physically and mentally challenged, those temporarily or permanently maimed from accidents at sea etc. who cannot go out for active fishing. The rest of the catch is put up for auctioning at the landing centre which is the first point of sale. The catch once landed is taken over by auctioneer (*tharakan)* for auction. After auction, the catch is transported to market or processors by the wholesalers or large traders.

After auction 10 per cent is deducted by the auctioner from the amount fixed for the fish catch, which is locally called *vilikuravu*. This actually benefits the merchants participating in the auction as they have to actually pay 10 per cent less than the auctioned amount. The auctioneer gets a share of 2.5 per cent of the rest of the amount as action charges. The entry of other merchants into the landing centre/harbour is effectively prevented by a system which excludes them from the benefit of the 10 per cent gain from the auctioned amount. The *vilikuravu* is thus a barrier to trade. Besides the *vilikuravu* and the auction commission, the fishermen also have to pay about 7 per cent as other shares and payments to the cooperative societies, a thrift share and as landing centre owners' rent, etc.

Usually, all ring seine fishermen group(s) borrow from the auctioneers to meet operational expenses or for capital investment running into several lakhs and depending on the borrowed amount, they are charged 4-10 per cent interest, thus reducing the income at the first point of sale by almost 18.55 per cent to 31.15 per cent. The variable costs as well as miscellaneous expenses incurred by the owner(s) (shareholders) are deducted from this revenue. The expenses include the fuel costs, sales commission, food expenses, ferry rent, travelling expenses of the crew members, credit repayments, donation, bata expenses, etc. The net income after deducting all the above is shared by the crew and owner in the ratio of 60:40.

Total crew strength = Number of crew onboard + *Karanila* fishermen

Total revenue = Auction value of fish – [*Vilikuravu* + other commissions and payments at landing centre or first point of sale]

Owner(s) share = Net income × 40/100

Onboard crew share =
{[Net income × 60/100]/ Total crew strength} + onboard bata

Karanila crew share =
[Net income × 60/100]/ Total crew strength

Net income =
Total revenue – Total variable and miscellaneous expenditure, including bata

The wage share is directly proportional to the revenue obtained on a particular day (Figure 3). The crew share is equally distributed among the crew members, including the *karanila* fishermen. Compared to the other crew members, the special category of fishermen onboard, the *aryakaaran*, skipper, engine mechanic and cook get higher share or are paid a fixed wage. They have to be paid the wages even if there is no catch or revenue on a particular day. The other crew members have to do with only the *bata* on such days. The *karanila* fishermen do not get *bata*.

The share of the *karanila* fishermen is called the *karapank* (share of the shore) (Kurien and Vijayan, 1995) and is depicted in Figure 4. It was observed that the bata that the crew got varied from vessel to vessel. However, on average, it was ₹ 50-250, depending on the total revenue for a particular boat (Table 1). If there was no catch for a few trips, the bata amount was increased to a minimum of ₹ 100. Unsuccessful fishing trips result in inadequate earnings to the crew. It also drives the owner(s) into debt as they have to bear operating costs even if there is no catch. It was also

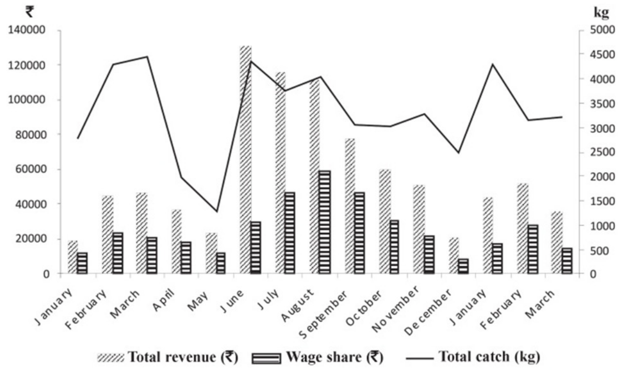

Figure 3. Total catch and revenue and crew wage share in ring seine units

observed that a few unsuccessful trips resulted in loss of labour strength because labour migrated to craft having satisfactory catches.

Table 1. Average on-board crew bata

Catch per day (₹)	Average onboard crew bata (₹)
0-10000	50
10000-25000	100
25000-50000	150
50000-75000	200
75000-100000	250

In the ring seine units, attendance is maintained for proper management of *karanila* and *karapank* and to regulate the shifts system of work sharing. However, there are no strict rules about work rotation; the system is basically voluntary.

Increased catch, however, did not necessarily mean higher revenue or higher crew share (Figure 5). The maximum revenue accrued was in the month of June when the catch was high, ₹ 130963 for 4.4 Mt of oil sardine. The catch of oil sardine was equally high during March, with 4.5 Mt of landing, but the revenue during that period was only ₹ 46790. It was because during June, there was no oil sardine from mechanized trawlers and the unit value realization was high. It was also reflected in the unit value of the landed fish, with higher unit value recorded during the months June to September (Figure 6). During this period, the wage share of the crew was also high.

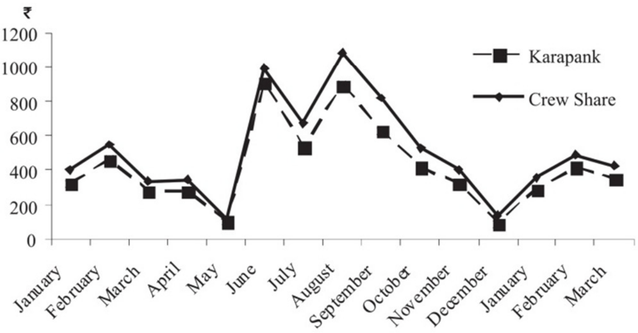

Figure 4. Wage share of onboard crew and *karanila* fishermen in ring seine

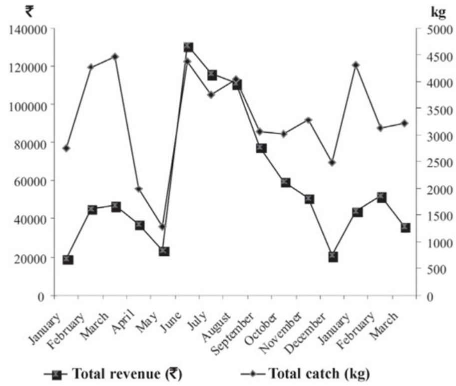

Figure 5. Total catch vs total revenue in ring seine units

Impact of Work and Wage Sharing Arrangement

The fishing communities have been a close-knit unit and the unique system of work and wage sharing in the ring seine fishery has evolved as a result of the necessity of the community to stay together, especially during the times of distress, besides providing adequate labour, especially during peak season, when the requirement of labour would be higher than at other times (Kurien, 1999). The *karanila* system has ensured that every able-bodied fisherman has a right to work, the right to work is now being reflected in the rural employment guarantee schemes propagated by the Government of India as well (Govt of India, NREGA, 2005). With the *karanila* system in place, even if a fisherman does not go out at sea and contribute to production, he is entitled to a share in the wages (which is a fixed percentage of the production or returns).

An analysis of the working crew on ring seine units in the region showed that for a total of 180 fishing days in a year, a total of 11,134 crew members were employed, on an average 62 fishermen per ring seine unit per fishing day. Out of the total fishermen 'employed' as per the existing work arrangement, 83.17 per cent were fishermen, who actually went onboard and 16.83 per cent were *karanila* fishermen, who stayed ashore. While the fishermen who actually went onboard earned a wage of ₹ 560/fishing trip, the *karanila* fisherman earned ₹ 460/fishing trip. Thus, even though not contributing to production directly, they could earn a wage which was assured on all the days fishing actually took place. Considering this as a form of disguised unemployment, the disguised unemployment rate was calculated based on the total working days possible (180 days) and the actual number of days a fisherman was employed (128 days). This did not imply that he was unemployed for the remaining days. He continued to be a *karanila* fisherman and got a share in the wage.

The disguised unemployment rate was calculated as 28.89 per cent. The flow of income into households had ensured that consumption needs of the family were met. Besides the wages, the fisher family also got a share in the catch (traditional share) which often was sufficient to meet the protein requirements of the family (Martone *et al.,* 1980; WHO, 2007).

Conclusions

It has been found that the traditional ring seine fishery in Kerala is still managed through an ingenious method of work and wage sharing in which all the active fishermen of a village or area can participate

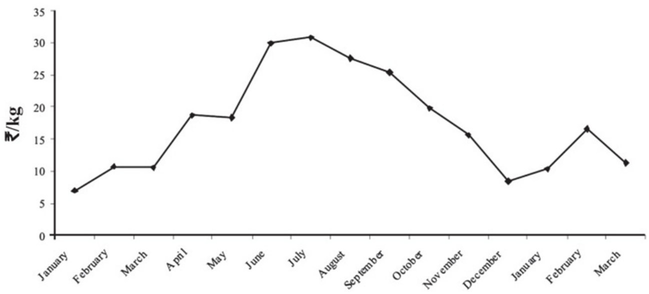

Figure 6. Unit value of landed fish

and earn their living. It has become part of the community tradition and has stood the test of time in spite of changes that have taken place in the fishery. Although the landings from trawl sector decides the unit value realized from ring seine catch, the ring seine fishermen, more than willingly take trawler workers on board during these period of unemployment. This system has ensured the distribution of income from accruing the fishery resources targeted by the ring seine units. Though it is a form of disguised unemployment, it has aided in reduction of abject poverty in the community in the area.

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Ring Seine for the Small Pelagic Fishery

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Introduction

The marine fisheries sector in India has witnessed a phenomenal growth during the last five decades both quantitatively and qualitatively. India ranks seventh in position, contributing about 2.72% (3.9 million tonnes including inland and marine production) to the world fish production for about 143.6 million t (FAO, 2009). The subsistence fisheries during the early 1950s produced about 0.5 million t, annually (Srinath, 2003). At present, the marine fish landings of India is about 3.21 million t with an increase of about 11.3%, compared to the estimate of the previous year (CMFRI, 2009). Out of this production, mechanized sector contributed 74%, followed by motorized (22%) and artisanal sectors (4%), during 2008. Out of marine landings, pelagic resources contributed 71% of the total marine production of Kerala (CMFRI, 2009). Major resources contributing to the pelagic landings were oil sardine (54%), mackerel (13%), carangids (9%), anchovies (6%), tunas (5%), ribbonfishes (4%), seerfishes (2%) and lesser sardines (2%). Ring seine is the most important gear employed for harvesting small pelagic resources like sardines, mackerel and anchovies in the southwest coast of India, especially along the Kerala coast. In Kerala, 86% of oil sardine, 71% of lesser sardines and 67% of mackerel landings were contributed by the ring seine fishery.

Central Institute of Fisheries Technology (CIFT), Cochin developed and introduced a mini purse seine which came to be known as ring seine, for operation from the traditional motorized craft, during 1982-83, as an efficient alternative gear for operation from the traditional boat seine craft *thangu vallom* (Panicker *et al.*, 1985). The uncontrolled increase in fishing effort, in terms of number of fishing units, dimensions of the gear and size and horsepower of the craft, accompanying increasing investment requirements and increase in the proportion of juveniles and sub-adults in the commercial landings have been major concerns in the ring seine fishery (Singh *et al.*, 2007; Kurup *et al.*, 2009). In this paper, the present status of the technology of ring seine fishing system and the prevalence of juveniles and sub-adults in commercial landings are discussed, based on investigations in the Chellanam area (Ernakulam, Kerala), in the context of the need for development and adoption of a standard design of ring seine, for responsible harvesting of small pelagic resources.

Materials and Methods

The study was conducted as a part of the benchmark survey on ring seine fishery of Chellanam under National Agricultural Innovation Project on *Responsible Harvesting and Utilization of Selected Small Pelagics and Fresh water Fishes*, to assess the present status of the ring seine fishing systems and their operation (CIFT, 2008). Chellanam is a progressive fishing village in the southern part of Ernakulam district (Kerala state, India) and an important centre of traditional ring seine activity. Three separate pre-tested schedules were used for collecting information on craft and gear and on operational expenditure. The data pertaining to the study were collected from twenty ring seine units operating mackerel-sardine ring seine locally known as *thanguvala* and anchovy ring seine known as *choodavala*. A total of 70 fishermen were interviewed out of 2701 registered fishermen of the Chellanam Kandakadavu Fishermen Welfare Development Cooperative Society (CKFDWCS). Representative commercial *thanguvala* and *choodavala* designs were surveyed and details collected. The proportion of juveniles in the ring seine landings were determined, based on the length statistics of the random samples taken from the ring seine landings, at regular intervals, during March-June 2008.

Results and Discussion

Ring seine craft

The large plank-built craft from which the *thangu vala* (ring seines for sardines and mackerel) is operated is locally known as *thanguvallom*. The L_{OA} of large *thanguvallom* used for *thangu vala* operation, varied from 19.8 to 25.9 m, breadth from 3.6 to 4.5 m and depth from 2.1 to 3.4 m and the vessels were powered by inboard diesel engine. Medium size boats with a length range of 10.7-13.7 m known as *vallom*, are used as carrier vessels for transporting the catch from the main ring seine vessel to the landing centre. Smaller vessels in the length range of 13.7-18.3 m known as *vallom* using OBMs were widely used for operating *chooda vala* (ring seine for anchovies) in the Chellanam area.

The *thanguvallom* fitted with marine diesel engines of ALM 370, ALM 400, ALM 402 and ALM 412 (Ashok Leyland, Chennai) are widely used in Chellanam area and such vessels of 25 m and above are operated in deeper waters along with the 12 m carrier vessel. The carrier vessels were fitted with either one engine of 25 hp or two engines of 9.9, 25 or 40 hp or three engines of 9.9 hp. Diesel engines were fitted in the mid-section of the craft and the rest of the deck space was utilized for storage of fish and fishing gear. Small purse line winches are used to facilitate closing of the gear, after encircling. The *chooda vala* were operated from smaller crafts powered by either inboard diesel engines or OBMs.

Ring seines

Two types of ring seines were operated in Chellanam area. The first type known as the *thangu vala* has a mesh size of 20 mm, hung length ranging from 600 to 1010 m and hung depth ranging from 83 to 105 m, weight ranging from 1500 to over 2500 kg and is used to harvest the pelagic shoaling fishes like the sardines and mackerel. The second type, the *chooda vala* or the *disco vala* has a mesh size of 8-10 mm, hung length ranging from 250 to 500 m, hung depth ranging from 45 to 75 m and is mainly used to harvest anchovies. It is operated within the limit of 50 m. The gear has a roughly rectangular shape, except for the extreme ends where the depth decreases.

Juveniles in ring seine landings

Juveniles are mainly caught in *chooda vala*, as the mesh size of the gear is small (8-10 mm) and the gear is operated in the inshore waters. The incidence of juveniles in *chooda vala* units was observed to be in the range of 20-33% and in *thangu vala* units, the incidence of juveniles was in the range of 5-15%. During the period of observations, the small sardines were sold at Rs. 2-4 per kg, medium size sardines at Rs. 4-6 per kg and large size sardines at Rs. 8-10 per kg, in Chellanam. Sardines and anchovies together accounted for nearly 70% of the total catch of juveniles and sub-adults landed by ring seiners of Chellanam and the rest were contributed by mackerel and shrimps. The juveniles of sardines and anchovies were landed mainly during the months from September to December. The juveniles of mackerel were usually landed during monsoon season and the fishermen get moderate prices, as the quantity landed is less.

Najmudeen and Sathiadhas (2008) reported that juveniles of fishes caught in ring seines constitute oil sardine (30%) and mackerel (15%) of the total catch along the Kerala coast. The gross estimate shows that the annual economic loss due to juvenile fishing made by trawlers, purse seiners, ring seiners and mini-trawlers together along the Indian coast was around USD 19,445 million whereas the annual revenue generated by these fishing units was only USD 836 million, causing a net deficit of USD 18,609 million per annum. The economic loss due to ring seiners with a fleet size of 2351 was USD 2037 million per annum and it ranked second in generating economic loss among the fishing units operated in Kerala coast. Among the juveniles landed, sardines account for the highest quantity and it is landed mainly in the months from August or early September (Balan, 1968 ; Kumaran *et al.*, 1992).

Increase in fishing effort in ring seine sector of Kerala

It is estimated that there has been an increase in the fishing effort by about 8 times between 1986 and 1994 (Balan and Andrews, 1995). A typical cotton *thanguvala* of the early sixties described by Kuriyan *et al.,* (1962) had a length of 42 m and a depth of 5.2 m. The mini-purse seine introduced by CIFT, during 1982-83, had an overall length of 250 m, and a depth of 15 m at the wing-ends and 33 m at the bunt (Panicker *et al.*, 1985). PA knotless netting of 18 mm mesh was used for construction. Although, the recommended number of ring seines, at the time of introduction, was 300 units, there has been a phenomenal increase in the number of ring seiners operating along the coast of Kerala. The number of ring seine nets in Kerala was estimated as 2259 in 1991 which increased slightly to 2277 in 1998 (SIFFS, 1992; 1999). The total number of ring seine units in Kerala in 1991 was 1738 consisting of 81% from plank canoes, 16% dug out canoes and 3% plywood canoes. The 1998 census showed a reduction of 6% in the number of ring seine units (SIFFS, 1999). A total of 1636 ring seine units were available in 1998, constituted by 75% plank built canoes, 15% plywood crafts and 10% dugout canoe units, showing a significant reduction in the dug out canoe units and increase in plywood canoe units. A significant development in this sector was the introduction of inboard diesel engine which was started in Ernakulam on experimental basis (SIFFS, 1999) (IBM ring seiners) and the trend has continued with increase in size of the craft and engine power. Operational economics of IBM ring seiners has been reported to be better and their environmental impact is considered to be less compared to OBM ring seiners (Kurup and Rajasree, 2003a, 2003b; Singh et al., 2007). A quick 'touch and count' survey of the anchored and hauled up vessels conducted during the trawl ban period in 2006 by the Project Management Cell, Department of Fisheries (DoF, 2006) gives the number of this category of the vessels in the state as 598.

In addition to the increase in number of units, there has been significant increase in overall dimensions of the ring seine, length of the craft and engine horsepower. The size of gear as reported by Edwin and Hridayanathan (1996) showed that average length of a *thanguvala* of Alleppey region was 630 m and depth 100 m with a mesh 18-20 mm. The *thanguvala* reported by D'Cruz (1998) showed that the *thanguvala* had much grown in dimensions. Boopendranath (2000) reported that ring seines operated in Chellanam area typically has a hung length of 585 m and a hung depth of 58 m. Large ring seines up to 900 m length and 90 m depth were reported by Srinath *et al.* (2004) from Thrissur District. In short, in the past twenty years, the ring seine has grown 3-4 times in dimensions, compared to the original design introduced by CIFT.

Contribution of OBM and IBM ring seiners in the marine fish production of Kerala, during 1997-2005 are presented in Table 1. During 2005, ring seine sector contributed nearly 50% of the total marine fish production in Kerala.

Table 1: Production and percentage contribution of OBM and IBM ring seiners in marine fish production of Kerala (1997-2005)

Year	IBM ring seiners		OBM ring seiners	
	Production (t)	Contribution to marine fish production (%)	Production (t)	Contribution to marine fish production (%)
1997	0	0	163335	28.42
1998	0	0	171325	31.57
1999	0	0	234272	40.34
2000	0	0	247943	41.04
2001	154	0.03	191877	37.32
2002	18985	3.22	204922	34.76
2003	27150	4.36	233001	37.38
2004	83689	13.57	205018	33.24
2005	102297	19.08	163245	30.44

Source: CMFRI statistics; adapted from Singh *et al.* (2007)

Standard ring seine design for commercial operations

Fishing trails conducted by Misund *et al.,* (1992) with large mesh netting in the last wing of the purse seine showed that neither herring nor mackerel escaped through the net either during day or night. It was observed that the use of large mesh sections in the wing-ends of the ring seine reduces the bulk onboard fishing vessel and invariably reduces the fabrication cost of the gear (Edwin and Hridayanathan, 2003). Earlier studies has shown that the escape of small pelagics is near the bunt region where gilling of fish is observed (Edwin and Hridayanathan, 2003). The observations made in the same study show that there exists a selection after pursing in the large mesh ring seines used in the Kerala coast.

In context of excessive fishing effort being expended in the ring seine fishery and the heavy incidence of juveniles in the catches as discussed above, a standard ring seine of length 600 m and depth 60 m with mesh size of 22 mm has been proposed for harvesting sardine and mackerel resources, off southwest coast was developed (Fig. 1). The design of the

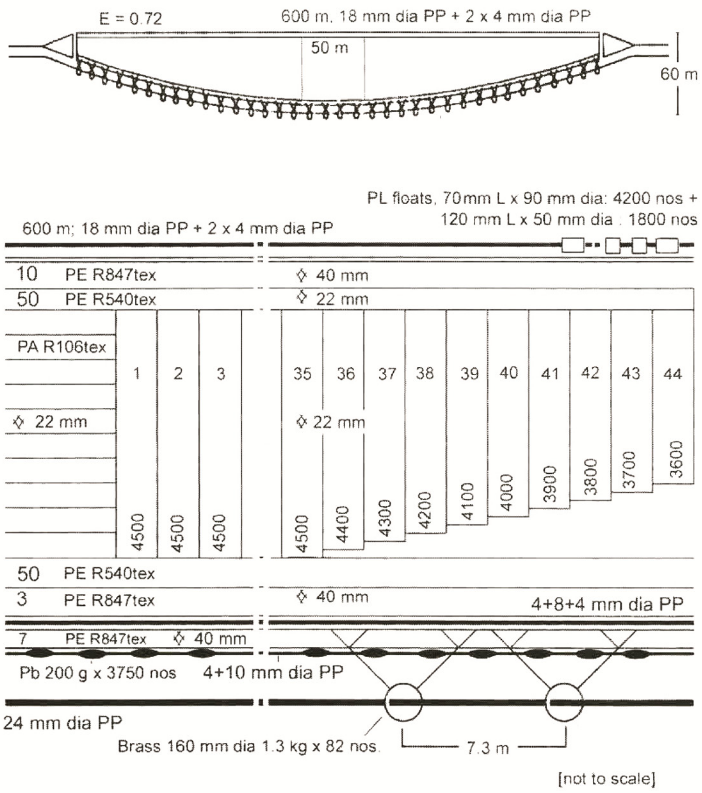

Fig. 1: Design of standard sardine-mackerel ring seine proposed for commercial small pelagic fishery

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gear was arrived at, by right-sizing the dimensions of the gear and the mesh size for sardine-mackerel harvesting operations. Two such ring seines have been put to experimental operations, through Chellanam Kandakadavu Fishermen Welfare Development Cooperative Society (CKFDWCS), Chellanam.

The Expert Committee for the Registration of Fishing Vessels (Kurup *et al.*, 2009), recommended that mesh size for sardine-mackerel ring seines for both IBM and OBM categories be regulated at 22 mm or more in the bunt and main body and maximum dimension of the gear be limited to <600 m hung length and <60 m hung depth, for all new and replacement ring seines; and length overall and engine horse power for propulsion be limited to <20 m and <65 hp, respectively, for all new and replacement ring seine crafts. In the case of anchovy ring seines, the recommendation was to regulate the mesh size at 12 mm and limit the maximum dimension of the gear to <250 m hung length and <50 m hung depth, for all new and replacement constructions and to limit engine horsepower to 25 hp; Similar recommendation were given by the Expert Committee for Impact Assessment of Ban on Bottom Trawling Imposed along Kerala Coast (Singh *et al.*, 2007).

Conclusion

In view of the deleterious effect of unregulated increase in size and capacities of the craft, engine power and dimensions of fishing gear and changes in design parameters that have direct influence on the fishing power, the ring seine fishing unit need to be brought under a regime of standardisation and regulation. The adoption of ring seines of standard dimensions and large mesh size will facilitate equitable access to resources, control of fishing effort and juvenile mortality in ring seine operations, in addition to advantages of reduction in investment requirements on fishing gear.

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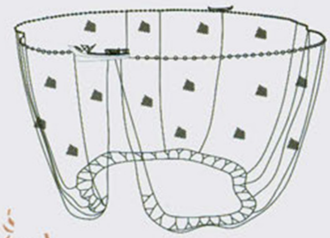
A modified method for calculation of sinking speed of ring seine

Ring seine and its operation

Ring seine is one of the most aggressive, effective and advanced fishing methods practised along the west and east coasts of India. The ring seine or the mini purse seine gear was first designed and introduced by the Central Institute of Fisheries Technology, Cochin as a new gear for the traditional craft. This gear has become very popular among fishermen along the entire coast of India with various modifications of the fishing gears and methods. This gear contributes to a major share of the total marine production of Kerala state with 51.6% of the total landings.

The ring seine differs from purse seine in the mode of operation. The peculiarity of ring seines, which are mostly operated in depths of 20-40m, is that the bottom of the gear touches the sea bed, unlike oceanic purse seine operations. Therefore the depth of the gear (which is mostly 80-100m) is more than twice the depth of operation.

Ring seine in operation



Diagrammatic view of ring seine operation

Sinking speed and catch efficiency

Studies on the underwater behaviour and sinking speed of the fishing nets are being carried out all over the world. The catch efficiency of ring seine depends on its length, depth, sinking speed, net type, hanging ratio, and the skill in operation among which, the sinking speed is one of the most important factors. Webbing weight, mesh size, mesh geometry, material used, twine size, and the hanging coefficients are the principal factors that influence the sinking speed. Effective encircling of a fish shoal with ring seine will take 8 to 12 minutes. Faster sinking speed prevent the escape of fish shoal which moves in the direction opposite to the gear and escape through the open end and bottom portion of the gear. With the help of theoretical sinking speed studies, it is possible to calculate the time required for the gear to touch the bottom of the sea bed and the parameters influencing the sinking. Knowledge of sinking speed coupled with gear related parameters will help in adjusting the operational parameters, thus increasing the efficiency of operation and reducing the production cost of ring seines.

Fishermen are also aware about the importance of sinking speed in ring seine fishing and they tend to increase the weight of the sinker line for faster sinking of the net. The addition of excess sinkers may tear the webbing when operation is carried out in muddy waters. The excess lead weight also increases the total weight and cost of the gear and makes handling/operation more cumbersome.

Although sinking speed has been worked out for purse seines that do not touch the sea bottom, it is for the first time that a method was derived for calculation of sinking speed of a seine that layers towards the bottom portion. In the case of purse seines operated in deeper waters, as described by Misund *et al.* (1992) the net during sinking has a snake part at the top, a twisted part and a straight part at bottom, whereas in the case of ring seine which is operated in shallow waters, the net sinks straight, due to excess weight of webbing, until the sinker line touches the bottom.

This method for theoretical calculation of sinking speed was based on the methods of Dickson (1980); FAO (1990) and Misund (1992) to suit the method of operation followed by ring seines used in shallow waters. The following parameters were taken for calculation of sinking speed: Specific weight of seawater (ρ), Acceleration of gravity (g), Twine drag coefficient (C_d), Skin friction drag (C_f), Hanging Coefficent Floatline (u_1), Hanging Coefficent Vertical direction (u_2), Knot dia.(d_k), Normal area of twine per unit length of headline (A_{ct}), Twine dia.(d), Bar length (a), Drag coefficent of sphere (C_k), Shadow drag coefficent (C_s), Area of webbing (A_s), Lead line sinking speed at depth z (v_z) and Lead line sinking speed at depth i (v_i). For the analysis an assumption was made that the ring seine when sinking

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makes a straight path and at all depths the ring seine sinks at a constant speed.

$$\text{Sinking Speed (m/min}^{-1}\text{) (Z)} = \sqrt{\frac{G\ X\ 2g}{\rho\ X\ C_{d0}\ X\ S}}$$

G = Weight of ring seine material in water (webbing + accessories)

g = Acceleration due to gravity (m/s^2)

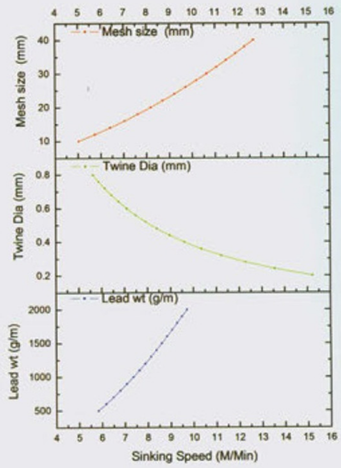
ρ = Density (g/cc) of sea water

C_{d0} = Drag coefficient of knotted meshes

S = Webbing surface area

The formula was applied for varying twine diameter, mesh size and lead weight as shown in the picture:

This method shows that mesh size, twine size, density of webbing material in water and sinker weight are the main factors influencing the sinking speed of ring seines commonly operated along the Kerala coast. Field trials with prototype designs are required for substantiating the theoretical findings.



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Wage-sharing is the way of life in this fishing village

- Anoop George Philip

Fishermen in Chellanam have set an example for the entire fishing community in the State by ensuring jobs and wages for everyone in the hamlet. —Photo: Special Arrangement

At 5 in the morning at the Chellanam beach, Kunjumon, a man in his 40s with sunbaked face and taut body, is marking attendance on a notebook. At the count of 45 names, he signals them they are in. They will ride the sea waves on a vessel he co-owns -- a 50-foot-long inboard engine boat named Behlel.

But there are more fishers eager to join aboard the vessel for the day's job. They can't, because there are already enough hands aboard to shoot the net and hoist the catch. If you expect them to be disheartened, they aren't. Kunjumon jots down their names under a subhead *karanila* (status on shore). When the vessel is back from the hunt, the grounded fishers too can claim wage share (*karapanku*) along with the crew aboard.

The slogan is equality

In this place of the world, when the jobseekers outnumber jobs on most days, they share the job and the wage. "In our fishing village no boat owner will turn away a job-seeking fisherman. If the fishers are in excess of the crew needed on a boat, the surplus men will be asked to stay on the beach. And they will get a share of the catch and the sale, which is only a notch lesser than what the crew will earn by sweating out in the sea," said Kunjumon.

The unique wage-sharing arrangement in Chellanam village, a narrow coastal landform close to Fort Kochi in Ernakulam, is a traditional system found in some closely-knit fishing communities. It means every able-bodied fisherman in this village has an assured job.

"Those who are grounded will replace the crew on board the next day and share their wages too," which is directly proportional to the revenue of a day, said Kunjumon. It's a kind of job guarantee scheme birthed by the community.

In Chellanam, there are around 3,000 fishermen and 63% of them work onboard vessels with ring seiners, a kind of traditional fishing net that encircles and captures pelagic shoaling fish like sardines and mackerel. But it calls for heavy muscle power -- from shooting the net to rounding up the catch, according to a research report authored by Dhiju Das P.S., Leela Edwin and Nikita Gopal of Central Institute of Fishing Technology (CIFT).

***Karanila* system**

The labour requirement for each ring seiner vessel ranges between 55 and 60. In the long past, there were more fishers than what was needed for the ring seine vessels going out into the sea, and the community had to find a way to accommodate all. *Karanila* system is possibly an upshot of that. “The monsoon fishing operations are highly labour-intensive and hauling the net against the strong currents and heavy winds is quite tough. Each fishing trip takes more than 16 hours. In such a situation, there is also a need to replace tired fishermen. So the traditional system also ensures that there are men ready to fill the vacancy,” said an author, who has done extensive research on the subject. Talk the corporate human resource department lingo, the karanila system is a kind of hotdesking, which ensures work optimisation.

In Europe too

Wage-sharing as an out-of-the-box thought was adopted by some companies in the Europe during the downturn to avoid layoffs. Under the programme, employers reduce their workers’ weekly hours and pay, often by 20 or 40 per cent, and then states make up some of the lost wages. It helped the companies to retain most of their employees.

The wage-sharing system is rarely found elsewhere. "It's not there even in Vypeen," another island where fishing is woven into the daily life, said Jenson, a fisherman.

“They have fixed crew mostly,” said Omana Berley of cooperative society for fishermen in Chellanam. “In chellanam, it’s a wonderful internal arrangement by the people to fight poverty. After the hunt, the fishers are also given a clutch of sardines or mackerels, which will also meet their daily protein need."

The system also works as a buffer against unemployment during the yearly trawl ban. During the ban, when labour supply overshoots demand, fishermen from the village working aboard the trawlers join the ring seine vessels, which don’t fall into mechanised trawl category. “But, we fishermen can’t think in terms of money alone. We know our profits take a cut. But sympathy is what leads us. We employ them too,” said Kunjumon.

According to the research paper, an analysis of the working crew on the ring seine vessels in the region last year showed that for a total of 180 fishing days in a year, a total of 11,134 crew members were employed -- on an average 62 fishermen per vessel per fishing day. While the fishermen who actually went onboard earned a wage of Rs. 560 per shipping trip, the fishermen on the beach earned Rs. 460.

Changing seasons

The number of grounded fishermen fluctuates every day – depending on the season. There are more jobseekers between June and September (south-west monsoon season), which is also the peak season for ring seine fishing as the unique fish aggregation phenomenon --*chakara* -- occurs in the near-shore area of Kerala.

A community can also wield the stick against freeloaders. “There are punishments for men who bunk work aboard the vessel after pocketing the *Karanila* benefits. They will be forced to do onboard job for one continuous week. Those who refuse punishment will be black-listed. They will not get job on any other boats in future,” said Kunjumon. But regular crew members on board a vessel can opt for *Karanila* for reasons like illness, funeral, marriage, etc.

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