Preliminary Results on the Exploration of Tuna Resources in the East Indian Ocean

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FOREWORD

In SEAFDEC's constant drive to locate and define new fishing grounds and sources of animal protein, this work stands as a shining example of the dedication I have come to expect from the research teams. The paper acts as a working document to any that have the wherewithal to undertake purse seine operations in the East Indian Ocean and serves as a guide to such operations. The work also serves to highlight peculiarities that can possibly occur through remote climatic disturbances like *El Nino* and *El Nina.* In any event, this work is a tribute to the dedication of the SEAFDEC research teams in their efforts to sustain the peoples of the region with new sources of marine production, be it in deep waters or in the near-shore areas of our member countries.

I expect nothing less than excellence in the work that is conducted by the Center and this work serves to encourage that expectation.

Panu Tavarutmaneegul
Secretary-General

Preliminary Results on the Exploration of Tuna Resources in the East Indian Ocean

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ABSTRACT

Tuna purse seine fishing operation of M.V. SEAFDEC in the East Indian Ocean has been carried out since 1994. Aggregating tuna by floating FADs (Fish Aggregating Devices) are used in the fishing ground. Tracking of the FAD drift route during each season of the year was recorded. It was found that, in the early months of the year (from February to March), FADs set above latitude 5° S drifted in northeasterly direction and some, after nearly reaching the equator, turned back toward the west whereas FADs set below latitude 05° S drifted in an eastly direction. In the latter period of the year (October-November), FADs drifted eastward and then turned to the southeast at about longitude 088° - 091° E. The track of the FADs in 1997 was exceptionally unusual, all FADs set during the year drifted rapidly westward, which is possibly a consequence of the *El Nino Effect*. Main catch during the fishing operation were Skipjack tuna *Katsuwonus pelamis* (Linnaeus, 1758), Yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788) and Bigeye tuna *T. obesus* (Lowe, 1839)

Keywords : Tuna purse seine, FADs, Early months of the year, Latter months of the year, Drifting direction, East Indian Ocean

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1. Introduction

MV SEAFDEC, the Fisheries training and Research Vessel, has conducted tuna purse seine fishing in the East Indian Ocean from 1994 until today. Because of the situation of declining coastal fishery resources in the Southeast Asia region, oceanic fishery resources are expected to be the new sources of protein in the future. Tuna and tuna-like species are also considered as under exploited oceanic fishery resources. The research objectives are to determine the abundance of tuna species, identify appropriate fishing methods and fishing techniques and also the oceanographic aspects that are related. Southeast Asian countries, especially Thailand, have an advantage in shorter distances from their base to the fishing grounds. Results of the exploration might be useful for those who would like to establish a tuna purse seiner fleet for operations in the East Indian Ocean, which is considered to be a new fishing ground for tuna purse seine compared with others.

2. Material

2.1 Purse seiner

M.V. SEAFDEC, Fisheries Training and Research Vessel, came into service in February 1993. Principal particulars including length over all and tonnage etc. are given in Table 1.

Table 1. Principal particulars of M.V. SEAFDEC

Principal particulars	
Length over all............................... 65.02 m.	Gross tonage................................1178 tons
Length between perpendiculars ....57.00 m.	Net tonage..................................... 354 tons
Breadth, molded ....12.00 m.	Total complement ....63 P.
Draft, molded ....4.658 m.	Fish hold capacity(bale).....................145.38 m^3
Service speed at 4.50 m. draft ....14.3 knots	Freezing room capacity ....20.48 m^3
Max. sea trial speed(measured)...... 16.640 knots	Freezing ability (brine)...........................20t/day
Dead weight ....744.42 tons	(Air blast)................1.6t/36hr

2.2 Purse seine net

The Tuna and skipjack purse seine net of M.V. SEAFDEC was made by Nichimo Co.,Ltd. With a total net length of 1,155.9 m.(contracted), it is composed of 20 portions. The netting yarn is all nylon and the bunt part (portions 1-2) are constructed with 90-160 ply/90 mm.-mesh size and 40 ply/105 mm.-mesh size in the body part of the net (portion5-18). The wing attached to the bunt (portion 3-4) is made of 60 ply/90 mm.-mesh size and the right wing (portion 19- 20) is 60 ply/105 mm. and 90 ply/105 mm. The upper and lower selvages are constructed of Polyethylene Ultra Cross (PE UC) 320 ply/150 mm.-5 meshes depth. The floats are made of Plastic EVA, with dimensions of 160(L) x 190(D) x 33(H.D.) and a buoyancy of 4,000 grams. They are yellow in color. The chain is made of Super Alloy, with a diameter of 11,13 mm. It is attached with a bridle chain with single rope 10 pcs. and plus bridle chain double 64 pcs. The purse ring is made of Galvanized Iron, 22 mm.-diameter x 260 mm.

In June 1994, the Japanese Master fisherman improved the purse seine net by changing the portion 7-15 from Nylon netting of 40 ply/105 mm. to Tetron 60 ply/210 mm. and 70 ply/210 mm. Two double bridle chains were alternated with a bridle chain with a single rope. Other components were retained. (Annex I)

In August 1997, the floats (model E-40) of the purse seine net were replaced with model E-50 (buoyancy 5,000 grams).(Annex II)

The last improvement was carried out in August 1998. When two portions were added to the body part of the net. Thus, the purse seine net now has 22 portions and its length is increased to 1,155.9 m.(Annex III)

2.3 Fish aggregating Devices (FADs)

The FADs are of the floating type composed of 3.5 m. bamboo poles sequentially

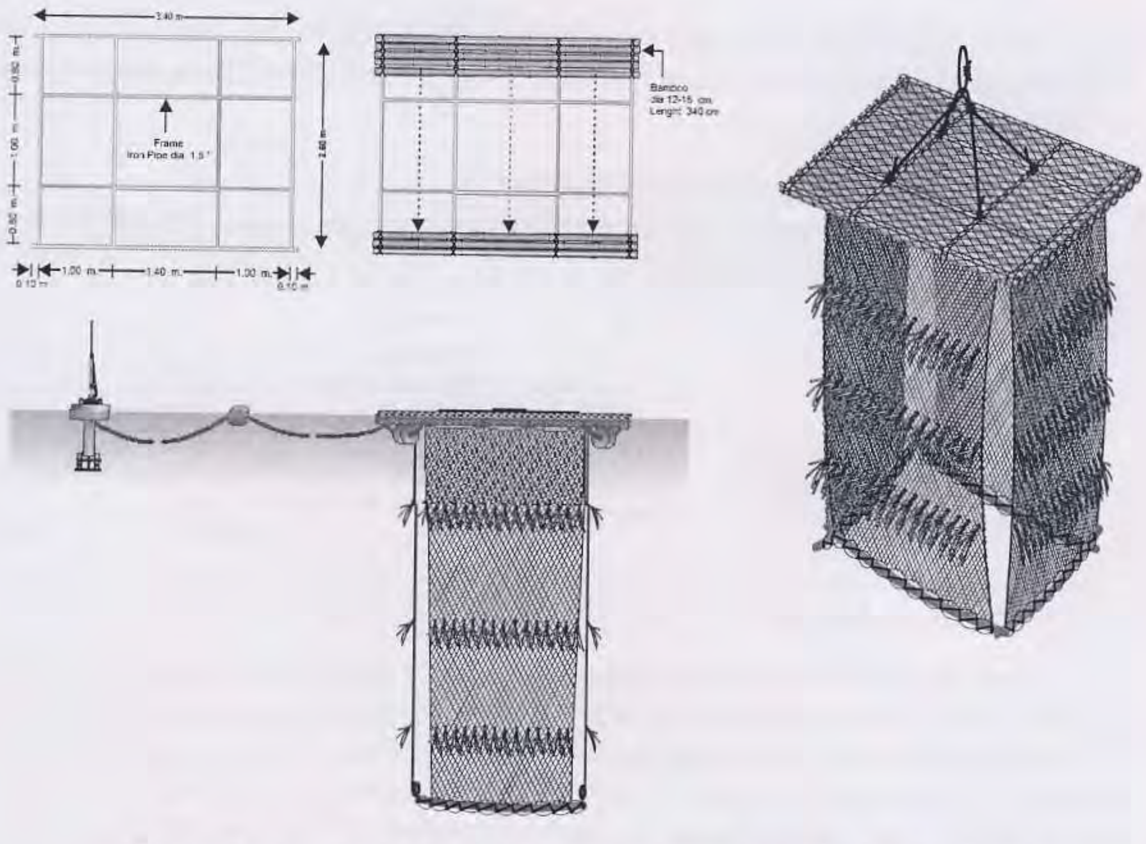

Fig.1. Construction of FAD (Fish Aggregating Device) of MV SEAFDEC

tied around a 1.5 inch-diameter iron-pipe frame of 3.4 x 2.7 m. The FADs are covered by large size twine net to provide more shade and strength. Beneath the FADs, there are four pieces of 7 m. net hanging like a 'skirt' and these are decorated with white rope to attract the fish to their shelter. Construction and dimension of M.V. SEAFDEC 's FADs are given in Fig.1.

2.3 Nautical instruments for fishing

M.V. SEAFDEC has three frequency (28 kHz, 75kHz and 94 kHz) Color Scanning Sonar installed, one 288 kHz Color Echo-sounder, two Wet-paper Echo-sounders with frequencies of 28 and 50 kHz. . There are also two sets of Radio direction finders for locating the position of radio buoys. Three Net-Zonde receivers, 40,50 and 60 kHz for detecting net depth while shooting and hauling the purse wire. There are also environment observation instruments related to fishing including a Doppler sonar current indicator and general weather observation systems and a NOAA receiving system.

In the work boats, SEAFDEC 3&4, a 200 kHz Tele-sounder is installed. These are used for detecting fish schoosl beneath FADs before and during fishing operations. Echo traces from Tele-sounders are converted and transmitted in the form of radio signals to M.V. SEAFDEC these are converted back to show a trace on the monitor on the bridge.

3. Method

Because SEAFDEC is a regional training center, the cruises of M.V. SEAFDEC are arranged in accordance with the training program of the center. Also, the fishing season in the East Indian Ocean fishing grounds are also considered. M.V. SEAFDEC has been operating purse seines twice a year, in February to March and October to November, these period are in between the tuna fishing season, which is mid September to mid March, for the East Indian Ocean (Chantawong,1995). In the period of operations there were two cruises made, the first was a preparatory cruise for setting the Fish Aggregating Devices (FADs), searching for other floating objects, collecting fishing ground information and environmental data and perhaps some purse seine fishing using the identified floating objects or some Japanese allies' FADs like those of Nippon Maru or Fuguichi Maru. The second cruise, had the main purpose of training on several types of fishing gear including purse seine. Purse seining was conducted using the FADs that were set in the first cruise. Because of limited time and the fish hold capacity of the vessel, 3-5 purse seine fishing operations were carried out in a cruise of 8-10 days in the fishing grounds.

3.1. Setting FADs and locating fish and fishing ground

Determination of environment information including wind, current direction and speed, the FADs were set in an area of latitude 01°N-06°S longitude 082°-090°E. This position is chosen because of the available information on the FAD's drift rate and direction, this is recorded year after year, to avoid FADs drifting into the Indonesian Exclusive Economic Zone (EEZ) and drifting away eastward which is too far for conducting fishing operations because of the limited time available. Others considerations for the selection of the FAD setting areas relate to the present catch information from the Japanese tuna purse seiner fleet. Other indications are the appearances of a front (or frontal zone)[1], drifting garbage or flocks of birds. Setting FADs in such areas may attract tuna schools sooner (Pokapan, 1997).

To locate and detect FADs all are fitted with Selective call (Sel-call) radio buoys, which will transmit only when they receive an interrogative signal from the vessel, this conserves the batteries.. The signals sent from the radio buoy are received by the Direction Finder on the vessel and are decoded to display the distance and direction from the ship to the buoy.

Searching for floating objects or flotsam like drifting logs and garbage etc. is another way to locate tuna schools. The attraction of fish to floating objects has long been observed. This behavior is explained, both in terms of floating objects serving as a single orientation point in the middle of the ocean and in terms of a gradual buildup of a food chain community under and around the floating objects (Ben-yami,1994). Searching for floating objects by the crew of M.V. SEAFDEC, was done after the vessel left the Indonesian EEZ from early morning until twilight. There are three size of enlarging power, 7x50, 10x50, and 20x120, binocular used in the ship for searching from the Compass Deck. After finding interesting flotsam, the vessel is maneuvered dead slow to check for fish schools by the Scanning sonar and Echo sounder. If a few fish are detected a small FAD and radio buoy are attached to attract more fish for operations at the next opportunity. On the other hand, if there are a lot of fish, the radio buoy and light buoy are attached for purse seine fishing operations the next morning.

3.2. Preparations for fishing operation

As soon as the vessel is in the fishing ground, the covering sailcloth over the net is removed the net is wetted by spraying sea water, this is to increase its sink rate while shooting. Sufficient purse line from the main drum is pulled out, threaded through the davit and all purse rings are arranged on the starboard side and connected with the bunt end and the skiff boat. The towing wire is also pulled from the drum and threaded through another block on the davit, then through the towing wire cage roller and connected to the other end of the net. The towing line used by the skiff to pull the net out of the vessel is prepared along the port side. The skiff launch preparation is by changing the normally held wire for a Pelican hook. A choker rope is also used to ensure holding the skiff until just before shooting when it is taken off.

Whether it is a FAD or a floating object for operation the next morning these are attached with the light buoy for easy sighting in the dark. The vessel will cruise away upwind at least 10 nautical miles, to avoid disturbing the fish school and will just drift back. Time usage at every step before shooting the net must be considered and calculated carefully. The twilight time of the operating day is determioned as a key time because of tuna behavior. They will appear near the sea surface before sunrise then dive into the deeper layers as the brightness increases (Shibata and Nishimura,1997). Therefore, the time of purse line hauling is scheduled to the twilight in order to catch all fish in the net before their behaviour pattern is activated. Thus, other working schedules prior to pursing including launching the work boat, setting the lure light and start shooting is fixed after the twilight. The timing of each step of the work can be determined as the sample in the following table:

Table 2. Sample of operating time calculation

Step	Description	Time usage	Supposition time sample
1.Launching work boat	-Launching two work boat -work boats running to FAD or floating object	20 min.	0515-0535 hrs
2.Luring light	-Work boat start luring light by underwater lamp -Confirm fish school target by Tele-sounder and Scanning sonar	15 min.	0535-0550hrs
3.Shooting the net	-Shooting and surrounding the net	10 min.	0550-0600 hrs
4.Finish pursing	-Purse line hauling -Finish purse line hauling	20 min.	0600-0620 hrs Civil twilight time

3.3. Fishing operation

On the operating day, the ship will approach the target are and will interrogate the radio buoy and receives both course and distance from radio direction finder and then using binoculars will search for the light buoy attached on the day before. Fish schools and environment conditions, including wind and current speed and direction, are considered in the decisions whether to fish or not and for net shooting. There are many times that the operation is canceled because of too few fish detected by the acoustic equipment, too strong a wind, too strong a current or strongly contravention directions among each current layer. The Master fisherman considers all related factors and makes his decision whether or not to go ahead.

When the proper time arrives, the two work boats-SEAFDEC No.3 and 4 are launched and ordered to go to the FAD. When the crew have made fast the boat to the FAD, the underwater lamp is prepared awaiting the order from the Master fisherman to switch it on. Meanwhile as the preparations and the luring light progress, The Master fisherman and staff observe the tele-sounder monitor on the bridge to estimate the amount of fish aggregated beneath and around the FAD. As previously mentioned, M.V. SEAFDEC is a starboard side shooting purse seiner, the vessel sets the surrounding net in a clockwise direction at a speed of 10 knots. The circling radius measures approximately 220 meters. Afterwards, the skiff sets the net bunt end and goes to the stern of the ship to pull it away from the net to prevent her propeller tangling in the net. Purse line hauling and rings transfer takes about 20 minutes and before starting to haul the net, SEAFDEC No.3 and 4 will drag the FAD out of the circle.

Time usage on net hauling depends on the quantity of catch. It may take 4-5 hours if the catch exceeds 70 tons. The skiff is used, during the catch transfer from bunt to fish holds, to keep the bunt float line at a distance from the seiner s' side and to help in scooping the catch from the bunt. After all the catch is transferred, the bunt part is pulled out into the water for cleaning then all gear is rearranged for the next fishing operation.

3.4. Catch handling

After scooping fish from the bunt part of the net, the catch is passed through the turntable funnel situated at the stern and then to the fish hold. Because the catch of a tuna purse seine is often a large amount, the brine-freezing system is used as the first step to refrigerate the catch rapidly and dry freezing will be used later to maintain the catch in good condition (Munprasit, 1993). The brine solution is prepared by dissolving salt in seawater, at a ratio about 1:4, this is pumped into the fish hold and mixed using a submerged pump circulating system. The specific gravity must be checked frequently untill it is 1.17(at 15°C) by Hydrometer or 21.1 in the Baume scale. This is the ideal specific gravity for achieving the lowest freezing point(-21.2°C) of the NaCl solution. The solution is then transferred to another fish hold and refrigerated to -18°C. Excess salt in the fish hold is used for dissolving for the next catch. Brine stock will be transferred to each fish hold about one-third of its capacity. Catch is transferred into fish hold until 90 percent of capacity is reached, This allows space for fish body expansion after freezing, the full fish hold is treated with brine solution and wooden screens are used to cover the hatch to press all fish under the brine. The catch is submerged in brine solution for at least 12 hours or until the temperature is -15°C, afterwards, the solution can be discharged and kept in other fish holds. The catch might then be transferred to dry freezing room or kept in the fish hold at a temperature of -40°C until it is unloaded ashore.

3.5. Data recording

Environmental data and technical data are recorded both during FADs setting and fishing operations. The drift tracks of the FADs are also defined for information for next setting. The catch of each haul is estimated in total quantity and sampled for species composition. Since 1994, researchers of the center also check and record the length-weight relationship of Skipjack tuna *(Katsuwonus pelamis)*, Yellowfin tuna *(Thunnus albacares)* and Bigeye tuna *(T. obesus)* by sampling 1 scoop from the catch during the transfer from bunt.

4. Result

4.1. FADs' drifting speed & direction detection

4.1.1 The Year of 1994

In the early period of the year, three FADs were set along longitude 082°40′ E in between latitude 04°42′ S to 04°53′ S on 12 February, they were found in the next cruise on 9-10 March in between latitude 00°39′-01°38′ S and longitude 085°52′-088°49′ E. The average drift speed is 14.14 NM/day in a NE direction.(Fig.2.) In the late period of the year on 27-28 October, four FADs were set along longitude 089°15′ E in between latitude 02°01′-02°52′ S, they were found in the next cruise on 12-13 November in the area of latitude 01°57′-03°12′ S, longitude 087°33′-088°22′ E. The average drift speed being 5.29 NM/day in a westerly direction.(Fig.3.)

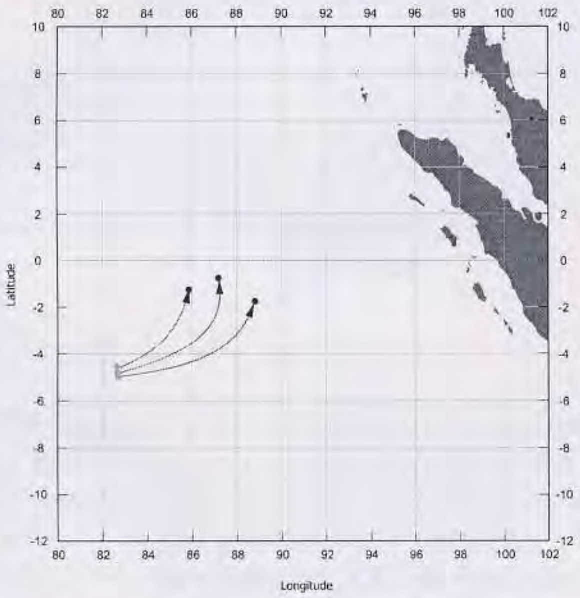

Fig.2. Drifting direction of FADs in early of year 1994

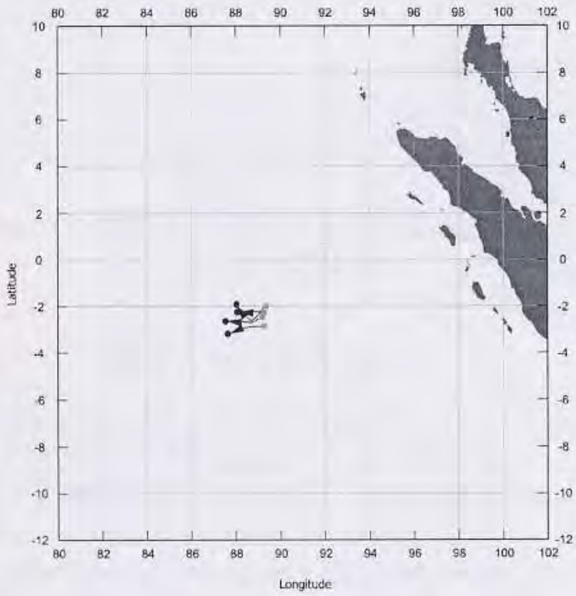

Fig.3. Drifting direction of FADs in lately of year 1994

4.1.2 The Year of 1995

In the early period of the year on 20 February, seven FADs were set. Five of them were set along longitude 88°57′ E in between latitude 02°12 -03°15′ S. The other two were set at latitude 01° 52′ S, longitude 090°48′ E and latitude 01°09′ S, longitude 089°53′ E. They were found on 20-24 February. The upper setting group above latitude 02°40′S, drifted in a northerly direction and the lower group drfted NE. The average drift speed being 5.09 NM/day.(Fig.4.)

In late period of the year on 28-30 October, seven FADs were set, five in the area of latitude 02°37′-03°17′ S, longitude 082°06′-084°36′ E. The upper setting one was found drifting in an East North Easterly direction, while the rest of this group was found in the area of latitude 03°22′-05°27′ S, longitude 086°05′-087°48′ E which is in the direction of ESE. Two FADs in another group were set along longitude 087°46′ E, latitude 04°20′ and 04°56′ S and found in latitude 04°51′-05°20′ S, longitude 090°15′-091°15′ E, these drifted to the ESE. The average drift speed of all FADs is 14.98 NM/day.(Fig.5.)

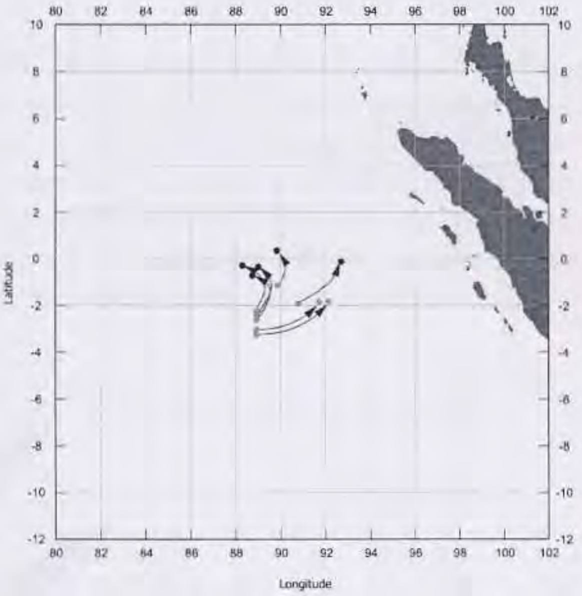

Fig.4. Drifting direction of FADs in early of year 1995

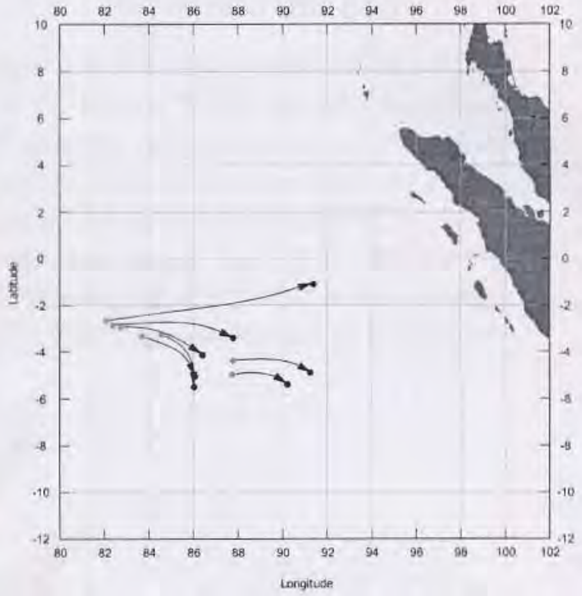

Fig.5. Drifting direction of FADs in lately of year 1995

4.1.3 The Year of 1996

In early period of the year on 1 March, six FADs were set along longitude 088°35′ E in between latitude 05°10′-06°16′ S, they were found in the next cruise on 19-21 March in between latitude 04°23′-05°00′ S and longitude 094°02′-094°56′ E. They had an average drift speed of 19.48 NM/day in an ENE direction. One drifting log was found and marked with a radio buoy on 7 March at latitude 06°13′S, longitude 091°18′ E, this was found again on 22 March at latitude 06°54′ S, longitude 091°18′ E. Its drifting speed being 4.38 NM/day in a SE direction.(Fig.6)

In late period of the year on 28-31 October, three FADs were set on latitude 01°40′, 02°18′, 05°20′ S in between longitude 086°34′-088°42′ E. They were found again on 11-14 November at latitude 01°39′, 01°41′, 04°56′, in between longitude 090°50-094°55′ E. The average drifting speed being 24.41 NM/day in an easterly direction.(Fig. 7)

4.1.4 The Year of 1997

In early period of the year on 17 March, two FADs were set along longitude 088°29′ E in between latitude 01°14′- 01°15′ E, and then were found in the next cruise on 30-31 March in between latitude 03°04′-03°13′ S, longitude 082°53′-083°18′ E. An average drift speed of 25.39 NM/day in a WSW direction.(Fig.8.)

In late period of the year, six FADs were set near longitude 090° E, three near latitude 04° 30'S and the rest near 02° E, and then found drifting eastward. Another group was set at the upper latitude of 02° S in between longitude 085°-087° E, and then found drifting in a WNW direction. All FADs were set on 24-30 October and found on 11-17 November. The average drift speed being 18.32 NM/day. (Fig. 9)

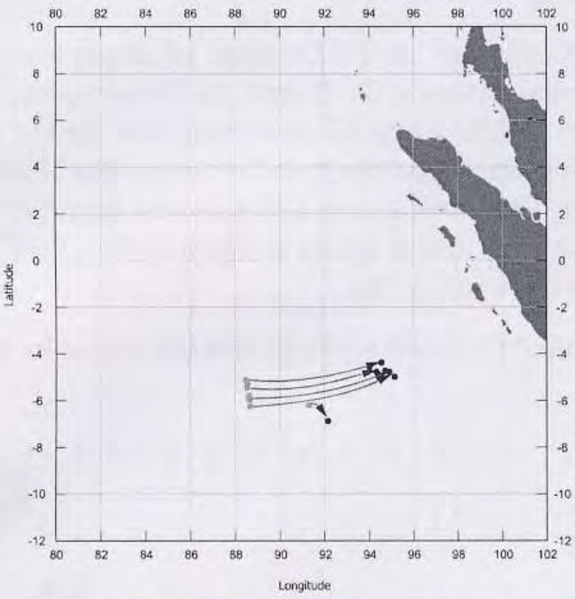

Fig.6. Drifting direction of FADs in early of year 1996

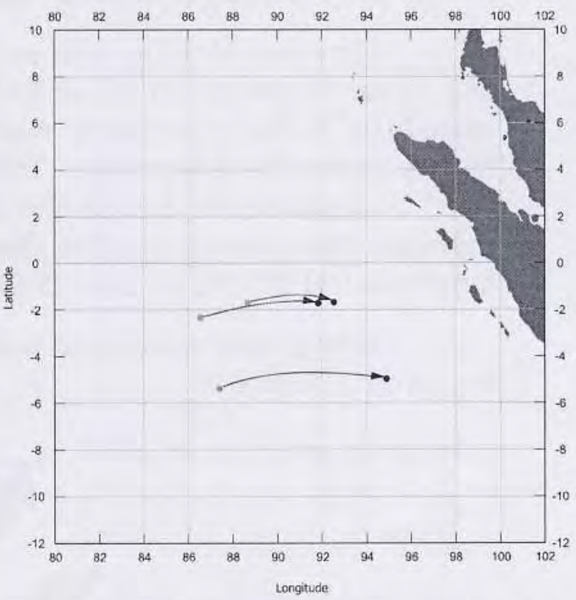

Fig.7. Drifting direction of FADs in lately of year 1996

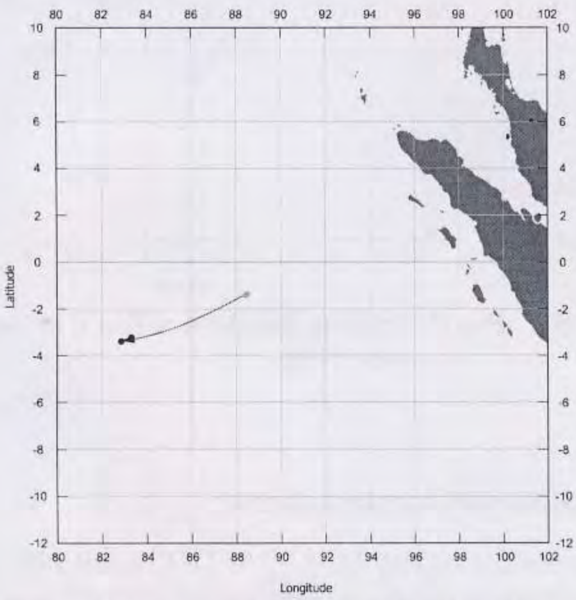

Fig.8. Drifting direction of FADs in early of year 1997

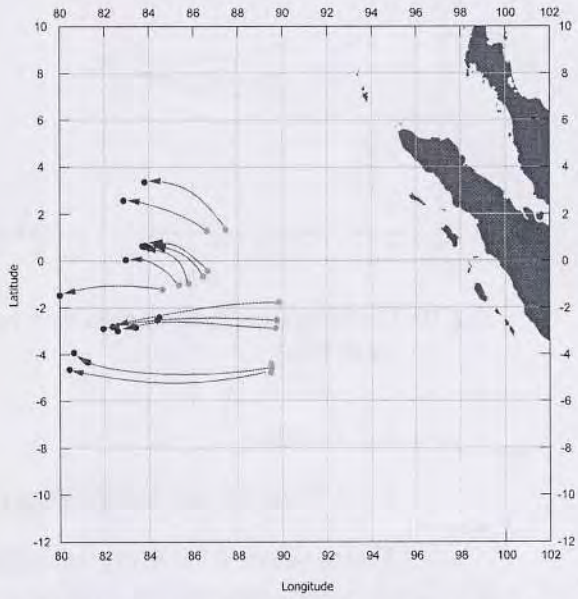

Fig.9. Drifting direction of FADs in lately of year 1997

4.1.5 The Year of 1998

In early period of the year on 19 February, five FADs were set in the area of latitude 04°25′-05°55′ S, longitude 087°15′-088°21′ E, then found again on 13-14 March in the area of latitude 04°53′-05°29′ S, longitude 092°05′-095°15′ E. Average drifting speed being 14.90 NM/day in easterly direction.(Fig.10.)

In late period of the year on 5-6 November, six FADs were set along longitude 088° E, the upper group (three FADs) near latitude 02° S and the lower group near latitude 04° S. The upper group was found drifting in a NE direction then turned to the SE direction on 11-12 November. This group was found again in the next cruise at latitude 04°35′ S longitude 098° E on 26 November. The lower group of FADs was found drifting eastward then turned in a SSE direction and found again at latitude 05°41′-07°39′ S longitude 090°34′-092°10′ E on 28-29 November.(Fig.11.)

Drifting information and positions of the FAD settings and the found locations are given in Annex IV.

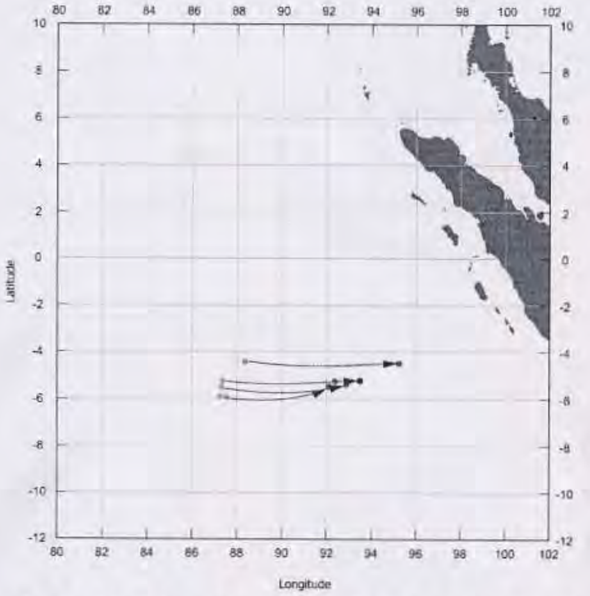

Fig.10. Drifting direction of FADs in early of year 1998

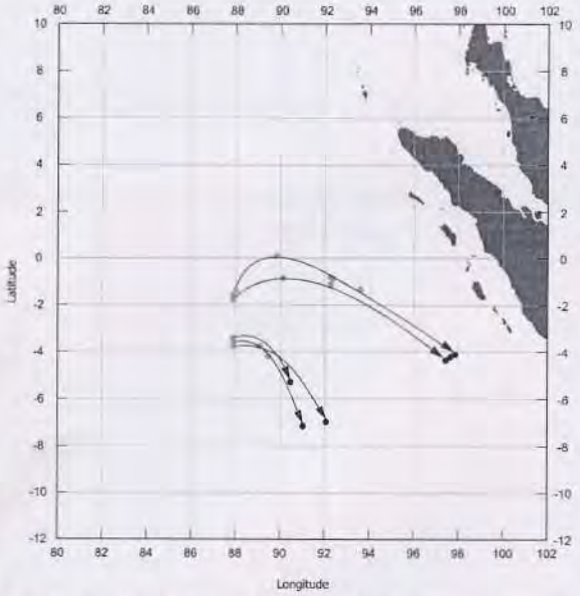

Fig.11. Drifting direction of FADs in lately of year 1998

4.2. Catch

4.2.1 Position of the fishing operations & Quantity of catch

There were 73 fishing operations conducted by M.V.SEAFDEC from 1993-1998. The total catch was 1955.4 tons and the average catch per unit effort (CPUE) was 26.79 tons. Fishing operations were carried out in the area of latitude 02° N-08° S, longitude 080°-098° E, radiating around The Ninety East Ridge (Fig.12.).

Fishing operations in 1993-1994 were carried out mostly to the northward and eastward of Ninety East Ridge. The five operations of 1993 were carried out in November and the total catch was 39 tons. In 1994, There were 7 operations in February-March and 6 in October-November. The total catch and average catch per operation were 354 and 27.23 tons, respectively. In 1995, twenty operations, 11 in February-March and 9 in October-November, were carried out. In the early period of 1995, M.V.SEAFDEC operated above latitude 03° S in between longitude 088° -096° E and had a total catch of 376.4 tons. In the late period, operations took place under latitude 03° S longitude 084° -094° E, with a total catch of 156 tons. Total average catch per operation in 1995 was 26.62 tons.

There were 14 fishing operations in 1996, eight times in March and six in October-November. All fishing operations in this year took place under latitude 01° S. The average catch per operation was comparatively high at 36.71 tons, and the total catch was 514 tons. In the following year, 1997, the total catch decreased to 142 tons in 13 operations which were carried out to the eastward of latitude 088° E in between latitude 02° -05° S. The average catch per fishing operation in 1997 was 10.92 tons. In 1998, there were eight fishing operations, five in February-March and the rest in November-December. The operation positions were below latitude 02° S to 08° S in between longitude 087° -098° E. The total catch during the year was 374 tons in which 340 tons were caught in the early period. There was a big haul of 200 tons, at latitude 04°53'.3 S longitude 095°14'.9 on 13 March which increased the average catch per operation of this year to 46.75 tons.

The positions and catches of each operation are displayed in the table in Annex V

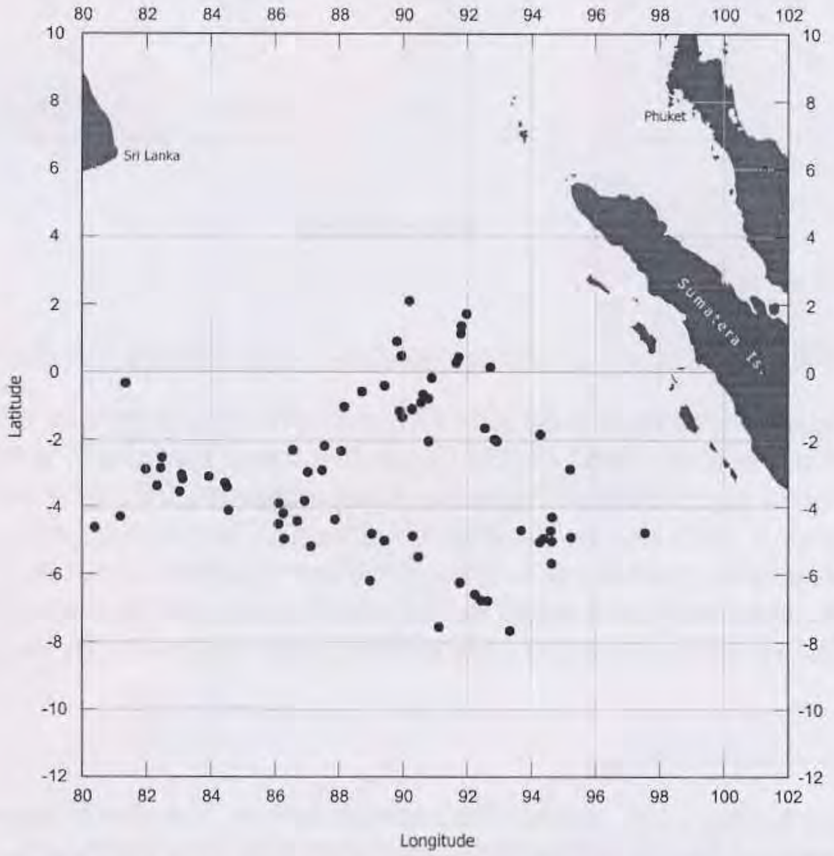

Fig.12. Purse seine fishing operation positions carried out in 1993-1998

4.2.2 Catch composition

Skipjack tuna (*Katsuwonus pelamis*), Yellowfin tuna (*Thunnus albacares*) and Bigeye tuna (*T. obesus*) are the main catch by tuna purse seine in the East Indian Ocean. Other catch species included Rainbow runners (*Elagatis bipinnulatus*), Dolphinfish (*Corypheana hippurus*) and Mackerel scad (*Decapterus macarellus*), but these were less than five percent of the total catch. There was a small quantity of by-catch species, like Rough triggerfish (*Canthidermis maculatus*), Unicorn leatherjacket (*Alutera monoceros*), Longfin yellowtail (*Seriola rivoliana*), White-tongued crevalle (*Uraspis helvora*), Brassy chub (*Kyphosus vaigiensis*) etc.

Table 3 shows the percentage composition of tuna caught by M.V.SEAFDEC from 1995-1998. The composition by average of individuals and their weight, Skipjack tuna is the highest except in the year of 1997. The average fork length (cm.) of Skipjack tuna, Yellowfin tuna and Bigeye tuna are 50.95, 56.05 and 56.49 in which their mode is 45.0, 50.0 and 43.0 respectively (Sukramongkol and Siriraksophon, 1999).

Table 3 . Catch composition of tunas species by individual and weight from 1995-1998

Year	Skipjack tuna		Yellowfin tuna		Bigeye tuna	
	% by individual	% by weight	% by individual	% by weight	% by individual	% by weight
1995	62.8	50.1	14.6	20.8	22.6	29.1
1996	69	58.2	28.1	31.1	7.9	10.7
1997	47.8	27.5	26.5	51.2	25.7	21.3
1998	83.7	75.5	10.9	15.2	5.4	9.3

Discussion

5.1. Fish school locating techniques related to fish behavior and schooling patterns

There are many reports on schooling patterns of tuna species in different fishing grounds. In the eastern North Pacific Ocean it is found that the Bluefin tuna (*Thunnus thynnus*) is main target catch of the purse seiner, appearing in boiling (feeding) schools[1], breezing schools[2] and also in black spot[3] patterns. The feeding schools are preferred for operations rather than the other two mentioned patterns (Scott & Flitter 1992). Ben-Yami (1994) explained that it might be the fact of directional motion of the feeding tuna school is slower, less prudent and swimming more shallowly. In the eastern tropical

[1] Boiling school, Feeding school, Boilers : Fish feeding intensively, and often in conjunction with marine birds, crowding upon the prey and creating an impression of the top of boiling pot.
[2] Breezing school, Breezers : Fish swimming very close to the surface of the water, usually in the single direction, creating ripples which resemble those created by a light breeze.
[3] Black spots : Subsurface schools appearing to the shipborne observer as black or dark spots.

Pacific Ocean, American tuna fishermen depend on porpoises for locating Yellofin and Skipjack tuna schools (Green, Perrin and Petrich, 1971). About half of the seine-caught Yellowfin tuna from the eastern Pacific are captured from schools associated with porpoises, spotted dolphins (*Stenella graffmani*), spinners (*S. longirostris*) and common dolphins (*Delphinus delphis*). Therefore, fishermen in these fishing grounds use binoculars to search for spouting of porpoises at the sea surface. Tuna purse seine fishing in the Pacific Ocean also use aircraft, both fixed-wing and helicopters, for scouting fish schools, porpoises, birds or flotsam in the wider areas. Similarly, Japanese tuna purse seiner fleets operating off the West Coast of Africa also search for signs of birds, whales or porpoises for locating tunas schools. On the contrary, schooling patterns like boilers, breezers or black spots are rarely seen in the east Indian Ocean. Schools of tuna in these fishing grounds are frequently found aggregating with flotsam or drifting garbage. Therefore, drifting FADs are widely used for aggregate tuna in the area. From the study of the relationship between days of FADs drifting and quantity of catch (correlation and regression analysis) by Veera (1997) found that there is a significant relationship between them (correlation coefficient = 0.5214). Japanese purse seiners operating in the East Indian Ocean have 28-46 FADs (Proalai, 1995) for alternating use in fishing operations all the season. When they find their FADs drifting too far or nearly inside the Indonesian EEZ, the FADs would be picked up and reset again in the selected area. M.V.SEAFDEC, as mentioned previously, is operating in only two periods of a year in February-March and October-November. Thus, during such long time intervals between the working periods, at the end of each period, all FADs must be picked up. This results in a lower amount of drifting days for the FADs in the fishing grounds. Anyway, a good relationship between SEAFDEC s' Japanese Master fisherman and other Japanese purse seiners', like the Nipponn Maru, Fuguichi Maru, could relieve this trouble by exchanging, setting and resetting FADs among each other. Furthermore, fishing ground information is exchanged to determine the best fishing spot for that period. Obviously, there is great advantage in fleet fishing operation over single-seiner operation.

5.2. Fishing operation positions and FADs drift directions

As mentioned earlier, the purse seine fishing operations of M.V. SEAFDEC in the East Indian Ocean are are carried out in conjunction with drifting FADs or flotsam. The operational positions and drifting routes of the FADs, may interpret directional movement of surface currents in this specific area. In Fig.2, 4, 6 and 10, display the routes of the FADs' drift in the early period of the years, show that FADs set above latitude 05°S drifted in a northeastly direction and some after nearly reaching the equator turned back to the west whereas, FADs set below latitude 05° S drifted in an eastly direction. Fig. 13 shows overlay of the FADs' drift routes and also displays a facsimile of the surface current direction in February-March in 1994-96 and 1998.

In the same way, Fig. 3, 5, 7 and 11 show that the FADs' drift direction in late period (October-November) of the years, are overlaid. These indicate that the FADs drifted eastward from about longitude 082°E then split into two tracks at about longitude 088°-089°E, the upper one drifting northeast then turning to southeast at about longitude 090°-091°E and the lower group drifted in a southeastly direction (Fig.14)

Pickard and Emery (1990) explained that the surface circulation of the Indian

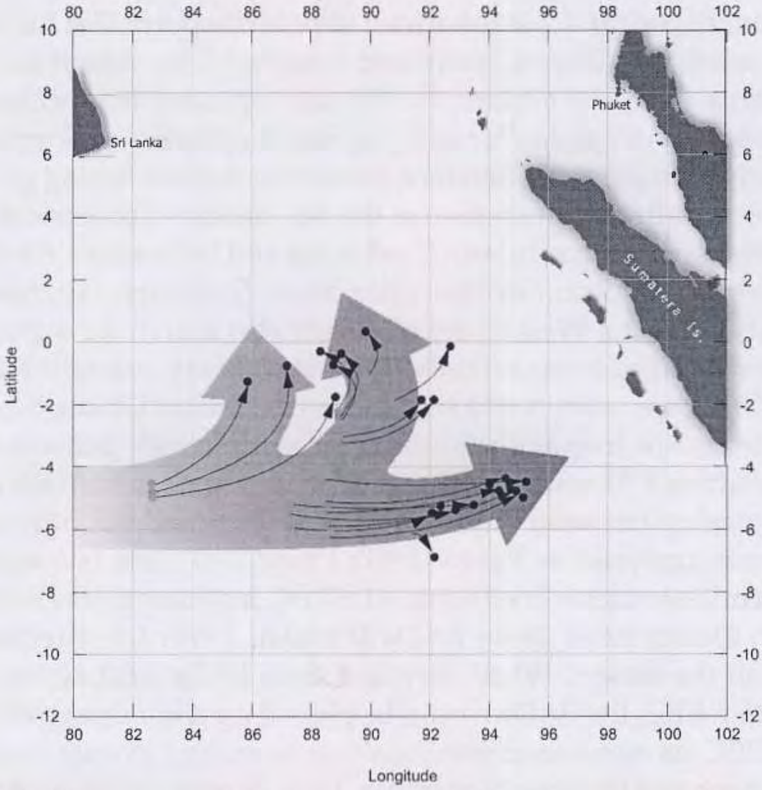

Fig.13. Overlaid drifting routes of FADs and model of surface current during Feb.-Mar. in 1994-96 and 1998

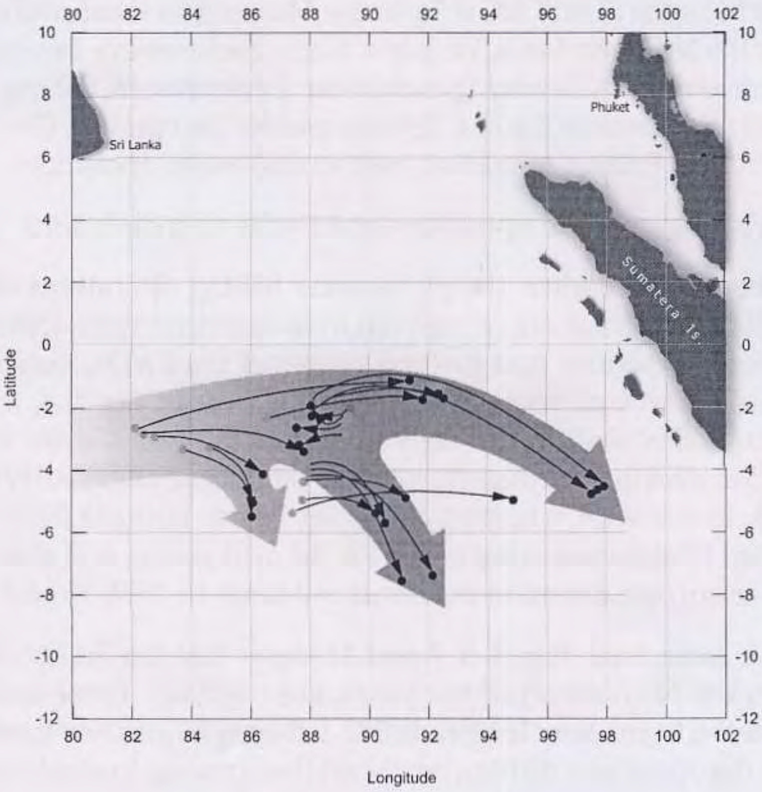

Fig.14. Overlaid drifting routes of FADs and model of surface current during Oct.-Nov. in 1994-96 and 1998

Ocean is because of the land mass to the north of the ocean. There is a seasonal variation in the wind north of the equator. From November to March, these winds blow from the northeast (North-east Trades or North-east Monsoon), from May to September they blow from the southwest (South-west Monsoon). The South-west Monsoon winds really continue across the equator of the South-east Trades which continue throughout the year. The change of wind direction north of the equator then results in a change of currents there. During the North-east Monsoon (November to March) there is a westward- flowing *North Equatorial Current* from 8°N to the equator; from the equator to 8°S there is a eastward-flowing *Equatorial Countercurrent*. During the South-west Monsoon (May to September) the flow north of the equator is reversed and is to the east. This combines with the eastward Equatorial Countercurrent and the whole eastward flow from 15°N to 7°S is called the *(South-west) Monsoon Current* (Fig.15.). The South Equatorial Current continues to the southwest of 7°S but is stronger than during the North-east Monsoon. Considered of the drift route of the FADs (Fig.13. and 14) and surface circulation model (Fig.15.).

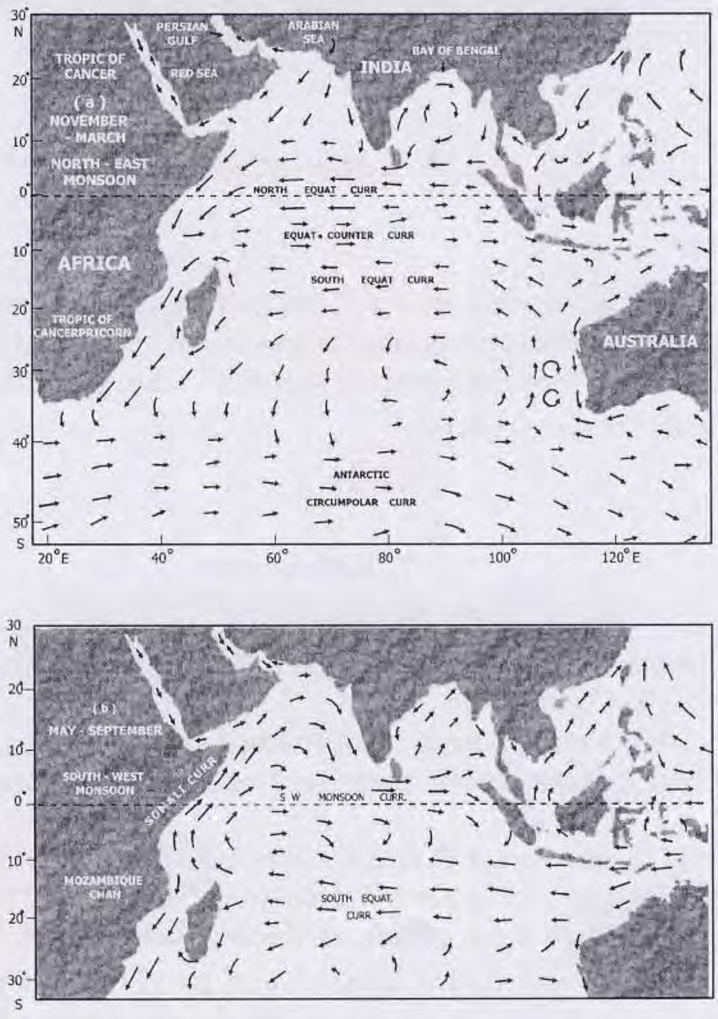

Fig.15. Indian Ocean-Surface circulations; in North-east Monsoon season(top) and South-west Monsoon season(bottom). (redrawn after Pickard, G.L. and Emery, W.J., 1990)

It is found that in the early fishing period (February-March) of M.V. SEAFDEC was in the North-east monsoon season. The FADs' drifting route was to the westward and some in the higher latitudes were northward then inclined to the west through the North Equatorial Current. In the late fishing period of the year, from October to November which is in between the North-east and South-west Monsoon seasons, FADs' drift routes seem much influenced by the South-west Monsoon Current. Thus, they were found mostly drifting in a southeast direction.

In the year of 1997, the drift directions of the FADs were absolutely different from others. All FADs set in the year were drifting rapidly westward (Fig.8, 9.). This phenomen may have been a consequence of the *El Nino Effect*. It was noticed that some characteristics of the sea had changed from the normal, for example; low temperatures and high salinity of the surface water, a narrow thermocline layer and the direction of the surface water changed from eastward to westward were observed (Siriraksophon, Rojana-anawat and Seurungreong, 1997).

Even though all FADs are equipped with radio buoys for detecting their direction and position, if the fisherman could predict their route roughly, it would be a great advantage in planning their work and also saving on fuel costs.

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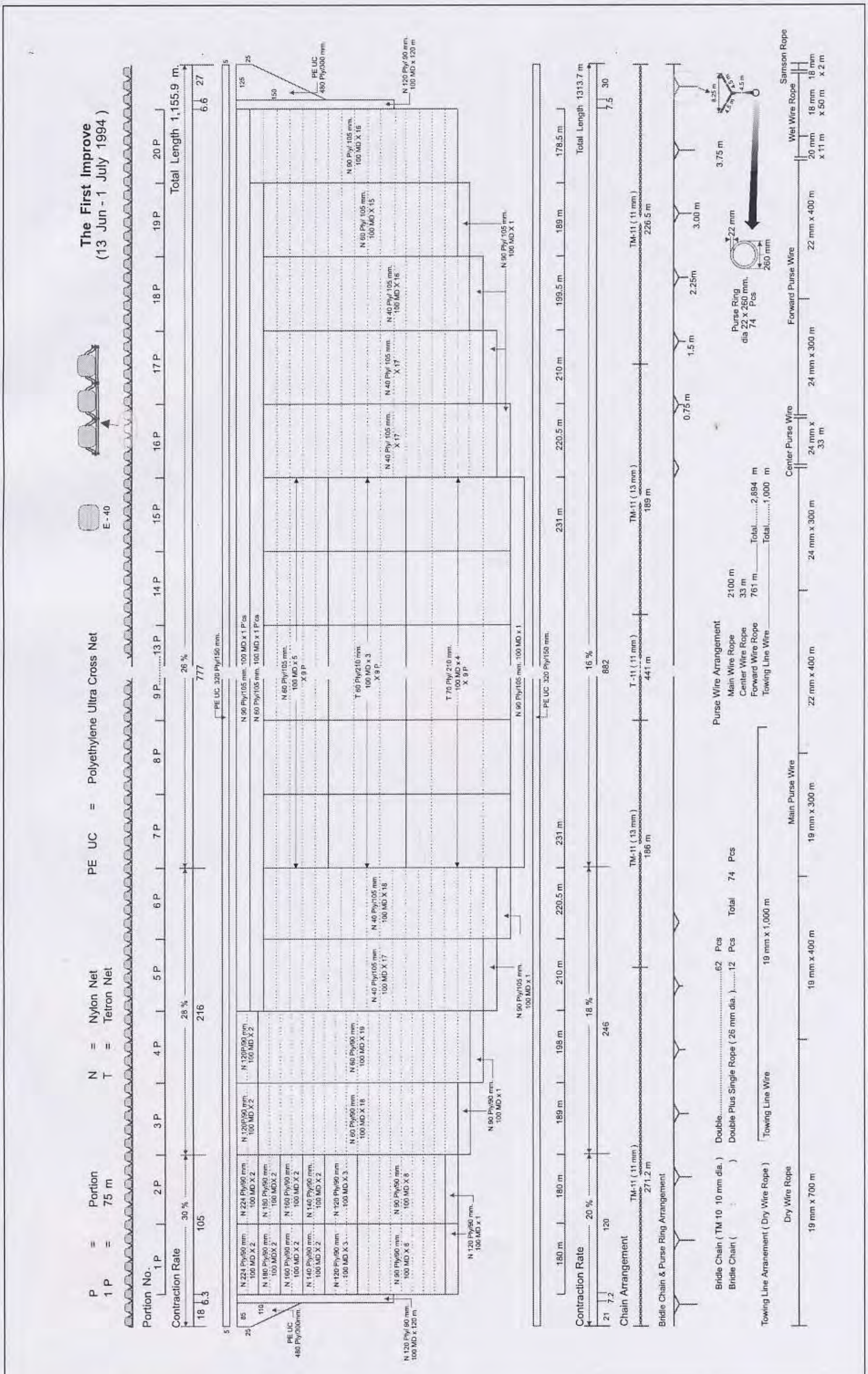
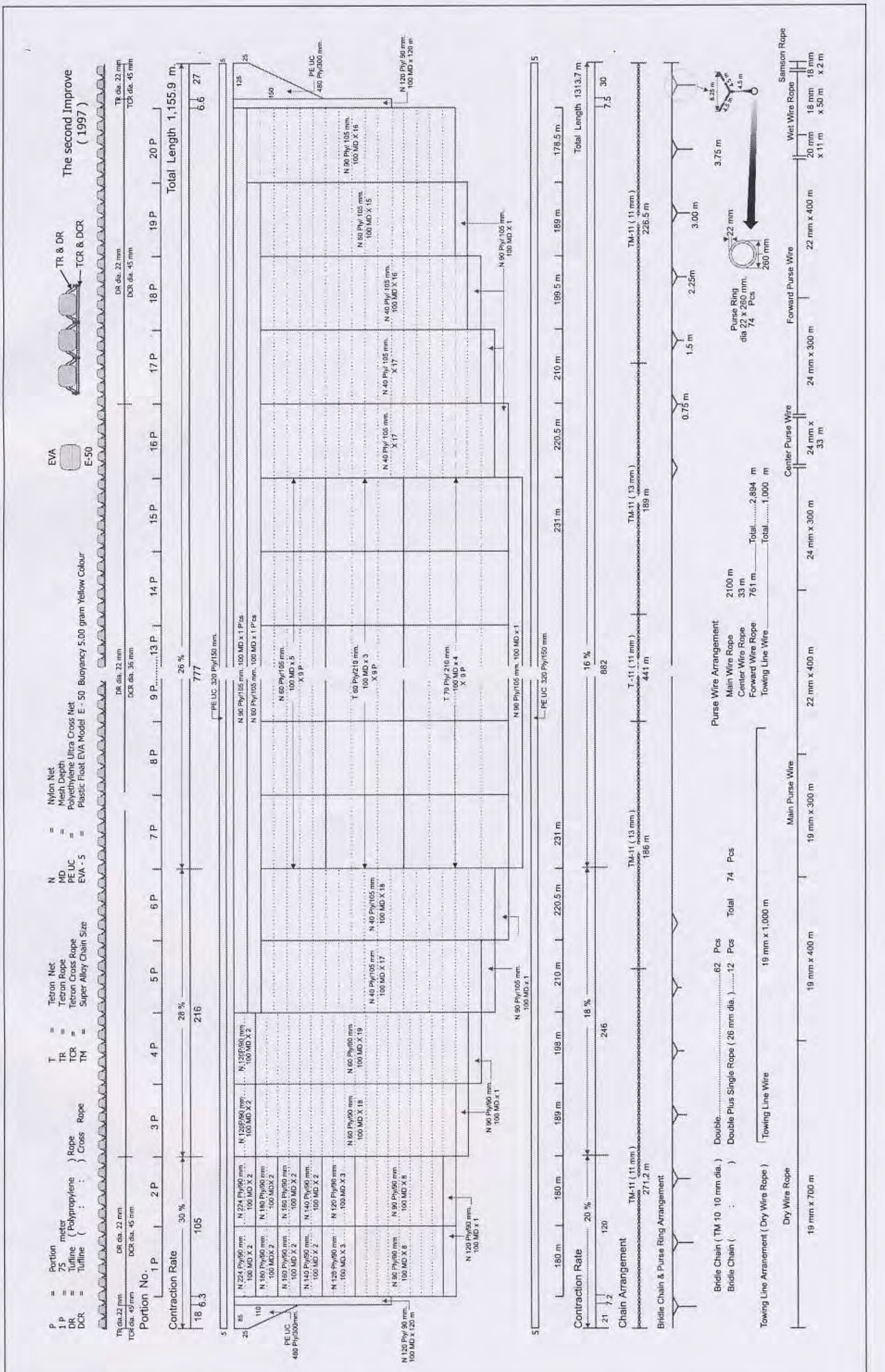
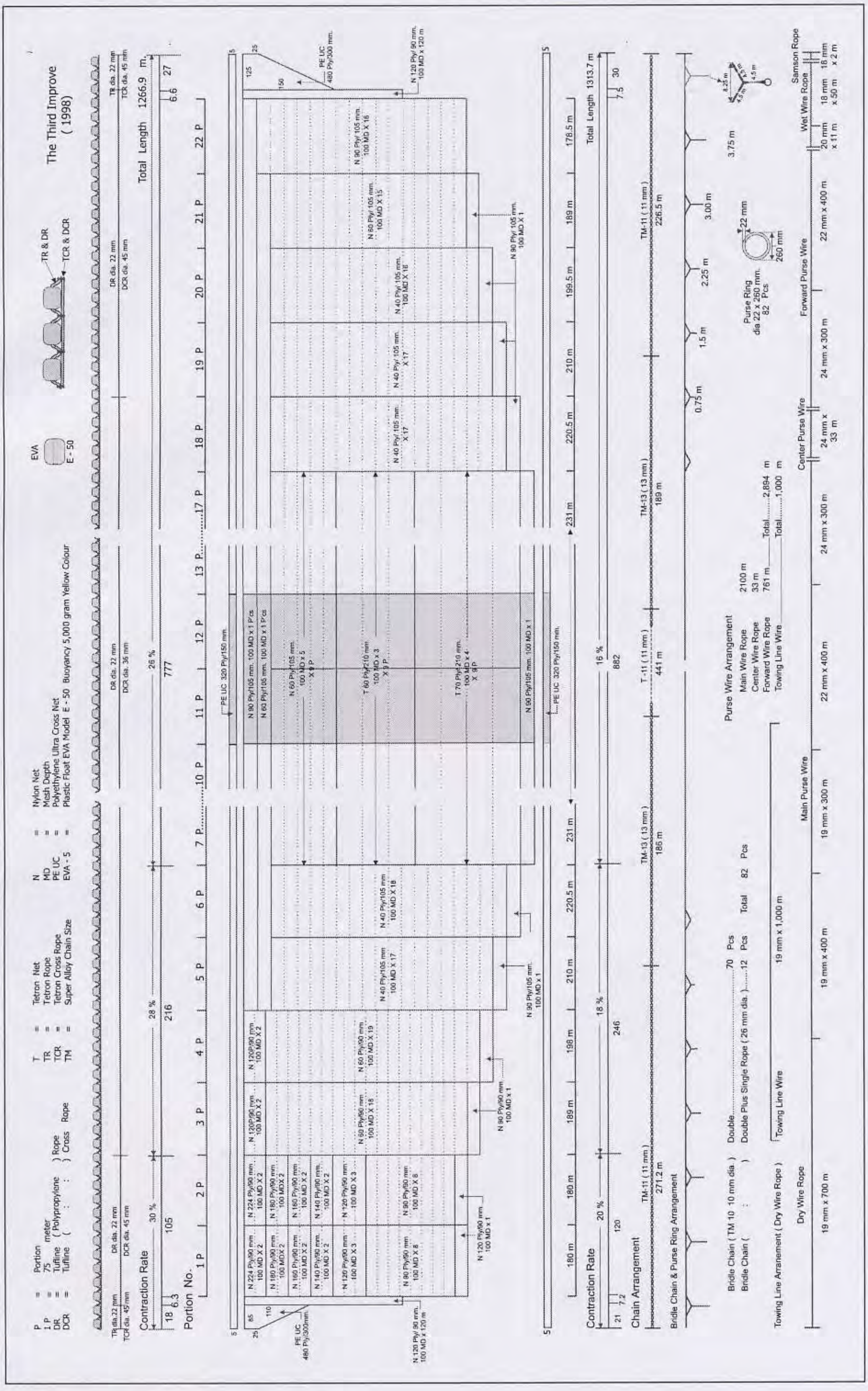
APPENDIX



Appendix I : Purse seine net plan; The First Improve



Appendix II : Purse seine net plan; The Second Improve



Appendix III : Purse seine net plan; The Third Improve

Year	Date	Position of operation		Catch	Remarks	Date	Position of operation		Catch	Remarks	Grand total	Avg. catch per
		latitude	longitude	(tons)			latitude	longitude	(tons)		Catch(tons)	operation (tons)
1993						31-Oct	03-22.00 S	082-20.54 E	20			
						4-Nov	01-00.79 S	088-28.13 E	2			
						16-Nov	01-43.32 N	091-59.75 E	3			
						17-Nov	01-09.29 N	091-48.75 E	8			
						18-Nov	01-22.11 N	091-48.94 E	6			
							Sub-total catch		39		39	7.80
1994	10-Feb	00-24.62 S	089-24.88 E	10		26-Oct	02-00.90 N	090-12.10 E	120	50 tons of catch were discarded		
	13-Feb	03-02.10 S	083-06.10 E	nil		31-Oct	00-54.72 N	089-49.46 E	40	10 tons of catch were discarded		
	15-Feb	00-20.30 S	081-21.80 E	4		12-Nov	02-18.81 S	088-00.42 E	10			
	6-Mar	01-18.90 S	089-59.10 E	13		13-Nov	02-39.71 S	087-33.40 E	30			
	7-Mar	01-04.85 S	090-16.90 E	60		14-Nov	04-11.68 S	086-15.63 E	45			
	8-Mar	00-53.40 S	090-33.60 E	nil		15-Nov	04-29.90 S	086-07.22 E	10			
	9-Mar	00-39.26 S	090-37.89 E	12								
		Sub-total catch		99					255		354.0	27.23
1995	16-Feb	01-49.31 N	094-17.36 E	70		25-Oct	04-21.60 S	087-53.10 E	5			
	18-Feb	02-51.74 S	095-13.82 E	1		26-Oct	04-24.50 S	086-40.10 E	3			
	21-Feb	02-02.06 S	090-48.36 E	15		27-Oct	03-20.30 S	084-30.70 E	30			
	22-Feb	01-08.88 S	089-53.84 E	25	10 tons of catch were discarded	28-Oct	03-05.80 S	083-56.70 E	40			
	7-Mar	00-28.77 N	089-56.84 E	120	47 tons of catch were discarded	30-Oct	03-17.00 S	084-27.00 E	22			
	8-Mar	00-46.46 S	090-47.45 E	50	30 tons of catch were discarded	10-Nov	04-41.43 S	093-41.79 E	5			
	22-Mar	00-08.20 N	092-43.70 E	1		11-Nov	04-51.49 S	091-17.89 E	7			
	23-Mar	00-10.00 S	090-53.43 E	74		12-Nov	05-28.00 S	090-29.00 E	40			
	26-Mar	00-34.40 S	088-43.20 E	0.4		14-Nov	04-56.35 S	086-17.72 E	4			
	27-Mar	00-26.50 N	091-14.60 E	15								
	28-Mar	00-16.68 N	091-39.98 E	5								
		Sub-total catch		376.4			Sub-total catch		156		532.4	26.62

Appendix IV : Positions of Fishing Operations

Year	Date	Position of operation latitude	Position of operation longitude	Catch (tons)	Remarks	Date	Position of operation latitude	Position of operation longitude	Catch (tons)	Remarks	Grand total Catch(tons)	Avg. catch per operation (tons)
	5-Mar	06-47.70 S	092-09.70 E	55		31-Oct	02-17.60 S	086-33.60 E	5			
	6-Mar	06-45.80 S	092-26.60 E	8		11-Nov	01-38.60 S	092-33.40 E	8			
	7-Mar	06-35.50 S	092-15.10 E	62	40 tons of catch were discarded	12-Nov	01-58.90 S	092-51.60 E	35			
	19-Mar	05-00.60 S	094-39.30 E	15		14-Nov	04-55.90 S	094-24.30 E	64			
	20-Mar	04-41.47 S	094-37.40 E	10								
	21-Mar	04-17.50 S	094-39.90 E	165	90 tons of catch were discarded							
	Sub-total catch			315		Sub-total catch			112		427.0	36.71
1997	14-Mar	02-53.60 S	087-29.00 E	8		26-Oct	02-57.67 S	087-02.93 E	2			
	15-Mar	03-52.60 S	086-07.90 E	10		28-Oct	02-31.05 S	082-29.55 E	18			
	16-Mar	03-49.40 S	086-56.10 E	20		14-Nov	04-16.50 S	081-12.20 E	20			
	30-Mar	04-06.20 S	084-32.80 E	20		16-Nov	01-28.00 S	078-54.90 E	4			
	31-Mar	03-09.60 S	083-07.80 E	5		17-Nov	04-36.90 S	080-23.90 E	2			
	1-Apr	03-32.30 S	083-03.00 E	2		18-Nov	02-52.00 S	081-59.20 E	17			
						19-Nov	02-49.80 S	082-27.10 E	14			
	Sub-total catch			65		Sub-total catch			77		142.0	10.92
1998	21-Feb	05-02.30 S	094-16.30 E	5		27-Nov	04-45.30 S	097-33.30 E	7			
	23-Feb	04-47.30 S	089-02.00 E	75		29-Nov	07-33.80 S	091-07.60 E	10			
	25-Feb	04-59.50 S	089-24.90 E	20		1-Dec	07-40.00 S	093-21.00 E	17			
	12-Mar	02-01.70 S	092-55.60 E	40								
	13-Mar	04-53.30 S	095-14.90 E	200	140 tons of catch were discarded							
	Sub-total catch			340		Sub-total catch			34		374.0	46.75

Appendix IV : Positions of Fishing Operation. (cont.)

Year	FAD(s)	Date/Position(Latitude: Longitude)								Total drifting	Total time	Average speed	Remarks ;
	number	Setting		1st. found		2nd. found		3rd. Found		distance (NM)	interval (days)	(NM./day)	SP : MV SEAFDEC 's FAD
1994	SP-4	12-Feb	04-53.3 S	9-Mar	01-38.9 S					415.9	25	16.64	FP : Fuguichi Maru 's FAD
			082-41.0 E		088-49.3 E								NP : Nippon Maru 's FAD
	SP-7	12-Feb	04-27.9 S	10-Mar	00-39.1 S					355.5	24	14.81	UNP : Unknown Owner FAD
			082-38.3 E		087-11.2 E								Log : Drifting Log
	SP-8	12-Feb	04-42.4 S	10-Mar	01-08.8 S					287.1	24	11.96	
			082-39.1 E		085-52.1 E								
	SP-13	28-Oct	02-17.2 S	11-Nov	02-16.5 S					72.6	14	5.17	
			089-16.5 E		088-04.0 E								
	SP-14	28-Oct	01-01.2 S	12-Nov	01-57.3 S					59.8	15	3.99	
			089-21.7 E		088-22.1 E								
	SP-12	28-Oct	02-29.1 S	13-Nov	02-39.8 S					99.0	16	6.19	
			089-11.7 E		087-33.4 E								
	SP-9	27-Oct	02-52.3 S	13-Nov	03-11.8 S					98.8	17	5.81	
			089-15.3 E		087-38.5 E								
1995	SP-17	20-Feb	02-36.7 S	25-Mar	00-43.3 S					113.4	33	3.44	
			088-56.8 E		088-45.3 E								
	SP-18	20-Feb	02-36.6 S	26-Mar	00-21.8 S					121.3	34	3.57	
			088-56.5 E		089-01.5 E								
	SP-19	20-Feb	02-12.9 S	25-Mar	00-17.3 S					121.2	33	3.67	
			088-55.6 E		088-15.5 E								
	FP-5	20-Feb	01-56.6 S	22-Mar	00-08.1 S					157.5	30	5.25	
			090-48.0 E		092-42.5 E								
	FP-32	20-Feb	03-02.2 S	24-Mar	01-51.1 S					181.8	32	5.68	
			088-56.8 E		091-44.1 E								

Appendix V : Drifting Positions of FADs.

Year	FAD(s) number	Setting (date)	Setting (position)	1st. found (date)	1st. found (position)	2nd. found (date)	2nd. found (position)	3rd. Found	Total drifting distance (NM)	Total time interval (days)	Average speed (NM/day)	Remarks ;
1995	SP-9	22-Feb	01-08.8 S	6-Mar	00-21.2 N				89.6	12	7.46	SP : MV SEAFDEC 's FAD
(cont.)			089-53.5 E		089-50.4 E							FP : Fuguichi Maru 's FAD
	SP-11	20-Feb	03-15.2 S	24-Mar	01-50.6 S				211.1	32	6.59	NP : Nippon Maru 's FAD
			088-56.0 E		092-09.4 E							UNP : Unknown Owner FAD
	NP-52	25-Oct	04-19.7 S	10-Nov	04-50.7 S				210.2	16	13.14	Log : Drifting Log
			087-47.0 E		091-15.2 E							
	NP-17	25-Oct	04-56.2 S	11-Nov	05-20.5 S				150.8	17	8.87	
			087-45.5 E		090-14.7 E							
	SP-25	28-Oct	02-54.2 S	13-Nov	04-05.4 S				230.8	16	14.42	
			082-45.6 E		086-25.3 E							
	SP-9	28-Oct	03-17.1 S	13-Nov	05-00.8 S				175.2	16	10.95	
			083-43.3 E		086-05.0 E							
	SP-26	30-Oct	03-12.8 S	14-Nov	05-27.3 S				159.1	15	10.61	
			084-36.2 E		086-02.3 E							
	SP-11	28-Oct	02-48.1 S	16-Nov	03-22.5 S				326.8	19	17.20	
			082-23.6 E		087-48.5 E							
	SP-22	29-Oct	02-36.8 S	17-Nov	01-03.5 S				565.7	19	29.70	
			082-06.0 E		091-23.3 E							
1996	SP-24	1-Mar	05-09.6 S	19-Mar	04-35.6 S	20-Mar	04-23.5 S		366.9	19	19.31	
			088-30.9 E		094-01.9 E		094-34.6 E					
	SP-22	1-Mar	05-18.6 S	19-Mar	04-46.7 S				347.3	18	19.29	
			088-33.7 E		094-20.3 E							
	FP-2	1-Mar	05-28.3 S	20-Mar	04-44.7 S				373.1	19	19.64	
			088-33.1 E		094-44.5 E							

Appendix V : Drifting Positions of FADs. (cont.)

Year	FAD(s)	Date/Position(Latitude: Longitude)							Total drifting	Total time	Average speed	Remarks ;
	number	Setting		1st. found		2nd. found		3rd. Found	distance (NM)	interval (days)	(NM./day)	SP : MV SEAFDEC 's FAD
1996	FP-36	1-Mar	05-59.5 S	20-Mar	05-00.3 S				393.9	19	20.73	FP : Fuguichi Maru 's FAD
(cont.)			088-39.3 E		095-09.0 E							NP : Nippon Maru 's FAD
	FP-10	1-Mar	05-49.9 S	20-Mar	04-47.7 S				382.0	19	20.11	UNP : Unknown Owner FAD
			088-38.3 E		094-56.2 E							Log : Drifting Log
	FP-8	1-Mar	06-16.0 S	21-Mar	04-55.5 S				356.5	20	17.82	
			088-41.3 E		094-29.7 E							
	Log	7-Mar	06-13.5 S	22-Mar	06-54.3 S				65.7	15	4.38	
			091.18.5 E		092-10.3 E							
	NP-13	31-Oct	01-39.8 S	11-Nov	01-38.6 S				231.9	11	21.08	
			088-41.8 E		092-33.4 E							
	SP-32	28-Oct	05-10.6 S	11-Nov	04-55.9 S				433.8	17	25.52	
			087-09.8 E		094-24.3 E							
	NP-10	31-Oct	02-17.6 S	12-Nov	01-41.0 S				319.4	12	26.62	
			086-33.6 E		091-50.5 E							
1997	SP-12	17-Mar	01-14.6 S	31-Mar	03-13.2 S				355.8	14	25.41	
			088-28.0 E		082-52.7 E							
	UNP	17-Mar	01-13.6 S	30-Mar	03-03.8 S				329.9	13	25.38	
			088-29.2 E		083-18.4 E							
	FP-16	30-Oct	01-23.7 N	11-Nov	03-26.2 N				251.9	12	20.99	
			087-31.0 E		083-50.8 E							
	FP-13	30-Oct	01-19.8 N	11-Nov	02-38.7 N				238.7	12	19.89	
			086-38.9 E		082-53.7 E							
	FP-14	29-Oct	00-36.8 S	12-Nov	00-39.1 N	12-Nov	00-41.0 N		181.3	14	12.95	
			086-28.7 E		083-59.2 E		083-45.1 E					

Appendix V : Drifting Positions of FADs. (cont.)

Year	FAD(s) number	Setting		1st. found		2nd. found		3rd. Found	Total drifting distance (NM)	Total time interval (days)	Average speed (NM./day)
		Date	Position (Latitude: Longitude)	Date	Position	Date	Position				
1997 (cont.)	FP-8	29-Oct	00-59.1 S 085-23.2 E	12-Nov	00-06.1 N 082-59.5 E				157.9	14	11.28
	FP-9	29-Oct	00-56.1 S 085-50.3 E	12-Nov	00-04.5 N 083-53.5 E				131.6	14	9.40
	SP-35	24-Oct	01-43.5 S 089-52.9 E	13-Nov	02-22.1 S 084-36.0 E	18-Nov	02-46.4 S 082-43.9 E		434.5	25	17.38
	SP-36	24-Oct	02-30.0 S 089-48.0 E	13-Nov	02-30.1 S 084-25.1 E	18-Nov	02-57.3 S 082-37.2 E		434.5	25	17.38
	SP-22	24-Oct	02-50.2 S 089-45.4 E	13-Nov	02-48.2 S 083-26.8 E	18-Nov	02-52.0 S 081-59.2 E		466.5	25	18.66
	SP-33	25-Oct	04-35.0 S 089-34.7 E	14-Nov	04-17.5 S 081-15.9 E				498.5	20	24.92
	SP-34	25-Oct	04-46.1 S 089-32.5 E	14-Nov	03-52.8 S 080.38.6 E				536.0	20	26.80
	FP-7	29-Oct	01-10.2 S 084-39.9 E	15-Nov	01-26.1 S 079-59.8 E				281.0	17	16.53
	SP-32	25-Nov	04-22.8 S 089-33.5 E	17-Nov	04-37.4 S 080-26.7 E				546.3	23	23.75
1998	UNP	19-Feb	04-25.1 S 088-21.4 E	13-Mar	04-53.3 S 095-14.9 E				413.8	22	18.81
	SP-32	19-Feb	05-14.4 S 087-21.7 E	14-Mar	05-13.1 S 093-29.2 E				366.6	23	15.94
	SP-34	19-Feb	05-33.3 S 087-18.9 E	14-Mar	05-22.9 S 092-52.2 E				332.6	23	14.46

Remarks ;

SP : MV SEAFDEC 's FAD

FP : Fuguichi Maru 's FAD

NP : Nippon Maru 's FAD

UNP : Unknown Owner FAD

Log : Drifting Log

Appendix V : Drifting Positions of FADs. (cont.)

Year	FAD(s) number	Setting		1st. found		2nd. found		3rd. Found		Total drifting distance (NM)	Total time interval (days)	Average speed (NM./day)	Remarks ;
		Date/Position(Latitude: Longitude)											SP : MV SEAFDEC 's FAD
1998	SP-41	19-Feb	05-53.4 S	14-Mar	05-14.9 S					308.6	23	13.42	FP : Fuguichi Maru 's FAD
(cont.)			087-15.1 E		092-22.2 E								NP : Nippon Maru 's FAD
	SP-40	19-Feb	05-55.3 S	14-Mar	05-28.7 S					272.6	23	11.85	UNP : Unknown Owner FAD
			087-32.6 E		092-04.8 E								Log : Drifting Log
	SP-43	5-Nov	01-49.6 S	11-Nov	01-12.7 S	26-Nov	04-36.5 S			657.1	21	31.29	
			088-00.4 E		092-22.2 E		097-58.0 E						
	SP-39	5-Nov	01-59.9 S	8-Nov	01-18.0 S	11-Nov	01-16.9 S	26-Nov	04-30.8 S	658.6	21	31.36	
			088-00.1 E		089-56.5 E		092-27.9 E		097-58.9 E				
	SP-36	5-Nov	02-10.0 S	8-Nov	01-14.8 S	11-Nov	01-31.4 S	27-Nov	04-45.3 S	640.6	22	29.12	
			088-00.0 E		090-13.5 E		092-22.5 E		047-33.3 E				
	SP-44	6-Nov	03-50.0 S	29-Nov	05-41.3 S					189.3	23	8.23	
			088-00.0 E		090-33.8 E								
	SP-42	6-Nov	03-59.9 S	9-Nov	04-09.9 S	13-Nov	04-35.5 S	29-Nov	07-33.8 S	307.0	23	13.35	
			088-00.0 E		089-11.4 E		089-35.2 E		091-07.6 E				
	SP-45	6-Nov	04-09.8 S	28-Nov	07-22.7 S					315.0	22	14.32	
			087-59.9 E		092-10.5 E								

Appendix V : Drifting Positions of FADs. (cont.)