Journal of Applied and Natural Science
14(2), 396 - 410 (2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Documentation of gill net operation and major fish landings at Andaman Islands, India, during 2014 - 2018

M. Kaliyamoorthy*
PRIST University, Thanjavur (Tamil Nadu), India
S. Dam Roy
Central Island Agricultural Research Institute, Port Blair (Andaman Nicobar Islands), India
V. K. Sahu
Department of Zoology, Jawaharlal Nehru Rajkeeya Mahavidyalaya, Port Blair (Andaman Nicobar Islands), India

*Corresponding Author. Email: kamuthy@gmail.com

Article Info
https://doi.org/10.31018/jans.v14i2.3298
Received: January 26, 2022
Revised: May 12, 2022
Accepted: May 22, 2022

How to Cite
Kaliyamoorthy, M. *et al.* (2022). Documentation of gill net operation and major fish landings at Andaman Islands, India, during 2014 - 2018. *Journal of Applied and Natural Science*, 14(2), 396 - 410. https://doi.org/10.31018/jans.v14i2.3298

Abstract
Three decades before, the gillnet was the major gear in Andaman and Nicobar Islands(ANI), India, because of the less expensive and simple method of operation with non-motorised small dinghies or without craft. Earlier, the gillnet landing was 39% of the total landings and a further report said 27%, which indicated the decrease in gillnet landings. The present study was carried out from 2014 to 2018 at four main fish landing centers (FLCs) Junglighat, Dignabad, Guptapara and Wandoor of ANI to investigate the present status of major gillnet landings. Altogether 1097 visits were carried out at all FLCs and 63.1% of visits occurred at Junglighat. The total landings of all FLCs were 3880.6 tons, of which 98.6% were recorded at Junglighat. The total gillnet landings were 330.4tons, of which Driftnet covered 82.1%, followed by bottom plastic(9.8%) and bottom nylon(8%) gillnets. Significant landings (P<0.0001) of Scombridae family were recorded through Drift gillnet (182.47tons) compared to other families. The family of Carangidae(7.71tons) and Clupeidae(16.54tons) were recorded dominantly through bottom plastic and bottom nylon gillnets, respectively. The gillnetters explored 31 fishing grounds in the South, Middle, North and Little Andamans sectors. The significant (P<0.0001) fish catch was recorded from the South Andaman sector. A total of 17 validation experiments carried out in each Potential Fishing Zone (PFZ) and Non-PFZ by using PFZ advisories indicated a significant(P<0.0001) catch from PFZ(3.5:1). There was a decline of 18.5% in the landings of gillnet than earlier studies. It is suggested that the fishermen may follow the PFZ forecast for a better catch. The gillnet fishing to be promoted to under-exploited pelagic fishes of these islands will benefit the gillnetters.

Keywords: Gillnetters, Junglighat, Landings, Scombridae, Validation

INTRODUCTION

Andaman and Nicobar Islands (ANI) is one of the Union Territories of India, located between 6º45'N and 13º 41'N Latitude and 92º12'E and 93º 57'E Longitude with 10°N channel separating the Andaman group and Nicobar group of islands in the southern reaches of the Bay of Bengal (BOB). It is the largest archipelago comprising 572 islands, islets and rocky outcrops with an aggregate coastline of 1,912 km, which is about a fourth of the Coastline of India. There are 51 beach landing centres, 8 fish markets, 169 fishermen villages, 5944 fishermen families with a population of 26521. A number of 5,617 full-time fishermen and 718 part-time fishermen are engaged in marine fishing activities in the Islands. They operate 1,346 non-motorized crafts, 1353 motorized crafts and 85 mechanized boats (Handbook on Fisheries Statistics, India 2019). According to Nithyanandan (2009), the gear drift gillnet is the main fishing gear used which contributes to over 40% of the marine fish landings and the rest by other fishing gears shore shine, hook and line, long line, anchor and cast nets etc., The important marine fishery resources of these Islands are mackerels, sardines, carangids, silver bellies, silver buddies, perches, anchovies, hilsa, mullets, elasmobranches, groupers, snappers, sweet lips, seer fishes, tuna fishes, shrimps, lobsters and crabs. Gill netters generally end up with low valued pelagic fishes like sardines and mackerels. A gillnet is made up of monofilament or multifilament nylon with designed mesh sizes to allow fish to get only their head through the netting. Gill of fish get caught in the net and try to back out caused entangled. Gillnet, a highly versatile gear, suitable for operation in the surface, column or bottom layers of the water column, can target fishes as small as anchovies to big sized sharks and rays. The gillnet fisheries of India are considered to be the mainstay of the artisanal sector, comprising of small scale localised operation (Thomas, 2019). Drift gillnet is mainly operated on high seas to catch large pelagic species like seerfish tuna, sailfish, swordfish, and shark. Gillnets are barrier nets deployed in the dark, relying on chance encounters of the fish with the net (Arur *et al.,* 2014).

ANIs are typically oceanic and encompass an Exclusive Economic Zone (EEZ) of 0.6 million km^2, which is about 30% of the total EEZ of the country while the coastline constitutes 26.10% of the country's coastline.. The present scenario in the country with respect to Fish Catch and efforts is that among active fishermen, 33% are employed in Mechanised sector, 62% in motorised sector and 05% in Artisanal Sector. Of the total marine fish production, 75% come from the Mechanised sector, 23% from motorised sector and 02% from Artisanal Sector (ANI Fisheries Policy 2018). The potential of fisheries resources in ANIs is 43794 tons, excluding oceanic with 0.83 % of the contribution. The Continental shelf is about 34965 Sq.kms, which nearly forms 6.60% of the total Indian Continental Shelf (ANDFISH 2005, Handbook of Fisheries Statistics, India, 2018, 2020 and ANI Fisheries Policy 2018). There are about 2500 species of flora and 6540 species of fauna, of which 4% of marine species are reported to be endemic (Venkataraman *et al.,* 2005). Estimates by the Fishery Survey of India (FSI) recommend that ANI is home to 9.2% demersal, 57.1% coastal, and 33.7% oceanic fish stocks (Anrose *et al.,* 2009). ANI is unique in possessing a high magnitude of harvestable marine fishery resources. The landing of marine fish was 1104 tons during 1975 and it increased to 31,000 tons in 2004, it was only 13% of the estimated annual potential yield 1.48 lakh tons of its EEZ (Pillai and Abdussamad 2009). It has also been increased to 41,190 tons for 2019 (Handbook on Fisheries Statistics 2020) and it was 28.2% of the estimated yield. During the earlier days, the main gear of ANI was gillnet. It is declining due to increases in other gear operation. The fishermen of ANI have the skill of multi-gear operation *viz* Ring net, Gillnets, Trawl net, Anchor net, Long line, Hand line, etc., following advanced fishing technologies (AFT).

Recognition of Potential Fishing Zones (PFZ) occupies an understanding of oceanic processes and the interaction of hydro-biological parameters (Desai *et al.,* 2000). Sea Surface Temperature (SST) is the mainly and easily observed environmental parameter and is quite often correlated with the especially availability of pelagic fish. Usually, chlorophyll and SST images are expected to reveal common gradients due to the inverse correlation between these two parameters (Solanki *et al.,* 2005). Indirect methods of monitoring selected parameters such as SST and Chlorophyll-a (Phytoplankton pigments) at the sea's surface from satellites are ideal, as it supplies high receptivity and large special coverage (INCOIS). SST affects fish species development during their life cycle on the upper ocean surface (1mm to 20m). Phytoplankton biomass, the primary food source within the sea, is another important factor (Karuppusamy *et al.,* 2020). According to Zhou *et al.* (2021), the thermodynamic anomalies are investigated in terms of sea surface temperature (SST), isothermal layer depth (ITD), and upper ocean heat content (HCT). Mesoscale eddies increase biological productivity by vertical and horizontal mixing of the water column in the pelagic zone (Yoder *et al.,* 1981). Mesoscale eddies enhance the productivity in a stratified coastal environment by upwelling. Eddies increase the local productivity in the oligotrophic regions of tropical oceans (Hyrenbach *et al.,* 2006). Eddies are known to impact the horizontal and vertical distribution of physical and biogeochemical tracers (McGillicuddy *et al.,* 2007; Chelton *et al.,* 2011b; Dong *et al.,* 2014; Amos *et al.,* 2019). Mesoscale eddies influence productivity at every trophic level, such as the primary production (Seki *et al.*, 2001; Mizobata *et al.,* 2002; Bakun, 2006) and concentration of zooplankton, micro-nekton (Sabarros *et al.,* 2009), and plankton feeders (Olson and Backus 1985), which in turn form a forage base and attract tertiary-level producers (tunas, marlin, turtles, sea birds, and cetaceans). ANIs have been found to have frequent mesoscale eddy activity and commercial fishing grounds coincide with upwelling areas associated with cyclonic and anticyclonic eddies supporting different types of fishing gears and fish. The eddies reduce thermocline depth and bring nutrients to the photic zone, improving the productivity in stratified tropical and subtropical regions of the oceans (McGillicuddy *et al.,* 1998; Arur *et al.,*2014). Mesoscale eddies are energetic entities that structure open ocean ecosystems on time scales of weeks to months and spatial scales of tens to hundreds of kilometers (McGillicuddy 2016). Movements of fish in the open ocean often cannot be determined with sufficient accuracy to correlate their position with specific mesoscale oceanographic features (Braun *et al.,* 2018). Eddies may trap distinctive plankton communities that can be transported hundreds to thousands of kilometers. The influence of eddies on the behavior of large pelagic fishes, however, remains largely unexplored (Braun *et al.,* 2019). Coherent oceanic mesoscale eddies with unique dynamical structures have great impacts on ocean transport and global climate (Mengrong Ding *et al.,* 2020). Simulated cyclonic eddies form between the rotational flow of an offshore anticyclonic vortex and a poleward flowing boundary current, with eddy potential energy being the dominant source of eddy kinetic energy (Dilmahamod *et al.*, 2022).

The objective of the present study is documentation of fish landings through gillnet operation in four main fish landing centres of South Andaman *viz* Junglighat, Dignabad, Guptapara and Wandoor.

MATERIALS AND METHODS

The data of fishing trip, fishing operations and major fish landings were collected from fishermen of 4 FLC (Junglighat, Dignabad, Guptapara and Wandoor) of South Andaman. The study is based on capturing fisheries at sea as a livelihood for fishermen. There is no breach of Animal Ethics in this study. Hence, animal ethics permission is not required for the study.

Study area

According to Grinson (2011), there were 20 Fish Landing Centres (FLC) recorded in ANI in which four main FLC viz., Junglighat, Dignabad, Wandoor and Guptapara, were selected from South Andaman to investigate the fish landings through gillnet operations. The study was carried out for five consecutive years between 2014 and 2018. Junglighat is a dominant FLC like the fishing harbor. The maximum gillnet landings are occurring here among four FLCs which is located in the main city of Port Blair (Fig. 1(i)). Junglighat was focused more on frequent visits because the maximum fishing gear operators are venturing for fishing from this FLC, including gillnetters. The Department of Fisheries maintains this landing centre, Andaman and Nicobar Administration which extends unloading, loading and whole/lot auction facilities. There is an action facility wherein the buyers, mediators and exporters interact, and proper security arrangements for the buyers, mediators and exporters are in place. As stated by Siar *et al.* (2011) regarding fishing harbours, fish landing centres (FLCs) are similarly important meeting places for artisanal fishers, buyers, traders, government officials (inspectors and extension staff) and those providing services to a fishing community. They are places of encounter between public and private institutions and a point of convergence between production and trade; as such, they offer the potential for the localized promotion of responsible fisheries, the reduction of waste and improvement of fish quality (Diffey 2012).

Gear gillnet

Gillnets are generally classified based on the type of capture, structure, area of operation, method of operation and targeted species. Three types of gill net operations were observed in this FLC during the period, i.e. Drift net (nylon 10/3 mesh size 115 mm and 120 MD) is a moving or drifting system according to the water cur-

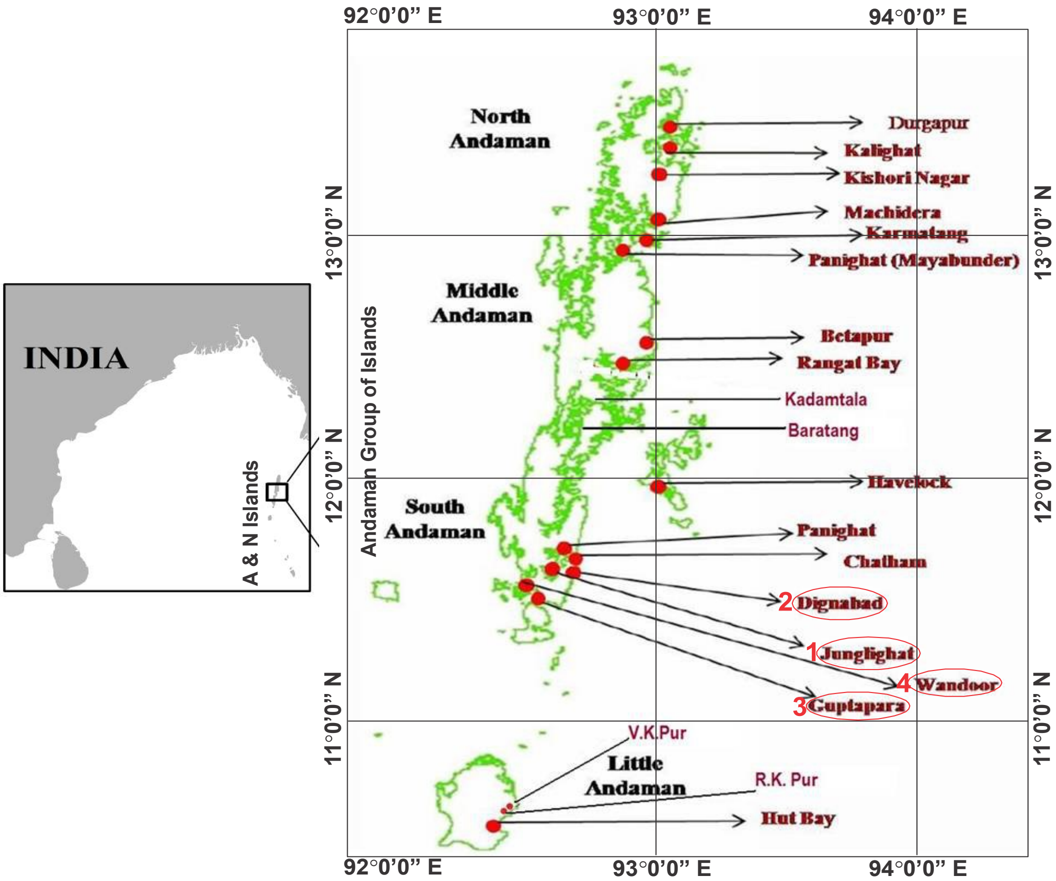

Fig. 1. *(i) Map is showing FLCs (1) Junglighat, (2) Dignabad, (3) Guptapara and (4)Wandoor*

rent, buoys attached to the head rope, footrope, or float line and required 5-8 person for operation in the deep sea. Required 3-5 persons are required for bottom gillnets (nylon 2/3 mesh size 18mm and 600 MD) and Plastic gillnets (0.32/75 mesh size 75 mm and 100 MD), which are operated in shallow waters (<50 m), including creeks, bays and coasts of these islands for capturing small pelagic fishes like Anchovies, sardine, lesser sardines, mackerel, small carangids, little tuna, gobids, prawn etc., fixed in the substrate to prevent movement (Table 1). The mesh size, length, and height of commercial gillnet, area fishing and targets of fish species determine the variation of regulations and factors. The construction of the small gillnet was also very few expenses. The long and hardliners also use gillnets to capture bait fishes like sardine, mackerel, flying fishes, shark, devil ray, etc.

Data Collection

An integrated approach was developed by Solanki *et al.* (2001) using Indian Remote Sensing satellite P4 Ocean Colour Monitor (IRS P4-OCM) derived chlorophyll concentration and National Oceanographic Aerospace Administration-Advanced Very High Resolution Radiometer (NOAAAVHRR) derived sea surface temperature (SST) features for locating Potential Fishing Zones (PFZ) in the Indian waters. Indian National Centre for Ocean Information Services (INCOIS), Hyderabad delineates PFZ forecasts indicating the availability of fish stocks for 2-3 days all along the Indian coast (Solanki *et al.,* 2003) to about 225 nodes (Nayak *et al.,* 2003) for operational use. PFZ forecasts from composite images based on latitude and longitude (Solanki *et al.,* 2005) were printed and disseminated to fishermen in person as the primary dissemination mode. In addition, telephone/text messages conveyed PFZ messages (Grinson *et al.,* 2014). The data was collected with positive results from the forecast succeeding fishermen. The reachable areas by the venturing fishermen mentioned in the forecast were validated by disseminators. Continuous periodic visits were carried out for five consecutive years from 2014 to 2018 at above mentioned four FLC and major landings of fishes were also documented (Kaliyamoorthy *et al.,* 2019 & 2020). The collected data were FLC visits, the fishing trip of gillnetters, haul operations and the landing of fishes. The data were analyzed like month and year wise landings of various gillnets. Ground and family-wise fishing of fin and shellfishes were also analyzed during the period. The fish catch has been reported only for the period of visit. It may be surmised that it is more than what is recorded.

The occurrence of all the gillnet operations, i.e. releasing net during high tide positively in the night time and untangle or collection of fish during low tide in the day time. The natural phenomenon is the schooling of pelagic fishes playing and rush to shallow water in search of fry during the high tide. The gillnetters select this tidal condition to release their nets with the help of dinghy; when fishes cross the net, the gills of fishes entangle in the net, so the net is called gillnet. Subsequently, fishermen spin their net along with fishes and untangle the fishes from the net (Fig. 1-ii). Small or bottom gill net operations are occurring before three decades in ANI at shallow waters according to the tidal conditions, i.e. high tide to low tide. During this operation, 2 to 3 persons (men or women) remain engaged without fuel and baits. Local fishermen still continued the same operation at remote areas of ANI like Rangat Bay, Panighat, Mayabunder, Diglipur, Little Andaman, Car Nicobar, Nancowrie group of Islands and Great Nicobar.

Table 1. Optimum and commonly used gillnet mesh sizes in Andaman and Nicobar Islands

Type of gill net	Targeted fishes	Filament	Mesh size	Depth	Time of operation	Fishermen engaged
Drift net	Seer fishes, Tuna, Marline, Manta Ray, Carangids, Barracuda, etc.	10/3	115mm/	120 MD	10 -12 hrs at nigh	5 – 7
Bottom Plastic gillnet	Carangids, Groupers, snappers, Siganus, Emperor, Silver bellies, Baracuda,	Mono filament 0.32	75mm/	100MD	3-5 hrs. at night	3-5
Bottom Nylon gillnet	Mackerel and Sardine lesser sardine and Anchovies,	2/3 1/3	18 mm / 16mm /	600 MD 600 MD	2-4 hrs at night	2-3
	Goat fishes, Baracuda etc.,	0.28	75 mm /	100 MD		
		0.23	65 mm /	100 MD		

Drift gillnetters: These are prepared for their operation during evening from 5 – 8 pm to next day 4 – 7 am at high tide with less moon light (10 –12 hours), 1- 2 operation per day. Multi-gear operators travel all around the Andaman coast, use drift net at night hours and hook line in day hours; *Bottom Plastic gillnetters:* These are prepared for their operation during evening 5 pm to next day 7 am at high tide, 3-5 operation per day; *Bottom Nylon gillnetters:* These are prepared for their operation during evening 6 pm to next day 6 am at high tide, 2-3 operation per day.

RESULTS

Altogether 1097 visits were carried out during the study period from 2014 to 2018 at four potential fish landing centres (FLC) in South Andaman. The maximum (261) and minimum (181) visits occurred between 2016 and 2018. The main FLC in A&N Islands, which was Junglighat, covered 63.1% of FLC visits, i.e. 692, followed by Dignabad (15.4%), Wandoor (11.8%) and Guptapara (9.8%) were 169, 129 and 107 respectively during the visiting period. The maximum number of visits occurred at Junlighat, i.e. 177 during 2014, followed by 2016 (137), 2017 (136), 2015 (129) and 2018 (113). The total fishing trips and haul operations of gillnet were 1488 and 4335, respectively. The maximum fishing trip (490) and haul operation (1262) was observed during 2014, while the minimum was observed during 2017, i.e. 167 and 536, respectively. The total landing of all gears was 3880.6 tons, with an average of 776.1±43.8. The maximum (923.7 tons) and minimum (675.1 tons) landings were observed during 2014 and 2015, respectively. The landing of 98.6% was recorded at Junglighat FLC (3825.9 tons) followed by Dignabad (30.37 tons), Guptapara (12.35 tons) and Wandoor 11.99 tons. According to the year wise landings at all FLCs, the maximum and minimum of landings occurred during 2014 (914.1 tons) and 2017 (665.7 tons) at Junglighat with an average of 764±43.9 tons/ years, followed by Dignabad during 2017 (7.7 tons) and 2014 (5 tons) with an average of 6.5±0.7 tons/ year, Wandoor during 2018 (3.4 tons) and 2014 (2 tons) with an average of 2.9±0.4 tons/year & Guptapara during 2016 (2.8 tons) and 2015 (1.9 tons) with an average of 2.8±0.2 tons/ year respectively (Table 2).

The fishermen engaged three types of gillnets from all FLCs. The contribution of gillnet in fishing trips and fish catch amongst all the gears in four FLC during the study period was 22.1 % and 8.5%, respectively (Kaliyamoorthy et al., 2020). The total fish landing of gill net was 330.4 tons during the study period with an average of 66.1±12.3, including finfishes 328.8 tons and shellfishes 1.6 tons with an average of 65.8±12.2 and 0.3±0.1 tons respectively. The maximum (314.1 tons) gillnet landing was recorded at Junglighat FLC, covering 95.1% and the remaining 16.3 tons, i.e. 4.9% were recorded at other FLCs Dignabad, Wandoor and Guptapara. According to year wise landings at all FLCs, the maximum and minimum fish landing of gillnetters at Junglighat were during 2014 (101.51 tons) and 2017 (32.39 tons), respectively, with an average of 62.8±12.7 tons followed by Dignabad during 2017 (3.1 tons) and 2015 (1.2 tons) with an average of 2.1±0.4 tons. The average landings recorded at Wandoor and Guptapara was 0.9±0.3 tons and 0.3±0.1 tons, respec-

Fig. 1. (ii). *Fishing operations of fishing gear Gill net and fish catch at Andaman coast Drift net, (b) Bottom nylong gillnet, (c) Plastic gillnet, (d) Scomberomorus sp., (e) Thunnus sp., (f) Manta ray, (g) Anchovies (h) Penaeus spp., (i) Portunids*

tively. Altogether 82.1% of landings were recorded through Driftnet, followed by bottom plastic gillnet (9.8%) and bottom nylon gillnet (8%) during the visiting period . The driftnet fish landings were dominant during 2014 (84.3 tons) and recessively during 2017 (30.3 tons), with an average of 54.3±9.8 tons. Fish landings through Plastic gillnet were observed maximum during 2014 (10.9 tons) and minimum during 2017 (3.4 tons) with an average of 6.5±1.5 tons. Similarly, the maximum and minimum landings through bottom nylon gillnet were observed during 2014 (8.97 tons) and 2017 (2.75 tons), with an average of 3.03 tons (Table 2).

Drift gillnet fish landing was dominant (> 80%) amongst the three types of gillnets during all the years. The bottom plastic gillnet was found in the second rank in 2014, 2015, 2017 and 2018 and it was observed to be in the third rank during 2016. The bottom nylon gillnet was observed third place in 2014, 2015, 2017 and 2018 and it was observed in second place in 2016 (Fig. 2a). Similarly, the landing of fishes through gillnetters was dominant (> 88 %) at Junglighat among four FLC during the study period. No landing was observed at Guptapara during the visiting period of 2014 and 2015 through gillnetters (Fig. 2b). The sector-wise fishing trips and fish catch through gillnet were analyzed (Fig. 2c).The maximum fishing trips were recorded on the coast of South Andaman (58.7%), followed by Middle (27.8%), North (11.6%) and Little (1.9%) Andamans. Similarly, the maximum fish catch occurred on the coast of South Andaman (51.4%) followed by Middle (36.7%), North (9.5%) and Little (2.4%) Andamans.

The total month-wise analysis was carried out during the study period (2014-2018). A total of maximum FLC visit (105), the fishing trip (140), fishing operations (439) and fish catch (35.6 tons) were observed during July, December, November and May, respectively. Similarly, the minimum FLC visit (82) was observed during April and November, the fishing trip (106) during November, fishing operations (288 hauls) and fish catch (13.9 tons) were observed during the month of August, respectively (Fig. 3). According to the year and month-wise analysis, the maximum FLC visited during 2014, 2015, 2016, 2017 and 2018 were in July (29), March (24), June (26), and January-February-September (23) and June-July (18), respectively. The minimum visit to FLC during above mentioned years was in the month of May (12), November (10), April (17), December (13) and April (12), respectively. The

Table 2. Details of FLC visit and fish landings during 2014-2018 at South Andaman FLCs

	FLC	2014	2015	2016	2017	2018	Total		%
Fish landing Centre visits	Junglighat	177	129	137	136	113	692		63.1
	Dignabad	24	21	54	42	28	169	**Average**±SE/ year	15.4
	Wandoor	10	15	35	28	19	129		11.8
	Guptapara	27	18	35	28	21	107		9.8
	Total	238	183	261	234	181	1097		
All gear landings (in tons)	Junglighat	914.1	665.7	747.2	802.3	696.5	3825.9	764.0±43.9	98.6
	Dignabad	5.0	5.3	7.0	7.7	5.4	30.4	6.5±0.7	0.8
	Wandoor	2.0	2.1	2.1	2.4	3.4	12.4	2.9±0.4	0.3
	Guptapara	2.5	1.9	2.8	2.7	2.5	12.0	2.8±0.2	0.3
	Total	923.7	675.1	759.1	815.1	707.7	3880.6	776.1 ±43.8	
Total fishing trips, haul operations, Gillnet landings (in tons)	Fishing trips	490	354	268	167	209	1488		
	Haul operation	1262	1039	738	536	760	4335		
	Junglighat	101.5	81.9	55.1	32.4	43.2	314.1	62.8 ±12.7	95.1
	Dignabad	1.4	1.2	2.5	3.1	2.3	10.4	2.1±0.4	3.1
	Wandoor	1.3	0.4	0.4	0.6	1.8	4.4	0.9±0.3	1.4
	Guptapara	0.0	0.0	0.4	0.6	0.7	1.4	0.3±0.1	0.4
	Total	104.1	83.6	58.4	36.4	48.9	330.4	66.1±12.3	
Gillnet landings (in tons)	Finfish	103.6	83.1	58.1	36.2	47.8	328.8	65.8±12.2	99.5
	Shellfish	0.5	0.5	0.2	0.2	0.2	1.6	0.3±0.1	0.5
	Drift net	84.3	68.3	48.6	30.3	40.0	271.4	54.3±9.8	82.1
	Bottom Plastic	10.9	9.3	4.0	3.4	4. 9	26.5	6.5±1.5	8.0
	Bottom Nylon	9.0	6.0	5.8	2.8	3.0	32.5	5.3±1.1	9.9

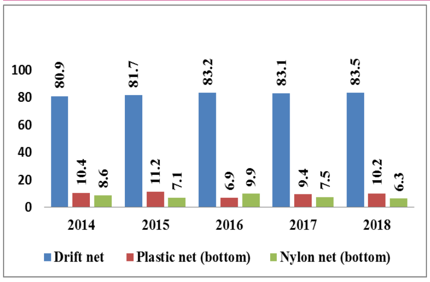

Fig. (2a). *Year wise landings of different gillnets in %;*

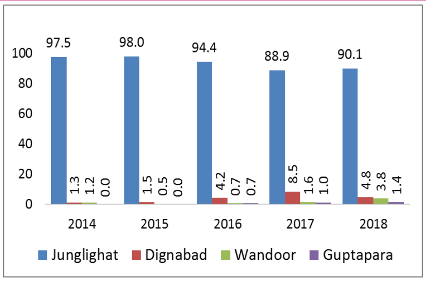

Fig. (2b). *FLC and year wise landings of gillnets in %;*

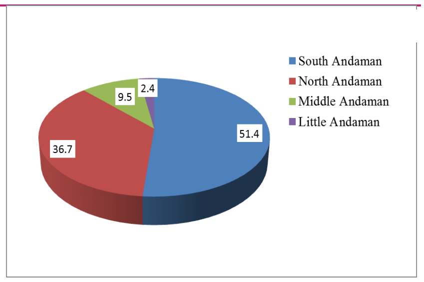

Fig. (2c). *Sector wise fish catch in %*

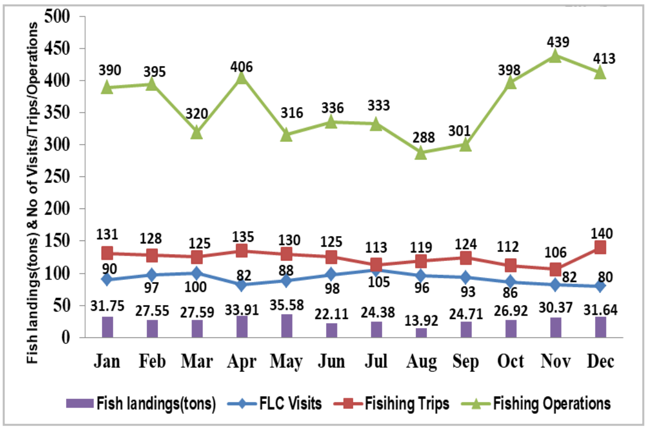

Fig. 3. *Month wise gillnet landings for the total period from 2014 to 2018*

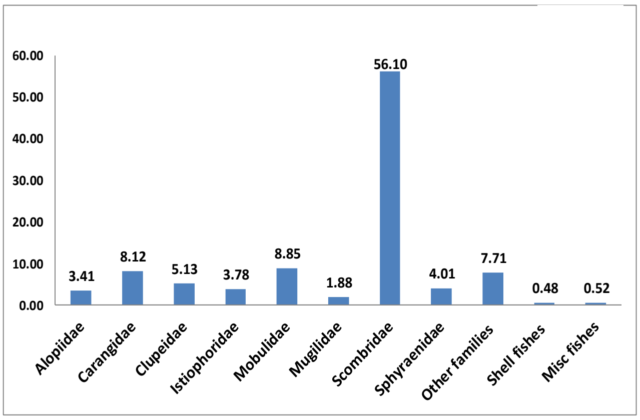

Fig. (4). *% of family wise gillnets landings during 2014 - 2018*

Table 3. Month wise FLC visits and other details for gill net operation during 2014 - 2018

Month/ Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FLC Visits												
2014	19	22	21	21	12	18	**29**	23	22	16	17	18
2015	11	18	**24**	13	21	16	14	16	15	14	10	11
2016	21	21	23	17	20	**26**	22	24	18	24	23	22
2017	**23**	**23**	17	19	19	20	22	19	**23**	18	18	13
2018	16	13	15	12	16	18	18	14	15	14	14	16
Fishing Trips												
2014	41	28	7	41	11	32	60	49	67	43	50	61
2015	18	59	27	37	71	30	10	15	30	21	18	18
2016	34	18	58	36	16	25	16	23	0	12	10	20
2017	16	8	11	9	17	20	12	19	10	14	13	18
2018	22	15	22	12	15	18	15	13	17	22	15	23
Haul Operations												
2014	114	85	37	157	14	37	144	96	97	126	213	142
2015	39	140	95	105	123	85	41	61	108	106	83	53
2016	101	85	93	81	73	68	62	23	0	30	54	68
2017	53	28	21	23	54	81	38	62	35	41	38	62
2018	83	57	74	40	52	65	48	46	61	95	51	88
Fish Catch (tons)												
2014	9.3	8.7	4.0	13.2	4.0	5.4	10.3	5.3	10.9	10.1	11.8	11.3
2015	3.0	7.3	9.0	6.0	15.2	5.8	2.5	4.2	10.8	8.9	7.1	3.6
2016	9.5	5.7	7.5	9.2	5.5	4.0	4.1	0.9	0.0	1.7	3.8	6.5
2017	4.7	2.6	2.6	3.0	4.5	3.6	3.2	1.2	0.5	1.9	4.2	4.5
2018	5.2	3.2	4.5	2.5	6.3	3.4	4.3	2.4	2.6	4.3	3.5	5.7

maximum fishing trip and fishing operations during above mentioned years were in the month of December (61) & November (213), January (59 & 140), March (58) & January (101), June (20 & 81) and December (23) & October (95) respectively. Similarly, the maximum and minimum fish landing was observed for 2015, 2016, 2017 and 2018 during May (15.2 tons) and July (2.5 tons), January (9.5 tons) and September (0.0 tons), January (4.7 tons) and September (0.5 tons) and May (6.3 tons) and August (2.4 tons) respectively (Table 3).

Analysis of family-wise fin and shellfish landing was carried out during the visiting period. The fishes of Scombridae were recorded dominantly, i.e. 56.1% (185.37 tons) followed by Mobulidae (8.86%), Carangidae (8.12%), Clupeidae (5.13%), Sphyraenidae (4.01%), Istiophoridae (3.78%), Alopiidae (3.41%), Mugilidae (1.88%), other families of fin fishes 7.71% recorded including Latidae, Leiognathidae, Lethrinidae, Lutjanidae, Mullidae, Nemipteridae, Rachycentridae, Scatophagidae, Sciaenidae, Sphyrnidae, Synodontidae, Trichiuridae, Serranidae, Siganidae, Ariidae, Bothidae, Carcharhinidae, Chanidae, Coryphaenidae, Dasyatidae, Drepaneidae, Engraulidae, Gerreidae and Haemulidae. Of the recorded shellfishes, 0.48% included the family of Sepiidae, Palinuridae Penaeidae and Portinidae. The miscellaneous fishes were recorded at 0.52% (Fig. 4).

The family-wise landing of Drift net was analyzed. The total landings of dominant family Scombridae were 182.47 tons with an average of 36.49±6.51 tons/year, followed by Mobulidae 29.24 tons with an average of 5.85±1.45tons/year, Carangidae 16.92 tons with an average of 3.38 ± 0.44 tons/year, Istiophoridae 12.50 tons with an average of 2.50±0.58 tons/year, Sphyraenidae 11.21 tons with an average of 2.24±0.69 tons/ year etc. (Table. 4).

The family-wise landing of Bottom Plastic gillnet was also analyzed; the landing of Carangidae family fishes was dominant, i.e. 7.71 tons with an average of 1.54±0.56 tons/ year, followed by Mugilidae 5.72 tons with an average of 1.14±0.33tons/year, Lutjanidae 3.87 tons with an average of 0.774±0.093 tons/year, Serranidae was 2.14 tons with an average of 0.43±0.111 tons/year etc. (Table 5).

The landing of Bottom Nylon gillnet was analyzed; fishes of the Clupeidae family found were dominant i.e. 16.54 tons with an average of 3.31±0.85 tons/year, followed by Scombridae (2.35 tons), Engraulidae (2.24 tons), Carangidae (2.21 tons) and the landing of other family were found below 1 tons (Table 6).

The fishermen repeatedly ventured to Potential Fishing grounds using PFZ forecast. The gillnetters explored a total of 31 fishing grounds, including the coast of South (17), Middle (6), North (6) and Little (2) Andamans and fishing trips were observed 874, 172, 413 and 27; similarly, the fish catches in tons were recorded in the same coasts 169.8, 121.2, 31.5 and 7.9 respectively during the study period (Fig. 5).

Altogether the maximum fishing trip ventured by the

Table 4. Drift gillnet catch in tons during study period (2014-2018)

Family and Genus / year	2014	2015	2016	2017	2018	Total	Average/yr
Alopiidae: *Alopias sp.*	5.67	2.92	1.21	0.63	0.84	11.26	2.251±0.944
Carangidae: *Alectis sp., Atule sp., Carangoid spp. Caranx sp.,Elagatis sp.*	3.02	4.36	4.52	2.54	2.48	16.92	3.382± 0.442
Chanidae: *Chanos sp.,*	0.02	0.03	0.01	0.02	0.02	0.09	0.018±0.001
Coryphaenidae: *Coryphaena sp.,*	0.03	0.02	0.07	0.04	0.05	0.20	0.040±0.008
Drepaneidae: *Drepane sp.,*	0.02	0.01	0.05	0.01	0.02	0.11	0.022±0.007
Gerreidae: *Gerres spp.,*	0.03	0.01	0.03	0.05	0.04	0.16	0.031±0.006
Istiophoridae: *Makaira sp., Istiophorus sp.,*	4.53	2.99	1.97	1.28	1.73	12.50	2.500±0.580
Latidae: *Lates sp.,*	0.15	0.67	0.10	0.73	0.23	1.88	0.376±0.134
Lethrinidae: *Lethrinus spp.*	0.06	0.19	0.35	0.15	0.32	1.07	0.214±0.055
Mobulidae: *Manta sp.,*	11.40	3.97	5.40	3.12	5.35	29.24	5.847±1.454
Rachycentridae: *Rachycentron sp.,*	0.07	0.08	0.04	0.05	0.13	0.37	0.073±0.016
Scombridae: *Thunnus spp., Acanthocybium sp., Sarda sp., Euthynnnus sp., Katsuwonous sp., Rastrelliger sp.,Scomberomorus sp,*	53.55	49.67	32.51	19.93	26.82	182.47	36.494±6.514
Sphyraenidae: *Sphyraena spp.,*	4.74	2.66	1.82	0.87	1.12	11.21	2.242±0.692
Sphyrnidae: *Sphyrna sp.,*	0.75	0.52	0.35	0.24	0.38	2.24	0.447±0.088
Miscellaneous finfishes	0.25	0.17	0.15	0.62	0.52	1.71	0.342±0.092

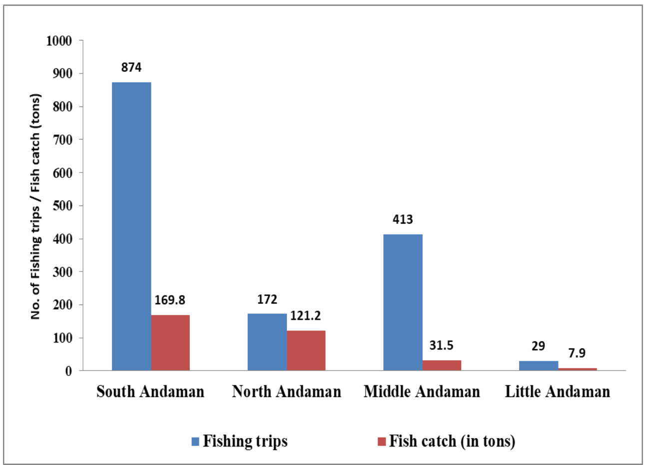

Fig. (5). *Sector wise fishing trip and fish catch of gill nets, during 2014 – 2018*

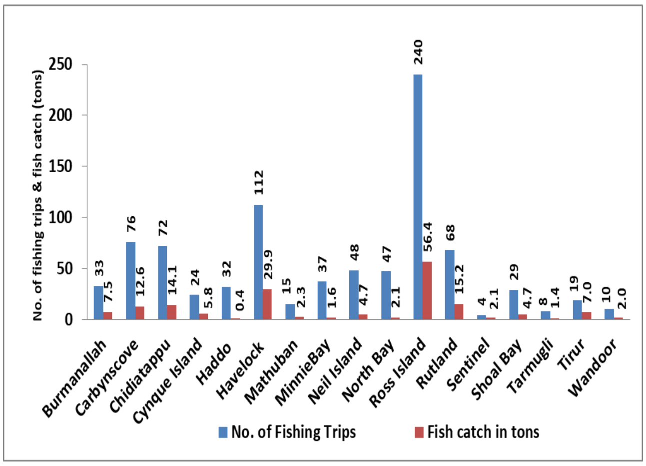

Fig. 6. *Fishing trip and fish catch at South Andamans coast during 2014 – 2018*

Table 5. Catch by Bottom plastic gillnet in tons during study period (2014-2018)

Family and Genus / year	2014	2015	2016	2017	2018	Total	Average/ year
Ariidae: *Arius* sp.	0.05	0.03	0.04	0.04	0.04	0.20	0.039±0.004
Bothidae: *Pseudorhombus sp.*	0.02	0.04	0.04	0.02	0.03	0.14	0.027±0.005
Carangidae: *Alectis* sp., *Atule* sp., *Carangoid* spp.,*Caranx* spp., *Decapterus* sp.,*Megolopsis* sp.	3.04	2.78	0.50	0.55	0.84	7.71	1.542±0.564
Carcharhinidae: *Carcharhinus* sp.,	0.13	0.16	0.31	0.22	0.33	1.14	0.228±0.039
Clupeidae: *Sardinella* spp., *Hilsa* sp.,	0.11	0.14	0.15	0.15	0.07	0.63	0.126±0.015
Dasyatidae: *Dasyatis sp.,*	0.33	0.08	0.24	0.12	0.15	0.92	0.183±0.045
Gerreidae: Gerres spp.,	0.13	0.27	0.22	0.13	0.06	0.80	0.160±0.038
Haemulidae: *Pomadasys* spp.,	0.31	0.06	0.07	0.04	0.04	0.51	0.102±0.051
Leiognathidae: Leiognathus spp.,	0.86	0.53	0.14	0.21	0.32	2.05	0.410±0.129
Lethrinidae: *Lethrinus* spp.,	0.26	0.59	0.09	0.11	0.09	1.13	0.226±0.097
Lutjanidae: *Lutjanus* spp., *Aphareus* sp, *Aprion* sp.,	1.12	0.61	0.75	0.62	0.77	3.87	0.774±0.093
Mugilidae: *Mugil* sp,	1.86	1.82	0.35	0.42	1.28	5.72	1.144±0.326
Mullidae: *Mulloidicthys* sp., *Upeneus* spp.,	0.11	0.27	0.14	0.16	0.12	0.80	0.159±0.030
Nemipteridae: *Nemipterus* spp.,	0.15	0.03	0.05	0.04	0.07	0.33	0.066±0.021
Scatophagidae: *Scatophagus* spp.,	0.09	0.05	0.05	0.05	0.06	0.30	0.060±0.008
Sciaenidae: *Johnius* spp.	0.06	0.05	0.06	0.04	0.07	0.28	0.056±0.005
Scombridae: *Rastrelliger* spp.,	0.13	0.05	0.10	0.15	0.13	0.55	0.109±0.017
Serranidae:*Epinephelus* & *Cephalopolis* spp.,	0.83	0.49	0.30	0.19	0.33	2.14	0.428±0.111
Siganidae: *Siganus* spp.	0.52	0.61	0.01	0.07	0.07	1.27	0.255±0.127
Sphyraenidae: *Sphyraena* spp.,	0.60	0.43	0.34	0.11	0.10	1.56	0.313±0.096
Synodontidae: *Synodus* spp.,	0.10	0.09	0.08	0.07	0.05	0.39	0.078±0.009
Trichiuridae: *Trichiurus* sp.,	0.04	0.05	0.06	0.02	0.04	0.19	0.037±0.007
Palinuridae: *Panulirus* sp.,	0.01	0.01	0.00	0.00	0.00	0.02	0.005±0.001
Penaeidae: *Peaneus* spp.,	0.12	0.28	0.03	0.04	0.03	0.50	0.099±0.048
Portinidae: *Portunus* spp.,	0.02	0.01	0.01	0.02	0.02	0.07	0.015±0.001
Sepiidae: *Sepiya* sp.,	0.03	0.06	0.03	0.02	0.04	0.18	0.036±0.007

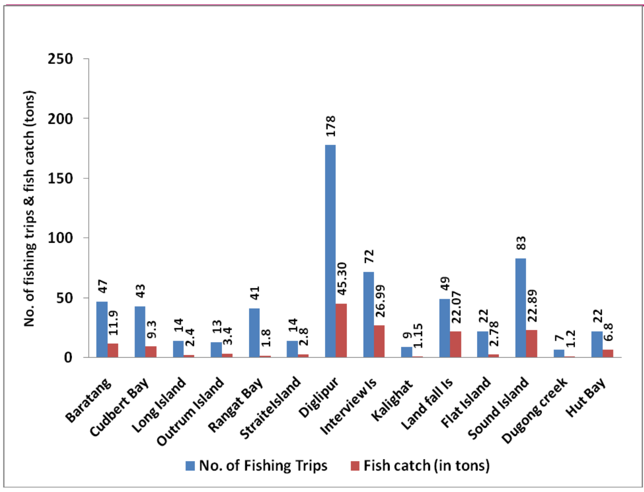

Fig. 7. *Fishing trip and fish catch at Middle, North and Little Andamans coast during 2014 - 2018*

gillnetters was 240 at Ross Island followed by Diglipur (178), Havelock (112), Sound Island (83), Carbynscove (76), Chidiatappu (72), Rutland (68), Interview Island (72), Rangat Bay (52), Land fall Island (49), Neil Island (48) etc; similarly, the maximum fish catch occurred at the coast of Ross Island was 56.4 tons with average of 11.3±3.3tons/year, followed by Diglipur (45.3 tons), Havelock (29.9 tons), Interview Island (27 tons), Sound Island (22.9 tons), Rutland (15.2 tons), Chidiatappu (14.1 tons), Carbynscove (12.6 tons), Baratang (11.9 tons) etc., during the study period (Fig. 6 and Fig. 7).
According to the year-wise analysis, the maximum fish catches recorded during 2014, 2015, 2017, 2016, and 2018 were 24.3 tons, 9.5 tons, 9.2 tons, 7.9 tons, and 5.6 tons at the Coast of Ross Island in the South Andaman Sector. The maximum catch was recorded in 2015 (5.33 tons), 2014 (2.72 tons) and 2018 (1.91 tons) at Baratang coast & during 2014 (3.15 tons) and 2017 (2.33 tons) at Betapur coast in the Middle Andaman sector. The maximum catch was recorded during 2014 (12.35) at Landfall Island coast, in 2016 (11.03 tons), 2018 (3.52 tons) and 2017 (1.49 tons) at Interview Island Coast, during 2015 (7.69) at Sound Island coast in North Andaman sector. The maximum catch was recorded during 2016 (3.35 tons) and 2017 (1.52 tons) at the Hut Bay coast in the Little Andaman sector (Table 7).

Validation

During the study period, 17 operations were carried out at each PFZ and Non PFZ in the Andaman coast. The fishes captured from the PFZ and Non PFZ were 3995 kg with an average of 235 ± 5.59 kg and 1156 kg with an average of 68±1.47 kg, respectively. The fish catch increased more than two-fold at PFZ (Table 8) without roaming and wasting time.

DISCUSSION

The drift gillnet operation was observed significantly ($P<0.001$)amongst various gillnets because of the big pelagic fishes like Scombrids, Devil Ray, Marline, Ca-

Table 6. Catch by Bottom nylon gillnet in tons during study period (2014-2018)

Family and Genus / year	2014	2015	2016	2017	2018	Total	Average
Ariidae: *Arius* sp.,	0.01	0.02	0.02	0.02	0.07	0.13	0.026±0.010
Carangidae: *Atule* sp., *Alectis* sp., *Carangoid* spp., *Caranx* spp., *Megolopsis* sp., *Selar* spp.,	0.55	0.39	0.40	0.39	0.48	2.21	0.441±0.031
Clupeidae: *Sardinella* spp., *Anodontostoma* sp., *Thryssa* sp.,	5.35	4.52	4.11	1.42	1.14	16.54	3.307±0.853
Engraulidae: *Stolephorus* spp.,	0.69	0.34	0.44	0.24	0.55	2.24	0.448±0.079
Gerreidae: *Gerres* spp.,	0.01	0.05	0.04	0.01	0.03	0.12	0.025±0.007
Leiognathidae: *Leiognathus* spp.,	0.04	0.15	0.15	0.13	0.21	0.68	0.136±0.028
Mugilidae: *Liza* sp., *Mugil* sp.,	0.03	0.05	0.16	0.16	0.10	0.49	0.099±0.027
Mullidae: *Upeneus* sp.	0.04	0.02	0.03	0.05	0.04	0.17	0.033±0.005
Scombridae: *Rastrelliger* sp., *Scomberomorus* spp.,	1.94	0.12	0.07	0.10	0.13	2.35	0.471±0.366
Sphyraenidae: *Sphyraena* spp.,	0.01	0.15	0.13	0.06	0.15	0.49	0.098±0.028
Serranidae: *Cephalopolis* spp.,	0.01	0.02	0.03	0.03	0.05	0.14	0.027±0.006
Synodontidae: *Saurida* sp.,	0.02	0.02	0.02	0.03	0.02	0.10	0.019±0.002
Portinidae: *Portunus* sp.,	0.01	0.02	0.02	0.01	0.01	0.06	0.012±0.003
Penaeidae: *Peaneus* spp.,	0.28	0.13	0.14	0.12	0.09	0.75	0.149±0.034

rangids, Baracuda, Sharks, etc., moving fast during the heavy current water in the long east coast from Little Andaman to Havelock Island. The fishing trip and fish catch also occurred significantly (>50%) on this coast, i.e. South Andaman Sector. The maximum fishermen of Junglighat FLC had the ability for significant multi-gear operation and kept different gears in their dinghy; the gear was changed in time to time according to the fishing area, the tidal, and weather conditions. PFZ changed every week in Andaman Sea due to water current and plankton density. The fish hunters recognized the wind and wave direction and tidal condition; then selected their fishing grounds every week.

Gill nets are the dominant type of gear at the all India level. According to early studies, the gillnet was the main gear in ANI, which formed 39% of the total fishing gear units and the next important gear is hook and line, which forms 34%. The total number of fishing gears in operation during 1998-'99 was 2,676, including 1,044 gill nets, 930 hooks and lines, 615 cast nets, 49 shore

Table 7. Analysis of ground wise gillnet fish catch in tons during 2014 – 2018

Fishing grounds	2014	2015	2016	2017	2018	Total	Average
1. South Andaman Coast				**Fish catch in tons**			
Burmanallah	3.00	3.55	0.51	0.12	0.32	7.50	1.5±0.7
Carbyn's cove	1.40	5.29	3.31	1.27	1.30	12.56	2.5±0.8
Chidiatappu	2.33	4.48	2.02	2.53	2.72	14.07	2.8±0.4
Cynque Island	1.08	2.55	0.13	0.95	1.05	5.76	1.2±0.4
Haddo Warf	0.18	0.11	0.01	0.03	0.11	0.43	0.1±0.0
Havelock Island	12.11	7.00	5.44	1.10	4.23	29.88	6.0±1.8
Mathuban	0.33	0.42	0.35	0.50	0.73	2.33	0.5±0.1
Minnie Bay	0.15	0.05	0.57	0.31	0.53	1.61	0.3±0.1
Neil Island	0.36	1.37	0.38	1.20	1.43	4.74	0.9±0.2
North Bay	0.60	0.43	0.25	0.37	0.40	2.06	0.4±0.1
Ross Island	**24.29**	9.46	7.90	9.20	5.55	56.41	11.3±3.3
Rutland	0.68	4.93	0.77	3.67	5.19	15.24	3.0±1.0
Sentinel Island	0.80	0.50	0.00	0.24	0.52	2.06	0.4±0.1
Shoal Bay	0.09	1.62	1.03	0.55	1.40	4.69	0.9±0.3
Tarmugli Island	0.12	0.47	0.00	0.45	0.35	1.39	0.3±0.1
Tirur	1.76	3.54	0.00	0.32	1.43	7.05	1.4±0.6
Wandoor	0.78	0.78	0.00	0.21	0.27	2.04	0.4±0.2
Total	50.06	46.53	22.66	23.03	27.52	169.80	34.0±5.9
2. Middle Andaman Coast							
Baratang Island	**2.72**	**5.13**	1.72	0.43	**1.91**	11.91	2.4±0.8
Betapur	1.35	1.91	**3.15**	**2.33**	0.55	9.28	1.9±0.4
Long Island	0.57	0.66	0.45	0.20	0.53	2.41	0.5±0.1
Outrum Island	0.60	0.65	0.23	0.25	1.63	3.36	0.7±0.3
Rangat Bay	0.10	0.60	0.56	0.32	0.18	1.76	0.4±0.1
Straight Island	0.53	0.22	0.83	0.70	0.50	2.78	0.6±0.1
Total	**5.87**	**9.16**	**6.93**	**4.23**	**5.30**	**31.48**	**6.3±0.8**
3. North Andaman Coast							
Diglipur	19.27	10.07	8.86	2.63	4.48	45.30	9.1±2.9
Interview Island	5.43	5.53	11.03	1.49	3.52	26.99	5.4±1.6
Kalighat	0.36	0.45	0.01	0.34	0.00	1.15	0.2±0.1
Land fall Island	12.35	1.97	3.23	1.13	3.40	22.07	4.4±2.0
Flat Island	1.28	0.58	0.40	0.52	0.00	2.78	0.6±0.2
Sound Island	8.57	7.69	1.60	1.31	3.73	22.89	4.6±1.5
Total	**47.25**	**26.27**	**25.12**	**7.42**	**15.13**	**121.18**	**24.2±6.71**
4. Little Andaman Coast							
Dugong creek	0.00	0.64	0.30	0.25	0.00	1.19	0.2±0.1
Hut Bay	0.94	0.94	3.35	1.52	0.00	6.75	1.4±0.6
Total	**0.94**	**1.58**	**3.65**	**1.77**	**0.00**	**7.94**	**1.6±0.6**

Table 8. Validation experiment of gillnetters at PFZ and Non-PFZ on the coast of Andaman

Validation conducted	No. of validation experiments	Fishes caught in kg	Average in kg	Remarks
Potential Fishing Zone	17	3995	235±30.8	> 3 fold increased in PFZ
Non-Potential fishing Zone	17	1156	68±5.9	

seines, and 38 anchor nets (Madhu *et al.,* 2000). According to Mariappan *et al.* (2019), the gill net fisheries of India are described as one of the mainstays of the artisanal as well as small-mechanized sectors of the fishing industry. The marine fishery in the ANI is dominated by pelagic catches, which comprise about 60% of the total catch. Gillnet (27%), hand-line (54%), long-line (5%), and ring net/seine (1%) are the major types of fishing gears used in the Andaman fishery (FSI 2007). It is understood that the using of gear gillnet is decreasing every year because of the increase of Hook and line operation for exporting selected dollar Groupers (i.e. *Plectropomus* spp., and *Epinephelus* spp.,) to other countries from these Islands.

The coastal tunas were mainly caught by drift gillnet during 2005. ANI is one of the best tuna fishing grounds, with an annual potential of 180,000 tonnes. Fishery and status of exploitation of coastal tunas have been reviewed by Dam Roy *et al.* (2002); and Madhu *et al.* (2002). Nithyanandan (2009) mentioned that the gear drift gillnet is the main fishing gear used, contributing to over 40% of marine fish landings. PFZ forecasts proved to be an excellent source for deriving pecuniary benefits and a potent tool in harvesting the under-exploited fishery resources of ANI (George *et al.,* 2011, 2014; Arur *et al.,* 2020). The indications that a single/similar stock of fish is being attracted to PFZ compared to Non–PFZ. Fishing expenses were comparatively less for vessels that operated within PFZ. The fish catch has been reported only for the visiting period. It may be more catch than the reported. A significant increase in total catch identified by a follower of PFZ forecasts has been documented from ANIs (Grinson *et al*., 2011). The sustainability of fisheries remains a concern (Pauly *et al.,* 2002; Asche *et al.,* 2018) due to various issues such as irresponsible and unsustainable fishing practices. Most of the active fishermen of ANI were sensitized by the Fisheries Science Division, Central Island Agricultural Research Institute, Port Blair. Few of them were also rewarded during Kisaan Mela (Grinson 2011). Still, there was some error in data collection; few avoided providing real landings due to fears of being fully sensitised for real data collection. Alternative sector development through industrial fishing activities should be promoted through proper monitoring, control and surveillance (MCS). Developing a stakeholder interface platform could promote participatory, transparent and science-based management of fisheries resources. Fisheries of ANI are underdeveloped attributable to operation of vessels with decreased far-sea endurance, underdeveloped infrastructure facilities such as harbour, cold storage and processing and transportation costs (Grinson *et al.,* 2013). The vessel size and the gears are not adequate for operating in deep waters and there is an absence of organized off-shore fishing from the Andaman base. The emerging body of evidence suggests the critical need to reliably estimate the fish catches and population dynamics for sustainable fisheries management (Kirubasankar *et al.,*2021). The fishermen of ANI have the skill of multi-gear operation *viz* Ring net, Gillnets, Trawl net, Anchor net, Longline, Handline, etc., following advanced fishing technologies (AFT).

Conclusion

ANI has remained a potential fishing ground to exploit the marine fisheries resources in India due to its vast coastline (1,912 km). Three decades before, the maximum fishermen depended on gillnetting fishery on the coast of ANI because of less expensive. The small gillnet can be operated simply without a craft or with a small non-motorised dinghy. It indicates that the gillnet operation is slowly decreasing. At present, the small gillnetters are decreasing day by day. The youngsters are changing their gear operation for exportable targeted fishes for better income. Drift netters, especially large pelagic fishes, also use multi gears according to the islands' turbulent tidal condition. The issues are isolated islands with difficulty in transportation and maintenance like mainland crafts also being faced. The other reasons for less exploitation of fishery resources through gill netters are unavailability of mechanized/ deep sea fishing vessels, expensive transport facilities, very far away (1400 km) from mainland India, shortage of fish landing harbours etc. It is essential to increase the potential fishing activities to meet our daily needs or demands of fish consumption by the exploding population in these islands. Concerned departments and policymakers to take good steps to promote the gillnetters to increase gillnet fishing in these islands will benefit the islanders. Fishing operation and fish landings of gillnet were reported only for the visiting period, and it may be more than the reported landings. From the quantitative results of the fishing operations done by identical vessels, PFZ and Non-PFZ areas have been simultaneously documented in this study. The average income generated by vessels operating in the PFZ areas was considerably higher than vessels operating in non PFZ areas. On the basis of validation experiments, it is suggested that satellite-based fishing is advantageous in ANIs. It is suggested that the fishermen may follow the PFZ forecast for better catch and that the gillnet fishing be promoted to under-exploited small pelagic fishes of these islands will benefit the gillnetters.

ACKNOWLEDGEMENTS

Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, India, provided the fund to conduct the research work. The cooperation from the fishermen for conducting validation experiments is acknowledged

Conflict of interest

The authors declare that they have no conflict of interest.

REFERENCES

1. Amos, C.M., Castelao, R.M. & Medeiros, P.M. (2019). Offshore transport of particulate organic carbon in the California Current System by mesoscale eddies. *Nat. Commun.,* 10, 4940, https://doi.org/10.1038/s41467-019-12783-5.
2. ANDFISH (2005). Roadmap for the development of fisheries in Andaman and Nicobar Islands. CMFRI and CIFT-Cochin, CIBA- Chennai, CARI- Port Blair and ICAR-Fisheries Division-New Delhi, June 2005 p 89.
3. ANI Fisheries Policy (2018). Andaman and Nicobar Islands Fishery Policy Draft. p 16. http://www.and.nic.in/pdf/policydocument.pdf.
4. Anrose, A., Sinha, M.K. & Kar, A.B. (2009). Oceanic tuna resources potential in Andaman and Nicobar waters. In: Proceedings of Brainstorming session on Development of Island Fisheries (Eds. Dam Roy, S., P. Krishnan, K. Sarma and G. George), *Central Agricultural Research Institute*, Port Blair. pp. 5–22.
5. Arur A, Krishnan P, Kiruba-Sankar, R., Suryavanshi, A., Kumar, K.L., Kantharajan, G, Choudhury, S.B., Manjulatha, C. & Babu, D.E. (2020). Feasibility of targeted fishing in mesosclae eddies: a study from commercial fishing grounds of Andaman and Nicobar Islands, India. *International Journal of Remote Sensing* 41:5011–5045. https://doi.org/10.1080/ 01431161.2020.1724347
6. Arur, A., Krishnan, P., Grinson, G., Goutham Bharathi, M.P., Kaliyamoorthy, M., Hareef Baba Shaeb, K., Suryavanshi, A.S., Srinivasa Kumar, T. & Joshi, A.K. (2014). The influence of mesoscale eddies on a commercial fishery in the coastal waters of the Andaman and Nicobar Islands, India. *International Journal of Remote Sensing*, 35(17), 6418–6443, http://dx.doi.org/10.1080/01431161.2014.958246.
7. Asche, F., Garlock, T.M., Anderson, J.L., Bush, S.R., Smith, M.D., Anderson, C.M., Chu, J., Garrett, K.A., Lem, A., Lorenzen, K., Oglend, A., Tveteras, S. & Vannuccini, S. (2018) Three pillars of sustainability in fisheries. *PNAS* 115(44):11221–11225. https://doi.org/10.1073/ pnas.1807677115. ,
8. Bakun, A. 2006. “Fronts and Eddies as Key Structures in the Habitat of Marine Fish Larvae: Opportunity, Adaptive Response and Competitive Advantage. *Scientia Marina* 70 (S2): 105–122.
9. Braun, C.D., Galuardi, B. & Thorrold, S.R. (2018). HMMoce: An R package for improved geolocation of archival-tagged fishes using a hidden Markov method. Methods Ecol. Evol. 9, 1212–1220 (2018).
10. Brauna, C.D., Peter Gaubec, Tane H. Sinclair-Taylord, Gregory B. Skomale and Simon R. Thorrold (2019). Mesoscale eddies release pelagic sharks from thermal constraints to foraging in the ocean twilight zone. *PNAS*, 116(35), 17187–17192.
11. Chelton, D.B., Schlax, M.G. & Samelson, R.M. (2011b). Global observations of nonlinear mesoscale eddies. *Prog. Oceanogr.,* 91, 167–216, https://doi.org/10.1016/j.pocean.2011.01.002.
12. Dam Roy, S., Soundararajan, R. & Sarangi, N. (2002). Marine fishery resources in the seas around Andaman and Nicobar Islands. Paper presented in the workshop on “Fishery Resources of Andaman and Nicobar Islands, organized by *Fishery Survey of India*, Port Blair on 7th May 2002.
13. Desai, P.S., Honnegowda, H. & Kasturirangan, K. (2000) Ocean research in India: Perspective from space. *Current Science* 78(3), 268-278.
14. Diffey, S. (2012). Developing Fish Landing Centres: Experiences and lessons from Sri Lanka. FAO Fisheries and Aquaculture Circular No. 1063. Published by the Food and Agriculture Organization of the *United Nations in collaboration with the Canadian International Development Agency Rome*. Pp 88.
15. Dilmahamod, A.F., Karstensen, J., Dietze, H., Löptien, U. & Fennel, K.(2022). Generation Mechanisms of Mesoscale Eddies in the Mauritanian Upwelling Region. *Journal of Physical Oceanography* 52,161-182
16. Dong, C., McWilliams, J.C., Liu, Y. & Chen, D. (2014). Global heat and salt transports by eddy movement. *Nat. Commun.*, 5, 3294, https://doi.org/10.1038/ncomms4294.
17. Grinson, G. (2011). Potential Fishing Zone Validation in Andaman Sea. Annual report (2010-11) submitted to INCOIS, Hyderabad. p 68.
18. Grinson, G., Kamal Sarma, Goutham Bharathi, M.P., Kaliyamoorthy, M., Krishnan, P. Kirubasankar, R. (2014). Efficacy of different modes in disseminating Potential Fishing Zone (PFZ) forecasts- a case study from Andaman and Nicobar Islands. *Indian J. Fish.*, 61(1), 84-87.
19. Grinson, G., Krishnan, P., Dam Roy, D., Kamal Sarma, Goutham Bharathi, M.P., Kaliyamoorthy, M., Krishnamurthy, V. & Srinivasa Kumar, T. (2013). Validation of Potential Fishing Zone (PFZ) Forecasts from Andaman and Nicobar Islands. *Fishery Technology* 50: 208 - 212
20. Grinson, G., Krishnan, P., Kamal Sarma, Kirubasankar, R., Goutham Bharathi, M.P., Kaliyamoorthy, M., Krishnamurthy, V. & Kumar, S.T. (2011). Integrated potential fishing zone (IPFZ) forecasts: A promising information and communication technology tool for promotion of green fishing in the islands. *Indian Journal of Agricultural Eco-*

nomics, 66 (3), 513-519.

21. Handbook on Fisheries Statistics 2018 (2019) Dept. of Fisheries, Ministry of Fisheries, Animal Husbandry & Dairying Govt. of India, New Delhi.
22. Handbook on Fisheries Statistics 2020 (2020) Dept. of Fisheries-Ministry of Fisheries, Animal Husbandry & Dairying Govt. of India, New Delhi.
23. Hyrenbach, K. D., R. R. Veit, H. Weimerskirch, & Hunt. G. L. (2006). Seabird Associations with Mesoscale Eddies: The Subtropical Indian Ocean. *Marine Ecology Progress Series* 324:271 –279. doi:10.3354/meps324271.
24. Kaliyamoorthy, M., Dam Roy, S. & Sahu V. K. (2020). Analysis of Ring Net operation from South Andaman fish landing centres (FLC) during 2014 – 2018. *Flora and Fauna,* 26 (1): 117-133. DOI : 10.33451/florafauna.v26i1pp117-133.
25. Kaliyamoorthy, M., Dam Roy, S. & Sahu, V. K., (2019). Analysis of landings of Indian Mackerel during the period 2014to 2018 at Junglighat fish landing centre, South Andaman. *Flora and Fauna*, 25 (2), 217-227. DOI : 10.33451/florafauna.v25i2pp217-227.
26. Karuppusamy, S., Ashitha, T.P., Padmanaban, R., Shamsudeen, M. & Silva, J.M.N. (2020). A remote sensing approach to monitor potential fishing zone associated with sea surface temperature and chlorophyll concentration. *Indian Journal of Geo Marine Sciences* 49 (06), 1025 -1030
27. Kiruba-Sankar, R., Krishnan, P., Grinson, G., Lohith Kumar, K., Raymond Jani Ange, J., Saravanan, K. & Dam Roy, S. (2021). Fisheries governance in the tropical archipelago of Andaman and Nicobar – opinions and strategies for sustainable management. *Journal of Coastal Conservation*, 25(16) https://doi.org/10.1007/s11852-021-00808-5
28. Madhu, K, Rama Madhu, Ahlawat, S.P.S. Ravindran, E. K. & Dam Roy, S. (2002). Status of exploitation of tuna, mackerel and seerfish in Andaman and Nicobar Islands. In N.G.K. Pillai, N.G. Menon, P.P. Pillai and U. Ganga (Eds). Management of Scombroid Fisheries, CMFRI, Kochi 49-55.
29. Madhu, K., Rema Madhu, Ahlawat, S.P.S., Raveendran, K. & Dam Roy, S. (2000). Status of exploitation of tuna, mackerel and seer fish in Andaman and Nicobar Islands. Book of Management of Scombroid Fisheries Edited by N.G.K. Pillai, N.G. Menon, P.P. Pillai and U. Ganga, CMFRI, Kochi, India.
30. Mariappan S, Kalaiarasan M and Felix S (2019). Design and technical specifications of marine gill nets of Pulicat, Tamil Nadu, India. *Journal of Entomology and Zoology Studies*, 7(4), 220-223.
31. McGillicuddy, D. J., and Coauthors, 2007: Eddy/wind interactions stimulate extraordinary mid-ocean plankton blooms. Science, 316, 1021–1026, https://doi.org/10.1126/science.1136256.
32. McGillicuddy, D.J.(2016).Mechanisms of physical-biological-biogeochemical interaction at the oceanic mesoscale. *Annu. Rev. Mar. Sci.,* 8, 125–159.
33. McGillicuddy, D.J., Robinson, A.R., Siegel, D.A., Jannasch, H.W., Johnson, R., Dickey, T.D., McNeil, J., Michaels, A.F. & Knap, A.H., (1998). Influence of Mesoscale Eddies on New Production in the Sargasso Sea. *Nature,* 394, 263– 266. doi:10.1038/28367.
34. Mengrong Ding, Pengfei Lin, Hailong Liu1, Aixue Hu & Chuanyu Liu. (2020). Lagrangian eddy kinetic energy of ocean mesoscale eddies and its application to the northwestern Pacific. Scientific Reports. https://doi.org/10.1038/s41598-020-69503-z
35. Mizobata, K., Saitoh, S.I., Shiomoto, A., Miyamura, T., Shiga, N., Imai, K., Toratani, M., Kajiwara, Y. & Sasaoka, K. (2002). Bering Sea Cyclonic and Anticyclonic Eddies Observed during summer 2000 and 2001. *Progress in Oceanography* 55, 65–75. doi:10.1016/S0079-6611(02)00070-8.
36. Nayak, S., Solanki, H.U. & Dwivedi, R.M. (2003) Utilization of IRS P4 Ocean colour data for potential fishing zone -A cost benefit analysis Indian Journal of Marine Sciences, 32(3), 244-248.
37. Nithyanandan, R. (2009). Development of Fisheries in Andaman and Nicobar Islands – A Case of the Potential going Abegging. In S.Dam Doy et al. (Eds), Proceeding of Brainstarming session on Development of Island Fsheries, *Central Agricultural Research Institute*, Port Blair pp. 1-4.
38. Olson, D.B., & Backus, R.H. (1985). The Concentrating of Organisms at Fronts: A Cold-Water Fish and a Warm-Core Gulf Stream Ring. *Journal of Marine Research,* 43, 113–137.doi:10.1357/002224085788437325.
39. Pauly, D., Christensen, V., Guenette, S., Pitcher, T.J., Sumaila, R., Walters, C.J., Watson, R. & Zeller, D. (2002) Towards sustainability in world fisheries. *Nature,* 418, 689 –695. https://doi.org/10.1038/nature01017.
40. Pillai, N.G.K. & Abdussamad, E.M. (2009). Development of Tuna Fisheries in Andaman and Nicobar Islands. In Dam Doy *et al.* (Eds), Proceeding of Brainstorming session on Development of Island Fsheries, Central Agricultural Research Institute, Port Blair pp. 23-34.
41. Sabarros, P.S., Ménard, F., Lévénez, J.J., Kai, E.T. & Ternon, J.F. (2009). Mesoscale eddies influence distribution and aggregation patterns of micronekton in the Mozambique channel. *Marine Ecology Progress Series,* 395, 101 – 107. doi:10.3354/meps08087.
42. Seki, M.P., Polovina, J.J., Brainard, R.R., Bidigare, R.R., Leonard, C.L., & Foley, D. G. (2001). Observations of Biological Enhancement at Cyclonic Eddies Tracked with GOES Thermal Imagery in Hawaiian Waters, *Geophysical Research Letters* 28, 1583–1586. doi:10.1029/2000GL012439.
43. Siar, S.V., Venkatesan, V., Krishnamurthy, B.N. & Sciortino, J.A. (2011). Experiences and lessons from the cleaner fishing harbours initiative in India. *FAO Fisheries and Aquaculture Circular* No. 1068. Rome, FAO. 94 pp.
44. Solanki, H.U., Dwivedi, R.M. & Nayak, S.R. (2001). Synergistic analysis of Sea WiFS chlorophyll concentration and NOAAAVHRR SST features for exploring marine living resources*. Int. J. Rem. Sen.* 22, 3877-3882.
45. Solanki, H.U., Dwivedi, R.M., Nayak, S.R., Gulati, D.K., John, M.E. & Somavanshi, V.S.. (2003). Potential Fishing Zone (PFZs) forecast using satellite data derived biological and physical processes. *J. Ind. Soci. Rem. Sen.* 31 (2), 67-69.
46. Solanki, H.U., Mankodi, P.C., Nayak, S.R. & Somvanshi, V.S. (2005). Evaluation of remote sensing based potential fishing zones (PFZs) forecast methodology. *Continental Shelf Research,* 25, 2163– 2173
47. Solanki, H.U., Pradhan, Y., Dwivedi, R.M., Nayak,

S.R.,Gulati, D.K. & Somvanshi, V.S. (2005). Application of Quick SCAT Sea Winds data to improve remotely sensed Potential Fishing Zones (PFZs) forecast methodology: Preliminary validation results. *Ind. J. Mar. Sci.* 34 (4), 441-448.

48. Thomas, S.N. (2019). Sustainable Gillnet Fishing. *ICAR Winter School: Responsible Fishing: Recent Advances in Resource and Energy Conservation 21 November – 11 December 2019, ICAR-CIFT, Kochi*
49. Venkataraman, K. (2005). Coastal and marine biodiversity of India. *Indian. J. Mar. Sci*. 34, 57–75.
50. Yoder, J.A., Atkinson, L.P., Lee, T.N., Kim, H.H. and McClain, C.R. (1981). Role of Gulf stream frontal eddies in forming phytoplankton patches on the outer Southeastern shelf. *Limnology and Oceanography* 26,1103–1110. doi:10.4319/lo. 1981.26.6.1103.
51. Zhou, J., Zhou, G., Liu, H., Li Z & Cheng, X. (2021) Mesoscale Eddy-Induced Ocean Dynamic and Thermodynamic Anomalies in the North Pacific. *Front. Mar. Sci.,* 8,756918. doi: 10.3389/fmars.2021.756918.