Chapter 4

Design and operation of trawls

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Introduction

Bottom or demersal trawling continues to be one of the most important fishing methods of the world.In Indiamore than 35,230 trawlers of various sizes ranging from 9 to 24 m L_{OA} with engine power ranging from 45 to 450 hp @ 2000 rpm are in operation. Trawl is a bag net towed through water to filter out fishes, the mouth of which is kept open horizontally by means of a beam or otter boards and vertically by means of floats, kite and sinkers. Horizontal mouth opening is also effected by dragging the net from two boats known as bull trawling or pair trawling. The main principle of trawling is the movement of the net under water filtering the water through the mesh in the netting, without either permitting the fish to escape or gilling them. Trawl net is fabricated using polyethylene netting after cutting and shaping the panels as per the design Fig.1.

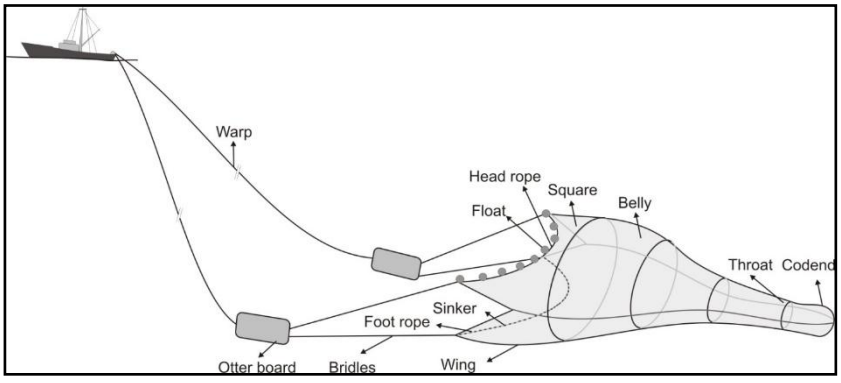

Fig.1 A demersal trawl in operation

In India, trawling was first attempted during exploratory surveys conducted from S.T. Premier off Bombay coast in 1902. Several designs of demersal trawls have been introduced in Indian fisheries in subsequent years.

The most important issue in this sector is the excess capacity in terms of number of trawlers. The size of the trawlers has also increased over the years. Since the in introduction of Chinese engines in the Indian waters, the horse power of the vessel has also increased tremendously and

as a result of these changes there is a tough competition out at sea within and between the sectors, which is leading to overexploitation of the resources.

Classification of trawls

Trawls are classified based on the device used for mouth opening, number of panels used for fabrication, depth of operation and based on target species.

Beam trawl

Beam trawl was the forerunner of all trawl gears. In beam trawls, mouth of the net is kept open using a rigid and curved metal frame with a shoe at the bottom known as beam. This is the simplest method of bottom trawling practiced mainly in the North Sea for flatfish and shrimps. Since the shoe penetrates the seabed and the marks remains for a long period, beam trawling adversely affects bottom ecosystem. Due to the plowing effect, resistance is high resulting in more fuel consumption than otter trawling. Moreover, a large net requires a large beam which is very difficult to safely handle onboard a fishing boat.

Otter trawl

In otter trawls, the most popular method of trawling, the mouth opening of the net is achieved by the attachment of two otter boards, through bridles, on each side of the net. The towing warps are attached to these boards at an angle, so that while towing the water force acting on them tends to diverge them resulting in the opening of the net mouth.

Pair trawls

In pair trawling or bull trawling the net is towed by two boats cruising on a pre-arranged parallel course and speed. The distance between the two boats is also maintained constant, so that the diverging warps keep the mouth of the net open. Main advantage of this method is that a much larger net can be used, as two boats are engaged. As the vessels are operated from a distance from each other scaring effect due to vessel noise is also minimal. Pair trawling is banned in many countries as it generates huge quantity of bycatch.

Trawl types based on number of panels:

Two seam netshave only two major parts, *i.e.,* upper and lower panels and these two are seamed together laterally to form the two seams. The upper part invariably includes the overhang or square. Cross section

of the net is elliptical in shape and since the vertical opening is comparatively less, these nets were mainly operated for shrimps. Presently all the trawls are two seem.

Four seam nets are having upper, lower and two side panels with or without overhang. Cross section of the net is rectangular in shape and hence the vertical opening of the trawl may be influenced by the width of the side panels.

Six seam nets have six panels and cross section of the net generally acquires oval shape. The six and eight seam nets are designed to have more vertical opening and hence suitable for catching fishes.

Main parts of the demersal trawl

Square: Square is defined as the front portion of the upper section of a trawl, which is fitted between the body and the two upper wings so that it partially overhangs, the lower parts of the trawl. Square prevents the fish from escaping the path of the trawl by swimming upward.

Wings: Wings are the forward extension of netting on both side of trawl mouth for guiding the fish towards the bag of the net. Wings and front part of the net are fabricated with netting having larger meshes to reduce the drag.

Bosom: It is the centre portion of trawl between the wings on upper and lower sections.

Jibs: Jibs are the two triangular pieces of webbing attached on either side of upper and lower bellies at their junction with wings to present a smooth shaping to the mouth of the net.

Quarters: They are two junctions where the top wings join the square.

Side panels: These are two identical pieces of webbing attached on both sides of the belly to join the upper and lower portion of a four-seam trawl. The portion of the webbing that comes above the belly is termed “top wedge” and the portion placed adjacent to the belly is termed as “lower wedge” or “side wedge”.

Belly: The channel of trawl body through which fishes move to the codend is known as belly. Upper belly is also called “top body” or “baiting”.

Throat: It is the portion of webbing placed in between the belly and cod end. It is also known as “lengthener” or extension piece.

Codend: It is the narrow rectangular end section of the trawl usually made of thicker twines with small meshes. A piece of rope is inserted

through the meshes of the lower periphery of the codend is used to close the cod end while trawling and it is removed to release the catch.

Apron: Apron is the codend cover used to protect the net from rough bottom particularly with catch. It is also known as "Hula skirt" or "Chafing gear". Net panels with large mesh made of thicker twines are used for fabrication of the cover. It is an optional component for the trawls operating in known grounds.

Head rope (head line): Rope line forms the upper lip of the trawl to which the upper edge of the net is finally attached. Polypropylene ropes are usually used as head rope in small trawls and combination ropes are used in large trawls. The ends of the line are spliced and mostly thimbles are inserted into the eyes. The vertical opening of the net depends mainly on the length of headline and footrope. Head rope and foot rope are attached along the upper and lower wings and across the square. Length of the net is expressed as length of head rope

Foot rope: It is also known as ground rope or fishing line, which forms the lower lip of the trawl to which the lower edge of the net is finally attached. Foot rope protects the lower edge of net mouth. Eyes are spliced to both ends of these ropes by which it is connected to the bridles using a shackle. Foot rope with attached sinker line serves as ballast preventing the trawl from rising. Length of foot rope is usually more than the length of head rope.

Bolch line: Prior to rigging of net to the head rope and foot rope it is hung to a thin rope known as bolch line. Bolch line is attached to the head rope and foot rope at constant intervals with uniform slack.

Design of trawls

The efficiency of a trawl mainly depends on the symmetry of construction of the body and mouth configuration. A trawl is designed in such a way that (i) it offers minimum resistance during tow (ii) total drag matches available towing force of the trawler, (iii) it achieves maximum mouth opening, and (iv) offers least hindrance to the movement of fish within the net towards the codend. While designing a new gear, different factors have to be taken into consideration such as strength and elasticity of webbing, resistance to the water flow, weight and bulk, speed of operation, cost of materials and conditions of fishing ground. A selective, environment friendly and energy efficient trawl system is generally the aim in design process.

Important design considerations in the design of trawl gear involve biological and behavioural characteristics of the target species; fishing

conditions in the trawling ground where the system is to be used; and characteristics of the fishing vessel from which the gear is to be operated. Length of the trawl is measured along the lastridges (side lines) from wing (jib) end to tip of codend and it varies from 1.1 to 1.5 times the head rope length. Right size of a trawl for a particular vessel can be selected according to the total twine surface area or by comparison with a trawl of the same type used by a vessel in the same horse power. Design drawing of the trawl net is prepared to provide all information relating to the size, shape, material and construction using recognized nomenclature and symbols, prior to the fabrication of the net.

Fabrication

The netting is cut to give shape to the required panels as per the design of the trawl. The different panels are laced together and the net is prepared. The mouth of the net is hung to a thin rope and the upper section is mounted to the head rope and foot rope is attached to the lower edge of the mouth. Eyes are spliced on both ends of the head rope and foot rope. Later side ropes are laced along the seams to strengthen the trawl body.

Rigging of trawls

Floats and sinkers are to be carefully distributed to head and foot rope to avoid excess sagging. For medium sized trawls the weight requirement of foot rope per feet is 0.2 to 0.5 kg.

The total buoyancy of floats required is between 1/2 to 2/3 of the total weight of sinkers and their size and strength depend on the size of net as well as hydrodynamic factors.

Various methods are in vogue for achieving comparatively higher vertical opening like the use of kite and triangular gusset, insertion of triangular wedges on the wings or splitting the wings along the selvedges (Dickson, 1959) or use of float or float like devices having higher lift drag ratio.

Resistance of trawl gear

The drag of trawl gear determines the power required to overcome the hydrodynamic resistance of the gear towed at a particular speed. Hydrodynamic resistance or drag is estimated from model studies and by scaling up the results so obtained, to the actual size. It is also estimated through theoretical calculations by adding up the drags of individual components of the trawl gear.The bollard pull (towing power) of a trawler

should be higher than the total drag at the maximum speed at which the trawl is towed. Trawl drag is contributed by netting (68%), otter boards (24%) and sweeps and warps (8%), approximately.

Trawl accessories

Otter boards

Otter boards are gear accessories used for keeping mouth of the trawl net open horizontally and its invention has revolutionized the stern trawling from single boat (Fig.2.). As already mentioned prior to the introduction of otter boards, a rigid metallic beam was used to keep the mouth of the trawl open, which creates lot of problem in handling.

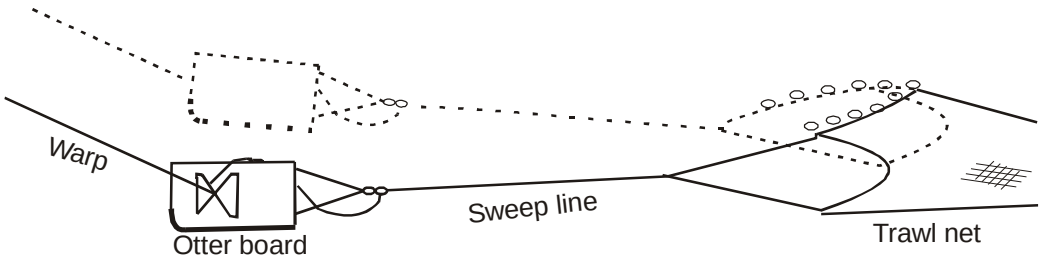

Fig.2. Rigging of otter boards in the trawl system

In the beginning, the boards were attached directly to the legs (Hoover Rigging) of the trawl. Since the introduction of Vigneron Dahl system, long bridles were introduced in between the net and otter boards. In the latter case the sweep lines are connected to the board by a back strop and the net by a bridle or danleno. The conventional type of otter board consists of a flat or curved surface for developing necessary shear force by diverting the flow of water, a bracket or chain for attaching the trawl warp, rings or back strop rings for attaching the legs or bridles and a heavy shoe to prevent the otter board raising off the ground and to provide stability. The following parameters influence the performance of otter boards.

Different types of otter boards used in bottom trawls

Rectangular flat otter boards

This is the widely used otter board for bottom trawling (Fig. 3.). In India all hard woods which can withstand sea water are used for fabrication. The board is assembled by joining wooden planks horizontally and fixing them together with long bolts or mild steel straps. A wide metallic shoe is used to maintain bottom contact and also to prevent digging into the mud. Some times a gap is left in between the planks which is said to prevent turbulence on the other side of the board. Though the boards are cheaper,

easy to fabricate and handle they are not hydro-dynamically very efficient and can not slide over obstacles.

Rectangular curved otter boards

These boards are hydrodynamically more efficient than flat rectangular boards due to streamlined flow of water (Fig.4.). Boards are fabricated by arranging wooden planks vertically and joining them by iron frames. Main advantage of this board is that greater spread can be achieved at low towing power. These boards work at smaller angle of attack, which results in a lower towing resistance and may also reduce the tendency of otter board to dig into soft ground. Though cambered boards are expensive they are hydro-dynamically efficient and durable. Greater spread can be achieved with a smaller board at low towing speed.

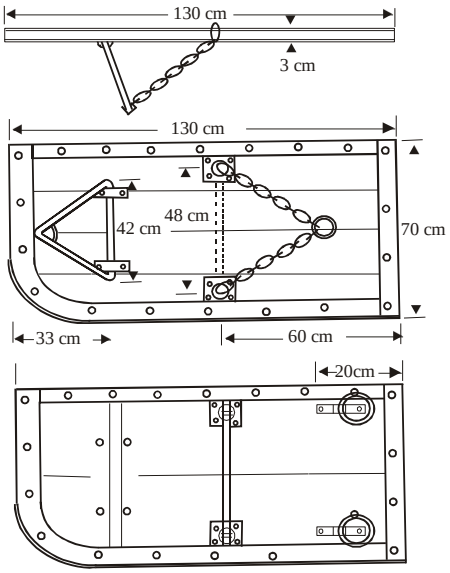

Fig. 3. Flat rectangular otter board

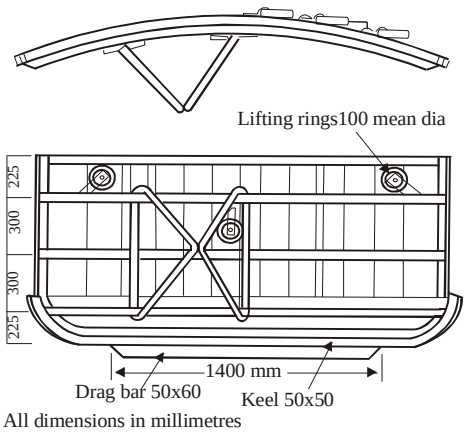

Fig. 4. Horizontally curved otter board

Oval flat slotted otter boards

These otter boards are also known as Russian type because these boards are very popular in Russia (Fig. 5.). They are designed for rough grounds. Hydro-dynamically it is slightly better than rectangular flat boards. The rounded lower edge though adversely affects the spreading performance, improves overall performance on uneven or hard ground because it reduces ground friction and mechanical stress.The vertical slot opening is intended to increase the hydrodynamic efficiency of the board by reducing the turbulence. The main limitation is its lower spreading force on clean ground as compared to cambered board of same area. This board is not suitable for midwater trawling. Hard wood is used for the construction.

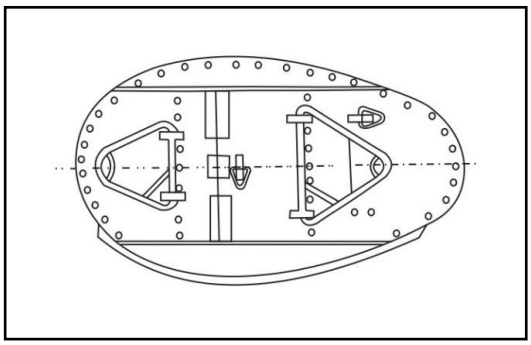

Fig. 5. Oval otter board

Oval curved slotted (Polyvalent)

As the name indicates it is a combination of the oval board and curved board, giving the increased spreading efficiency and ability to traverse the hard ground. They were first introduced in France with full steel body. A slot is cut in the main plate for generating a suitable angle for water flow through the slot. The polyvalent boards are relatively expensive but handling onboard is easy. These boards can be used for bottom and midwater trawling. It is reported that due to lack of proper ground contact they are also found to be unstable in bottom trawling.

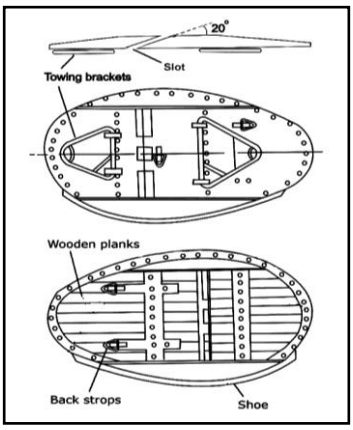

Fig.6. Oval otterboards

V-form otter board

V-form steel boards are the most popular boards in bottom trawling in many states of India. These boards are simple in construction relatively inexpensive, durable and stable on uneven grounds (Fig.7.). The interchangeability of the towing bracket is an important factor of this board, because spare board can be either way around to make either a port or starboard otter board. The V-form boards are heavier in weight but this is necessary to counter act the upward shear component which comes to play due to the shape of the board. Boards weighing 60-85 kg each can be used in vessels having 200-230 hp.

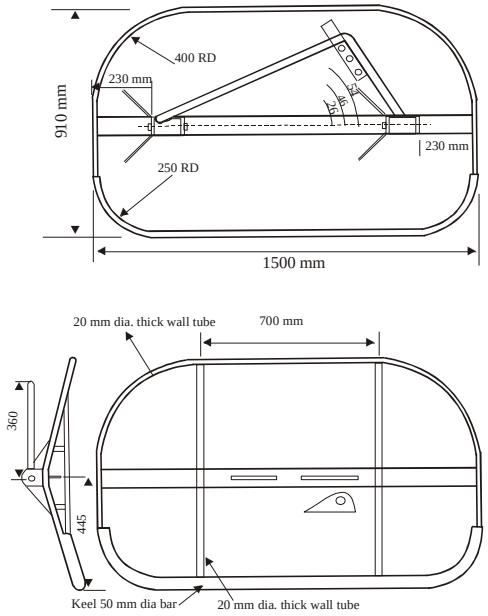

Fig. 7. V-form otter board

Suberkrub Otterboards

Suberkrub otterboards are used for semi-pelagic and midwater trawling. Thyboron boards are used for midwater trawling for krill and mesopelagics.

Floats

Floats are essential component of the trawl net for maintaining the head rope always upward. EVA (ethylene vinyl chloride), ABS (acrylonitrite-butadiene-styrene) and high density polyethylene (HDPE) are the most common floats used in trawls. Size of floats generally ranges from 100 to 300 mm. EVA is having maximum pressure withstanding

capacity and buoyancy and hence most suitable for trawls. Trawl plane float, hydrodynamic float, up thruster float and siamese twin floats were developed to maintain the head line lift while trawling at great speed. Heavy duty plastic floats are used in the net made for deep sea trawling to withstand the pressure.

Sinkers

They are used for stretching the ground rope down to obtain the vertical gape and bottom contact. Iron having cylindrical shape and 250g weight and barrel or bean shaped lead with 100-200g weight are the commonly used sinkers at present.

Pennants

Pennants, also known as lazy line (since there is no strain on these lines when the trawl is being towed), serves as the connection between shackle and connecting link of the warp. It is made of galvanized steel wire, with same thickness of warps and bridles or PP rope. The pennants, one with each otter board, are used for hauling the net after the otterboards are detached.

Bridles

Bridles or sweep lines are the connecting wire linking the otter board and the legs of the net in order to widen the fishing path. Polypropylene ropes of about 20 m length are used in smaller vessels where as steel wire rope having 20-60 m length are used in large vessels for achieving better horizontal spread of the net. Where trawls are worked at towing speeds exceeding 3 knots, it is advisable to increase the length of sweep lines. At lower towing speed, long sweep lines sag badly and are dragged over the ground and thus wear out fast. Ground contact can be increased by lengthening the lower bridle or shortening the upper bridle. To increase the vertical height, lengthen the upper bridle or shorten the lower bridle.

Trawl warps

They are well lubricated steel wire ropes of identical length with marking at intervals, fully wound on the winch drum when not in use. While shooting the net the warps are connected to the otter boards by means of G-link assembly. The diameter of the warp may vary from 9 to 16 mm, depending on the size of the vessel and net. The length of warp to be released while towing the net depends on the depth of the fishing

ground. Usually the depth and warp length ratio (scope ratio) is 1:5 or more depending on depth and bottom conditions. In deep sea trawling scope ration used is 1:3, plastic coated steel ropes and UHMWPE ropes are also being used as warps.

Bobbins

For fishing on rocky and coral areas an additional rope with rollers or bobbins has to be fastened to the ground rope to protect the net. The rollers or bobbins can be plastic or rubber or any other hard materials. They may be of various shapes, mainly round, disc or spherical.

Trawling operation

Demersal trawls can be operated from a few meters to more than around 1000 meters in the sea. The demersal trawl is designed and rigged to have bottom contact during fishing and is, depending on the bottom substrate equipped with different kinds of ground rope rigging. This is for the purpose of shielding lower leading margin of the trawl from ground damage whilst maintaining ground contact and easy move on the bottom.

The trawlers must have sufficient towing force for towing the gear and require a winch or mechanical hauling system. However, in some small-scale operations hauling is done manually. The methods adopted for demersal trawling are beam trawling, side trawling, stern trawling, double rig trawling, bull trawling and multi-rig trawling. Stern otter trawling is the most popular method in India.

Beam trawling

On arrival at the fishing ground, the beam trawls are hoisted on the booms which are then swung out. The operation is undertaken while the fishing vessel sails on a straight course. When hauling, the net is heaved in until it is at the boom tips. The cod end is taken by the line attached to the cod end strap and the catch is emptied out directly.

Otter trawling

The Vigneron-Dahl system was introduced during 1920s where the otter boards were attached to the wings by means of sweep lines and bridles. This helped in increasing the effective swept area and thus increased the catch due to the herding effect of sweep lines and otter boards. In larger trawls, in addition to the weight on the foot rope, iron bobbins or rubber discs are attached depending upon the nature of fishing ground. The towing warps are provided with markers at distinct intervals for facilitating the release warp, in small-scale operations. In

large scale operations it is hydraulically or electrically controlled with metering arrangements. The length of warp released in bottom trawling depends on the depth of the fishing ground and nature of sea bottom. The ratio of depth of fishing ground and the warp released is known as scope ratio or in other words, it is the warp-length ratio. The length of warp to be released is generally (i) 5-6 times the depth in shallow waters below 50 m, (ii) 4-5 times the depth in off shore waters of 50-100 m, (iii) 3-4 times the depth in deep waters of 100-200 m and (v) 2-3 times the depth in deep sea of 200 m and more

The speed at which the trawl is towed over the bottom range from about 2 to 2.5 knots for slow swimming species to 3- 4½ knots for fast swimming fish. Towing a particular trawl too slowly may cause the otter boards to close together, providing insufficient spreading power to the net which tends to sag on to the bottom. Towing too fast may result in the net lifting off the bottom and floating which may lead to fouling of gear.

Winches are used to pay out and haul the warps. The winches have two drums, one for each of the two warps; an additional drum is provided for operation of try net in shrimp trawling. In larger trawlers, single drum split winches are used for each of the warps. Hauling speeds could vary from 30 to 60 $m.min^{-1}$. Stern ramps are provided in larger stern trawlers, which facilitate the shooting and hauling up of the large trawl gear with less manpower. In large trawlers net drums are used to haul up, pay out and store the sweeps, bridles and net with its rigging. The factors such as (i) availability of fish (by using echo-sounders, fishery charts and fishery forecasts), (ii) depth and nature of sea bottom of the fishing ground, (iii) current and wind speeds are to be taken into consideration before the commencement of fishing operation.

On reaching the ground the warps are attached to the net and the codend is closed properly. The codend is the first part to be released, followed by the main body of the net. The vessel steams forward slowly releasing the net and the otter boards. The winch is stopped after releasing few meters of the warp to ensure the proper spreading of the bridles and otter boards. The gear is then lowered to the desired fishing depth by releasing sufficient length of warp. The net is dragged for a duration of about 1 to 4 hours, depending on the concentration of catch.

The net is hauled by heaving in the trawl warps evenly on to the winch drums, until the otter boards reach the gallows. Sweeps and bridles are then hauled up followed by the main body of the net and finally the codend. In small trawlers, the sweeps and the net are shot and hauled in manually and sweeps may remain connected to the otter boards. In large trawlers, a Kelley's eye, independent wire and back-strop is used for

facilitating the hauling of the sweep lines and net on to the net drum after the otter boards have reached the gallows.

Conservation Strategies: Design improvements

Large mesh trawls*:* In these trawls, the front trawl sections are made using large mesh panels which results in reduction of trawl resistance. The reduced drag permits greater trawling speed and operation of a large trawl with the available installed engine power. Trawls with a mesh size up to 5 m is now under operation in Kerala. Such trawl use only 3 large floats for lifting the head line.

Rope trawl: In rope trawl, the front trawl sections are replaced by ropes, which as in the case of large mesh demersal trawl, results in reduction of trawl resistance with the same advantages as in large mesh trawls. Finfishes are retained due to the herding effect of the ropes.

High opening trawls*:*High opening demersal trawls are designed to harvest off bottom fishes, which are beyond the reach of conventional demersal trawls, along with bottom resources. It has been reported that the large mesh high opening trawls offer 18% lesser resistance compared to conventional bottom trawls which in turn results in utilization of lesser horse power.

High Speed Demersal Trawls: Commercial exploitation of active fishes with low population density fishery resources requires high speed trawling. High speed demersal trawls (HSDTs) have been developed with light material, large meshes, smooth tapering along the belly facilitating even distribution of stress along the framing and strengthening ropes facilitating smooth filtration and herding.

Bulged belly trawl: In the bulged belly design, wide side panels are provided to increase the vertical opening, and at the same time tapering of the belly is streamlined so as to improve herding and filtration efficiency. The improved bulged belly trawl fitted with tapering jibs consistently landed better shrimp catches.

Technological Strategies

Increasing awareness on responsible fishing methods has resulted in studies to improve the selectivity of the trawls. Size selectivity in bottom trawls can be achieved by controlling the mesh size and shape. Species selectivity can be achieved using separator panels and grids by making use of the behavioral differences in species in the fishing area.

Separator trawls*:* It is designed to separate shrimp from fishes based on the difference in their swimming behaviour. Insertion of a horizontal panel in the separator trawl, separates the fish and shrimp catch, leading them to separate codends. The selection process of this device is based on the fact that shrimps which are usually distributed close to the bottom move to the lower codend while the high swimming species usually end up in the upper codend. Separator trawls reduce the sorting time, as the catch is landed in a pre-sorted condition.

Short body shrimp trawl*:* CIFT has developed and successfully field tested a 27 m shrimp trawl with relatively short body and large horizontal spread suitable for selective retention of shrimp. The width and length of the trawl funnel has been reduced by increasing the tapering ratio and the vertical opening of the mouth has been reduced to eliminate bycatch. Because of the larger horizontal spread of the mouth the effective sweep area is more, which is the most vital requirement for a shrimp trawl.

Trials carried out along the coastal waters off Cochin with a prototype of short body shrimp trawl reveals considerable reduction in the catch fish due to the behavioral difference of the targeted species.

Cut-away top belly shrimp trawl: A shrimp trawl without top belly has been developed and field test at CIFT. Results reveal that considerable reduction in the quantity of bycatch landed. The net was able to cover more area within the stipulated speed and time due to reduced drag.

Semi-pelagic trawls: 27m four panel CIFT-SPTS in combination with high aspect ratio Suberkrub otterboards weighing 85kg each with front weights is designed to catch fishes, which are up to 4 m above the ground, with minimum impact to the sea bottom (Fig.9).

Krill trawl

Krill (*Euphausia superba*) is a small crustacean found in the Antarctic waters of the Southern Ocean. Large trawls with small mesh inner lining is operated in Antarctic waters for krill fishing (Fig.10).

Mesopelagic trawls

Mesopelagics are small fishes in the size range of 3 to 30 cm inhabiting the disphotic oxygen minimum zone in world oceans in the depth range of 200 to 1000 m. Large trawls are used in Oman and South Africa for commercially harvesting mesopelagics mainly for making fishmeal and fish oil (Fig.11).

Environmental impact of bottom trawling

Bottom otter trawls interact physically with the bottom sediment, which might result in removal or damage of sedentary living organisms (including seaweed or coral) and in the case of uneven bottom surface displacement of stones or other larger objects. On flat sandy/muddy bottom the sediments might be whirled up into the water masses and suspended. The short and long-term impact on the bottom environment is still poorly documented. The major negative impact of bottom trawling is the capture and discarding of huge quantity of juveniles of fishes and other aquatic organisms.

Conclusion

Trawls are non-selective fishing gears creating plowing effect on the sea bottom leading to the destruction of benthic ecosystem. In trawl design and improvement, the aim should be to produce a trawl system which can selectively and efficiently catch the target fish, eliminating juveniles and other aquatic organisms with minimum environmental impacts. Since trawling is an energy intensive fishing method, development of low drag trawl systems to save energy and cost of operation is imperative. Resource specific trawls like semi-pelagic trawls should be popularized to minimize the impact on ecosystem. Excess capacity in terms of number of trawlers, size, engine power and trawl efficiency are major issues which needs to be addressed to make the trawling economical and sustainable.

Further reading

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Fig.8. Suberkrub otterboards and Thyboron type-7 otterboard

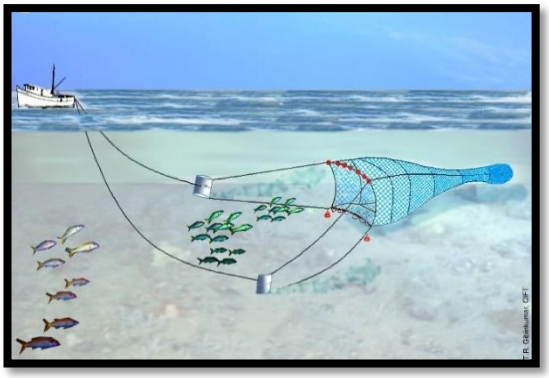

Fig. 9. Semi-pelagic trawl

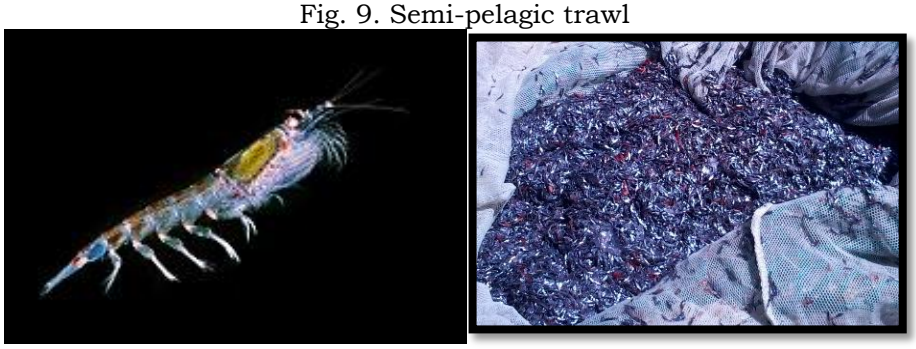

Fig.10. Antarctic krill and krill trawl with nylon inner lining

Fig.11. Myctophids and mesopelagic trawl