Harvest Technologies for Tuna and Tuna-like Fishes in Indian Seas and Bycatch Issues

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Harvesting techniques for tuna vary from simple hand lines operated by single fisherman to long lines which stretch kilometers in the sea and bulk fishing methods like purse seining. Tuna and tuna-like fishes are commercially important species because of their global economic importance and their international trade demands. Ocean wise tuna production during 2004 was 12% from Pacific Ocean, 15% from Atlantic Ocean, 30% from Indian Ocean and 43% from Southern Ocean (Pillai and Jyothi, 2007) and the species-wise composition of world tuna has a high percentage of skipjack tuna (47%) followed by yellowfin tuna (32%). Tuna catches have increased substantially over the years in the world largely due to tuna purse seining. For example, landings of tunas and bonitos increased by 50% from 3.1 million t to 4.65 million t during 1984-93 decade (Ben Yami, 1997). Most of the world's tuna catches, including about 70% of skipjack and yellowfin are caught by some 400-450 large purse seiners operating worldwide with each landing on an average of 4000-5000 t, annually.

The potential of tuna resources in the India EEZ is estimated to about 2.78 lakh tonnes (Pillai and Jyothi, 2007). Tuna resources of India, their potential and exploitation have been given by Ganga and Pillai (2006). As a commercially exploitable resource, tunas and related species still remain the least exploited pelagic resource from the EEZ of India (Silas and Pillai 1982). Vijayan (2002) elaborated on the present status and future exploitation strategies for tuna fishing in Indian EEZ. Varghese and Shanmugham (1987) have given the status of tuna fisheries and also described various methods for harvesting tunas in Agatti Island and Swamy (1975) has given the exploitation and utilization of the tuna resources in the Minicoy Island in Lakshadweep. Similarly there are very good prospects of line fishing for tunas in Andaman and Nicobar Islands

(Parasuraman et al., 2003). Tuna long line operations on the west coast of India have been reported by Eapen (1964). The results of tuna long lining operations carried out in Indian waters was encouraging (Swaminath and Nair, 1983). Oceanic tuna fishery could be a feasible fishery in Indian EEZ (Swaminath et al., 1986;1987).

Tuna fishing in Indian waters is mainly confined to the small-scale motorized / mechanized sector and can broadly be classified into coastal fishery and oceanic fishery. They operate various fishing gears like pole and line, drift gillnet, purse seine and lines (hand lines, troll lines, horizontal and vertical lines). Drift gill nets is the major contributor to tuna fisheries in the mainland where as pole and line is the most important contributor in Lakshadweep Islands followed by troll lines and hand lines. The pole and line, troll-line and gill netting mainly exploit skipjack and tuna like fishes and long line fishing the oceanic tunas like yellowfin and bigeye. Over the years, small to medium sized mechanized fishing vessels have switched from single day fishing to multi-day fishing (up to 20 days) and operate multi-gear (drift gillnets, long lines, handlines) in deeper water beyond 100 m depth. Most of these vessels have modern electronic equipments like Echosounder, Global Positioning Systems (GPS) and VHF radiotelephone. Many trawlers in the north-west coast of India prepare their vessels for gill net operations for tuna during monsoon by removing the trawl winch and gallows facilitating smooth operations. Deployment of FADs in the oceanic waters for harvesting tuna is being done at Nagapatnam, east coast of India.

The prevalent commercial fishing methods for tuna fishing in India have been described by Gopalakrishnan (1998). Menon and Neinan (1975) have given the availability of tuna resources and described various fishing gears and methods for harvesting tunas of the Indian Ocean. Various traditional fishing methods for harvesting tunas are practiced in Lakshadweep (Koya et al., 1984 and Anon,1989). Puthran and Pillai (1972) have described in detail the operation of tuna pole and line fishing at Lakshadweep islands. Over the years, catch efficiency of pole and line fishing operations in Lakshadweep have been improved by Namboodiri (1998) by modifying water spray chumming system. The traditional fishermen of Visakhapatnam, Andhra Pradesh, operate hand lines for tuna using *Kattumaram* (Prathibha, 2007). Though there are few fishing vessels exclusively deployed for trolling, this fishing practice is usually carried out by many motorized and mechanized vessels during steaming to the fishing ground and also while returning to the port. Gopakumar. and Ajithkumar (2005) have reported troll line fishing for yellowfin tuna at Colachal, Kanyakumari District. The use of artificial baits (mostly imported) of various shapes, sizes and bright colours are very common. Fishers use coloured polyethylene strips as artificial baits in trolling operations (Sujatha et al., 2006). Drift gill net fishing for large pelagics have been carried out by Pajot (1993). Drift gill netting for tunas in and around Lakshadweep Islands showed encouraging results (Pillai, 1993; Pravin et al., 2004). The traditional fishermen of Thoothoor fishing village, Kanyakumari district, are skilled in operation of and operate long lines and hand lines for tuna and tuna like species. Few trawlers in Tamil Nadu were modified to drift gill netters for harvesting tunas (Balasubramanium, 2000). Design details of conventional tuna long line gear and its operation has been described by Joy et al. (1985). Similarly, technical details and operation of modern monofilament pelagic long line for tunas is given by SEAFDEC (2003). Details of tuna long line fishing operations carried out by CIFNET has been reported by Kasiviswanathan (1999). Various experiments with tuna long line fishing operations in India proved that it could be taken up on a commercial scale (Premchand and Pandian, 2004).

Tuna long lining in India commenced in an exploratory scale in the early seventies. The Govt. of India with the assistance of FAO expert launched a tuna exploratory long line fishing programme from Cochin in 1964. Some observations on the exploitation of the Indian ocean tuna resources were made by Joseph (1972). Similarly, during the early eighties, the Govt. of India, with the help of a Japanese expert, carried out survey for the oceanic tuna resources in India through the Fishery Survey of India and initiated capacity building in the operation of tuna long lines through CIFNET.

Harvesting the oceanic tuna resources was confined to large commercial long line vessels fishing in the Indian EEZ under joint-venture schemes for a brief period and the exploratory survey/training have been carried out by the Govt. of India vessels. The Maritime Zones of India (Regulation of Fishing by Foreign Vessels) Act of 1981, and the Rules (1982) permitted the charter of foreign vessels for fishing in the Indian Exclusive Economic Zone (EEZ). Under this scheme tuna long line vessels operated in Indian waters from 1985 to 1995. Fishing vessels also operated under three other schemes introduced in 1991 by leasing of foreign fishing vessels by Indian entrepreneurs for operation in the Indian EEZ, test fishing using foreign fishing vessels and joint ventures between Indian and foreign companies. The charter scheme was gradually phased out between 1992 and 1995 in favour of joint ventures and Indian-owned vessels. Tuna conference held at Visakhapatnam in 1999 recommended the conversion of 30 % of the existing fleet of Indian trawlers of 23-27 m L_{OA} for undertaking monofilament tuna long lining. Subsequently, two trawlers were converted into tuna long liners by installing imported equipments at Visakhapatnam. Since then many large and medium trawlers are being converted to tuna long liners under different schemes provided by MPEDA.

Fishing methods

Drift gill netting

Gill nets are passive fishing gears and the principle of fishing is by gilling the fish. They are selective, eco-friendly and fuel efficient fishing gear. Drift gill nets are used mainly for catching small schools of tuna and tuna-like fishes swimming not far from the surface. It is a wall of fine, large-meshed synthetic netting with floats on the top and sinkers at the bottom to maintain it vertically in water. Gill nets are very popular among the small-scale fishermen due to its simplicity in construction and operation. Small to medium sized gill netters ranging from around 10 to 20 m are operated in the Indian seas. The fishermen use gill nets with mesh size ranging from 90 to 160 mm for harvesting tuna and tuna-like fishes. A typical design of a gill net for tuna used by Kolachal fishermen, Tamil Nadu is given in Fig. 1. These nets are operated all along the coast line. Major species caught are *Euthynnus affinis* (43%), Auxis spp. (25%), *Thunnus tonggol* (12%), *Thunnus albacares* (10%), *Katsuwonus pelamis* (4%) and *Sarda orientalis* (6%) (CMFRI, 2003).

Operation of gill nets

Fishermen usually go to known fishing grounds and the net is set from the stern diagonally across the current and is hauled manually from the side of the vessel. The gill nets are stacked properly on the aft deck of the vessel facilitating hassle free paying of the net. The nets are usually set before dusk. One fisherman takes care of paying out the floats and upper part of the net, while the other is in charge of the middle portion of the net and the third one takes care of the lower and sinker part of the net. The boat is steered forward as the net is layed-out of the vessel. When the net have been shot, the end is connected to the boat and both drift together. Patrolling is also done every two to three hours to check for catch. When there is fish at a certain point of the net which is indicated by submerged floats in that region of the gill net, the portion

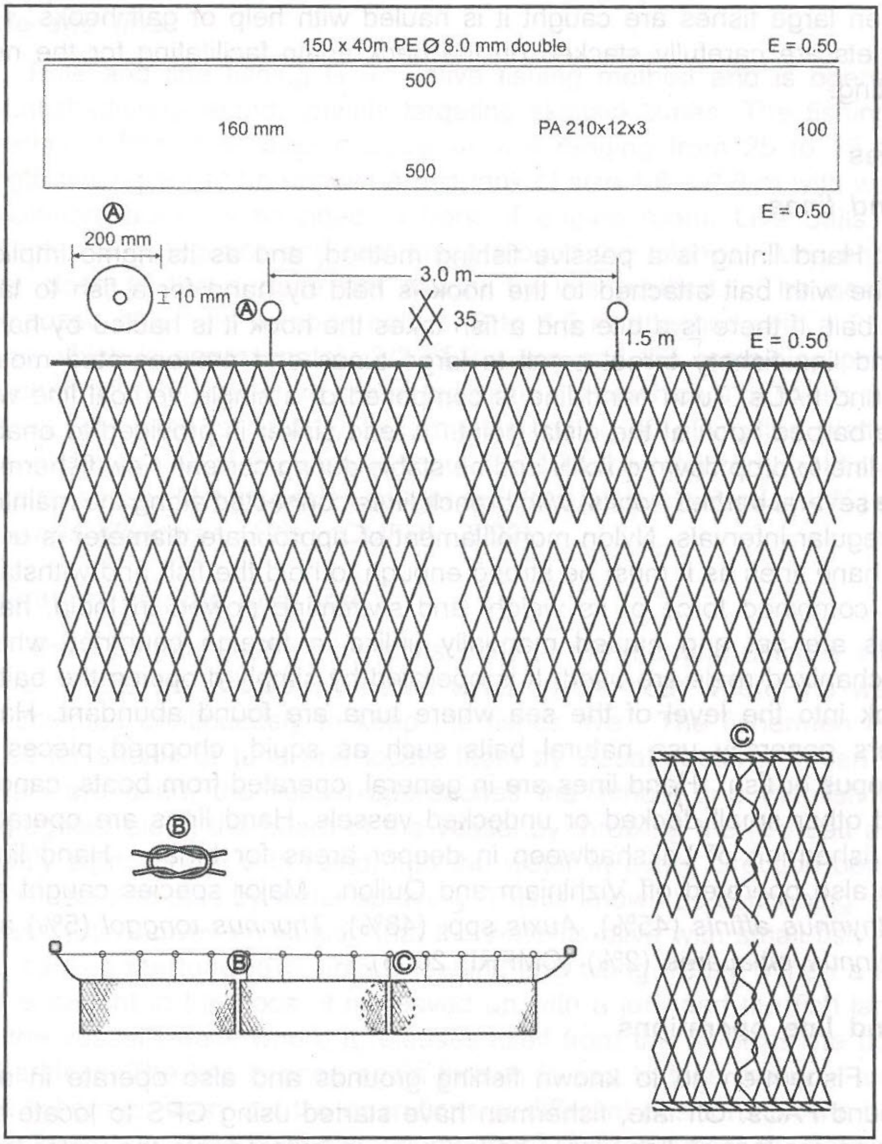

Fig. 1. Drift gill net for tuna

of the net is hauled and the catch is removed and the net is put back to sea.

Hauling often starts at dawn. The first buoy is hauled first and followed by the net. One crew member takes care of the head rope and floats, other, the main webbings and the third one handles the foot rope and sinkers. Fishes caught are ungilled and hauling of the net continues.

When large fishes are caught it is hauled with help of gaff hooks. The gillnets are carefully stacked on the deck again facilitating for the next setting.

Lines

Hand lines

Hand lining is a passive fishing method, and as its name implies, a line with bait attached to the hook is held by hand for a fish to take the bait. If there is a bite and a fish takes the hook it is hauled by hand. Hand line fishery target small to large tunas and are operated mostly around FADs. Tuna hand line is composed of a single vertical line with one barbed hook at the distal point. A lead sinker is provided to enable the line to drop down quickly and be stable during current. Few fishermen use several barbed hooks, with branch lines connected along the mainline at regular intervals. Nylon monofilament of appropriate diameter is used for hand lines as it must be strong enough to hold the fish and withstand the combined force of its weight and swimming power. In India, hand lines are set and hauled manually unlike in foreign countries where mechanized reels are used. It is operated by simply dropping the baited hook into the level of the sea where tuna are found abundant. Hand liners generally use natural baits such as squid, chopped pieces of octopus or fish. Hand lines are in general, operated from boats, canoes and other small decked or undecked vessels. Hand lines are operated by fishermen of Lakshadweep in deeper areas for tunas. Hand lines are also operated off Vizhinjam and Quilon. Major species caught are *Euthynnus affinis* (45%), *Auxis* spp. (48%), *Thunnus tonggol* (5%) and *Thunnus albacares* (2%) (CMFRI, 2003).

Hand line operations

Fishermen go to known fishing grounds and also operate in and around FADs. Off late, fishermen have started using GPS to locate the fishing grounds. A line with a baited hook is lowered into the water from a drifting, anchored or moving boat after reaching the fishing ground. Fishing operations begin by jerking constantly the lines to let the fish bite the bait. If there is a bite, the fisherman comes to know of it as the line jerks. The line is hauled up carefully to take out the fish. The hook is removed from the fish and is once again baited for the next operation. The size of the hook and the depth of operation play a vital role in elimination of juveniles in the catch. If the fish caught in the hook is big and heavy then a gaff hook is used to haul the catch on to the boat.

Pole and line

Pole and line fishing is an active fishing method and is operated in Lakshadweep islands mainly targeting skipjack tunas. The fishing is conducted from mechanized boats of size ranging from 25 to 35 feet length having 10-40 hp engine. A bait tank of size 1.6 x 0.8 m with water circulation facility is provided in front of engine room. Live baits are collected from lagoons and reef areas around the Islands. Tuna shoals very close to the surface are caught by this method. The gear is composed of a rigid bamboo pole of 3 to 4.5 m attached with a 2 mm twine which is approximately 2/3 of the line and the remaining part is attached with monofilament line at the extremity of which a barbless hook is tied. The pole is held by fishermen standing all along the platform provided at the aft of the vessel. About 8 to 10 fishermen carry out fishing simultaneously. Major species caught are *Katsuwonus pelamis* (88%) and *Thunnus albacares* (12%) (CMFRI, 2003).

Operation of pole and line

The fishermen collect live baits early in the morning using a small seine. These are stored in special tanks in the boat where the water is circulated continuously to keep the fishes live. The fishermen then scout for shoals of tuna and locate them by visual spotting. When the shoals are seen, the vessel approaches the school and the fish are aggregated along the board of the vessel by throwing the live bait after slightly squeezing it with hand, into the water in every direction behind the vessel and also by water spraying. This is known as chumming. The spray system gives an illusion that the water is alive with small fish and this causes the tuna to go into a feeding and biting frenzy. When a fish get is caught in the hook, it is heaved up with a jerk and the fish lands on the vessel's deck where it releases itself from the hook as the hook is barbless. The line is once again thrown to sea to take the next tuna. The fishermen carry out the operations at different positions on the boat simultaneously. Live baits play an important role for successful pole and line fishing. FADs are also used to aggregate fishes and it becomes easier for the fishermen to locate the shoals.

Troll lines

Trolling is also an active fishing method in which natural or artificial bait, fitted with hooks, is towed from a line attached to a moving boat. Predatory and carnivorous fishes get attracted to the appearance and motion of the bait and attack it and get hooked. The design of a troll

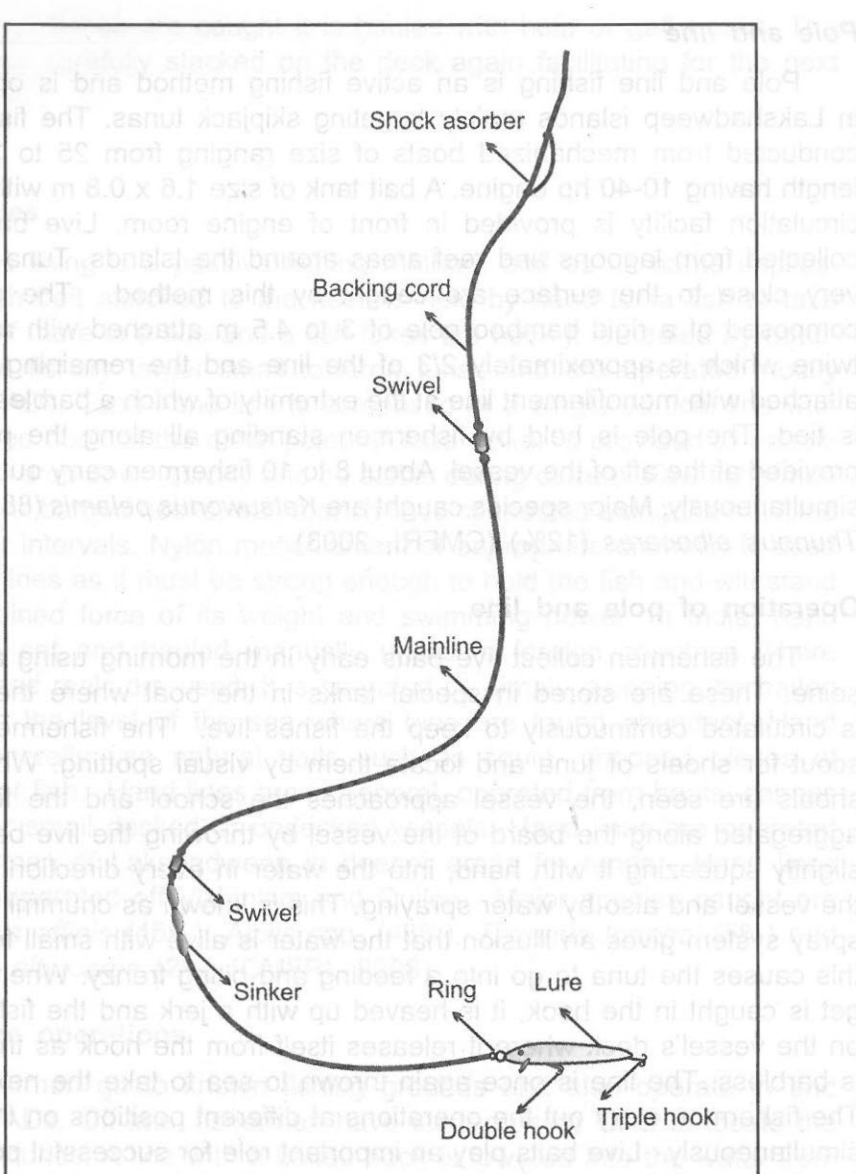

Fig. 2. Troll line

line is given in Fig. 2. This method is mainly used to catch pelagic fish not too far from the surface. It requires relatively little investments on gears and vessels and requires fewer fishermen for operation of the troll lines. In small fishing vessels one to three lines are towed from a craft powered with an outboard engine, whereas in larger fishing crafts, several lines are towed at the same time from two or more booms or outriggers. Mainlines are made up of synthetic material and has a short leader line made of steel wire. At the extremity a simple, double or triple hook with natural or artificial bait or lure to attract fish are used.

Operation of troll lines

A fishing boat drags a set of 5-10 hooked lures through the water at slow to moderate speed. The fishing lines are of different lengths and are also spread out to prevent entanglement with each other. When trolling several lines, those furthest from the boat is paid out first. Choice of apt bait and lure is vital. The speed and depth at which the lure is trolled is also important in the capture of some species. The season of the year, moon phase and tides, and the time of day all have significant effects on trolling success. Tuna attack the lures and get hooked. Fisherman has to keep a constant vigil on the lines to detect a strike of fish on the line. A rubber shock absorber is provided on the line to detect the catch as it would stretch. Some fishermen tie a loop knot in the backing cord. A pull on the line makes the knot slip and disappear. FADs are extensively used to attract and hold surface schooling tunas in a given area. The depth of the hook can be adjusted by changing the speed of boat. Once the line gets hooked by a fish, it is detached from the outrigger and the fish is retrieved. The hook is removed from the tuna's mouth and tossed overboard and the fishing continues.

Long lines

Long lining is a passive gear and is operated as horizontal long lines (Fig 3 and 4) and vertical long lines (Fig. 5). The latter method is used mainly near FADs. In horizontal long lines, there are two main types of gear - traditional, or basket type, and compact, or monofilament gear - with many combinations and variations in between. Basket gear was originally developed by Japanese fishermen decades ago. Introduction of 'Mono-lines' (Nylon monofilament) for branch lines and main lines, Autoline system for shooting and hauling of long lines are recent introductions in India to improve the performance of tuna long lining.

The fishing method is specially suited to catch scattered, sparsely distributed fish and is one of the most effective fishing method to harvest tunas. This method is also ecofriendly, fuel efficient and size and species selective. The depth where the hooks are set in the water column is a crucial element, and can be regulated mainly by modifying the intervals of the main line between float lines and partially by adjusting the length of float-line and/or the speed of shooting, and to a lesser extent, by modifying the length of the branch-lines.

Tuna long line consists of main line (monofilament), branch line (monofilament), swivel, floats with reflectors, nylon rope, stainless steel snap, S.S hook, luminous heart, Aluminium lock, Lead swivel, snood wire, etc. The monofilament nylon (polyamide) mainline can range from 3.0 mm to 3.5 mm in diameter depending on the size of the vessel. The branch lines (snoods, gangions) can be made from 1.25 mm to 2.5 mm diameter. Branch lines usually have swivels. (barrel, bullet, or leaded) and snood wire at the hook end. Hooks can be with or without rings. Connections are usually made with crimps. Connected ends are protected from chafing with plastic tubes. An half meter 3 to 4 mm dia Nylon rope can be provided in the branch line just after the branch clip (stainless steel snap) and is attached with a swivel so that it becomes easy to handle the branch line with hands. This is attached to the monoline which is further attached to a lead weight. A snood wire can be provided just before the hook so as to prevent sharks from cutting off the monofilament branch line.

Operation of long lines

A typical set operated by small scale fishermen consists of 50 or more units or "baskets" connected together, with a buoy at each connection, and a total of about 500 hooks. Recently, fishermen have switched over to mono lines and few of them have converted their trawlers to mechanized tuna long liners.

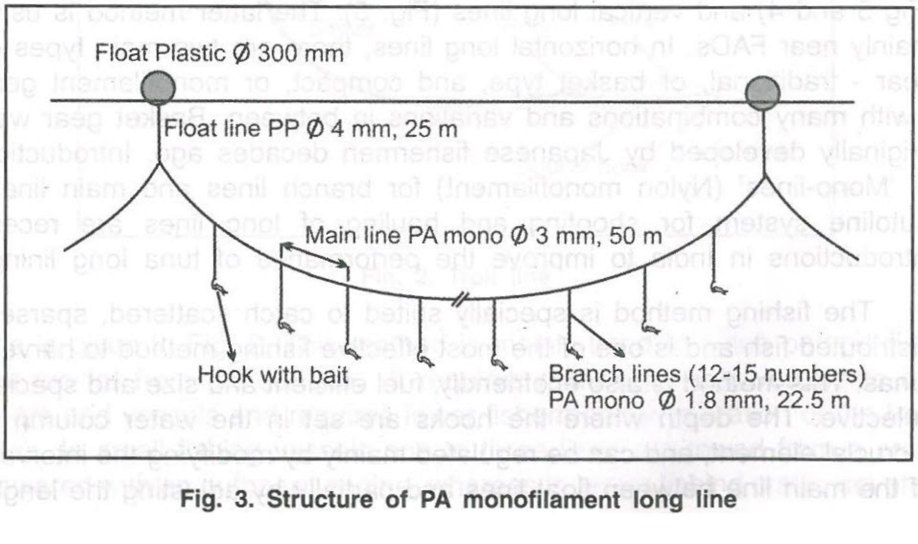

Fig. 3. Structure of PA monofilament long line

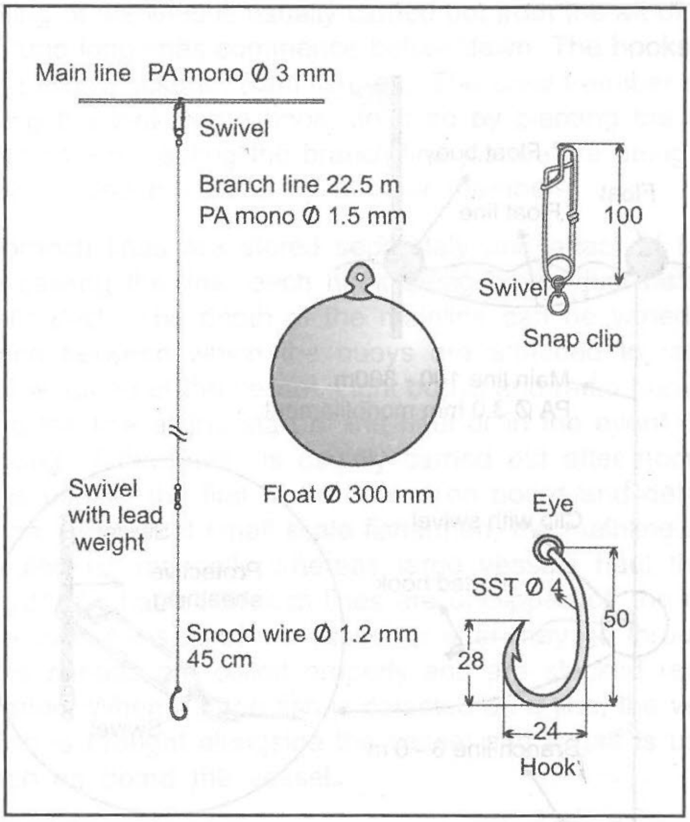

Fig. 4. Structure of branch line of tuna long line

Traditional basket gear: It is usually set manually, as the branch lines are permanently attached to the mainline. There are mainly three crew in the aft during setting operations i. e. baiter, the line thrower, and the float man. The baiter baits the hooks and throws the baited branch lines at regular intervals. The line thrower throws the coils of mainline off the stern from a setting table at a regular pace. The float man throws floats and float lines. The other men pass coils of mainline back to the thrower, carry baskets of gear to the stern and tie them together, pass floats and bait, etc.

Automated rope gear: In this case the rope is fed to the stern of the vessel via blocks, with a line setter usually used. The branch lines are individually coiled and transported to the stern on a conveyor. One person attaches the bait to the branch line and throws the baited hook and branch line. The snapper then attaches the snap to the mainline. Another person attaches the floats and float lines at regular intervals.

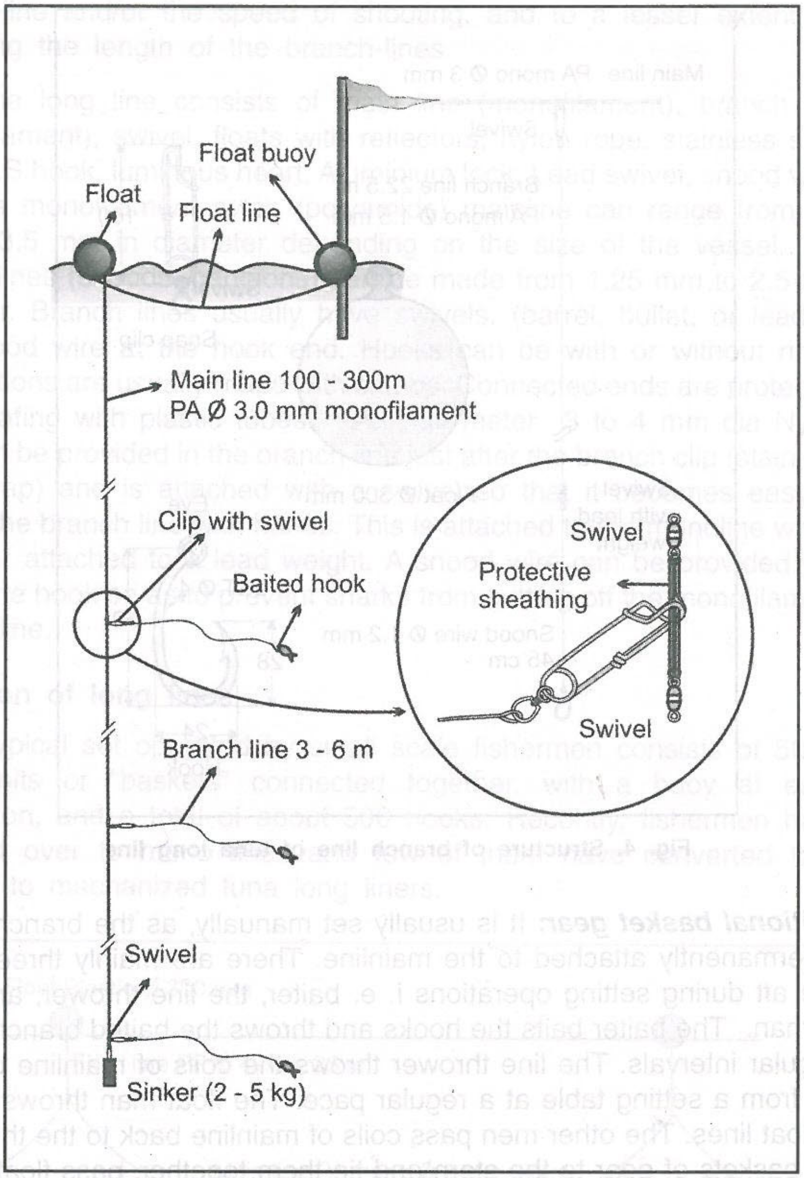

Fig. 5. Vertical long line

Monofilament gear: The fishing operation is similar to that of automated rope gear. The main line is released from the main line drum and the branch lines which are stacked in a bin are attached to the main line after baiting it. Float lines with floats and baited branch lines are snapped on at appropriate intervals.

Shooting of the lines is usually carried out from the aft of the vessel. Setting of tuna long lines commence before dawn. The hooks are baited using flying fish, mackerel, Rani fish, etc. The crew member responsible for attaching the bait to the hook, does so by piercing the bait by the hook at the time of casting the branch line just before being connected (clipped on) to the main line by another member.

The branch lines are stored separately and attached to the main line while casting the line, each hook being baited just before leaving the vessel's deck. The depth of the mainline can be varied mostly by the distance between which the buoys are attached to, and also by changing the speed of the vessel. Light buoys and radio buoys are used for locating the line at the start of the haul or in the event of a broken line. Hauling of the lines is usually carried out after noon. The last buoy set is usually the first to be hauled on board and detached from the mainline. In case of small scale fishermen, the mainline and branch line is hauled up manually whereas large vessels haul the mainline through hydraulic hauler. Branch lines are unclipped off the mainline as they come over the side of the vessel or after they go through the line hauler. The snoods are coiled properly and are stacked ready for the next operation. When a large fish is detected on a line, the vessel slows and the fish is brought alongside the vessel and a gaff is used to take out the fish on board the vessel.

Baits for longlines

Baits play a significant role in successful longline operations. The species, size of fish, and the way it is rigged to the hook is equally important. Baits used for long line fishing is usually frozen whole finfish such as milkfish, mackerels, *Decapterus* spp. *Nemipterus* spp. and flying fish. Live fish is also used for tuna long lining.

Purse seines

Purse seining is an active and bulk catching method. Tuna purse seines are used to capture fish aggregated and swimming not too far from the surface (above thermocline) in the high-sea waters, as well as in the near coast waters. Purse seine and its operations are described in detail by (Ben Yami, 1994). Tuna and tuna like fishes generally feed baitfish near surface. These shoaling fishes are targeted by purse seiners. Purse seining in India mainly target small pelagics and operate in the coastal waters. However, a few purse seiners operate nets (mesh size 45 - 60 mm) for small coastal tunas like frigate tunas and bonitos.

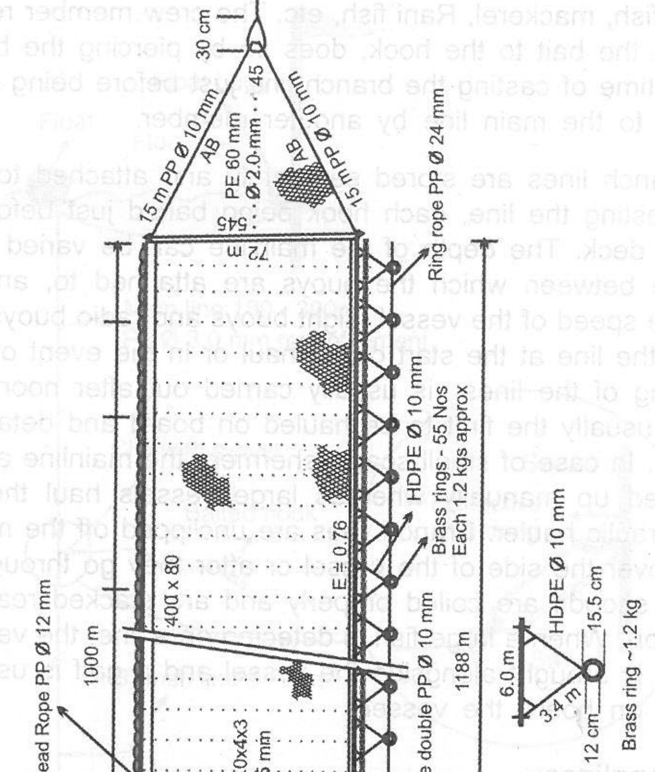

Fig. 6. Design of Tuna purse seine

Design details of coastal tuna purse seine is given in Fig. 6. The top of the net is mounted on a float line and the bottom on a lead line, with brass rings known as "purse rings" which facilitate pursing of the net. Major species caught are *Euthunnus affinis* (45%), *Auxis* spp. (48%), *Thunnus tonggol* (5%), *Thunnus albacares* (2%) (CMFRI, 2003).

Purse seining operation

The complete fishing operation from the beginning of the shooting of the net up to the end of the hauling, back on board of the seine is known as a "set". The vessel scouts for schooling fishes and when a school is detected, the fishermen sitting on the crows nest, at the top of the mast, guides the boat for encircling the fish. Once the shoal is located, the vessel is set at full speed. The skiff has one end of the purse seine the other end is attached to the winch on the purse seiner. The vessel encircles the school at maximum speed. After encircling the fish school, the extremity of the net that stayed attached to the skiff is transferred aboard the purse seiner and the two extremities of the purse line cable are hauled with the winch as quickly as possible in order to close the net at its bottom known as "pursing". If the net stays from the surface all the way down to the thermocline, the chance of fish escape from the bottom would be minimal. During the pursing, the skiff is attached to the starboard side of the vessel and pulls it away from the net. The net is manually pulled aboard the purse seiner and is stacked on the stern of the boat by fishermen in such a way that it will come smoothly off the stern at the beginning of the next set. In case of large purse seiners purse wince, power block triplex winches are used for fast pursing and hauling operations. When most of the purse seine net has been retrieved, the tunas are within a restricted area along the portside of the vessel. Then the fish are brailed out from the purse seine net using a large scoop net.

Fish Aggregating Devices (FAD)

Oceanic fishes such as tunas have a habit to gather in large numbers around floating logs and other drifting objects either for shelter and protection or for orientation for migratory fishes. The fishermen observed that the catches often were higher when they fished around floating objects than when they fished in the open ocean. Huge quantities of tuna have been harvested around even small bodies of floating debris by industrial fishing vessels. The first aggregating devices were built by the fishermen of Indonesia and the Philippines in the early 1900s and are popularly known as *Payaos* (Fig. 7). These were made up of floating

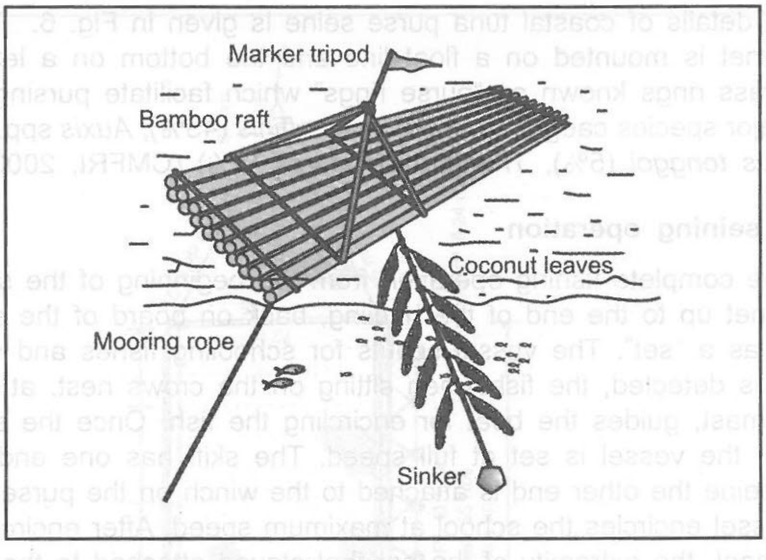

Fig. 7. *Payao*

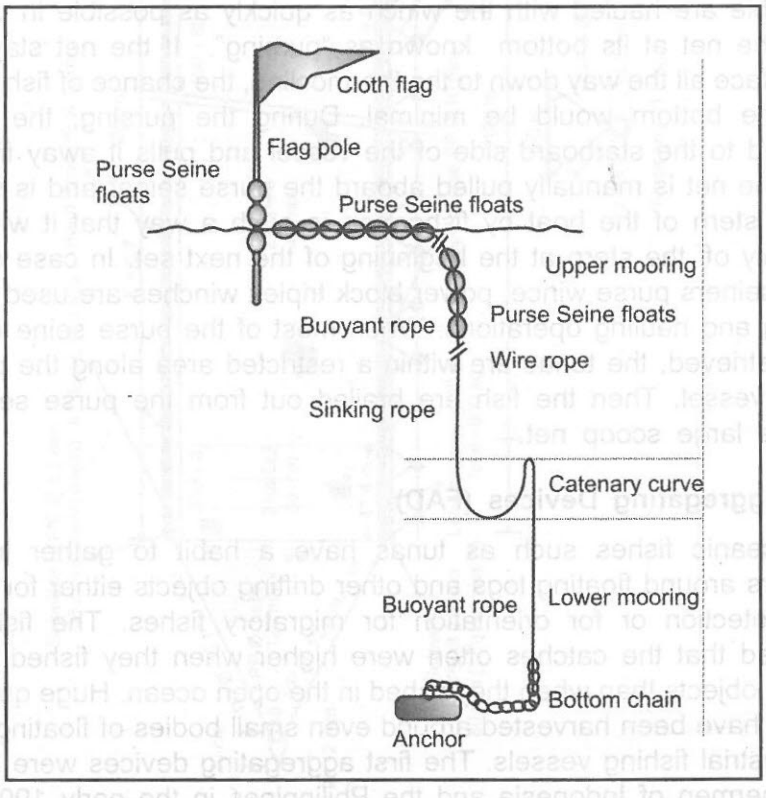

Fig. 8. Oceanic FAD

rafts of bamboo, a bunch of coconut, banana or palm leaves, and other materials to attract schools of fish and secured to the sea floor with anchors and moored with ropes. FADs are now made up of various materials including old tyres, drums, buoys and fitted with radio beacons or radar reflectors.

A FAD is made up of a heavy anchor, mooring chain and mooring rope having few purse seine floats strung to the surface (Fig. 8). The ropes and chains are joined together with the help of shackles, rope connectors and thimbles. A flag pole is used as a marker to locate the FAD. There are shallow water and deep water FADs. The deep water FADs aggregate more number of tunas as compared to the shallow water FADs. FADs aggregate different fish at different depths. Small tunas are usually found schooling near the surface. Larger yellowfin, bigeye and albacore tunas generally gather near FADs at depths between 50 m and 300 m. In addition to these, other fish species, like rainbow runner, mahi-mahi, sharks and billfish also are attracted to FADs.

FAD assisted fishing operations

There are several fishing methods associated with FADs like trolling, pole and line fishing, drop stone hand lining, vertical long lining, traps and ring netting and purse seining. The use of fish aggregating devices (FAD) is getting very popular in all the oceans in recent years. Several FADs are set by fishing vessels in the ocean with radio buoy for easy location. The shoals gathered around FADs are detected by sonar and the boat sets the net around the FAD to harvest the fish. FADs can reduce the scouting and fishing time thereby saving on fuel.

In India, presently around 28 numbers of FADs have been installed in and around different islands of Lakshadweep by National Institute of Ocean Technology for the benefit of the fishermen.

Major technological changes expected in tuna capture techniques in India

Well aware of the potential tuna resources in the Indian Ocean, the Government of India has constantly strived to enhance tuna fishing capabilities through exploratory surveys and capacity building since 1980s. The encouraging catch of tunas and high hooking rates attracted schemes like chartering of fishing vessels and joint ventures to exploit the tuna resources. Various other schemes were also put forward to exploit the untapped resources. Many subsidy schemes were offered to the entrepreneurs to convert their existing fishing trawlers to tuna long liners. It was initially presumed that only large vessels could be used for oceanic tuna long line fishing. But with the example of neighbouring nations like Sri Lanka and Maldives who operate small sized commercial tuna long liners and are able to export high quality chilled tuna meat, India too started gearing up with medium sized vessels for tuna long line fishing in India waters. Fishermen from Tamil Nadu are traditionally using lines are considered to be expert in the filed. They operate combination vessels, having gill nets, long lines and hand lines on board. A substantial quantity of tunas are also landed. The materials used for the long line gear has changed from the traditional conventional ropes to nylon monofilament, though the fishing operations - shooting and hauling in these vessels are presently being carried out by hand. With the increase in the operation of number of hooks, it is likely that a mechanical or hand operated spooler or drum for taking in the main line will be put to use by the fishermen. Presently indigenous hooks are being used. The lines and hooks and other accessories will have to be tested for its quality and strength and improved accordingly so as to reduce loss of catch by snapping of lines and hooks. Scientific methods for location of potential fishing zones for tuna and skill in the operation of tuna long lines are pre-requisites for successful tuna fishing operations. With increasing number of fishing vessels in the near future and competition among fishermen for a common resource, it is likely that there would be increased spurt in fishing effort and the use of mechanical and hydraulic equipments like line setter and spooler, increased dependence on automated sytems and high technology such as remote sensing and bird radar to detect shoals. On board handling for prime quality tuna catering to the sashimi market will be the primary issue as this is directly related to price and economics of operation. Skilful handling of the catch and post processing techniques and speedy transportation to destined markets will be the key to success. It is envisaged that in future, there would be two distinct groups of vessels, large sized vessels (above 18 m) having facility for RSW and freezers and medium class vessels (below 18 m) having provisions for chilled tuna catering to the export markets

Bycatch issues and mitigation measures in tuna fisheries in Indian seas

Though the different fishing methods described above are primarily targeting tunas, a number of non-target species are also caught and this incidental catch of other species is known as bycatch. On some occasions, the bycatch is of economic value and the fishermen haul up the catch as it would add to their income and profit.

Pole and line fishing can have bycatch of little tuna, frigate mackerel, mahi-mahi and rainbow runner. Usually if the bycatch gets too large, the vessels stop fishing and move to other tuna fishing grounds to save wasting of bait. Further, the use of barbless hook in pole and line fishing may improve the survival rate for accidentally caught non-target fishes that are released back to the sea.

Drift gill nets also may catch marine mammals, sea turtles and, occasionally, sea birds. Use of large scale drift gill nets are regulated and in some cases prohibited in the northeast Atlantic. However, drifting gillnets are still widely used, and very popular, in many coastal and small to medium-scale fisheries in developing countries. One unique method to reduce bycatch in drift gill net is by altering the chemical properties of nets to prevent bycatch of Cetaceans. This could help marine mammals to detect and avoid gillnets before coming into contact with them. Metal oxide nets - nylon nets infused with barium sulfate or other metal compounds that facilitate improved acoustic detection by cetaceans may reduce their incidental catch in gill nets. They are stiffer than conventional nets that may contribute to reducing entanglement. Holy et al. (2005) treated the netting with barium sulfate, which makes the netting stiffer and more acoustically detectable for whales, dolphins and porpoises that use echolocation to find objects. Andy (1997) used reflectors and acoustic pingers on the net to deter Porpoises. When an echo-locating porpoise emits a sound pulse, the reflectors transmit back a strong echo, making the reflectors appear to the porpoise to be much larger objects than they really are.

In the case of hand lines, incidental catch like sharks may occur. Optimization of the design and size of the hooks and appropriate selection of bait and its size, can to a certain extent reduce the bycatch. The area and time of fishing, depth of the hooks, type and size of the hooks and of bait can be adjusted to the target species. Sharks are usually caught live and can be released back to the sea. In case of trolling non-targeted fish is relatively less.

Although long line fishing is often regarded as an environmentally friendly fishing method, with no destructive impact on bottom habitats, good selectivity and low fuel consumption, a disadvantage is the incidental catches of billfishes, turtle, sharks and seabirds. There also could be unpredictable discards of target tuna species because they are damaged by sharks. Myers and Worm (2003) reported the rapid decline in the abundance of large predatory species by tuna longline in Indian Ocean. Pelagic long lines are the most widespread fishing gear and are a serious threat to the sharks. Sharks constitute one of the major bycatch components in tuna long line fishing (John and Neelakandan, 2003). Due to increased demand for shark products, targeted fishery for them by long lining and hand lining is also prevalent. Peter et al. (2007) suggested the use of nylon leaders to reduce shark bycatch. Polacheck (2005) studied the impact of tuna longline catch rates in the Indian Ocean on the rapid decline of predatory fishes.

An interesting way to reduce bycatch of sharks in long lines was proposed by Herrmann (1996). Sharks are able to detect magnetic fields using special organs located on their snouts and some species of shark are repelled by strong magnetic fields. The problem of sea turtle bycatch in long line tuna fisheries in the Pacific Island countries has been specifically addressed by Beverly (1996). The existing fishing gear was modified to operate in deeper waters (more than 100 meters) which allowed long line fishermen to minimize encounters with sea turtles while maximizing their tuna catch. The shape and size of hooks also play an important role in reducing bycatch. Circle hook design is known to reduce the number of sea turtles hooked in longlines as well as improve their survival once de-hooked. Kerstetter and Graves (2006) showed that circular hook generally had higher tuna catch rate compared to conventional J-hooks.

Considerable number of sea birds are accidentally caught in long lines. There are many solutions proposed by researchers world wide. Cherel et al. (1999) suggested that dumping of the homogenized offal during line setting greatly reduced the incidental catch of the seabirds, mainly because birds were more attracted by offal than by hooked baits. Incidental catch of seabirds in long line fisheries can be reduced by making the baited hook invisible, by dyeing the bait with blue colour to reduce its visibility to birds, setting of the lines during darkness as the seabirds may not be able to see the baits easily, scaring the seabirds away from the area behind the vessel using a bird-scaring line that deters birds from taking baited hooks and by using underwater bait setting device so that the birds will not be able to access the bait.

Since catching performance of purse seine are not very selective (in terms of both species and sizes of fish) significant bycatch of non-targeted species or small size groups of target species are possible. This is particularly true when the set is made with fish aggregating devices. Romanov (2002) carried out extensive survey on the bycatch in the tuna purse seine fisheries of the western Indian Ocean and reported more than 40 fish species and other marine animals among the bycatch. The capture of dolphins in tuna purse seine is very common. Special panels known as Medina panels are used. It is a fine mesh attached to the part of the purse seine farthest from the boat when the net is "pursed." The fine mesh panel prevents dolphins from becoming snared and creates an escape ramp in the top of the net. A Medina panel included as part of the seine used in conjunction with a "back down" manoeuvre proved to be a very effective method for dolphins to escape (Ben Yami, 1994). Audio recording of predator sounds of an animal in distress or of its predator are also used to deter individuals of that species from entering into a fishing area. Prado (1997) has discussed gear related and non-technical parameters affecting selectivity of tuna fishing gear. Some important gear design and operation related approaches which are

Table 1: Approaches for reducing bycatch in tuna fishing gear

Tuna fishing gear	Gear design related	Operation related
Purse seine	Seine design and depth appropriate for schools target species; Mesh size; excluder devices, aprons and Medina panel.	Choice of fishing area; Choice of fishing depth; Choice of time and season; Capability of vessel and crew to use selective manoeuvres.
Drift gill net	Mesh size; netting material; hanging ratio; use of scaring devices and acoustic deterrents	Choice of fishing area; Choice of fishing depth; Choice of time and season.
Hand line and Pole and line	Bait type and bait size; hook design, shape and size.	Choice of fishing area; Choice of fishing depth; Choice of time and season
Long line	Bait type and bait size; hook design, shape and size; hook spacing; Use of bait hiding mechanisms or bait throwing machine to avoid birds; Bird scaring lines;	Choice of fishing area; Choice of fishing depth; Choice of time and season

useful in improving selectivity and reducing bycatch are listed in Table 1.

With increasing fishing operations around encircling floating objects, including man-made FADs there is likelihood in the rise of capture of small sized, immature fish and bycatch aggregating around such devices which could be of very serious concern.

Conclusions

There are various fishing methods and techniques to capture tunas. They are caught by seining, drift gill netting, pole and lining, long lining or trolling. With rich resources of tuna and tuna like fishes in the Indian seas and high demand and lucrative price for the *Sashimi* grade tuna in the world market, targeted fishing for tuna in the country is going to pick up at a faster pace in the near future. The initial hiccups like proper and hygienic handling and processing of catch on board for quality tuna, availability of skilled manpower in the fishing techniques for operation of tuna long lines and knowledge of productive fishing grounds, fishing season will be overcome over time. Large tunas are usually found at greater depths than smaller ones, so fishing gears which reach deeper into the water catch larger fish than those which fish close to the surface i. e. when long liners fish at great depth, they catch, in general, large fish; poles and lines used by bait boats fishing just a few meters under the surface, usually catch a smaller size of tuna. Utilization of artificial Fish Aggregating Devices (FADs) for seining, long lining or gillnetting has increased the catch substantially with a high proportion of small fish. There is a serious concern regarding the increased by-catch, as well as the higher proportion of small fish in the catch. Many mitigation measures for reducing incidental catch and by catch has been developed during the last decade. Fishing gears will have to be used judiciously taking into consideration the bycatch issues. For responsible fishing practices, appropriate selection of fishing area, season, time and various environmental factors and fishing gear position and maneuvering becomes essential.

With ever increasing advances in technology and rapid progress in the field of electronics, it becomes easier to precisely control the various fishing gears during its operation to better adjust position and depth to reduce bycatch. Use of satellite imagery for distribution and migration of tuna and other fishes Meenakumari and Ravindran (2000) also could enhance the fishing efficiency.

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