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FISHING TECHNOLOGY OUTLINE

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FISHING TECHNOLOGY OUTLINE

compiled by

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PREFACE

The Training Department (TD) of the Southeast Asian Fisheries Development Center (SEAFDEC) conducts training and research regarding marine capture fisheries. Under its training activities, the Department offers a regular course in both fishing technology and marine engineering. The Department also organizes a number of short-term training courses related to marine fisheries and fishery extension services.

This book is mainly concerned with fishing gear and methods: trawling, seining, purse seining, dredging, lining and all types of set-netting, potting and trapping - in fact, most of the methods used throughout the world for catching fish for profit. Details may vary, but essential principles remain. This book is therefore, a valuable introduction to new forms of fishing technology for both trainees and experienced fishermen wishing to diversify their operation.

It is my sincere hope that this textbook will be widely utilized by those engaged in fisheries education and training.

January 1989

S. Soodhom.

Somyos Soodhom
Training Division Head
Southeast Asian Fisheries Development Center

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I. CLASSIFICATION OF FISHING GEAR*

INTRODUCTION

The International Standard Statistical Classification of Fishing Gear, drawn up in 1971 by FAO with the assistance of distinguished specialists, such as Professors A. von Brandt and A.I. Treshev, is now used by most of the international organizations connected with fisheries. Initially designed to improve fishery statistics, this classification has also been found very useful for fisheries technology and the training of fishermen. It has been used in particular for reference in work dealing with the theory and construction of gear and for the preparation of specialized catalogues on artisanal and industrial fishing methods.

On many occasions the use of this classification of fishing gear for fishery statistics has proven to be of prime importance if exploitation conditions are to be assessed accurately; however, it has also been realized that the use of the classification is often restricted, or rendered difficult, by the lack of technical knowledge of the administrators and staff of the fisheries and statistical offices responsible for identifying the gear categories to which a country's catches and landings relate.

These issues have led us to prepare this document, in which the staff responsible for statistics will find concise but sufficiently precise descriptions, complete with simplified overall illustrations, which should enable them to identify the various categories of gear used in the different fisheries sectors (artisanal, semi-industrial and industrial), either in marine or inland waters. Furthermore, this document should be useful as basic reference material and for general information to all specialists, technicians and workers concerned with fisheries administration, control and surveillance, training, research and extension services.

As regards the illustrations, in case of doubt or for more details, reference can be made to the FAO fishing gear catalogues and particularly the FAO Catalogue of Small-Scale Fishing Gear[1], prepared on the basis of the existing International Standard Classification.

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* From Definition and Classification of Fishing Gear Categories by C. Nelelec, FAO Fisheries Technical Paper No. 222

1/ Published by Fishing News, Books, Long Garden Walk, Farnham, Survey English

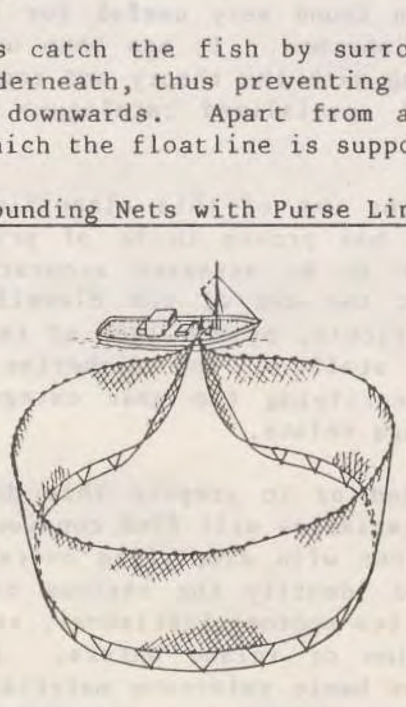
The sequence and numbering of the gear categories correspond to the numerical code used in the International Standard Statistical Classification of Fishing Gear (ISSCFG)1/, as adopted during the 10th Session of the Coordinating Working Party on Atlantic Fishery Statistics, Madrid, 22-29 July 1980 (See FAO Fisheries Report No.242)2/, except for one or two minor exceptions which could be made the subject of later amendments to the Classification.

DESCRIPTION OF THE MAJOR CATEGORIES OF GEAR

1. SURROUNDING NETS

These nets catch the fish by surrounding them both from the sides and from underneath, thus preventing them from escaping in deep waters by diving downwards. Apart from a few exceptions, they are surface nets in which the floatline is supported by numerous floats.

1.1 Surrounding Nets with Purse Lines (Purse Seines)

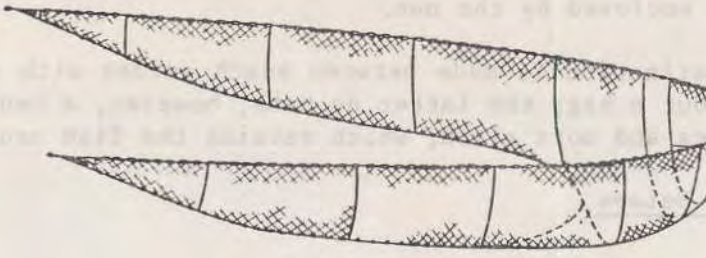


The nets in this category are purse seines characterized by the use of a purse line at the bottom of the net. The purse line enables the net to be closed like a purse and thus retain all the fish caught.

The purse seines, which may be very large, are operated by one or two boats. The most usual case is a purse seine operated by a single boat, with or without an auxiliary skiff.

1/ See p. 21

1.2 Surrounding Nets without Purse Lines (Lampara Nets)



The lampara net is the type most representative of this category. Its particular design, with the central bunt in the form of a spoon and two lateral wings, makes it possible to retain the shoal of fish when the two wings are hauled up at the same time.

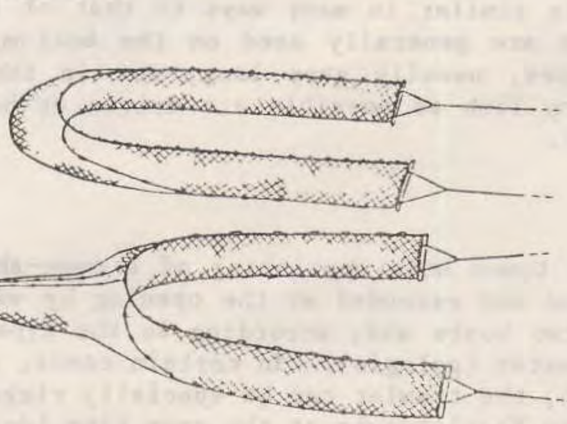
Lampara nets are generally operated by a single boat, most often of small tonnage.

2. SEINE NETS

These nets, which are usually set from a boat, can be operated either from the shore (beach seines) or from the boat itself (e.g., Danish seines).

The manner of capture is to surround an area of water with a very long net, with or without a bag at the center. The net is usually operated by two ropes fixed to its ends, used both for hauling it in and for herding the fish.

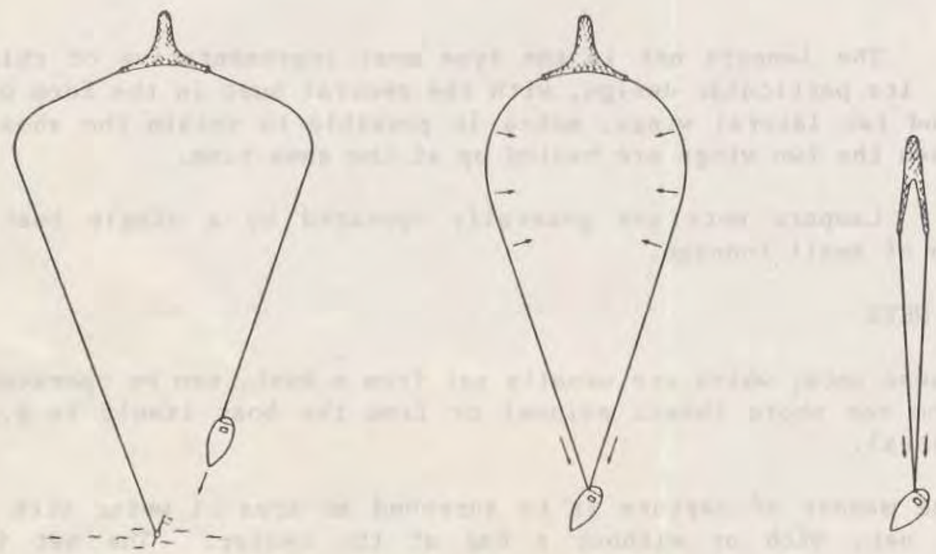
2.1 Beach Seines



This category comprises the seines operated from land, which are generally used in shallow waters, near the shore; the bottom and surface act as natural barriers which prevent the fish from escaping from the area enclosed by the net.

A distinction is made between beach seines with a bag and beach seines without a bag; the latter do have, however, a central part with smaller meshes and more slack, which retains the fish caught.

2.2 Boat Seines



The type most representative of this category is the Danish seine. The design of these nets, consisting of two wings, a body and a bag, is similar in many ways to that of trawls. Operated from a boat, they are generally used on the bottom, where they are hauled by two ropes, usually very long, set in the water so as to ensure that as many fish as possible are driven or herded towards the opening of the net.

3. TRAWL NETS

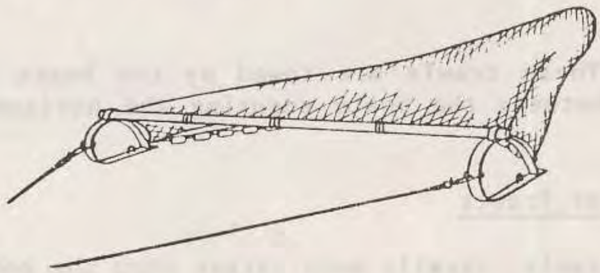
These are towed nets consisting of a cone-shaped body, closed by a bag or cod end and extended at the opening by wings. They can be towed by one or two boats and, according to the type, are used on the bottom or in mid-water (pelagic). In certain cases, as in trawling for shrimp or flatfish, the trawler can be specially rigged with outriggers to tow two (or even four) trawls at the same time (double rigging).

3.1 Bottom Trawls

These trawls are designed and rigged to work near the bottom. According to the type used, one may distinguish: low opening trawls, especially adapted to the capture of demersal species, such as beam trawls and shrimp, sole or nephrops trawls; and high-opening trawls, suitable mainly for the capture of semi-demersal or pelagic species.

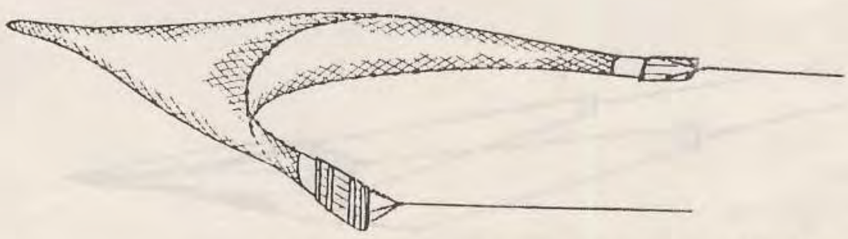
In bottom trawls, the lower edge of the net opening is normally protected by a thick groundrope ballasted with chain sinkers and often covered with rubber discs, bobbins, etc.

3.1.1 Beam trawls



In these trawls, the horizontal opening of the net is provided by a beam, made of wood or metal, which may be 10 m long or more. Beam trawls are used mainly for flatfish and shrimp fishing1/.

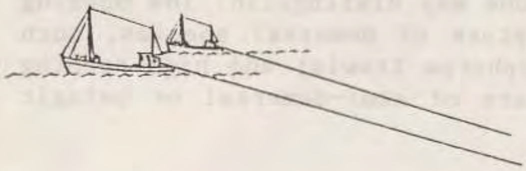
3.1.2 Bottom otter trawls

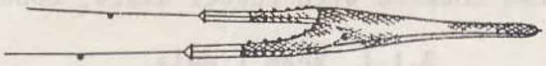


These are trawls towed by a single boat; their horizontal opening is obtained by otter boards, relatively heavy and equipped with a steel sole designed for a marked contact with the ground1/.

1/ Both beam trawls and bottom otter trawls can be used either with single ring, i.e., operated generally from the stern or more rarely from the side of the vessel, or with a double rig, i.e., two gears towed simultaneously.

3.1.3 Bottom pair trawls



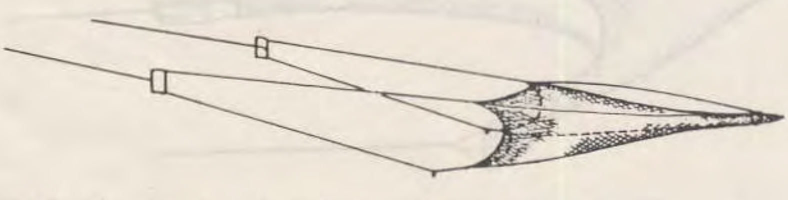


These trawls are towed by two boats at the same time, the distance between the boats ensuring the horizontal opening of the net.

3.2 Mid-water Trawls

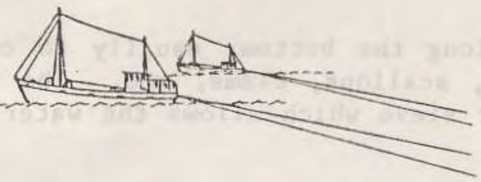
These trawls, usually much larger than the bottom trawls, are designed and rigged to work in mid-water, including surface water. Their front net sections are very often made with very large meshes or ropes, which herd the fish schools towards the net aft sections. The fishing depth is usually controlled by means of a net sounder (netsonde). They may be towed by one or two boats.

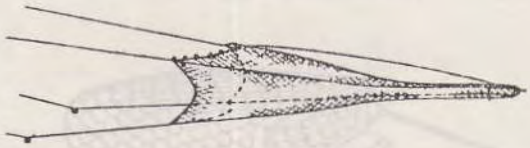
3.2.1 Mid-water otter trawls



These trawls are towed by a single boat. The horizontal opening of the net is controlled by otter boards, usually of a hydrodynamic shape, and which normally do not touch the ground.

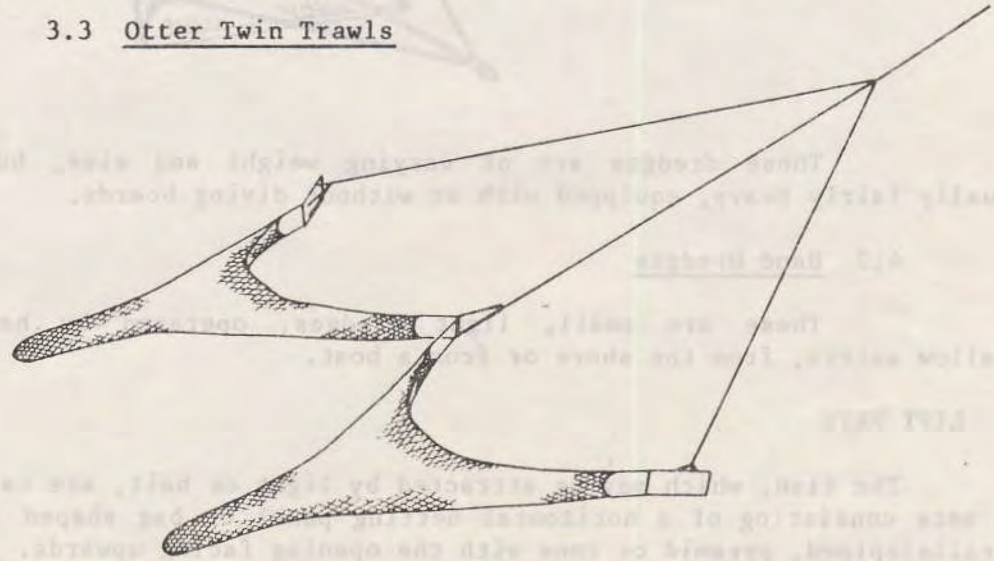
3.2.2 Mid-water pair trawls





Towed by two boats, thus ensuring the horizontal opening of the net, these nets are designed and rigged to work in mid-water. Surface trawls are also included in this category.

3.3 Otter Twin Trawls

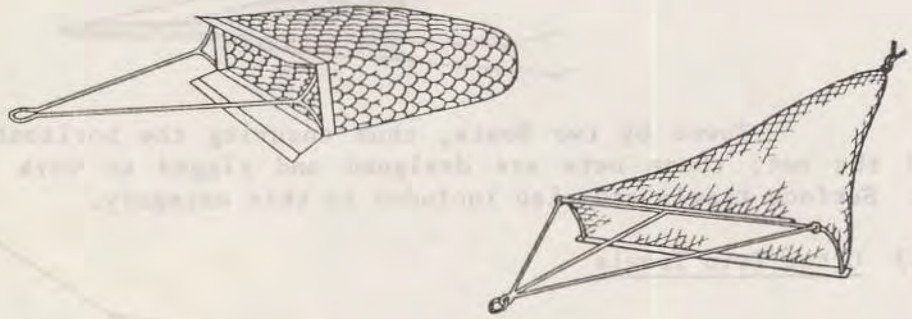


This rather peculiar gear comprises two identical trawl nets ('twin') working together, opened horizontally by a single pair of otter boards. Their inner wings are attached to a sledge towed simultaneously with the otter boards from a common crowfoot. They are generally used for catching shrimp.

4. DREDGES

These are gear dragged along the bottom, usually to collect molluscs such as mussels, oysters, scallops, clams, etc. The shellfish are held in a sort of bag or sieve which allows the water, sand or mud to run out.

4.1 Boat Dredges



These dredges are of varying weight and size, but are usually fairly heavy, equipped with or without diving boards.

4.2 Hand Dredges

These are small, light dredges, operated by hand in shallow waters, from the shore or from a boat.

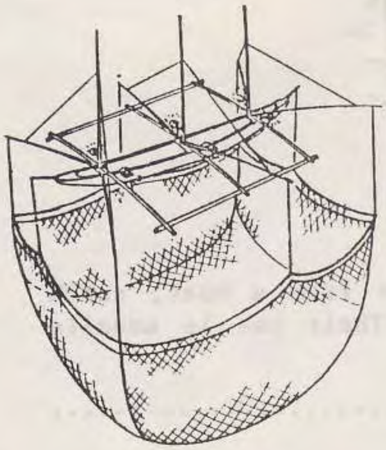
5. LIFT NETS

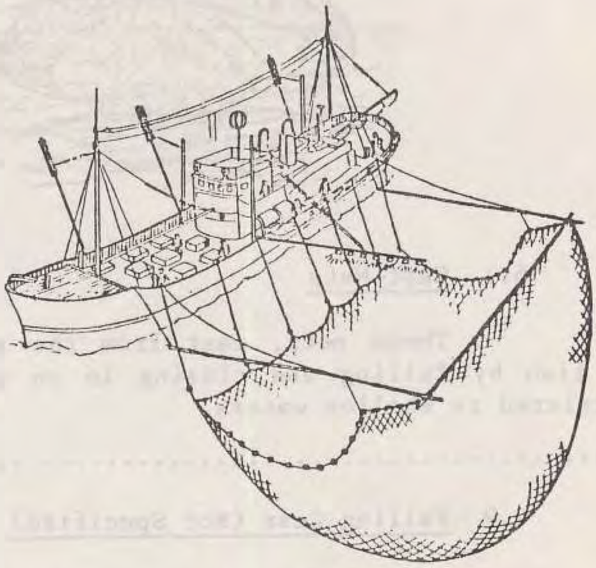
The fish, which may be attracted by light or bait, are captured in nets consisting of a horizontal netting panel or bag shaped like a parallelepiped, pyramid or cone with the opening facing upwards. After being submerged at the required depth, the nets are lifted or hauled out of the water, by hand or mechanically, from the shore or from a boat. The fish which are above the net are retained in it when the water runs away.

5.1 Portable Lift Nets

Small nets operated by hand, with no fixed installation.

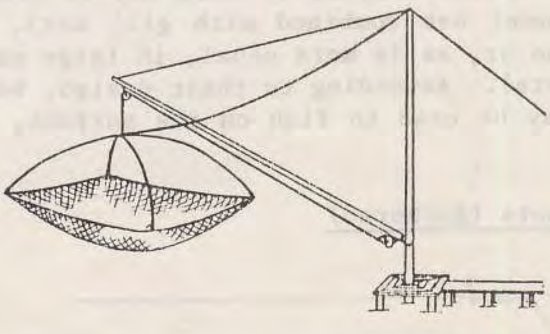
5.2 Boat-Operated Lift Nets





This group comprises the bag nets ('basnig') and the blanket nets, operated from one or more boats.

5.3 Shore-Operated Lift Nets



These lift nets are usually operated from stationary installations situated along the shore, the lifting system sometimes being mechanized.

6. FALLING GEAR

6.1 Cast Nets

These nets, cast from the shore or from a boat, catch the fish by falling and closing in on them. Their use is usually restricted to shallow waters.

....

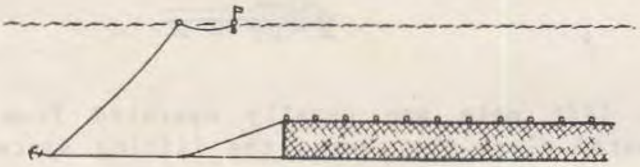
6.9 Falling Gear (Not Specified)

Cover pots and lantern nets, generally hand-operated in very shallow waters, are included in particular in this category.

7. GILL NETS AND ENTANGLING NETS

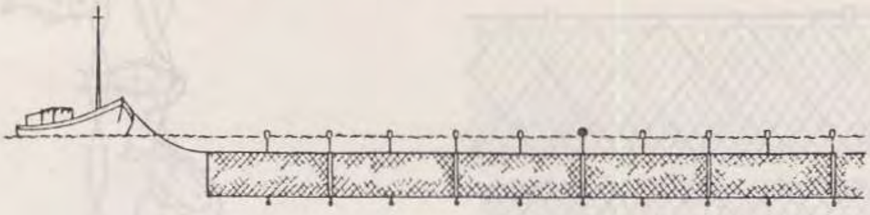
With this type of gear, the fish are gilled, entangled or enmeshed in the netting, which may be either single (gill nets) or triple (trammel nets). Several types of nets may be combined in one gear (for example, trammel net combined with gill net). These nets can be used either alone or, as is more usual, in large numbers placed in file ('fleets' of nets). According to their design, ballasting and buoyancy, these nets may be used to fish on the surface, in mid-water or on the bottom.

7.1 Set Gill nets (Anchored)



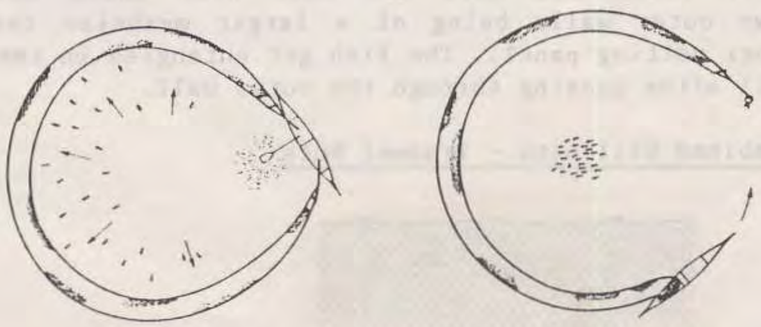
These nets are fixed to the bottom, or at a certain distance above it, by means of anchors or ballast sufficiently heavy to neutralize the buoyancy of the floats.

7.2 Drifting Gill nets (Driftnets)



Kept on the surface, or a certain distance below it, by numerous floats, these nets drift freely with the current, separately or, more often, with the boat to which they are attached.

7.3 Encircling Gill nets

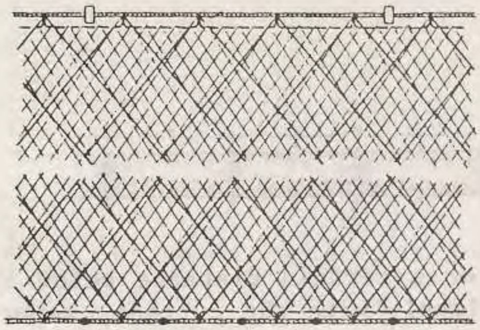


This gear is generally used in shallow water with the floatline remaining at the surface. After the fish have been encircled by the net, noise or other means are used to force them to gill or entangle themselves in the netting surrounding them.

7.4 Fixed Gill nets (On Stakes)

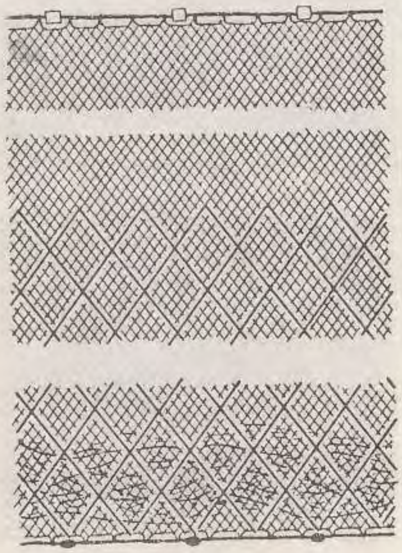
Used essentially in coastal waters, these nets are mounted on stakes driven into the bottom. The fish are collected at low tide.

7.5 Trammel Nets



These bottom-set nets are made with three walls of netting, the two outer walls being of a larger meshsize than the loosely hung inner netting panel. The fish get entangled in the inner small meshed wall after passing through the outer wall.

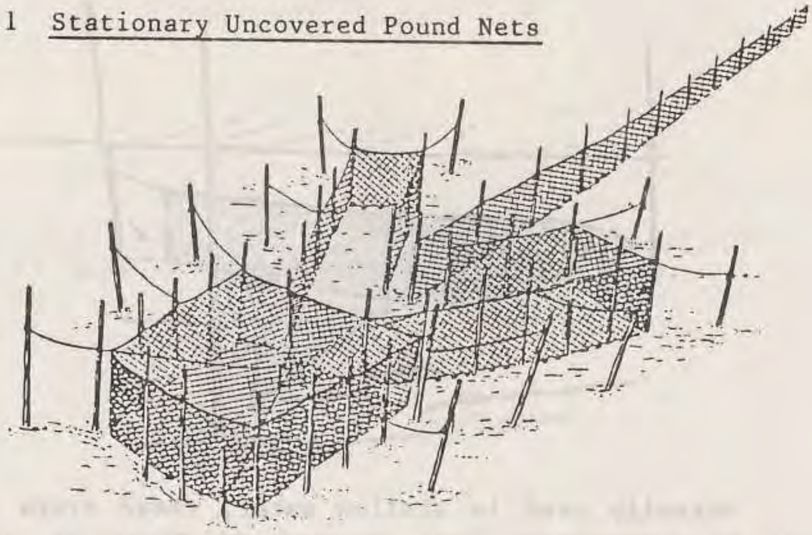
7.6 Combined Gill nets - Trammel Nets



This bottom-set gear is made with a gill net, the lower part of which is replaced by a trammel net. It may catch bottom fish in the lower trammel net part, together with semi-demersal or pelagic fish in the upper gill net part.

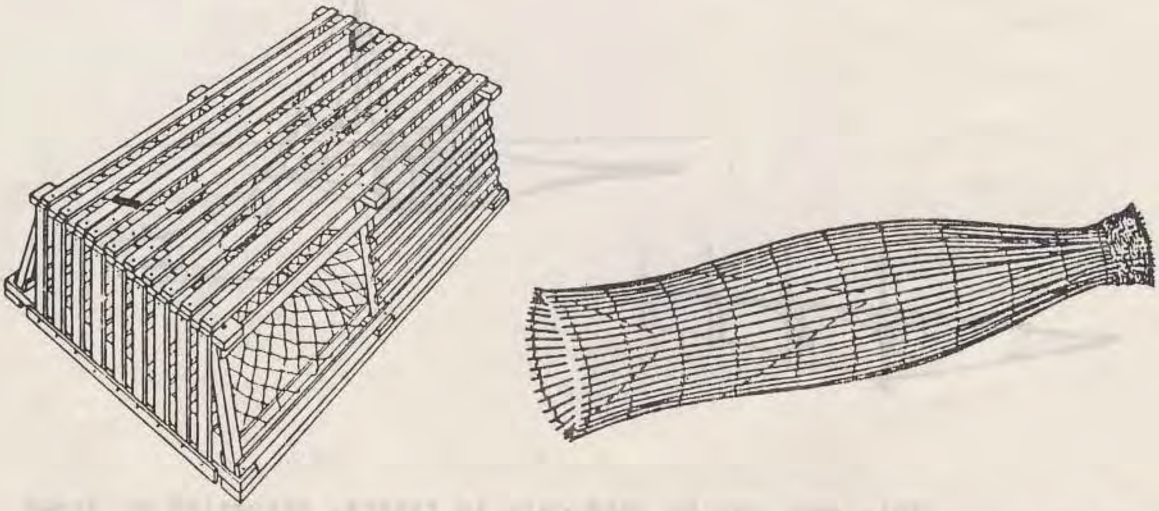
8. TRAPS

8.1 Stationary Uncovered Pound Nets



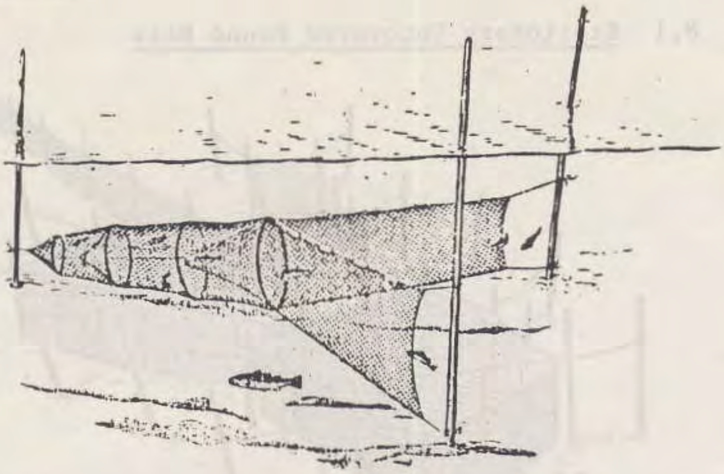
These are usually large nets, anchored or fixed on stakes, open at the surface and provided with various types of fish herding and retaining devices. They are mostly divided into chambers closed at the bottom by netting. In Japan this group is usually referred to as 'set nets' (not to be confused with the fixed gill nets referred to above).

8.2 Pots



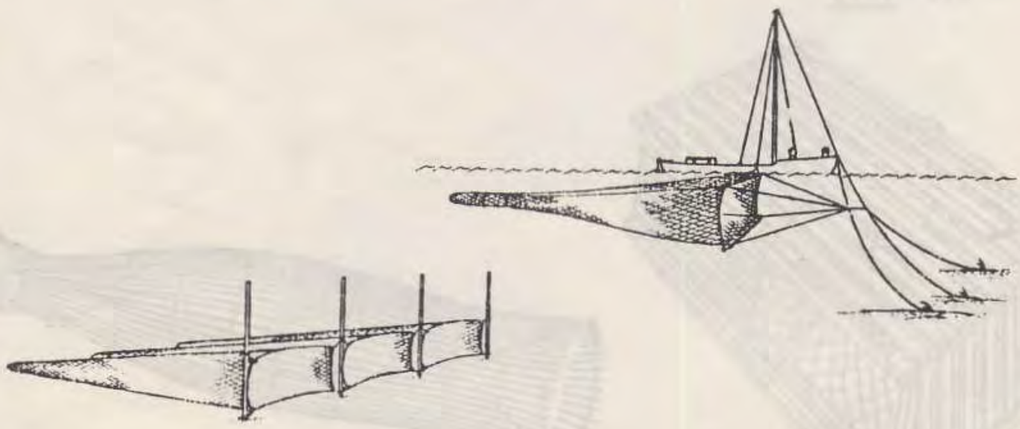
These traps, designed to catch fish or crustaceans, are in the form of cages or baskets made with various materials (wood, wicker, metal rods, wire netting, etc.) and have one or more openings or entrances. They are usually set on the bottom, with or without bait, singly or in rows, connected by ropes (buoy-lines) to buoys showing their position on the surface.

8.3 Fyke Nets



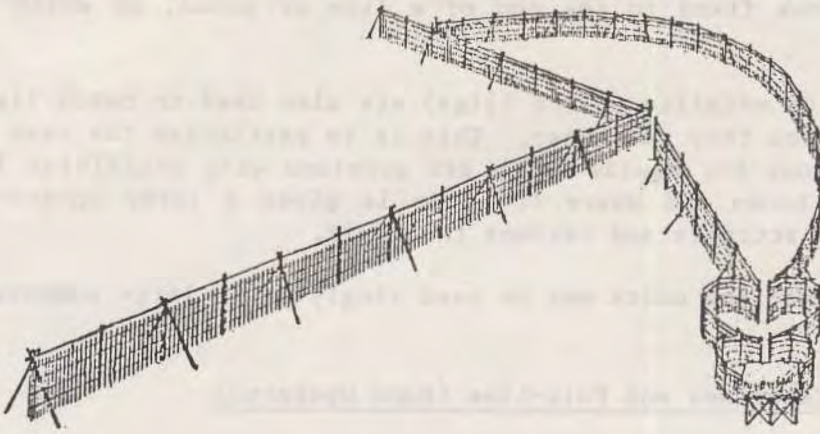
Normally used in shallow water, these traps consist of cylindrical or cone-shaped bags mounted on rings or other rigid structures, completely covered by netting and completed by wings or leaders which drive the fish towards the opening of the bags. The fyke nets, fixed on the bottom by anchors, ballast or stakes, may be used separately or in groups.

8.4 Stow Nets



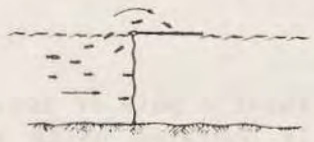
This gear can be used only in rivers, estuaries or areas with strong currents. Usually in the form of a cone or pyramid, these nets are fixed by means of anchors or stakes, placed according to the direction and strength of the current. The mouths are usually held open by a frame, which may or may not be supported by a boat.

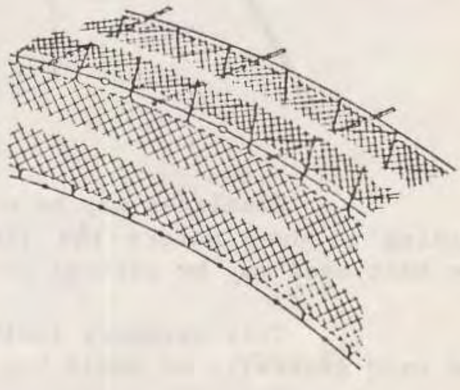
8.5 Barriers, Fences, Weirs, Corrals, etc.



Gear of this type, made of various materials (stakes, branches, reeds, netting, etc.), are usually constructed in tidal waters. They differ from the fixed gill nets (see 7.4) which, when the tide ebbs, may eventually allow the fish not entangled or gilled to pass freely underneath their bottom line.

8.6 Aerial Traps





Jumping fish (e.g., mullet) and gliding fish (flying fish) can be caught on the surface in boxes, rafts, boats and nets ('Veranda nets'). The fish are sometimes frightened to get them to jump out of the water.

9. HOOKS-AND-LINES

The fish are attracted by a natural or artificial bait (lures) placed on a hook fixed to the end of a line or snood, on which they get caught.

Hooks or metallic points (jigs) are also used to catch fish by ripping them when they pass near. This is in particular the case with the jigging lines for squids which are provided with artificial lures with multiple hooks and where the line is given a jerky up-and-down movement which attracts and catches the squid.

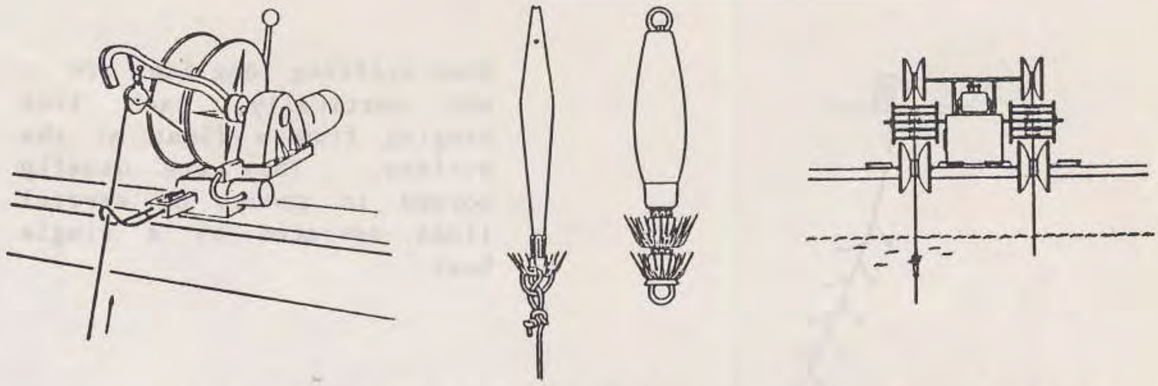
Hook-and-line units may be used singly or in large numbers.

9.1 Handlines and Pole-Line (Hand Operated)

Handlines may be used with or without a pole or rod. For fishing in deep waters the lines are usually operated using reels. The bait used may be natural or artificial.

This category includes the jigging line, operated by hand and used generally on small boats.

9.2 Handlines and Pole-Lines (Mechanized)



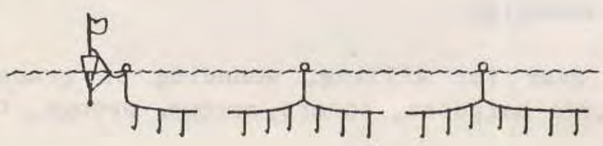
Handlines can be worked mechanically, using powered reels or drums. They are generally used on medium-size vessels, but they may also be used on relatively small boats.

Pole-lines can also be mechanized, e.g., for tuna catching, with the pole movement being entirely automatic.

9.3 Set Longlines

This category comprises bottom longlines, baited or unbaited, which are placed on or near the bottom. Bottom longlines consist of a main line, sometimes of considerable length, to which snoods are fixed at regular intervals, more or less close together.

9.4 Drifting Longlines

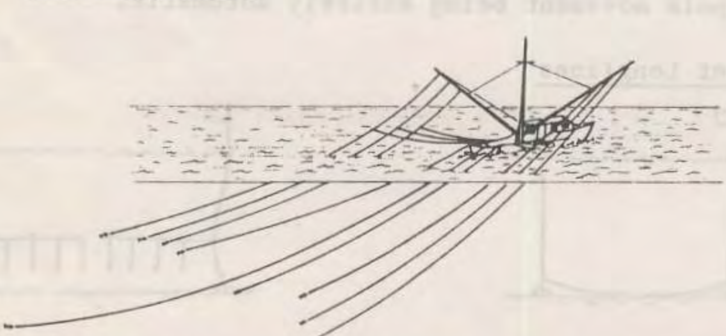


These lines are kept on the surface or at a certain depth by means of regularly spaced floats. Drifting longlines may be of considerable length, but the snoods are usually longer and more widely spaced than for the bottom longlines.

9.5 Longlines (Not Specified)

Some drifting longlines are set vertically, each line hanging from a float at the surface. They are usually worked in groups of several lines operated by a single boat.

9.6 Trolling Lines



These are simple lines, provided with natural or artificial bait and trailed near the surface or at a certain depth by a vessel. Several lines are usually towed at the same time, with the help of out riggers.

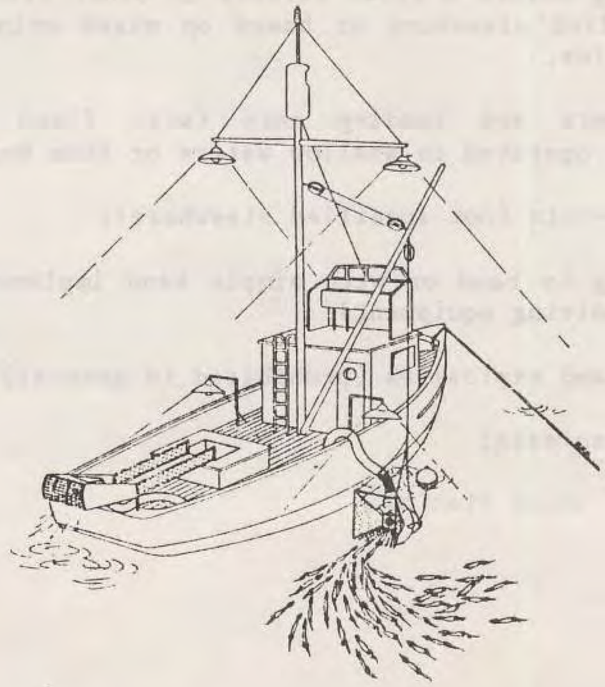
10. GRAPPLING AND WOUNDING

This is a gear for killing, wounding or grappling fish or molluscs. It includes harpoons, spears, arrows, prongs, tongs, clamps, etc.

11. HARVESTING GEAR

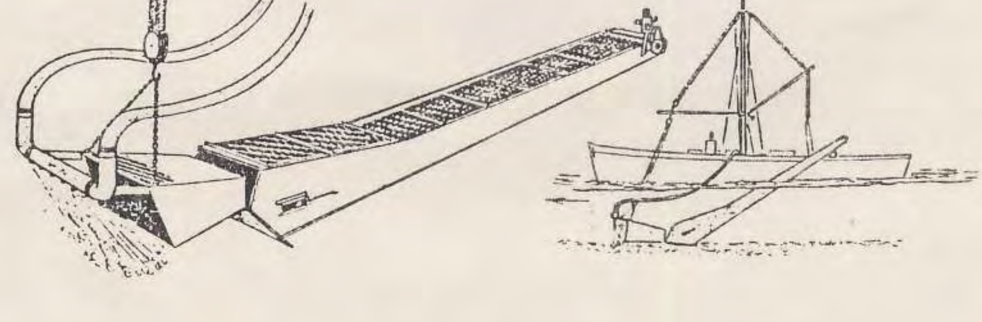
These are relatively new and highly efficient types of gear used to extract fish from the water by direct pumping or forced sifting. Their use is, however, limited to a small number of species.

11.1 Pumps



These pumps serve to catch fish, usually attracted by light; they should not be confused with the pumps used to transfer fish already caught.

11.2 Mechanized Dredges



This gear digs molluscs out of the bottom by means of powerful underwater jets. The molluscs collected are sometimes transferred into the boat carrying the dredge by a conveyor-belt type device or by suction. ....

12. MISCELLANEOUS

This heading covers a great variety of other fishing gear and methods, not specified elsewhere or based on mixed principles. The following are examples:

- scoop nets and landing nets (with fixed or variable opening, operated in shallow waters or from boats);
- drive-in-nets (not specified elsewhere);
- gathering by hand or with simple hand implements (with or without diving equipment);
- poisons and explosives (prohibited in general);
- trained animals;
- electric shock fishing.

International Standard Statistical Classification of Fishing Gear (ISSCFG) (29 July 1980)

Gear Categories	Standard Abbreviation	ISSCFG Code
SURROUNDING NETS		01.0.0
With purse lines (purse seines)	PS	01.1.0
- one-boat operated purse seines	PS1	01.1.1
- two-boat operated purse seines	PS2	01.1.2
Without purse lines (lampara)	LA	01.2.0
SEINE NETS		02.0.0
Beach seines	SB	02.1.0
- boat or vessel seines	SV	02.2.0
- Danish seines	SDN	02.2.1
- Scottish seines	SSC	02.2.2
- pair seines	SPR	02.2.3
Seine nets (not specified)	SX	02.9.0
TRAWLS		03.0.0
Bottom trawls		03.1.0
- beam trawls	TBB	03.1.1
- otter trawls1/	OTB	03.1.2
- pair trawls	PTB	03.1.3
- nephrops trawls	TBN	03.1.4
- shrimp trawls	TBS	03.1.5
- bottom trawls (not specified)	TB	03.1.9
Mid-water trawls		03.2.0
- otter trawls1/	OTM	03.2.1
- pair trawls	PTM	03.2.2
- shrimp trawls	TMS	03.2.3
- mid-water trawls (not specified)	TM	03.2.9
Otter twin trawls	OTT	03.3.0
- trawls (not specified)	OT	03.4.9
Pair trawls (not specified)	PT	03.5.9
Other trawls (not specified)	TX	03.9.0
DREDGES		04.0.0
Boat dredges	DRB	04.1.0
Hand dredges	DRH	04.2.0
LIFT NETS		05.0.0
Portable lift nets	LNP	05.1.0
Boat-operated lift nets	LNB	05.2.0
Shore-operated stationary lift nets	LNS	05.3.0
Lift nets (not specified)	LN	05.9.0

1/ Fisheries agencies may indicate side and stern bottom and stern mid-water trawls, as OTB-1 and OTB-2, and OTM-1 and OTM-2, respectively.

Gear Categories	Standard Abbreviation	ISSCFG Code
FALLING GEAR		06.0.0
Cast nets	FCN	06.1.0
Falling gear (not specified)	FG	06.9.0
GILLNETS AND ENTANGLING NETS		07.0.0
Set gillnets (anchored)	GNS	07.1.0
Driftnets	GND	07.2.0
Encircling gillnets	GNC	07.3.0
Fixed gillnets (on stakes)	GNF	07.4.0
Trammel nets	GTR	07.5.0
Combined gillnets-trammel nets	GTN	07.6.0
Gillnets and entangling nets (not specified)	GEN	07.9.0
Gillnets (not specified)	GN	07.9.1
TRAPS		08.0.0
Stationary uncovered pound nets	FPN	08.1.0
Pots	FPO	08.2.0
Fyke nets	FYK	08.3.0
Stow nets	FSN	08.4.0
Barriers, fences, weirs, etc.	FWR	08.5.0
Aerial traps	FAR	08.6.0
Traps (not specified)	FIX	08.9.0
HOOKS-AND-LINES		09.0.0
Handlines and pole-lines (hand operated)1/	LHP	09.1.0
Handlines and pole-lines (mechanized)1/	LHM	09.2.0
Set longlines	LLS	09.3.0
Drifting longlines	LLD	09.4.0
Longlines (not specified)	LL	09.5.0
Trolling lines	LTL	09.6.0
Hooks-and-lines (not specified)2/	LX	09.9.0
GRAPPLING AND WOUNDING		10.0.0
Harpoons	HAR	10.1.0
HARVESTING MACHINES		11.0.0
Pumps	HMP	11.1.0
Mechanized dredges	HMD	11.2.0
Harvesting machines (not specified)	HMX	11.9.0

1/ Including jigging lines

2/ Code LDV for dory-operated line gears will be maintained for historical data purposes

Gear Categories	Standard Abbreviation	ISSCFG Code
MISCELLANEOUS GEAR[1/]	MIS	20.0.0
RECREATIONAL FISHING GEAR	RG	25.0.0
GEAR NOT KNOWN OR NOT SPECIFIED	NK	99.0.0

1/ This item includes: hand and landing nets, drive-in-nets, gathering by hand with simple hand implements with or without using diving equipment, poisons and explosives, trained animals, and electric shock fishing methods.

II. FISHING GEAR MATERIALS

1. INTRODUCTION

Fishing gear materials are a branch of fishing gear technology in which we study fish catching methods scientifically. Fishing gear materials can be considered the various materials used in the construction of the different kinds of fishing gear.

We have to consider the twines used to make nets and lines, the different kinds and types of ropes, and the materials employed in weights, floats and other ancillary parts of fishing gear.

However, here we will cover mainly twines and ropes, because the major share of the catch today is by nets and lines, and they are basically made up of twines and ropes.

When fishermen plan to go fishing with a certain kind of fishing gear they must first understand and assess the performance and behavior of the gear.

It is a fact that by far the greater part of most types of fishing gear is made up of ropes and netting with the exception of the miscellaneous fishing implements such as hooks, poles, synthetic gut, spears, traps, gaffs and so on.

Both ropes and netting twines are made up of textile fibres which are spun and woven to produce a line of the required thickness and texture.

Textile fibre for fishing is made from both plants and animals. However, those which are produced by artificial processes in factories are called man-made or synthetic fibres.

Since synthetic fibres were invented, natural fibres have more or less been replaced by synthetic ones in the greater part of fishing gear. There are a large number of synthetic fibres, but the ones used mostly in commercial fishing are as follows:

The scientific names of synthetic fibre	Trade/commerical brand names
(1) NYLON	AMILAN, CAPRON
(2) POLYESTER	TETORON, TERYLENE
(3) VINYLON	CREMONA, KURALON
(4) VINYLIDEN	KREHALON, SARAN
(5) POLYETHYLENE	HI-ZEX
(6) POLYPROPYLENE	TOPLON, PHYLENE
(7) VINLY CHLORIDE	TEVIRON, ENVILON

For convenience's sake both the commercial and scientific names has been listed since the trade names vary with the different manufacturers.

These synthetic fibres are more costly to produce than natural fibres, but since they are mostly stronger, easy to handle and do not rot without treatment, fishermen prefer them to the natural fibres, because natural fibre ropes have to be treated with preservatives to improve their strength and durability and to prevent or delay their weakening due to the rotting effect of bacteria. They must also be dried before storing for any length of time. If fish slime and/or dead fish are entangled in the nets or ropes they must be washed off.

The usual method of preservation is simply to soak the rope or netting in a solution of preservative substance for a set period of time.

Synthetic fibres are not susceptible to rot but they are affected by sunlight and must not be exposed to it over prolonged periods. Coloring by special dye affords some protection from sunshine. Sometimes a preparation is used to help add stiffness to the twines, or to eliminate knot slippage. When making nets fishermen are trying to dye netting a special colour to increase net catching efficiency.

Characteristics of these fibres differ to a certain extent in regard to tenacity, elasticity and reaction to heat.

2. CLASSIFICATION

(1) Due to raw materials:

Raw materials to be used for fishing gear are roughly classified as follows:

i. Organic materials

- o Natural fibre
- o Synthetic fibre
- o Synthetic resin
- o Rubber
- o Wood, cork
- o Bamboo

ii. Metallic materials

- o Iron
- o Lead
- o Copper
- o Brass
- o Others (Tin, Chromium, etc.)

iii. Nonmetal-inorganic materials

- o Concrete
- o Glass
- o Stone
- o Ceramic

Of the above materials, textiles comprise the main constituent of the fishing gear materials used as netting twine, netting and ropes. Although, formerly, wood and bamboo were used for floats and/or fishing poles a synthetic resin has replaced them recently. As for metallic materials, iron and lead are mainly used for fishing hooks, wire leaders, wires and sinkers and also iron is used for iron floats. Of the other materials, a concrete mass is used for sinkers/anchors, ceramic for sinkers, glass for floats, rubber for bobbers and shock absorbers, and wood and cork for floats.

There are now many types, varieties and modified fishing gears used in the world since fishing or fish catching has been pursued since prehistoric times by mankind. However, according to statistical reports of catches, it is obvious that comparatively few types of net and line gears take the major share (about 90%) of the catch. These net and line gears are mainly made up of synthetic fibres.

(2) Due to construction of fishing gear

i. Net fishing gear

- o Fibre/Twine/Rope/Netting
- o Wire/wire rope/Wire netting
- o Accessories (Buoy, Ring, Float, Anchor, Sinker, Chain)

ii. Line fishing gear

- o Fibre/Twine/Rope
- o Wire
- o Accessories (Buoy, Float, Anchor, Sinker, Chain, Hook, Lure, Jig, Snap, Swivel, Shock-absorber, Diving board, Fishing rod, Balance, Ring, Fishing lamp (small attraction lamp)

iii. Miscellaneous fishing gear

- o Fibre/Twine/Rope/Netting
- o Wire/wire rope/wire netting
- o Accessories (Same as the above mentioned accessories for Line fishing gear).

- Textile Fibre
  - Chemical Fibre (Man-made Fibre)
    - Regenerated Fibre
      - Rayon — Viscose rayon
      - Cupra — Cuprammonium rayon
    - Semi-synthetic Fibre
      - Acetate
      - Acetate oxide
    - Synthetic Fibre
      - Poly Amid
        - Nylon 6 — (Asahikasei-Nylon, Kureha-Nylon, Toray-Nylon, Unichika-Nylon, Teijin-Nylon)
        - Nylon-66 — (Du Pont-Nylon)
        - Nylon-11 — (Rilsan)
        - Nylon-610 — (Du Pont-Nylon)
      - Poly Vinyl Alcohol (Cralon, Kuremona), Unichika-vinylon
      - Poly Vinyliden chlorid (Saran, Kurehalon, Rovana, Velon)
      - Poly Vinyl chlorid (Teviron, Envilon, Rohvyl, Movil)
      - Poly Ester (Tetoron, Terylen, Dacron, Vycron, Kodel, Crafter)
      - Poly Ethylene (Kanerite, Ethylon, Bellex, Hi-zex, Sanline, Toron)
      - Poly Propylene (Phylen, Danline, Meraklon)
      - Poly Acrylic (Orlon, Kanekalon, Vonnel)
      - Poly Urethane (Lycra, Vyrene)
      - Poly Fluorethylene (Teflon)
    - Inorganic Fibre
  - Natural Fibre
    - Vegetable Fibre (Cotton, manila hemp, jute)
    - Animal Fibre
    - Mineral Fibre

Fig. 1. Classification of Fibre used for Net and Ropes

3. CONSTRUCTION OF TWINE AND ROPE

3.1 When considering twines or ropes from the point of view of their construction, they are classified as follows:

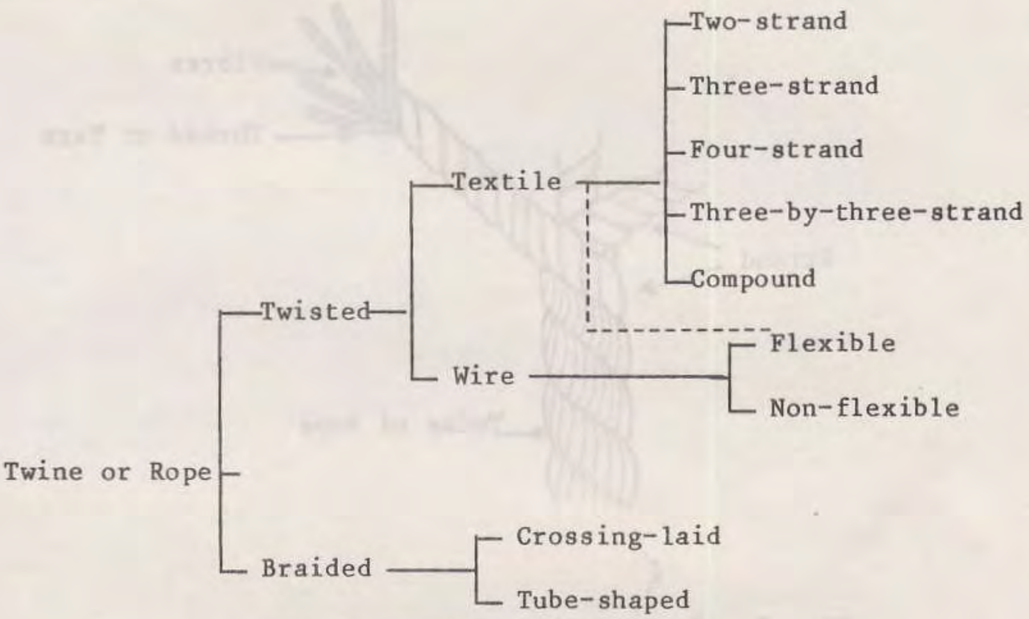


Fig. 2. Classification of twine or rope

3.2 Most twines and ropes belong to the twisted variety, and are composed of a certain number of threads or strands twisted together, each thread of strand being made of the same fibre.

Braided twines are made by plaiting several threads or strands together.

The term "twine" means comparatively fine twist, while for heavy twist of over 3 millimetres in diameter, the term "rope" is used. For heavier ropes of over 40 millimetres in diameter the term "cable-laid rope" is sometimes used.

3.3 The following is a schematic diagram showing the construction of twisted twine or rope:

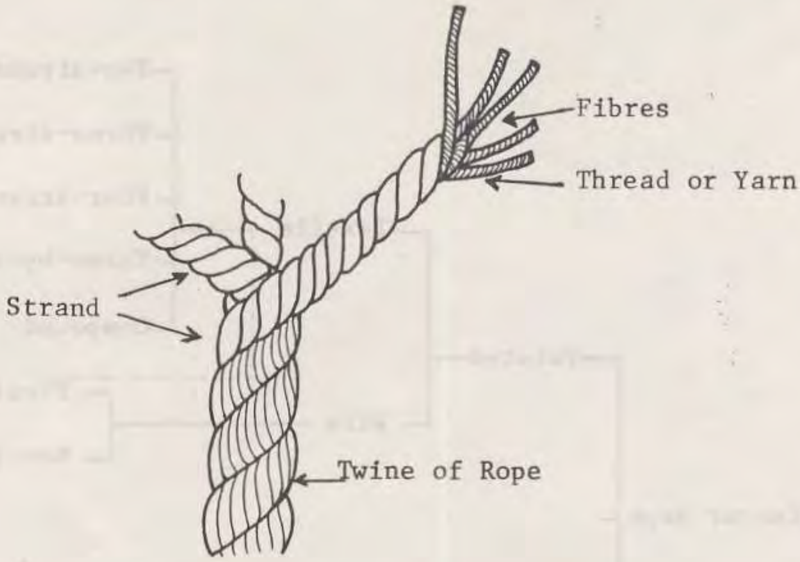


Fig. 3. Construction of twine or rope

According to the number of strands used to make twine or rope, the terms: (a) two-, three- and four-strand twine or rope are used. In making the three-by-three-strand, three small three-strand twines or ropes are twisted together to make a larger three-strand one. Compound twist is made up of textile fibre and wire. There are two kinds of compound twist: (b) one is three-strand rope enclosing a single wire, and the other has a single wire in each strand. Wire rope manufacture is basically the same as that of compound rope, except that it is made almost entirely of wire. The core used is either hemp or metal. When constructed with one or more hemp cores in order to be flexible, it is called a "flexible wire rope". When constructed with one or more metal cores, it is called "non-flexible wire rope".

Most twisted netting twines and ropes are three-strand. For tuna longline fishing three-by-three-strand twist is generally used. Compound ropes are used mainly in trawling. Non-flexible wire ropes are used for the frame line of fixed nets or trap nets, while flexible wire ropes are employed in the purse line of purse seines and the warp of trawl nets.

3.4 There are two types of braided twine or rope. One is produced by plaiting two strands or four strands together, and is called "crossing-laid". The other is made by knitting together several strands into a tube-shaped twine and is called "tube-shaped braided". This is used in line or heavy twine construction. Comparatively heavier twines of this type are sometimes made with their center space packed full of bundled fibres like a compound rope.

The following is a schematic diagram showing the construction of braided twine and rope:

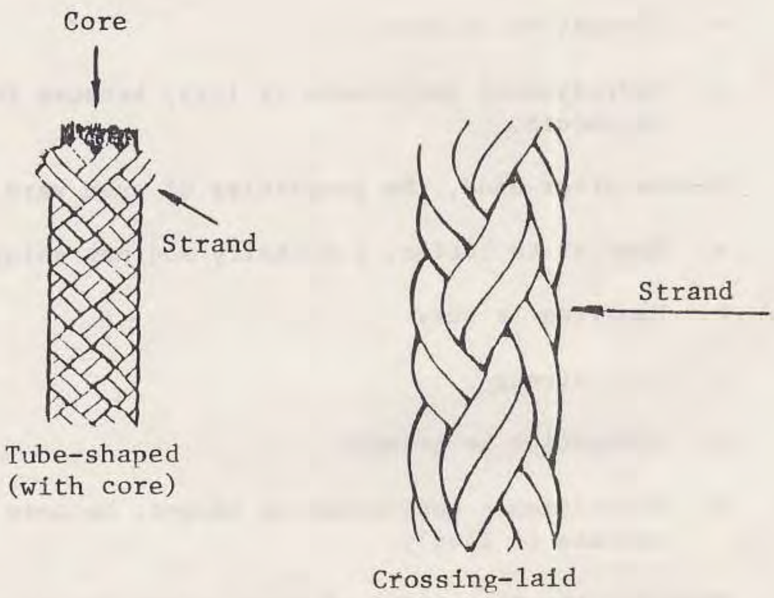


Fig. 4. Construction of braided twine and rope

3.5 In tube-shaped braided twine, the interstices are wider than those of twisted twine, therefore it is expected that the water resistance of tube-shaped braided twine is greater than that of twisted twine. However, it has the advantage of not twisting or "kinking" as sometimes happens with twisted twine.

3.6 There are different kinds of thread of yarn, which make up twine or rope, as follows:

- Thread or Yarn
  - Continuous
    - Multifilament
    - Monofilament
  - Staple or Spun

Most synthetic twines or ropes are made of continuous filament yarns, however, a few are made of staple yarns. All vegetable twists are made of staple yarns. A monofilament yarn is seldom used for making fine netting twine. It is used only for comparatively heavier twines or ropes.

3.7 Continuous filament yarn has the following properties:

a. Shiny and lustrous appearance

b. Very strong

c. Elongation is less

d. Hydrodynamic resistance is less, because the surface is smooth.

On the other hand, the properties of spun yarn are:-

a. Similar to cotton, i.e. hairy and not shiny

b. Handling is easy

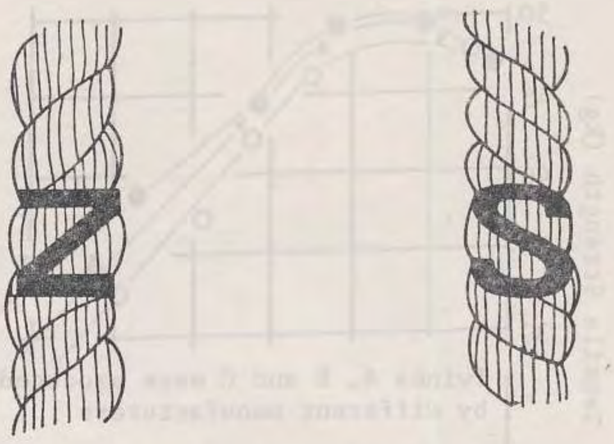
c. Less strong

d. Elongation is greater

e. Hydrodynamic resistance is larger, because the surface is fluffy.

3.8 Usually, the directions of twist given the strand and the twine are contrary to each other. The direction of twist in twine or rope is generally clockwise, and is called "Z" type. If the twist is anticlockwise it is called "S" type.

Cotton fibre possesses a natural "Z" type twist. Because of this it is easier to make the strands with "Z" twist when using cotton. Then the completed twine will have an "S" type twist. To make cotton strands with the opposite twist to its natural type would result in a weaker twine. Experiments show that the strength of cotton "S" twisted twine is about 10% better than "Z" twisted.



Clockwise "Z" Twist

Anticlockwise "S" Twist

Fig. 5.

3.9 The number of twists will be indicated by the numerical value of turns per unit length, e.g. turns per metre, turns per inch, etc. In the case where the number of twists in both strand and twine balance each other, the tensile strength of the twine is at its maximum.

3.10 To summarize, additional twist in twine has the following effects:

a. Breaking strength is reduced

b. Elongation at break is increased

c. Length per weight is reduced

d. Resistance to abrasion and normal wear is improved.

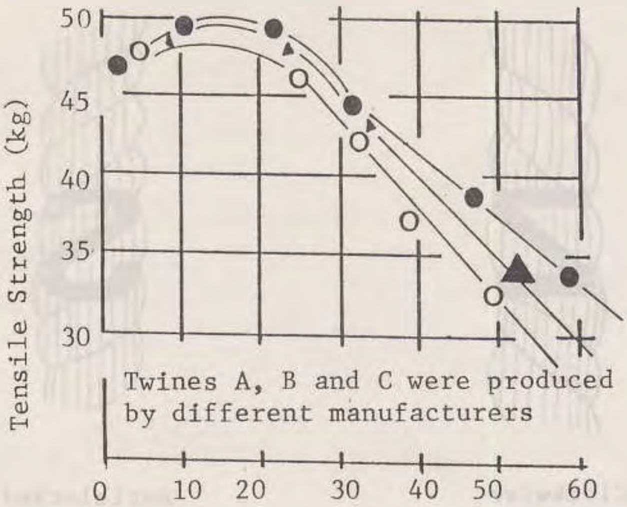


Fig. 6. Number of twists for twine per 30 cm.

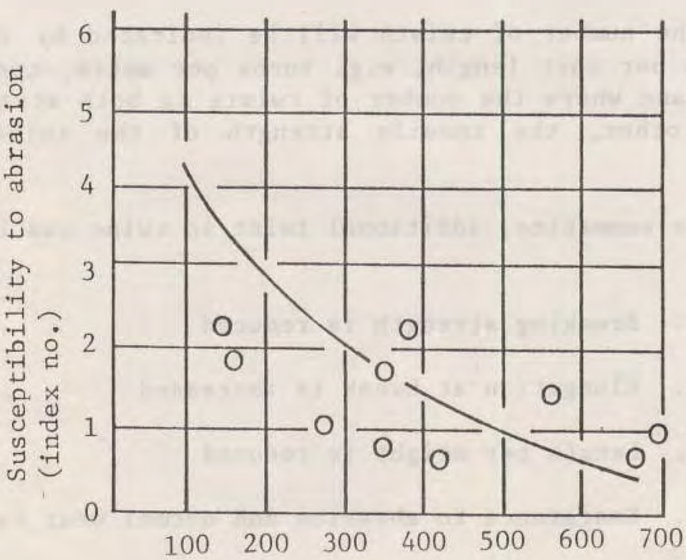


Fig. 7. Difference between the amount of twists in strand and twine per 30 cm.

3.11 However, for mass production one standard is adopted for all netting twines manufactured in a factory. The twine is a compromise of the characteristics most generally in demand and the economic production possibilities.

Currently, four degress of hardness: soft, medium, medium-hard and hard are commonly used in twine manufacture. Most fishing nets are made from medium-laid twine. Sometimes, hard-laid is used in the portions of the net most subjected to strain or abrasion. Lacing twine is often hard-laid.

4. SIZE OF TWINE OR ROPE

4.1 The classification of the different sizes of twine or rope is very complicated because the terms used appear to vary depending on the manufacturer, raw material and locality. However, it may be summarized as follows:

Twine or Rope
- Fine Twine ← Yarn size + Twine construction
- Heavy Twine ← Weight per length of length per weight
- Rope ← Diameter or circumference

4.2 The size of most fishing twine is commonly shown together with the size of yarn used in making up the twine and the classification of the construction of the twine, e.g. 120D/5/3. The first part of the specification, 120D, signifies the yarn size. The following figures, 5/3, show the construction of the twine, that is 5 yarns per strand, 3 strand construction. The yarn size is classified by either the weight per length or the length per weight. The D, of 120D means international denier numbering, in which the unit is a yarn of such a size that 9,000 metres of it weigh one gram. 120D is a yarn, 9,000 metres of which, would weigh 120 grams. Other numbering, systems used extensively include English numbering and Tex numbering. In the English numbering system, for which symbols S, 'S, /S or Nec are used, one unit is a yarn of such a size that 840 yards of it weigh one pound, 20S shows that one pound of this yarn would be 840 x 20 = 16,800 yards long. Tex numbering expresses the mass in grams for a unit length of 1,000 metres of yarn. 30 Tex yarn is a yarn 1,000 metres of which would weigh 30 grams. Therefore, in the denier and Tex numberings the runnage becomes larger as the thickness of the yarn increases, while in English numbering the runnage is in inverse proportion to the thickness of the yarn.

For hemp, manila, flax etc., another English numbering system is used, often called the English linen count, in which the runnage is always 2.8 times the English cotton count (English cotton numbering). English cotton numbering is used for cotton and synthetic spun yarn, e.g. spun nylon, vinylon, etc. International denier numbering is used for silk and synthetic continuous filament yarn. Tex numbering is used for all kinds of yarn.

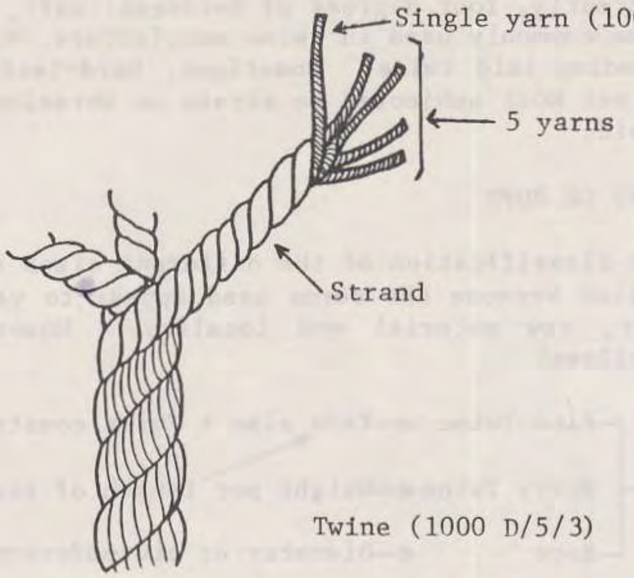


Fig. 8. Construction of 1000 D/5/3 twine

4.3 The main classifications of yarn size are as shown below, where the measurements are indicated either by the length per weight or the weight per length.

Material	System	Classification	Measurement
Cotton, synthetic spun yarn	English	Number (S, 'S, /S, Nec)	Yards per ℓb/840
Flax, Hemp Ramie, etc.	English	Lea Number (Nel)	Yards per ℓb/300
Silk, continuous filament synthetic yarns	Denier	Number (D, d, Td)	9000/metres per gram
All	Tex	Number	1000/metres per gram

4.4 The conversion figures among the notations indicating the yarn size are shown below:

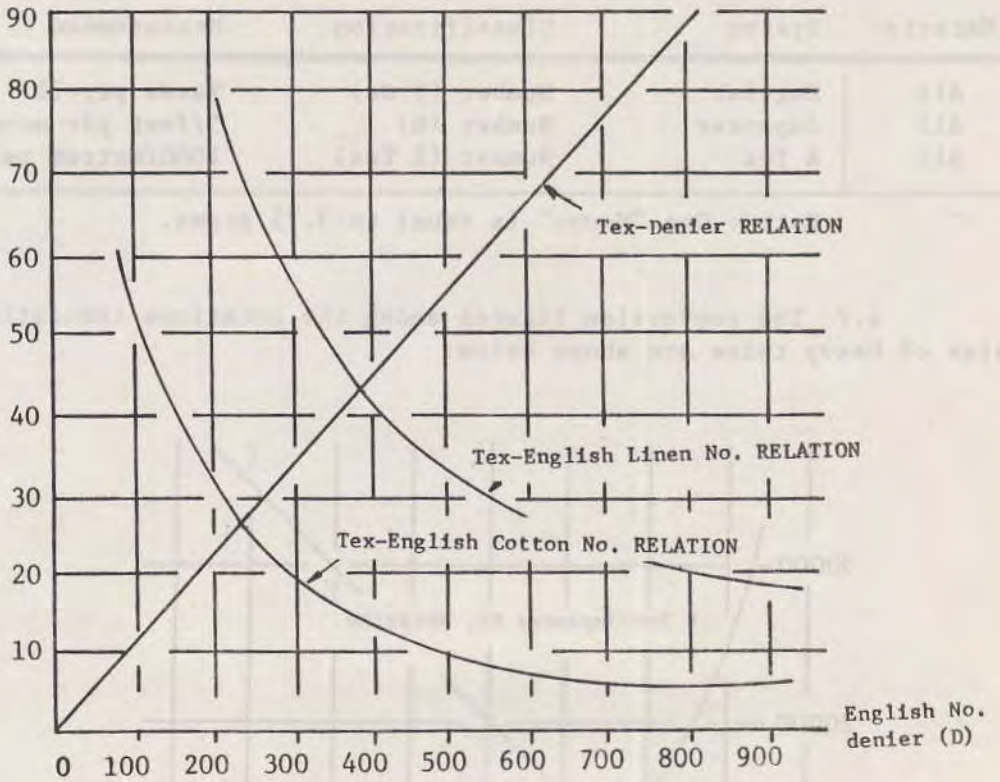


Fig. 9. Conversion figures among the notations indicating the yarn size

4.5 The size of heavy twine is usually shown by either the weight per length or the length per weight of the completed twine. This can be specified in three ways. One is the English system, in which the size is indicated by the length of twine in yards per pound. A 150-yard twine in this method shows a twine of such size that 150 yards of it weigh one pound. Another is the Japanese system, in which the size is shown by the weight of twine in monme units (one monme is equal to 3.75 grams) per 5 feet in length. Thus, 3 monme twine is a twine of such size that 5 feet of it weigh 3 monmes, that is 3 x 3.75 = 11.25 grams. The third is the R Tex system, in which the size is expressed by the weight in grams for a unit length of 1,000 metres of twine. 500 R Tex twine means a twine of such a size that 1,000 metres weigh 500 grams. In the first system the runnage becomes larger, as the thickness of the twine decreases. In the second and third systems the runnage becomes larger as the thickness increases.

4.6 The classification of size for heavy twine as adopted for all types of material, is summarized below:

Material	System	Classification	Measurement
All	English	Number (Y ds)	Yards per *lb*
All	Japanese	Number (M)	5/feet per monme
All	R Tex	Number (R Tex)	1000/metres per gram

Note : One "Monme" is equal to 3.75 grams.

4.7 The conversion figures among the notations indicating the size of heavy twine are shown below:

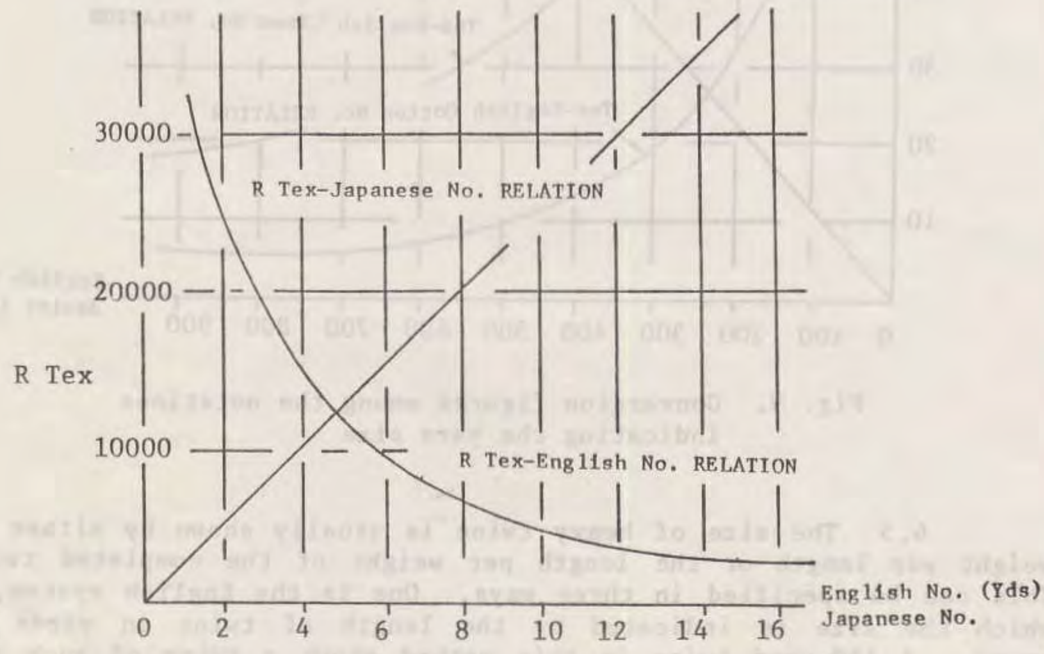


Fig. 10. Conversion figures among the notations indicating the size of heavy twine

4.8 Note that all size measurements of twine express basically either the length per weight or the weight per length. It is, therefore, impossible to use them to compare the thickness of twines of different material. The difference in the specific gravity of twine produces variations in diameter even if the yarn size used and twine construction are the same. The apparent diameter of twine possessing a large specific gravity is smaller than that of light twine of the same runnage. The diameter of twine also varies with its composition, i.e., whether it is made of continuous filament yarn or of staple yarn. Naturally the latter has a larger diameter than the former. It is needless to say that finer twine has less water resistance.

4.9 The rope size is shown by either the diameter or circumference of the rope, and such values are expressed in millimetres or inches. Because this measurement is very distinct, confusion never occurs.

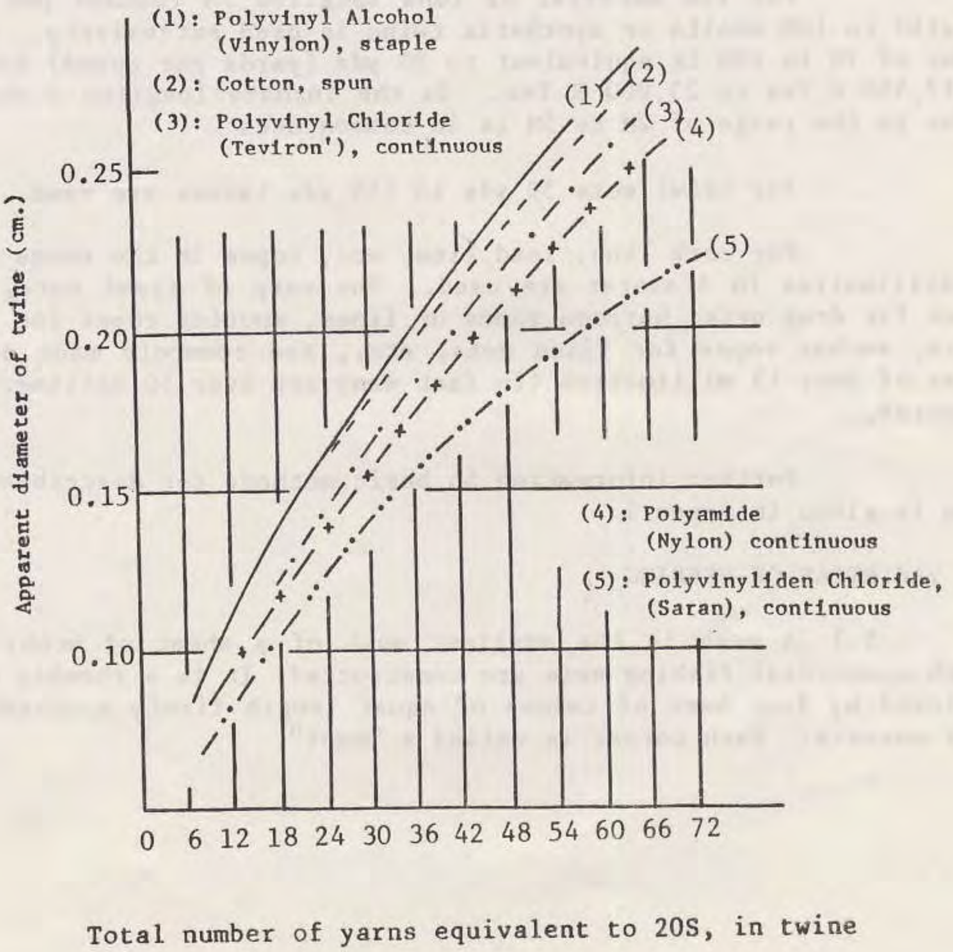


Fig. 11. Rope sizes

4.10 Broadly speaking, a thread of 20'S is used for netting twine. Occasionally 10'S is used. Smaller thread such as 30'S and 40'S is not used in ordinary commercial fishing nets. Synthetic yarns in the range of 170D to 300D (equivalent of 20 Tex to 30 Tex) are commonly used for fishing twines.

A yarn of 1,000D (equivalent to 111 Tex and 5'S) is used mainly where manila twine and rope is being employed or where thicker cotton twine of over 20'S by 60-ply (20/S/60 or 20/S/20/3) is being used.

When cotton ranging between 20/S/60 and 20/S/30 is used, and if more elasticity is desired, 120D multifilament may be used.

For the material of tuna longline 7M (monmes per 5 feet length) to 10M manila or synthetic twine is used extensively. A heavy twine of 7M to 10M is equivalent to 30 yds (yards per pound) to 20 yds or 17,500 R Tex to 25,000 R Tex. In the inshore longline fisheries a twine in the range of 2M to 5M is in common use.

For trawl nets 50 yds to 160 yds twines are used.

For cork line, lead line, etc, ropes in the range of 5 to 20 millimetres in diameter are used. The warp of trawl nets, towing lines for drag nets, harpoon ropes or lines, mooring ropes for fishing boats, anchor ropes for fixed nets, etc., are commonly made of heavy ropes of over 15 millimetres (in fact many are over 50 millimetres) in diameter.

Further information on basic methods for describing twine size is given in Annex 1.

5. VARIETIES OF WEBBING

5.1 A mesh is the smallest unit of a sheet of webbing from which commercial fishing nets are constructed. It is a rhombic opening enclosed by four bars of twines of equal length firmly knotted at the four corners. Each corner is called a "knot".

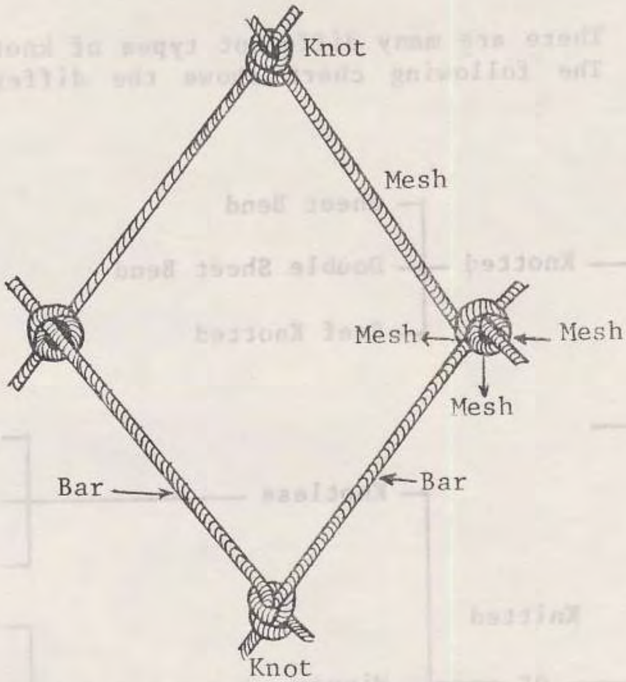


Fig. 12. Knotted Webbing

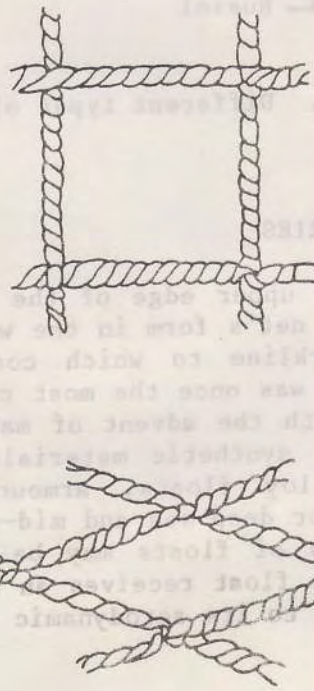


Fig. 13. Knotless Type

5.2 There are many different types of knots used in net construction. The following chart shows the different types used in webbing.

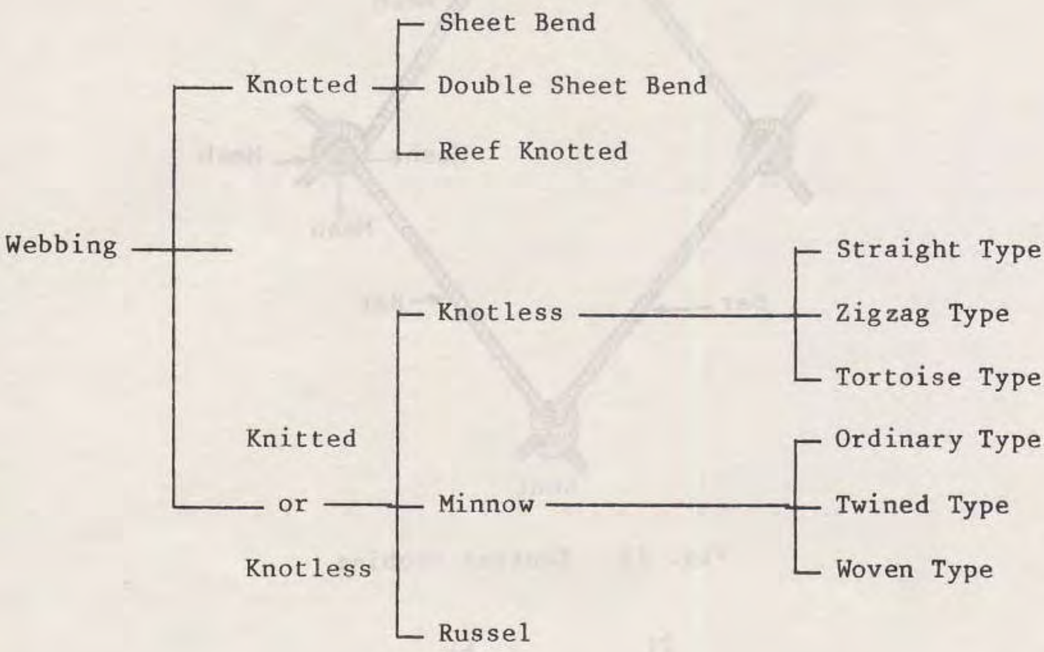


Fig. 14. Different types of webbing

6. FISHING GEAR ACCESSORIES

6.1 To keep the upper edge of the net at the surface or to maintain effectively the net's form in the water, the webbing is hung from a headrope or corkline to which corks or other floats are attached. Ordinary wood was once the most common material from which floats were made, but with the advent of materials such as synthetic rubber and polyethylene, synthetic materials are increasingly used. Sometimes, aluminium alloy floats, armoured steel floats, glass floats, etc., are used for deep-sea and mid-water fishing. For trawl nets some modified types of floats may be used. With the forward movement of the boat, the float receives an upward thrust against the force of the water, owing to its aerodynamic shape.

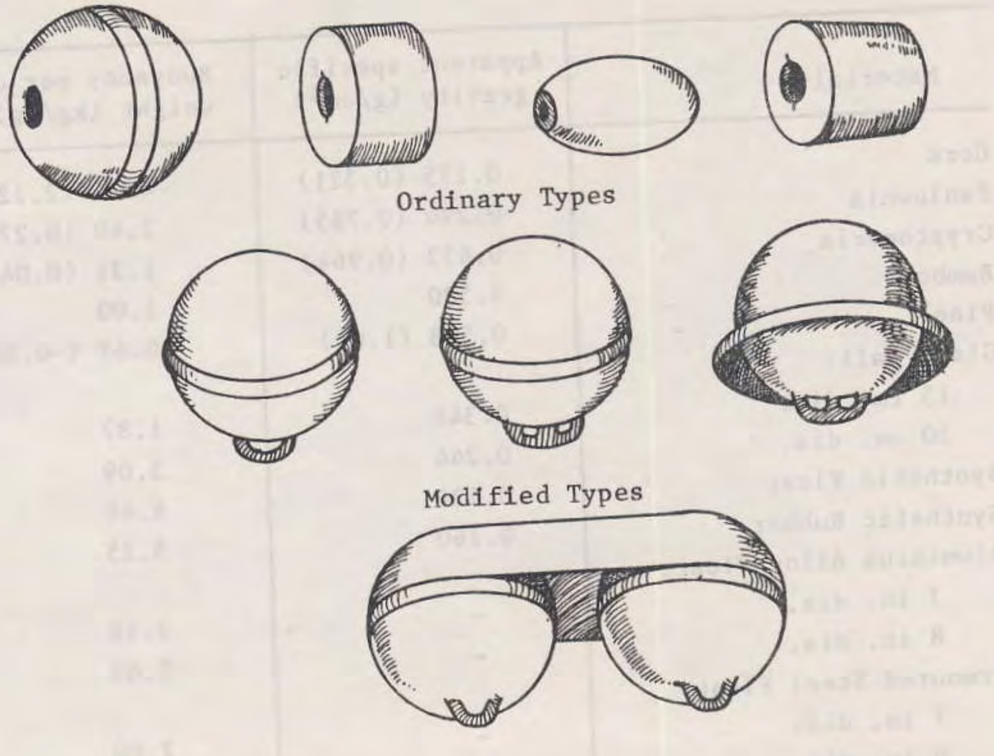


Fig. 15. Floats

Although their lift forces are dependent on the towing speed and their own shape, experiments have shown that they are of 5 to 8 times their own static buoyancies at normal towing speed, i.e. 2 to 3 knots.

6.2 The static buoyancy of floats of different materials are listed as follows:

Table 1. Buoyancy of floats of different materials

Material	Apparent specific gravity (g/cm^3)	Buoyancy per unit weight (kg/kg)
Cork	0.175 (0.321)	4.71 (2.12)
Paulownia	0.294 (0.785)	2.40 (0.27)
Cryptomeria	0.432 (0.964)	1.31 (0.04)
Bamboo	0.500	1.00
Pine	0.598 (1.09)	0.67 (-0.08)
Glass Ball:		
15 cm. dia.	0.348	1.87
30 cm. dia.	0.244	3.09
Synthetic Float	0.134	6.46
Synthetic Rubber	0.160	5.25
Aluminium Alloy Float:		
7 in. dia.	-	2.16
8 in. dia.	-	2.49
Armoured Steel Float:		
7 in. dia.	-	2.00
8 in. dia.	-	2.24
10 in. dia.	-	3.47

Note: Figures in parenthesis denote the value after 30 days left in the water, e.g. the buoyancy of cork of 1 kg, weight is 4.71 kg. but it decreases to 2.12 kg. after 30 days in the water.

6.3 To hold the fishing gear at a certain depth and mark the position of the gear set, various buoys are used. Wooden barrels or drums, logs, glass balls or hollow iron balls, etc., are used as buoys.

6.4 The sinkers fixed on the bottom edge of a net help to give it a suitable sinking speed and maintain the proper net shape by exerting a force opposite to that of the floats. Lead, stone, porcelain and concrete are typical materials used to make sinkers for ordinary use, while metal anchors or sand bags are sometimes employed for sinking large fixed nets. For roundhauls and trawl nets a footrope or lead line weighted with chain may be used. For drift nets a footrope made of wires and textile fibres, i.e. compound rope, is sometimes used.

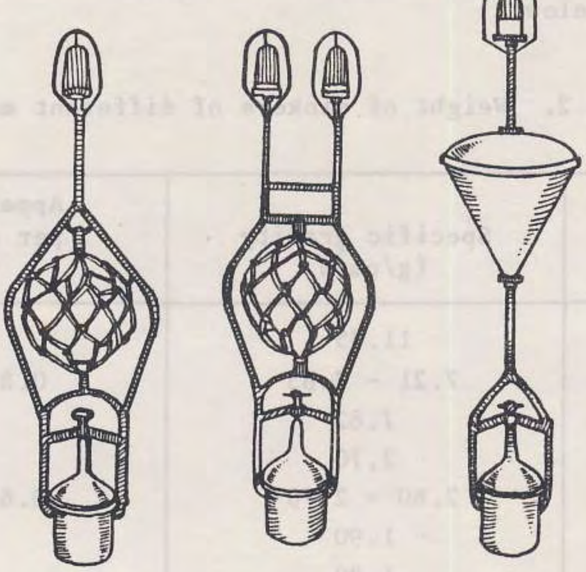


Fig. 16. Varieties of Buoys

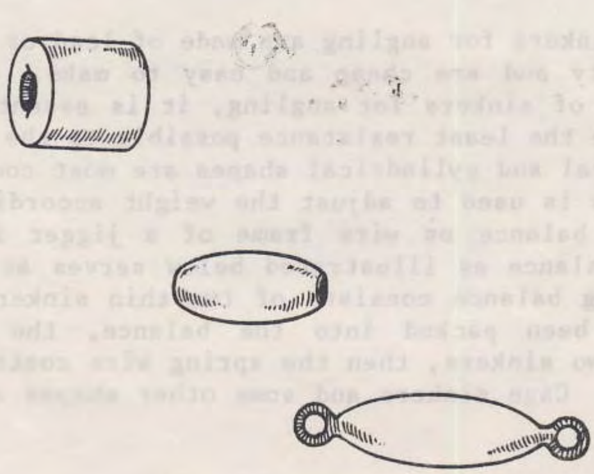


Fig. 17. Typical Forms of Sinkers made of Lead

6.5 The apparent weights of sinkers of different materials are tabulated below:

Table 2. Weight of sinkers of different materials

Material	Specific gravity (g/cm^2)	Apparent weight per unit weight (kg/kg)
Lead	11.35	0.912
Iron	7.21 - 7.83	0.861 - 0.872
Brass	7.82	0.872
Glass	2.70	0.630
Stone	2.60 - 2.70	0.615 - 0.630
Brick	1.90	0.474
Sand	1.80	0.444
Soil	1.50	0.333
Porcelain	1.72 - 2.13	0.420 - 0.530
Concrete	3.00 - 3.15	0.666 - 0.682

6.6 Sinkers for angling are made of lead or iron, have a high specific gravity and are cheap and easy to make. Though there are several shapes of sinkers for angling, it is essential that a sinker be made to have the least resistance possible to the water. Therefore, globular, conical and cylindrical shapes are most common. Sometimes a thin lead plate is used to adjust the weight according to the circumstances. The balance or wire frame of a jigger is also used as a sinker. The balance as illustrated below serves as a bait holder as well. A spring balance consists of two thin sinkers and wire. Once the bait has been packed into the balance, the central wire is connected to two sinkers, then the spring wire contracts and the bait exudes slowly. Cage sinkers and some other shapes are sometimes used similarly.

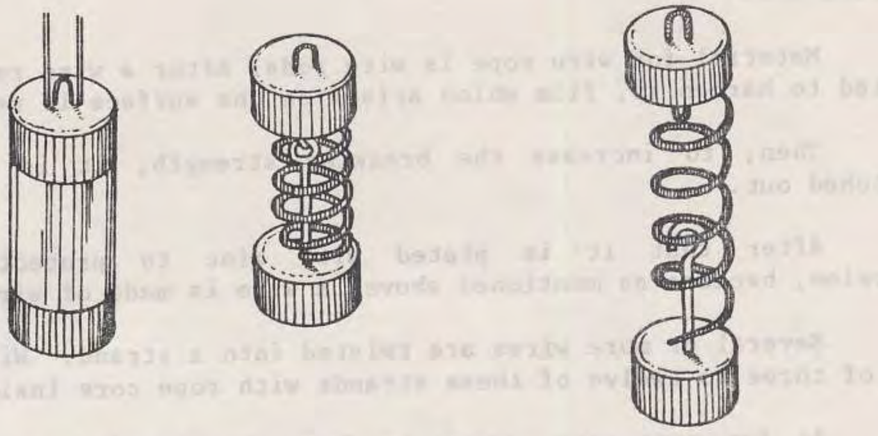


Fig. 18. Sinkers of cylindrical shapes

6.7 There are many types of hooks for angling. Although previously fishermen used wooden or bamboo hooks for angling, most hooks used nowadays are made of iron or brass. Their shape and size depend on the species of fish to be caught.

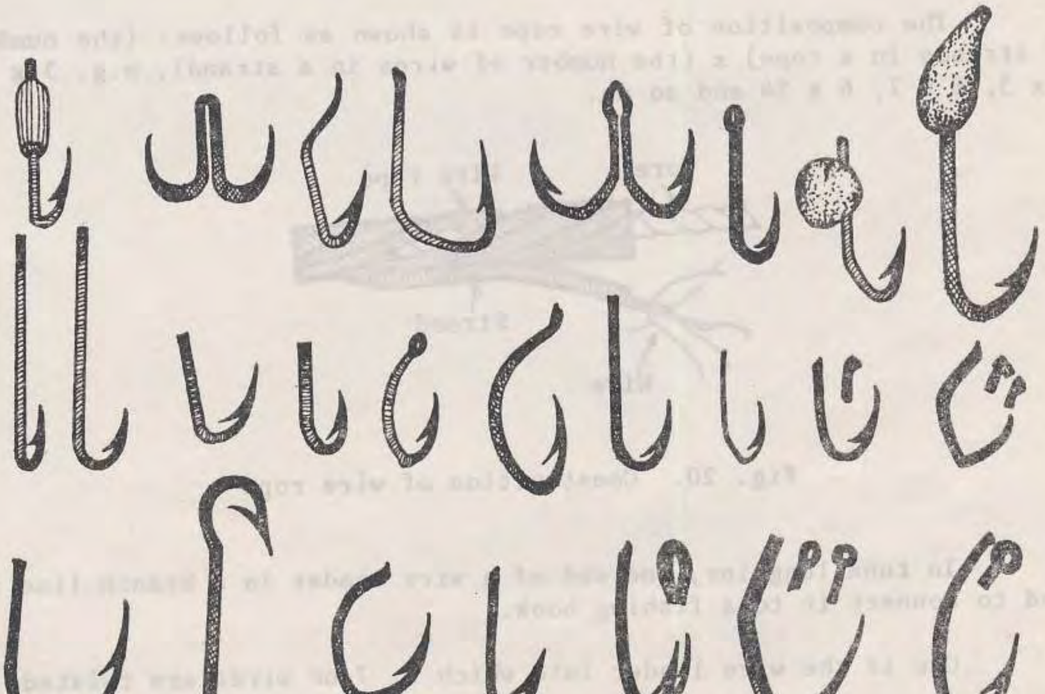


Fig. 19. Shapes and sizes of many hooks

7. WIRE ROPE

Material for wire rope is wire rods. After a wire rod is heat-treated to harden it, film which arises on the surface is removed.

Then, to increase the breaking strength, it is repeatedly stretched out.

After that it is plated with zinc to protect it from corrosion, because as mentioned above, a wire is made of wire rods.

Several or more wires are twisted into a strand. Wire rope is made of three to twelve of these strands with rope core inside it.

As for rope core, three to four strands of jute, manila or sisal are twisted into a rope core.

Since rope core of wire rope requires flexibility, it is soaked in special oil.

The oil also protects wire rope from corrosion and prolongs its useful life.

The composition of wire rope is shown as follows: (the number of strands in a rope) x (the number of wires in a strand), e.g. 3 x 4, 4 x 3, 6 x 7, 6 x 24 and so on.

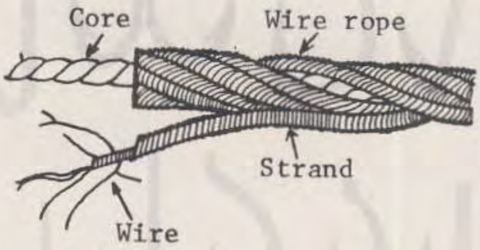


Fig. 20. Construction of wire rope

In tuna longline, one end of a wire leader in a branch line is used to connect it to a fishing hook.

One is the wire leader into which 3, 7 or wires are twisted.

Another is the wire leader into which 3 to 4 strands that consist of 3 twisted wires are twisted. e.g. 3 x 3, 4 x 3.

Wire ropes are divided into 2 kinds, namely well tempered ones and those not well tempered.

The former is superior in breaking strength and abrasion resistance compared to the latter.

As the latter is made of many fine wires, it is soft and has high flexibility.

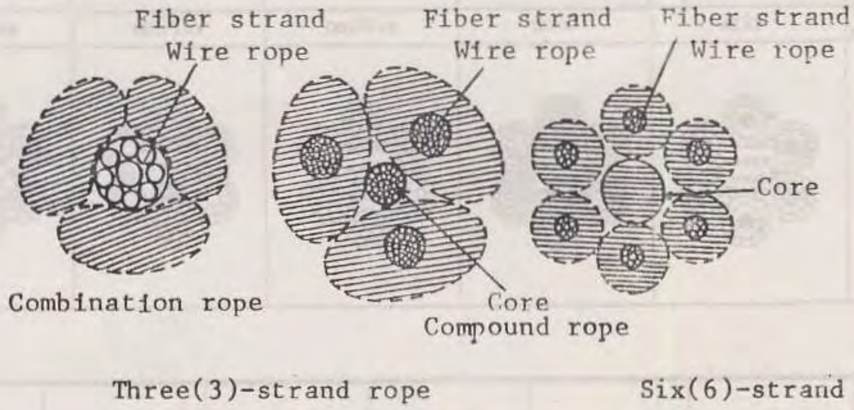


Fig. 21. Construction of special ropes (Shimozaki)

Combination rope and compound rope are made of fibre ropes and wires for flexibility.

As shown in Fig. 21, a wire rope is utilized as a core rope in a combination rope, and in a compound rope each strand has a wire rope inside it.

Thickness of wire rope is shown by its diameter or circumference in millimetres.

There are many kinds of wire ropes. In fishery, JIS* No.4 or No.6 are generally utilized in Japan.

As the scale of trawl fishing nets has been getting larger and larger JIS No.12, 13 or 19, which have high breaking strength, abrasion resistance and toughness, are being used.

The construction of the above-mentioned rope and the wire leader in tuna longline fishing gear is shown as follows:

No.in JIS.	No.4	No.6	No.12	No.13	No.19
Mark of Composition (No.strand x No.Wire)	6X24	6X37	6XFi(25)	6XFi(29)	6XWS(26)
Cross section of wire rope					

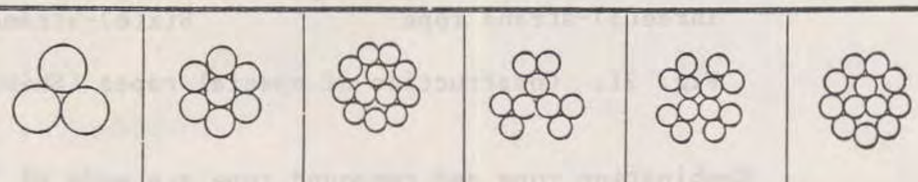
Cross section of wire leader					
Mark of composition (No.strand x No.Wire)	1X3	1X7	1X(3+9)	3X3	4X3	3X3+3(M3X3)

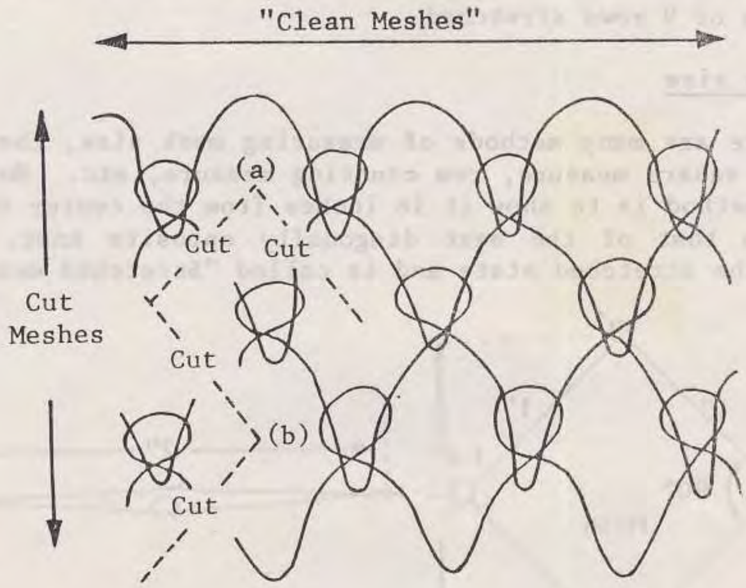
Fig. 22. Cross section of various wire ropes and wire leader (Honda)

III. FUNDAMENTALS OF FISHING GEAR CONSTRUCTION

1. MEASURING THE SIZE OF WEBBING

1.1 Webbing size

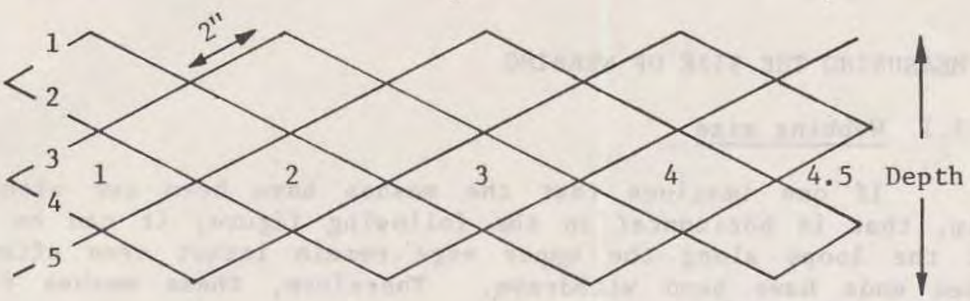
If one imagines that the meshes have been cut along the strip, that is horizontal in the following figure, it can be noted that the loops along the upper edge remain intact even after the broken ends have been withdrawn. Therefore, these meshes can be called "clean meshes".



However, when a cut is made across the strip, it can be clearly seen that the knots cannot be untied without completely breaking down the meshes. Consequently the meshes along this edge can be referred to as "cut meshes".

Generally, the edge with clean meshes of webbing is called "length", while that with cut meshes is called "depth".

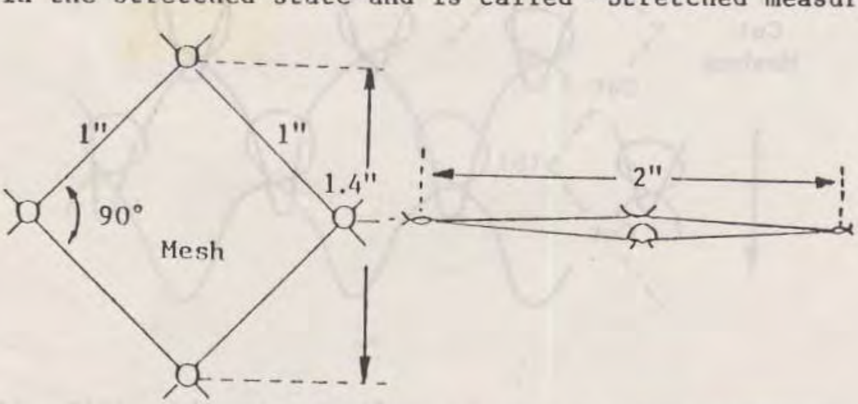
Webbing size is shown by the depth and the length. The depth of webbing is indicated by either (a) number of meshes or (b) number of rows. The length of webbing is shown by either (a) number of meshes, or (b) metres, feet, yards or fathoms. In the latter case it is understood that length is measured by stretching the net lengthwise.



Webbing 2.5 meshes deep or 5 rows deep and 4.5 meshes long or 9 rows stretched

1.2 Mesh size

There are many methods of measuring mesh size, the stretched measure, the square measure, row counting measure, etc. However, the most common method is to show it in inches from the center of the knot of a mesh to that of the next diagonally opposite knot. This is measured in the stretched state and is called "Stretched measure".



A two-inch mesh in stretched measure, open and stretched

In some of the European countries the size of a mesh is sometimes shown in millimetres from the center of one knot to that of the adjacent knot and is called "Square measure" or "Bar measure". Hence stretched measure is twice the bar measure.

In addition, another convenient method called "row counting measure" is in common use among fishermen. This is shown by the number of meshes or rows per unit length when stretched. In Spain and Portugal a method called the "Pasada" is used, which gives the number of meshes within a length of 20 cm.

The "Omfar" method is found in some parts of northern Europe, especially in Norway and Sweden, by which mesh measurement is determined according to the number of half meshes in one "alen" which is equivalent to 0.628 metre in Norway and 0.594 metre in Sweden.

In Holland and England mesh measurement is indicated by "Row", which is the number of rows per one yard, while in Japan it is described by the number of knots per six inches using the term or "Setsu" or "Fushi".

METHODS OF INDICATING MESH SIZE

System	Where in use	Measurement
Stretched measure	Internationally	Length of two bars
Square measure	Some European countries	Length of one bar
"Pasada"	Spain, Portugal	Number of meshes per 20 cm.
"Omfar"	Norway, Sweden	Number of half meshes in one "alen"
"Row"	Holland, England	Number of rows per yard
"Fushi" or "Setsu"	Japan	Number of knots per six inches.

Note: One "alen" is equivalent to 0.628 metre in Norway and 0.594 metre in Sweden.

2. SHORTENING (SHRINKAGE)

The correct hang-in or hanging of the webbing to the framing or supporting lines is an important factor in all nets. At present, there are two expressions for shortening.

1) The first is to express the amount of excess or loose webbing (total stretched length of webbing minus length of line) as a percentage of the total stretched length of webbing. It is called hang-in in Japan and other Asian countries.

$$S = \frac{\text{Excess webbing}}{\text{Total webbing}} = \frac{l - l'}{l} = 1 - \frac{l'}{l} \quad \text{hang-in}$$

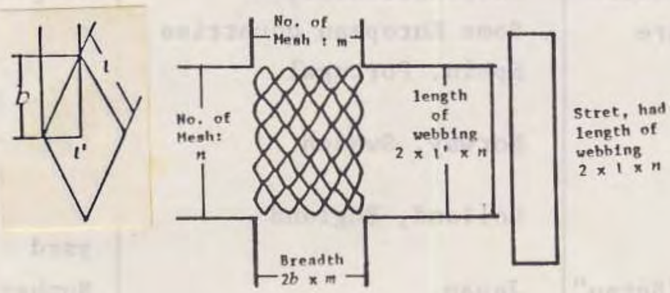
2) The second is to express the length of the line, to which the webbing is hung, in a percentage of the total stretched webbing. It is called hanging in US, Canada and European countries.

$$\text{Hanging} = \frac{\text{Length of line}}{\text{Length of stretched webbing}} = \frac{l'}{l} = 1 - s$$

(hanging)

So, Hanging = 1 - (hang-in)

Denoting hang-in as s, then the following calculation can be made.



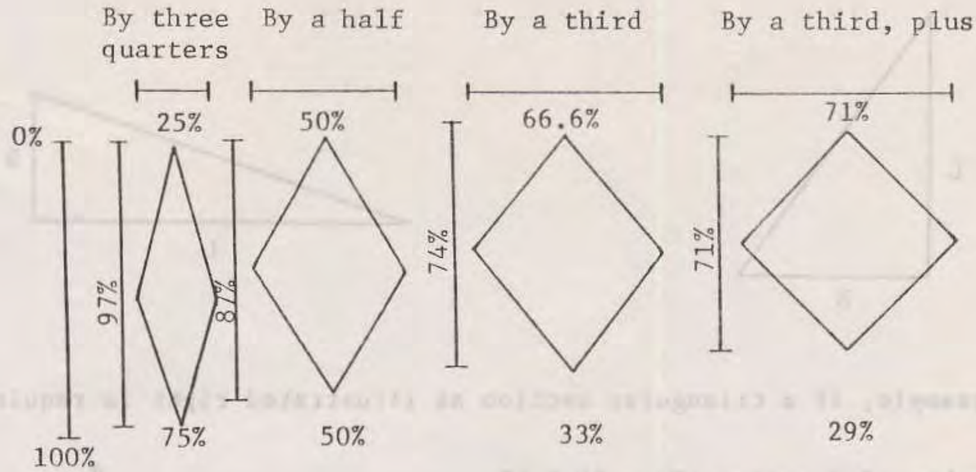
In a mesh, the following equation is formed as:

$$b^2 + (l')^2 = l^2 \qquad b^2 = l^2 - (l')^2$$

$$\left(\frac{b}{l}\right)^2 = \left(\frac{l}{l}\right)^2 - \left(\frac{l'}{l}\right)^2 = 1 - (1 - s)^2 = 2s - s^2$$

$$\therefore \frac{b}{l} = \sqrt{2s - s^2}$$

The relationships between the opening of a mesh and the hanging coefficient are as follows:

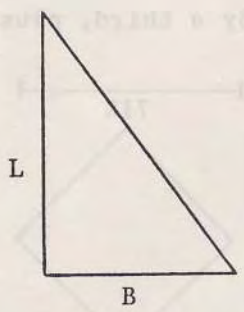


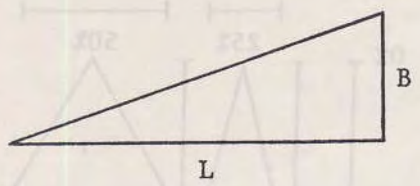
3. CUTTING

3.1 Point and bar cutting

To cut a bar from a knot is called "b" and to cut two bars from a knot is called "p". When cutting a slope of a section whose horizontal and vertical edges are the same in number of meshes, the repetition of only "b" cuts is adopted. If two edges are not the same in number of meshes, the number of "p" cuts equivalent to the difference must be added. The number of "b" cuts needed to cut the slope is always double the number of meshes of the shorter edge. Thus, any required slope can be cut, or in other words, any triangular section can be tailored by distributing the proper number of "b" and "p" cuts in good balance. If the above is expressed in formula,

$P = L - B$	(P : necessary number of "p" cuts)
$b = B \times 2$	(b : necessary number of "b" cuts)
	(L : number of meshes of longer edge)
	(B : number of meshes of shorter edge)





For example, if a triangular section as illustrated right is required,

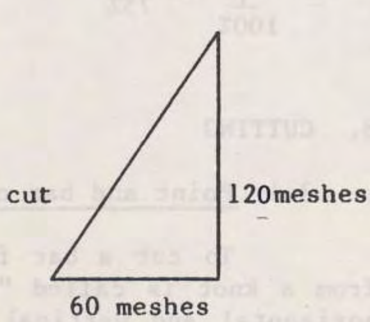
Number of P cuts = 120 - 60 = 60

and

Number of b cuts = 60 x 2 = 120

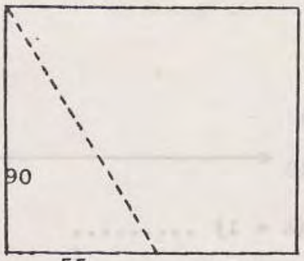
P : b = 60 : 120 = 1 : 2

So, 1 P 2 b cutting is needed.



Sixty repetitions of (P b b), (P b b) ...... will make the required section.

It is recommendable to adopt the above mentioned formula, Example - 1



P = 90 - 55 = 35

b = 55 x 2 = 110

3 .... (3 + 1)

35) 110
105
5

.... (35 - 5)

Ⓐ P = 1, b = 3] 30 times

Ⓑ P = 1, b = 4] 5 times

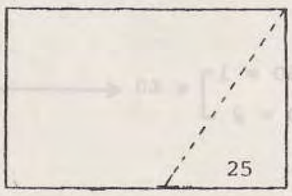
*Reverse Operation

Ⓐ P = 1 x 30 = 30
b = 3 x 30 = 90

Ⓑ P = 1 x 5 = 5
b = 4 x 5 = 20

Ⓐ + Ⓑ P = 30 + 5 = 35
b = 90 + 20 = 110

Example - 2



P = 70 - 25 = 45

b = 25 x 2 = 50

1 .... (1 + 1)

45) 50
45
5

.... (45 - 5)

Ⓐ P = 1, b = 1] 40 times

Ⓑ P = 1, b = 2] 5 times

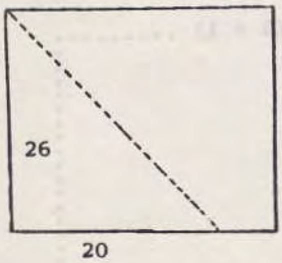
*Reverse Operation

Ⓐ $P = 1 \times 40 = 40$, $b = 1 \times 40 = 40$

Ⓑ $P = 1 \times 5 = 5$, $b = 2 \times 5 = 10$

Ⓐ + Ⓑ $P = 40 + 5 = 45$, $b = 40 + 10 = 50$

Example - 3



$P = 26 - 20 = 6$

$b = 20 \times 2 = 40$

6 .... (6 + 1)

6) 40
36
4

(6 - 4)

Ⓐ $P = 1$, $b = 6$ — 2 times

Ⓑ $P = 1$, $b = 7$ — 4 times

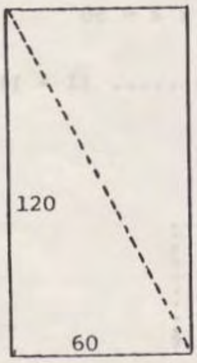
***Reverse Operation**

Ⓐ $P = 1 \times 2 = 2$, $b = 6 \times 2 = 12$

Ⓑ $P = 1 \times 4 = 4$, $b = 7 \times 4 = 28$

Ⓐ + Ⓑ $P = 2 + 4 = 6$, $b = 12 + 28 = 40$

Example - 4



$P = 120 - 60 = 60 = 1$, $b = 60 \times 2 = 120 = 2$] x 60

2

60) 120
120
0

(60 - 0) 60 times

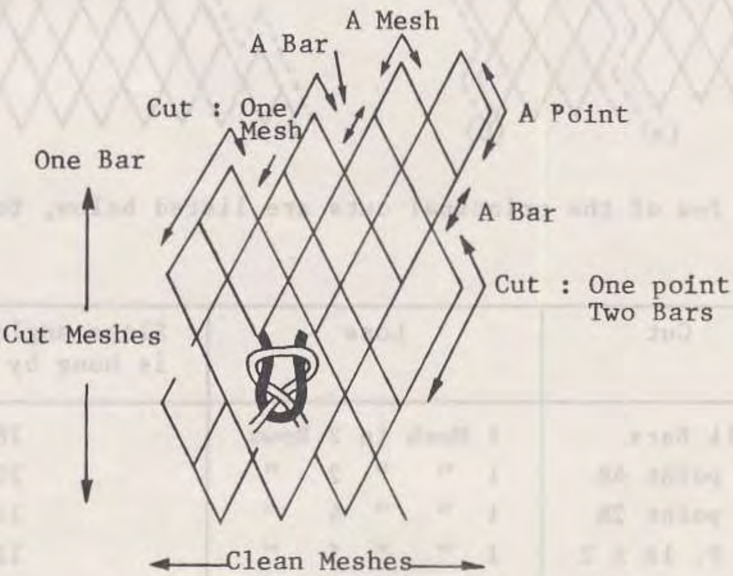
$P = 1$, $b = 2$

*Reverse Operation

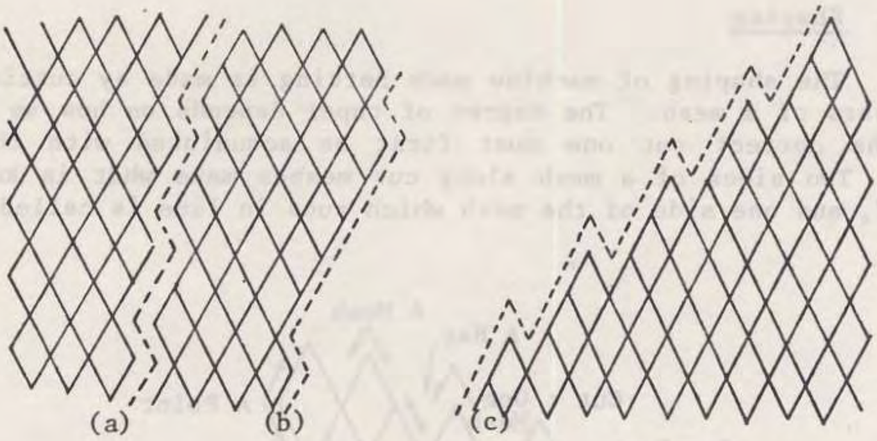
Ⓐ $P = 1 \times 60 = 60$, $b = 2 \times 60 = 120$

3.2 Shaping

The shaping of machine made netting is made by cutting two or three bars of a mesh. The degree of taper depends on how we cut. To make the correct cut one must first be acquainted with the proper terms. Two sides of a mesh along cut meshes make what is known as a "point", and one side of the mesh which runs in line is called a "bar".

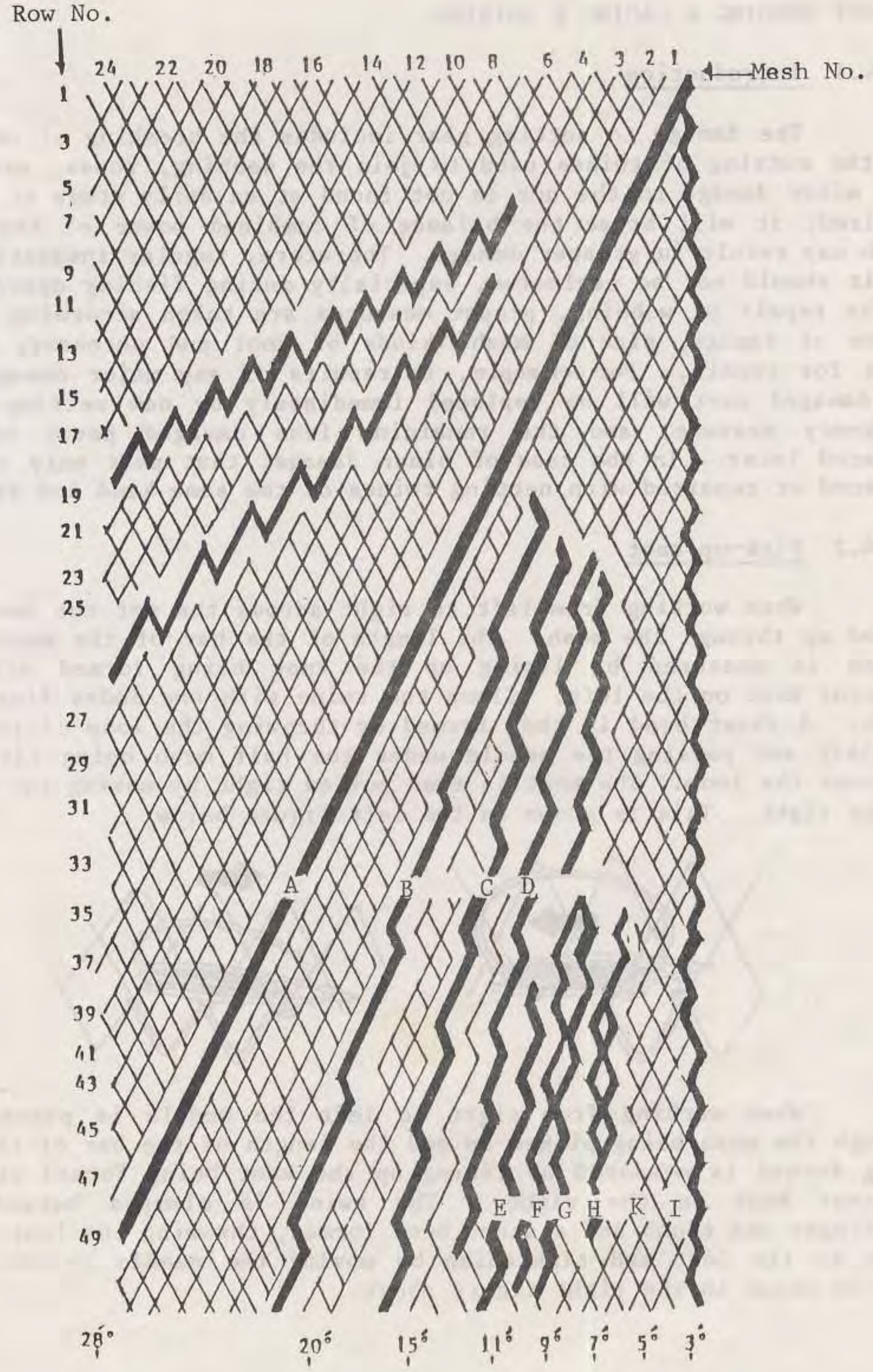


The cut combining a point and a bar is referred to as "one point on bar", which would decrease the width of netting by one mesh in every six rows or three meshes of depth as shown in diagram (a) below. The shaping with "one point four bars" would decrease the width of netting by one mesh in every three rows in depth, diagram (b). The cut with "one mesh two bars" would decrease the width of netting by one mesh in every two meshes, diagram (c).



A few of the principal cuts are listed below, followed by a diagram.

Line	Cut	Loss	Slope angle when net is hung by a half
A	All Bars	1 Mesh in 2 Rows	28°
B	1 point 4B	1 " " 2 "	20°
C	1 point 2B	1 " " 4 "	15°
D	1 P. 1B x 2	1 " " 5 "	11°
E	1P. 1B	1 " " 6 "	-
F	1P. 1B x 3	1 " " 7 "	9°
G	2P. 1B 1P. 1B	1 " " 8 "	7°
H	2P. 1B 2P. 1B x 3 1P. 1B	1 " " 9 "	-
I	2P. 1B	1 " " 10 "	-
J	2P. 1B	1 " " 12 "	5°
K	2P. 1B 5P. 1B 6P. 1B	1 " " 24 "	3°
L	All points	None	0°
M	1 Mesh 1 Bar	1 Mesh in 3 Meshes	-
N	1 Mesh 2 Bar	1 " " 2 "	-


Row No.
Mesh No.
24 22 20 18 16 14 12 10 8 6 4 3 2 1
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49
A B C D
E F G H K I
28° 20° 15° 11° 9° 7° 5° 3°

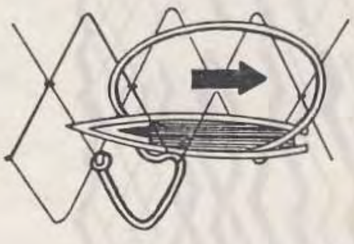
4. NET MENDING & LACING & JOINING

4.1 Introduction

The damage to netting gear includes the breaking of netting, and the cutting of twines used to join the webbing, ropes, etc. If even minor damage to the net is not found at an early stage or is not repaired, it will break the balance of combined power of the gear, which may result in greater damage. Therefore, regular inspection and repair should not be neglected, especially during fishing operations. In the repair of webbing, proper measures are taken according to the degree of damage, size of mesh, kinds of knot and necessary conditions for repair. For example, in repairs of any major damage only the damaged part will be replaced immediately by new netting as an emergency measure, and the remaining less damaged parts will be replaced later. In the case of minor damage, that part only need be replaced or repaired with netting twines of the same kind and size.

4.2 Pick-up knot

When working from left to right across the net the needle is passed up through the mesh. The length of the bar of the mesh being formed is measured by lining up the knot being formed with the adjacent knot on the left. Clamp the twine with the index finger and thumb. A sheet bend is then formed by throwing the loop of twine to the left and passing the needle under the half mesh being picked up and over the loop. The knot is then pulled tight by moving the needle to the right. This is shown in the left figure below.



When working from right to left the needle is passed down through the mesh being picked up and the length of the bar of the mesh being formed is measured by lining up the knot being formed with the adjacent knot on the right. The twine is clamped between the forefinger and thumb and a sheet bend formed, throwing the loop in the twine to the left and tightening by moving the needle to the left. This is shown in the right figure above.

4.3 Cutting out

In a piece of netting each knot always has four bars leading to it, never three or two unless it is on the edge of the netting, and never five under any circumstances. When the starting knot is tied the twine on the needle forms the fourth bar to the knot. On half mesh, pick up and side knots, the twine on the needle forms one bar as it is brought to the knot and another as it leaves after the knot is tied. In the finishing knot the twine on the needle forms one bar as it is brought to the knot and tied.

Therefore, when cutting out a hole, preparatory to mending it, the knot to which the starting knot is to be tied must have three bars leading to it, only one of the normal four bars being cut away (Fig. 23). All the other knots tied in mending the hole, except the finishing knot, must be tied to a knot with only two bars leading to it, requiring two bars to be cut away. The finishing knot is tied to a knot with three bars leading to it, so only one bar is cut away.

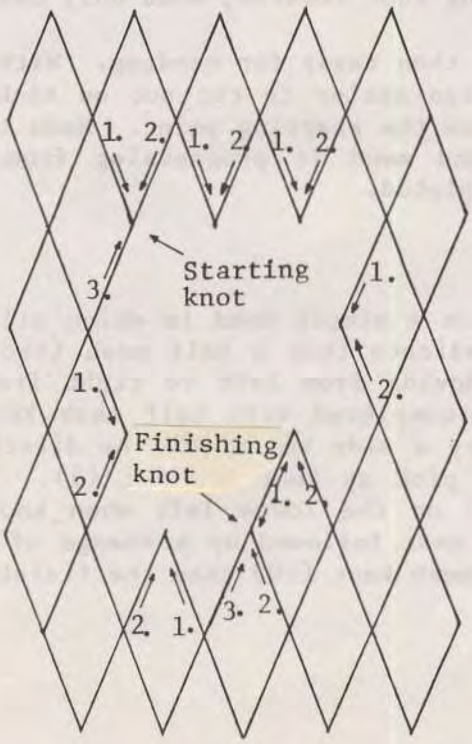


Figure. 23

The procedure for cutting out is therefore:

1. Arrange and support the net so that it is pulling in the right direction with the rows of knots in line.

2. Select the starting knot at the highest point of the hole and cut away one bar, leaving three bars to the knot.

3. Work down the left hand side of the hole cutting away two bars from each knot, leaving two bars to within a few meshes of the bottom of the hole.

4. Starting at the top again, immediately to the right of the starting knot, work down the right hand side of the hole, cutting away two bars from each knot and leaving two bars to within a few meshes of the bottom of the hole.

5. Cut two bars away from each remaining knot alternately on the left then the right hand side of the hole until a finishing knot remains, when only one bar is cut away.

The hole is then ready for mending. With large holes or rips in the net it is often easier to cut out on each side for the first five to 10 meshes from the starting point. Mend this and then cut out a further section and mend it progressing from cutting to mending until the job is completed.

4.4 Mending

Fig. 24 shows a simple mend in which all the knots are used. The curved arrows indicate that a half mesh (two bars) is formed to complete a mesh. Moving from left to right from the starting knot (1), two meshes are completed with half mesh knots at (2) and (3). These are followed by a side knot (4); the direction is changed from right to left and a pick up knot made at (5). Half mesh knots are made at (6) and (7) on the loops left when knots (2) and (3) were made; (8) is a side knot followed by a change of direction to a pick up knot (9), a half mesh knot (10) then the finishing knot (11).

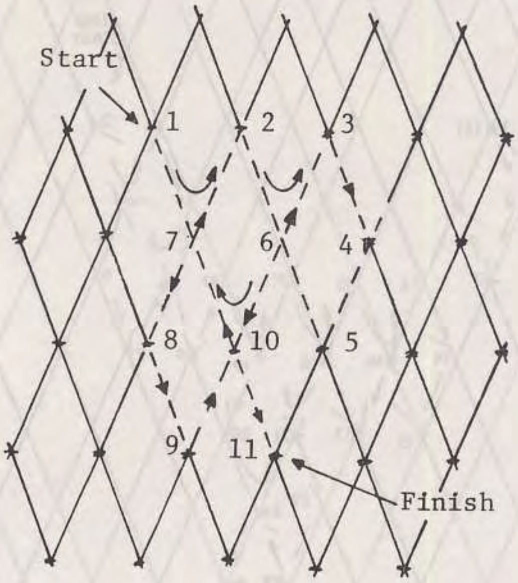


Fig. 24

Ordinarily, all holes are not so simple and straight forward as shown in Fig. 24. When a damaged net is examined, it will often be found that two or more tears run down the net, meeting at the point of most damage, and leaving a tongue or tongues of net hanging down between the tears. In Fig. 25 there are two tears running down the net and meeting in the center with a single tear running on down from there. As all mends must progress down the net half a mesh at a time, to repair this hole it is necessary to make two separate mends. The first small mend (1st start, 1 to 4) closes the left hand tear. It is then possible to complete the repair work, starting at the top of the right hand and progressing down the net (2nd start, 1 to 26).

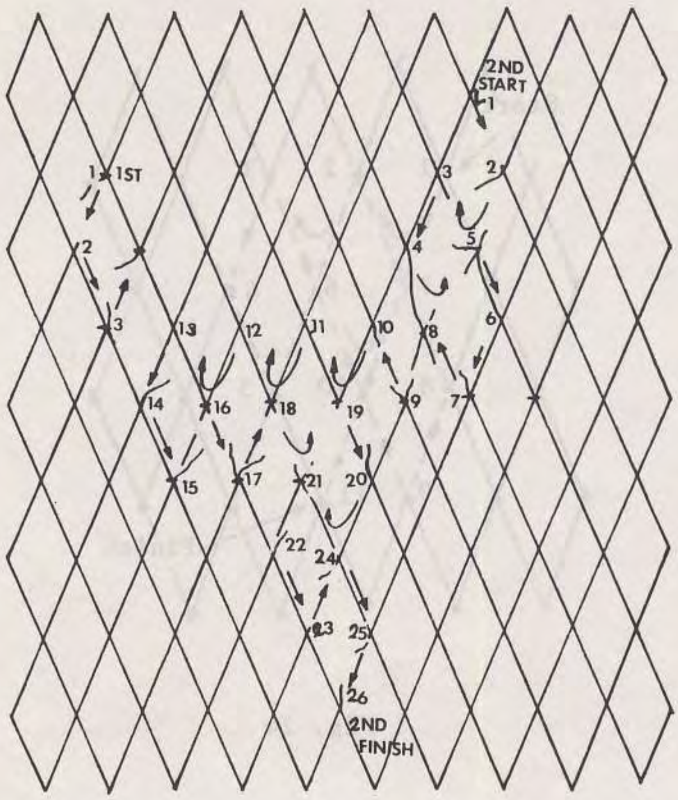


Fig. 25

4.5 Patching

When damage to a net is extensive and part of the netting is missing, rather than just torn, it is quicker to put in a patch than to attempt to mend the hole in the normal way. To put in a rectangular patch cut out the hole as shown in Fig. 26. The patch is cut one mesh smaller in depth and width than the hole to allow for the half mesh formed on each side when sewing it into the hole. Starting in the top right hand corner at 1 and 2 work around the patch to finish at 1 and 2 in the bottom left hand corner. If two men are available, one can work in each direction and so save time.

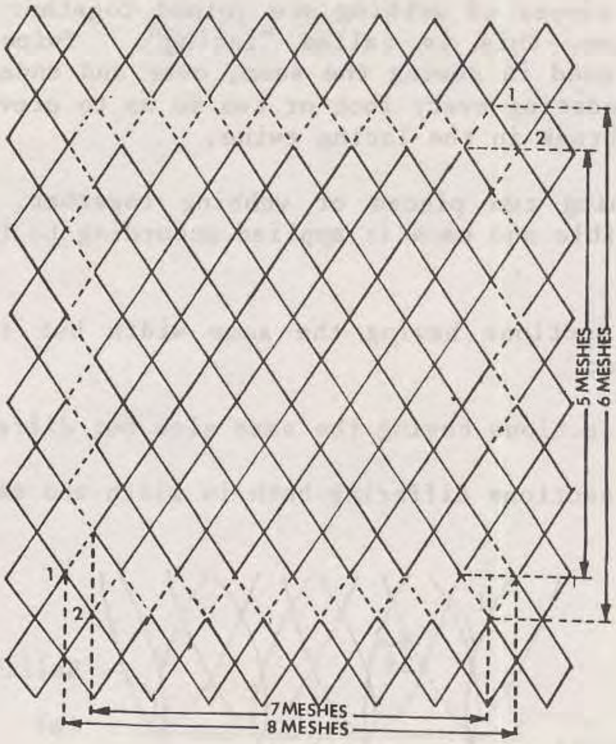
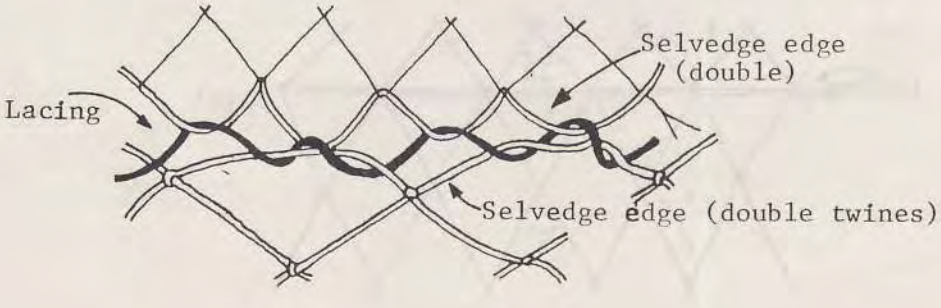


Fig. 26

When putting in a patch it is not essential to cut out a square or rectangular hole and then a patch to fit it. The most commonly used method of patching is to cut out part of the hole and then part of the patch to fit. Join this in, then cut out a further section of the hole and a corresponding section of patch to sew to it. Continue cutting the hole, cutting the patch and joining until the job is completed. The completed patch can be any shape so long as each corner turned during cutting out the damaged netting is a right angle.

4.6 Joining & Lacing & Stapling



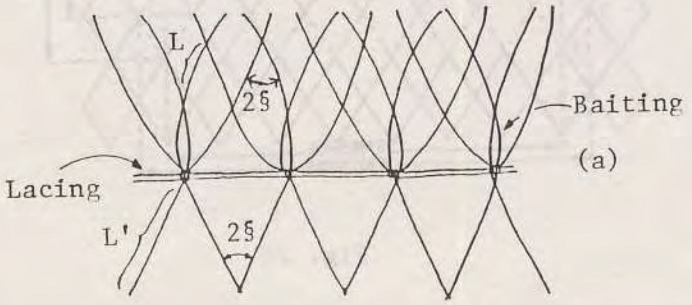
When two pieces of webbing are joined together along a seam using netting twine, this is called "lacing". Twine wound on a netting needle is used in sewing the seam, over and under through the seam meshes, and knotting every foot or two so as to prevent ravelling in the event of a break in the lacing twine.

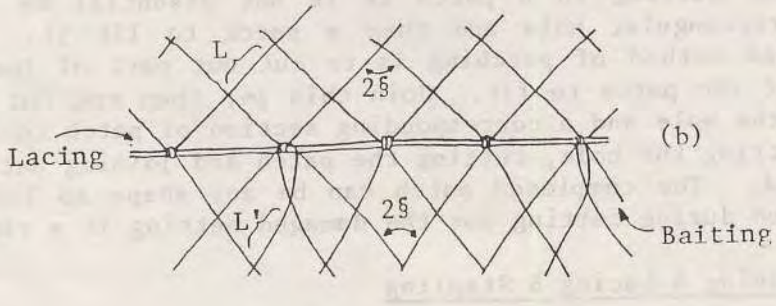
When joining two pieces of webbing together, several combinations are possible and each is applied according to the purpose of the join:

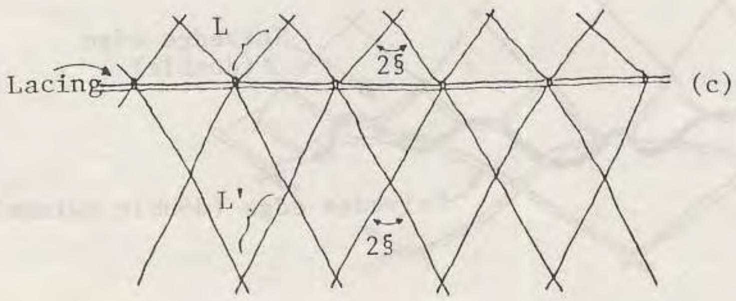
(a) the sections having the same width but different mesh sizes;

(b) the sections having the same size but different widths;

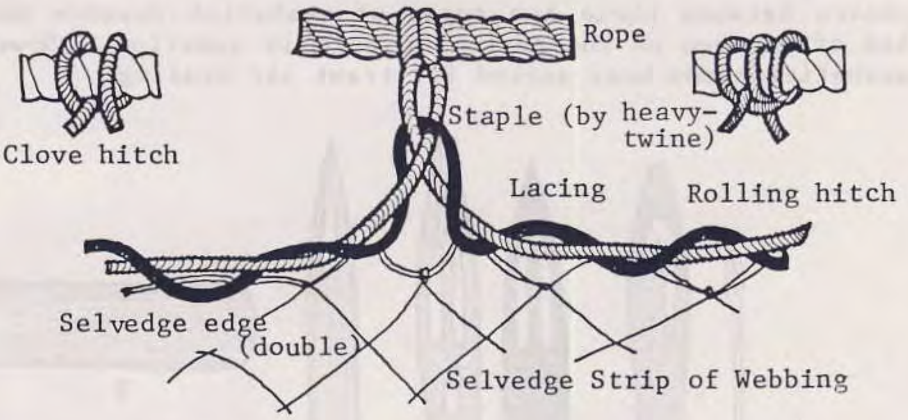
(c) the sections differing both in width and mesh size.



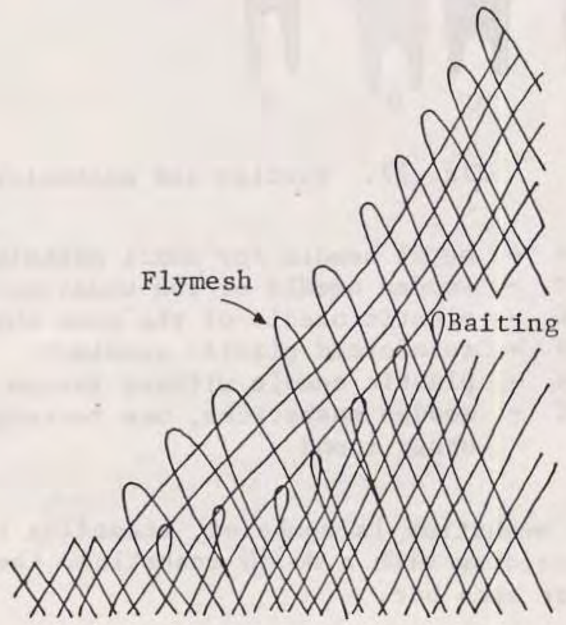




When webbing is hung to a line, it is laced with a heavy hanging twine in loops. The loop is formed by knotting the hanging twine to the line at six or eight-inch intervals, usually by a clove hitch with an extra turn around the line. A rolling hitch is generally used when the webbing is hung to a chain or wire. This lacing to a line by knotting and loops is sometimes called "stapling".



There are only two ways to taper when braiding webbing by hand, namely by using baitings and flymeshes.



4.7 Tools for making nets

1) The meshstick

The meshstick is indispensable in continuous hand braiding. It is made of a piece of hard smooth wood, either flat or rounded, about 10 cm long. Its cross-section, which varies with the size of the mesh of the net being made, is equal to the length of two sides of the mesh laced on it. In cross-section it may be either rectangular (Fig. 27) round, or even oval shaped (Fig. 27). The choice between these two types of meshstick depends on local custom and often even on the region or port in question. However, the flat meshstick seems best suited for trawl net mending.

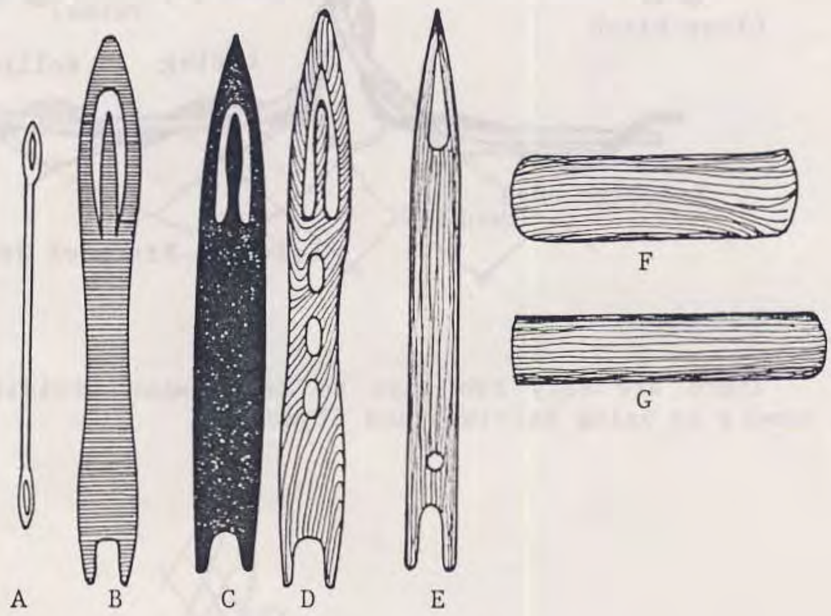


Fig. 27. Needles and meshsticks

A - metal needle for small meshsize
B - wooden needle or the usual model
C - plastic needle of the same shape as B
D - reinforced plastic needle
E - plastic needle without tongue
F and G - wooden meshsticks, one rectangular and the other round

Each meshstick is numbered, according to the meshsize it makes. Thus in braiding with a No.10 meshstick, the meshes are 10 cm long, i.e. 5 cm for each bar.

During mending, the meshstick is used in the workshop when several meshes are to be braided or when it is difficult to work without a meshstick, for instance in mending netting sections with very small or very large meshes.

2) The needle

In fishermen's language the needle is the instrument that holds the twine necessary for work on netting. It may be made of wood, bone, plastic or metal and comes in various shapes (Fig. 27); here we shall discuss only those most commonly used.

The metal needle (Fig.27A) is particularly suited to work on meshes less than 10 mm in size. For larger ones, the conventional type needle is used (Fig. 27 B, C, and D), of a convenient dimension for the size of the meshes to be made.

The plastic needle (Fig.27E), without a tongue but with the fore portion open has an additional advantage of permitting machine refilling. Some of these needles are designated by a number varying with the manufacture. For instance, for those made of wood, No.1 is the smallest and No.5 the largest; for reinforced plastic needles, No.0 is the largest and No.16 the smallest.

5. DRAWING AND DESIGN OF FISHING GEAR

The FAO Department of Fisheries, prepared the Catalogue of Fishing Gear Designs in 1972, in which drawings of fishing gears are presented in due form as follows:

The detailed drawings are not meant to be to scale or to be exact. They are meant to give essential impressions to any gear expert, who wishes to choose one gear rather than another and who may then wish to construct one.

The total Tex system (R tex) is adopted in the expression of twine size. Therefore, twine strength charts are also given on a separate page.

<u>Units adopted</u>

The metric system is adopted as standard, but where a net was designed in another commonly used system the units in which it was designed should be used.

<u>Conventional sections of design</u>

The first section classifies the gear, the second specifies the webbing, the third specifies the ropes, the fourth the floats, sinkers and any additional auxiliaries indicated by reference numbers on the drawings with any vital information in addition.

Mesh size

Mesh sizes are always given in mm followed by the design units only where applicable. True mesh size is used, that is, the length of one lumen plus one knot with the meshes stretched.

Number of meshes

Upper edge, the number of meshes along the top of each panel is given.

Lower edge, the number of meshes along the bottom of each panel is given.

Depth, the number of meshes down the side of each panel is given.

Baiting rate

By use of cutting pattern which can be applied quickly to obtain the desired taper from either hand made or machine made webbing. It will be seen that this system of specifying the points, bars and meshes cut, also designates the direction in which the knots lie. Where the webbing is tapered differently on its two edges, then the baiting rate for both the inner and outer edge is specified on successive lines.

Take-up

The joining of different panels, where joining method is not obvious, is given as a simple ratio of the number of meshes of one panel joined to the number of meshes in the other, e.g. A : B = 4:5.

Selvedge

Sometimes when the edging of a panel is only one row or a few meshes wide it is more convenient to express this in the form of a selvedge, than to give it a separate panel designation, e.g. cotton R 500 tex means that a border in 500 Tex cotton is braided along the edge of the webbing panel.

Material

All materials both natural and synthetic are all taken as names being in common international use.

Construction of lines and ropes

The number of strands and the direction of twist is given because of its general applicability internationally. It indicates the "resultant linear density" of the finished netting yarn by its weight in grammes per one thousand metres. For monofilament, also, the diameter in millimetres is given in brackets. This serves at the same time to indicate monofilament as compared with twisted or braided netting yarns. The selection of a particular type or construction of netting yarn is usually based on the best judgement of the designer with regard to operability and catching efficiency. It may, however, also depend on other considerations such as availability, price, local preference. The construction given by the designer is therefore not necessarily binding.

In netting the type of knot or connection is specified only when considered essential. The same applies to the orientation of the meshes which is defined as "normal" (N) when it is perpendicular to the general course of netting yarn in knotted netting, or when it follows the longest possible mesh axis in knotless netting. The relevant symbols are abbreviated.

The meshsize given in millimetres (mm) and defined according to what is commonly called "meshsize stretched", i.e. the distance between the centers of the two opposite knots (or connections) in the same mesh when fully stretched in the "normal" (N) direction. This corresponds exactly with the practical method of meshsize measurement.

The dimensions of net panels or sections in width and length or depth are defined by the number of meshes in a straight row along the edges where applicable as already mentioned. In trawl net drawings, the width of the bosom is given in brackets in addition to the mesh number for the total width of the netting section. When applicable (e.g. trawls, Danish seines) upper, lower and side panels are denoted by symbols to facilitate understanding of the design drawing.

Double braided netting is mostly restricted to narrow strips along edges or to corners. In such cases the number attached to the symbol for double braiding indicates the depth or width in number of meshes which is already included in the number specifying the overall dimension of the respective net panel or section to which the strip or corner of double braided netting belongs. When whole sections, such as trawl cod ends, are double braided, the symbol is attached to the mesh number designating one of the main dimensions of this section, e.g. the length.

For practical reasons the shape of netting sections is indicated by the cutting rate at its edges, irrespective of whether hand braided or shape cut. Horizontal or vertical edges in the drawing obviously designate straight lines of knots without any bar cuts. For tapered edges point cuts, i.e. cuts of a mesh in "normal" direction are specified by N or P (point cut) and full mesh cuts rectangular to "normal" direction by T (transversal) or M (mesh cut). Bar cuts are specified by symbol B; AB indicates all bar cut. In cases where the taper does not follow a reasonably simple cutting rate the next best is given together with a symbol indicating its only approximate applicability.

The hanging ratio (E) i.e. the length relation between the rope and the netting to be attached to it is defined as the numerical value of the decimal fraction of the length of the rope divided by the stretched length of the respective netting section, the latter being the product of the meshsize stretched multiplied by the number of meshes in a straight row.

(e.g. $E = \frac{440 \text{ m}}{628 \text{ m}} = 0.71$). It is shown where considered essential, e.g. in purse seines, as for instance E = 0.71. The expression of hang-in (e.g. $E = \frac{628 - 440}{628} = 0.29$) is also commonly used.

Ropes are drawn by thick lines and specified by their length in metres, the material and their diameter in millimetres (e.g. 37.20 PES Ø 12). Abbreviations for materials used in rope-making, e.g. for steel wire rope and combination rope are used. Because of the variety of items for the specification of accessories a certain amount of improvization had to be accepted. They are mostly shown in the additional detail or schematic drawings and in such a way as to be self-explanatory. Designations by terms or symbols are restricted to the absolute minimum and only the most essential dimensions or properties are given (e.g. ground rope bobbing: material, diameter = ST Ø 530 - trawl floats: number, material, diameter = 40-50 AL Ø 200 - purse seine floats: number, material, buoyancy = 1200 PL 0.66 kgf- purse rings: number, material, weight = 45 BT 7 kg) given, e.g. 3 Z denoting 3 stranded rope with right-hand twist. Left-hand twist is designated by S. For wire rope the construction of the rope may be given, e.g. 6 x 19 signifying 6 strands each containing 19 wires.

Conventions adopted in the specific drawings

For comparison of overall sizes and shapes of gear the following drawing rules have been adopted.

1. Gill nets, Trap nets, Lift net, etc. : Nets where the overall size is determined by the length of the ropes on all edges of the net.

2. Surrounding nets : Purse seines, Lamparas, etc. The convention adopted is to draw the netting to the length of the floatline but the depth of each panel is drawn to the depth of the stretched webbing, unless otherwise stated on the drawings.

3. Trawls, Danish seines : The width of the panel is drawn at half the stretched width. The length is drawn at the stretched length. Small gaps are shown between panels where there is "take up". Where two major parts of netting are joined along their edges, with their ends level and where the parts are of different stretched lengths, the slack occurs in the longer part. In the drawings, the ends are either shown level with each other or as in the case of trawl wings they are drawn to their true length.

Construction in detail

To facilitate comparison of designs, the drawings normally contain the following specifications.

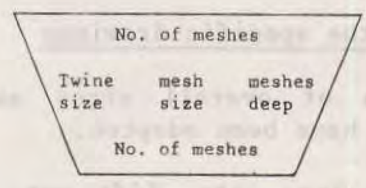
1. The number of meshes at the top and bottom of each panel

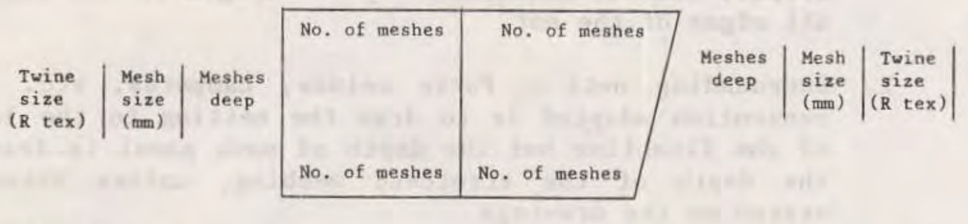
2. The depth of each panel in meshes

3. The mesh size in the panels, in mm.

4. The twine size of the panels.

Depending on the layout of the net, the number of meshes in depth, the mesh size and the twine size may appear either on or alongside the panels thus:





Other indications

1. Other gear (dredges, pots, lines, etc.). In view of the great variety in construction and the limited number of designs of the different other gear types, a standardization of presentation would be impractical. Schematic or partly perspective overall sketches complemented by detailed drawings according to requirements are considered preferable at this stage to provide self-explanatory specifications. Dimensions are given and scales indicated where applicable.

2. General outline drawings, e.g. of the rig of a complete gear, which are meant to facilitate the understanding, as well as detailed drawings of components, are mostly not to scale. Instead, essential dimensions are given. Materials are indicated only when considered necessary.

3. Of the metric system, which has been adopted throughout for dimensions, only the units metre (m) and millimetre (mm) are utilized. The metre is used for larger dimensions such as lengths of footropes, headlines, floatlines, bridles and applies to figures having a point followed by two decimals (e.g. 5.25:90.20). The millimetre is used for smaller dimensions such as meshsize (stretched), diameters of ropes, floats or bobbins and in the detailed drawings. It applies to the figures without a point (e.g. 12; 527:2305).

4. The unit for mass and weight is the kilogramme (kg). Forces such as breaking load of netting yarns or ropes and buoyancies of floats are given in kilogramme-force (kgf) or gramme-force (gf).

5. Materials are indicated by abbreviations which are preferably based on terms in common international use, such as plastic (PL), sisal (SIL), polyamide (PA). (See abbreviations)

6. As is well known the choice of material and construction has influence on certain characteristics of netting yarns and ropes, such as elasticity, stiffness, specific gravity, which may be considered significant for certain types of gear and fishing conditions. The same applies to all kinds of treatment (preservation, knot stabilization, stiffening, etc.) and also colour. Since in many cases there is no uniformity of opinion regarding the importance of these features and also for lack of space they are not included in the gear specifications.

7. The size of netting yarns is designated according to the tex system, and R-tex was adopted as the only unit because of its general applicability internationally. It indicates the "resultant linear density" of the finished netting yarn by its weight in grammes per one thousand metres. For monofilament, also, the diameter in millimetres is given in brackets. This serves at the same time to indicate monofilament as compared with twisted or braided netting yarns.

8. The selection of a particular type or construction of netting yarn is usually based on the best judgement of the designer with regard to operability and catching efficiency. It may, however, also depend on other considerations such as availability, price, local preference. The construction given by the designer is therefore not necessarily binding.

9. In netting the type of knot or connection is specified only when considered essential. The same applies to the orientation of the meshes which is defined as "normal" (N) when it is perpendicular to the general course of netting yarn in knotted netting, or when it follows the longest possible mesh axis in knotless netting. The relevant symbols are abbreviated.

10. The meshsize given in millimetres (mm) and defined according to what is commonly called "meshsize stretched", i.e. the distance between the centers of the two opposite knots (or connections) in the same mesh when fully stretched in the "normal" (N) direction. This corresponds exactly with the practical method of meshsize measurement.

11. The dimensions of the net panels or sections in width and length or depth are defined by the number of meshes in a straight row along the edges where applicable as already mentioned. In trawl net drawings, the width of the bosom is given in brackets in addition to the mesh number for the total width of the netting section. When applicable (e.g. trawls, Danish seines) upper, lower and side panels are denoted by symbols to facilitate understanding of the design drawing.

12. Double braided netting is mostly restricted to narrow strips along edges or to corners. In such cases the number attached to the symbol for double braiding indicates the depth or width in number of meshes which is already included in the number specifying the overall dimension of the respective net panel or section to which the strip or corner of double braided netting belongs. When whole sections, such as trawl cod ends, are double braided, the symbol is attached to the mesh number designating one of the main dimensions of this section, e.g. the length.

13. For practical reasons the shape of netting sections is indicated by the cutting rate at its edges, irrespective of whether hand braided or shape cut. Horizontal or vertical edges in the drawing obviously designate straight lines of knots without any bar cuts. For tapered edges point cuts, i.e. cuts of a mesh in "normal" direction are specified by N or P (point cut) and full mesh cuts rectangular to "normal" direction by T (transversal) or M (mesh cut). Bar cuts are specified by symbol B; AB indicates all bar cut. In cases where the taper does not follow a reasonably simple cutting rate the next best is given together with a symbol indicating its only approximate applicability.

14. The hanging ratio (E) i.e. the length relation between the rope and the netting to be attached to it is defined as the numerical value of the decimal fraction of the length of the rope divided by the stretched length of the respective netting section, the latter being the product of the mesh-size stretched multiplied by the number of meshes in a straight row.

(e.g. $E = \frac{440\ m}{628\ m} = 0.71$). It is shown where considered essential, e.g. in purse seines, as for instance E = 0.71

The expression of hang-in (e.g. $E = \frac{628-440}{628} = 0.29$) is also commonly used.

15. Ropes are drawn by thick lines and specified by their length in metres, the material and their diameter in millimetres (e.g. 37.20 PES Ø 12). Abbreviations for materials used in rope-making, e.g. for steel wire rope and combination rope are given in abbreviations.

16. Because of the variety of items for the specification of accessories a certain amount of improvization had to be accepted. They are mostly shown in the additional detail or schematic drawings and in such a way as to be self-explanatory. Designations by terms or symbols are restricted to the absolute minimum and only the most essential dimensions or properties are given (e.g. ground rope bobbing: material, diameter = ST Ø 530 - trawl floats: number, material, diameter = 40-50 AL Ø 200 - purse seine floats: number, material, buoyancy = 1200 PL 0.66 kgf - purse rings: number, material, weight = 45 BT 7 kg).

Abbreviation and symbols

AL	aluminium
BR	brass
CEM	cement
COC	coir, coco
COP	copolymer-fibre
COMB	Combination rope
D	depth
ELEV	elevator, float with incorporated kite
FAC	facultative
FE	iron
GALV	galvanized
L	length (mm)
MAN	manila
MAT	material
MONO	monofilament
PA	polyamide
PB	lead

PE	polyethylene
PES	polyester
PL	plastic
PP	polypropylene
PVA	polyvinyl alcohol
PVC	polyvinyl chloride
PVD	polyvinylidene chloride
RUB	rubber
SELV	selvedge
SIA	siamese (float)
SIS	sisal
SST	stainless steel
ST	steel
SW	swivel
SYN	synthetic fibre
WD	wood
WIRE	steel wire rope
Ø	diameter
⊤	upper panel
⊥	lower panel
⇤ ⇥	side panels
O	purse ring
↕	N-direction in netting
→|←	thickness
/	optional
↻	circumference
◈	double braided
~	approximately

IV. FISHING GEAR AND METHODS

4.1 PURSE SEINE

1. INTRODUCTION

The purse seine is one of the most advanced types of fishing gear for surrounding fish schools used for catching pelagic fish species such as sardine, anchovy, mackerel, hard-tail scad, bonito and skipjack. The purse seine consists of pieces of rectangular netting, a cork line or float line with floats attached and a foot rope or sinker line with sinkers attached. At both ends of the seine, there are side lines to which hand ropes are fixed. However, the most salient feature of the gear is that it is used to encircle and impound fish schools by closing the bottom either with hooks (in the case of no purse line), or by purse line which passes through purse rings fixed to the ends of bridles attached to the sinker line at regular intervals, thus preventing the fish escaping downward. The bunt or cod end part of the net is generally located at the end of one of the wings, however, in a Thai purse seine it is located at $\frac{2}{5}$ of the length of the net from the left side wing, except in the case of two-boat type purse seine where the bunt or cod end is located in the middle.

Purse seines originated from beach seines and were developed to catch fish schools in deeper water. The shape of the net has evolved both in its features and size. Purse seine fishing methods are always advanced. Nowadays most purse seiners are equipped with fishfinder, sonar, radar, and some have a net hauler, power blocks, wireless instruments, fish luring lamps, current meters, etc. These show how modern purse seine fisheries are nowadays. Schematic diagrams of different types of purse seines are shown in Fig. 28 below:

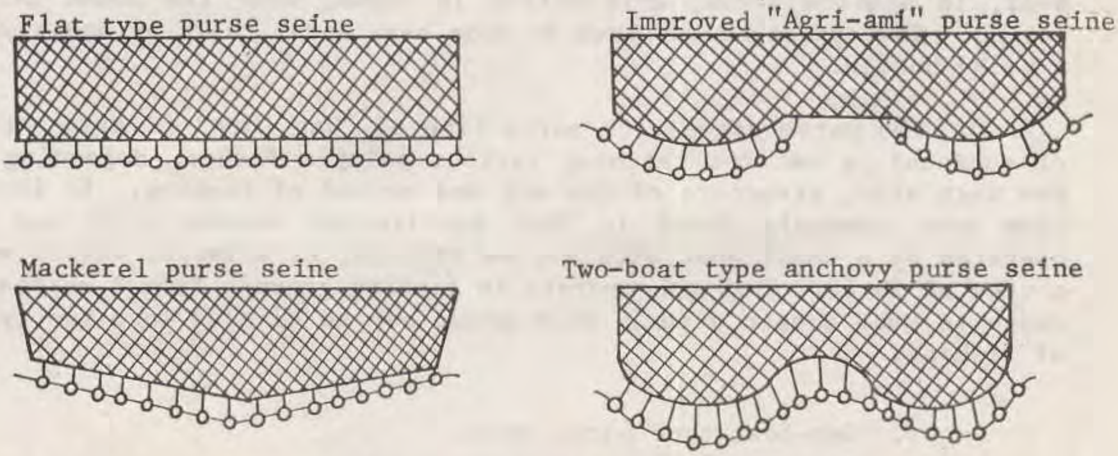


Fig. 28. Schematic diagrams of different types of purse seines

2. CLASSIFICATION OF PURSE SEINE FISHERIES

The purse seine fishery is generally classified as follows:-

1. One-boat sardine purse seine fishery;
2. Two-boat sardine purse seine fishery;
3. One-boat horse mackerel and mackerel purse seine fishery;
4. Two-boat horse mackerel and mackerel purse seine fishery;
5. One-boat skipjack and tuna purse seine fishery;
6. Two-boat skipjack and tuna purse seine fishery.

In the above fisheries, 2, 3, and 5 are the commercially important ones.

They are also classified, from the point of view of fishing operations, into the one-boat type purse seine and two-boat type. In the Thai purse seine fishery, there are many kinds of purse seine fisheries: anchovy purse seine, sardine purse seine, bonito purse seine, coconut-leaf shelter purse seine, light raft purse seine, etc. Generally however, they are divided into two big groups based on their structure:

a) without purse line
b) with purse line

The purse seine without purse line or "Uan Glud Takho" is a surrounding net for catching anchovy, sardine, etc. It is a small-scale fishing gear, generally operated by a small boat with a crew of 6-12, in shallow areas, 2-12 metres in depth, near the coast or an island. The operation can even be done near coral reefs or areas with a rocky bottom.

The purse seine with purse line of "Uan Lorm" is also a type of surrounding net for catching various pelagic fishes, depending on the mesh size, structure of the net and method of fishing. It is the type most commonly found in Thai territorial waters. It can be operated by a small boat with a crew of 6-10, or a larger vessel with a crew of 30-40. They can operate in fishing grounds from 2 metres in depth to much deeper areas. This group can be divided into two types of fishing:

1. One-boat type purse seine
2. Two-boat type purse seine

In the operation of one-boat type, one end of the net is held by a skiff or tied to floats or light raft while the net is paid out by the boat proceeding at full speed while making a circle to close the net with the other end. After paying out the net, the purse line is retrieved and the bottom of the net pulled closed. Then after pursing the line, the net is hauled in and the fish are driven into the bunt.

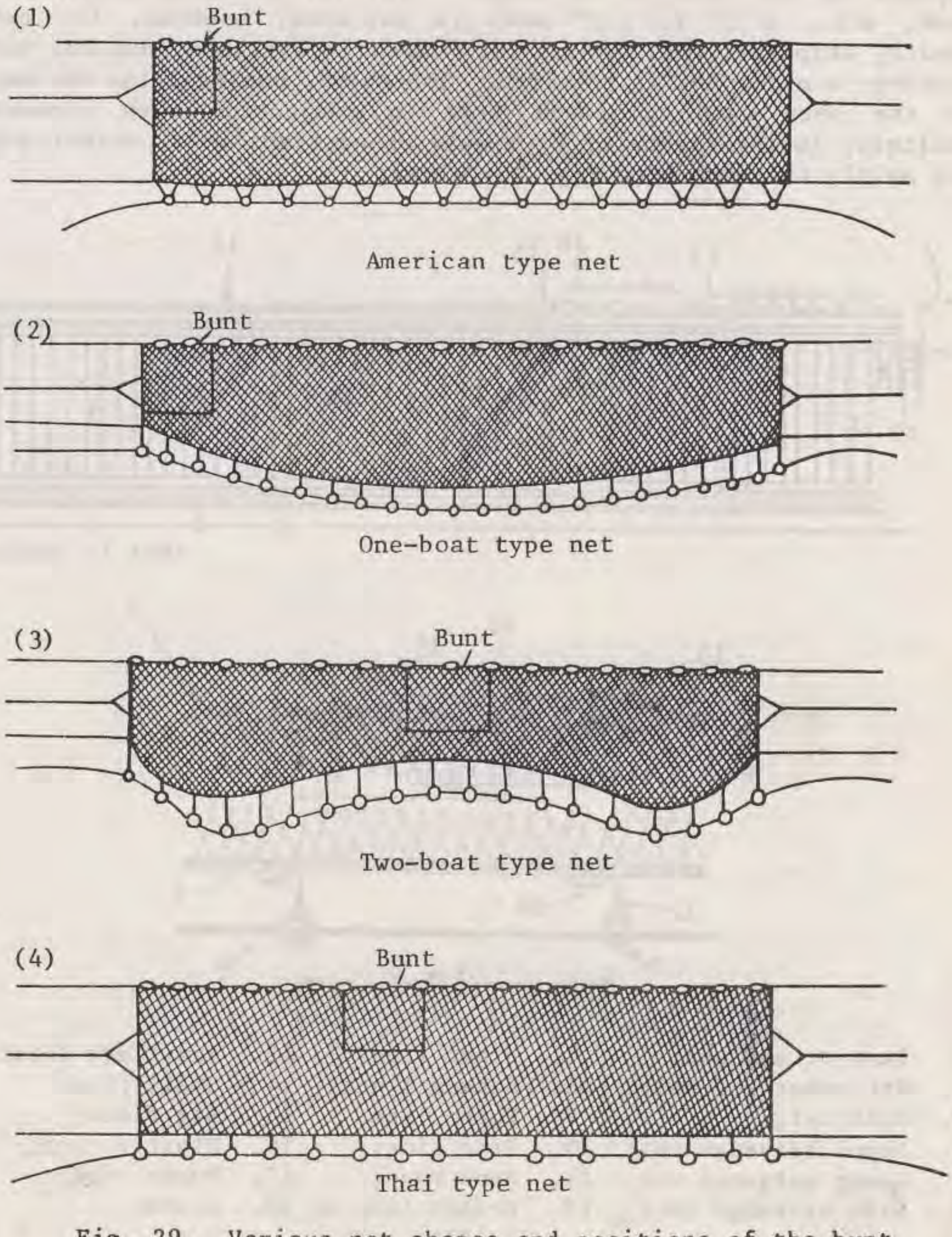
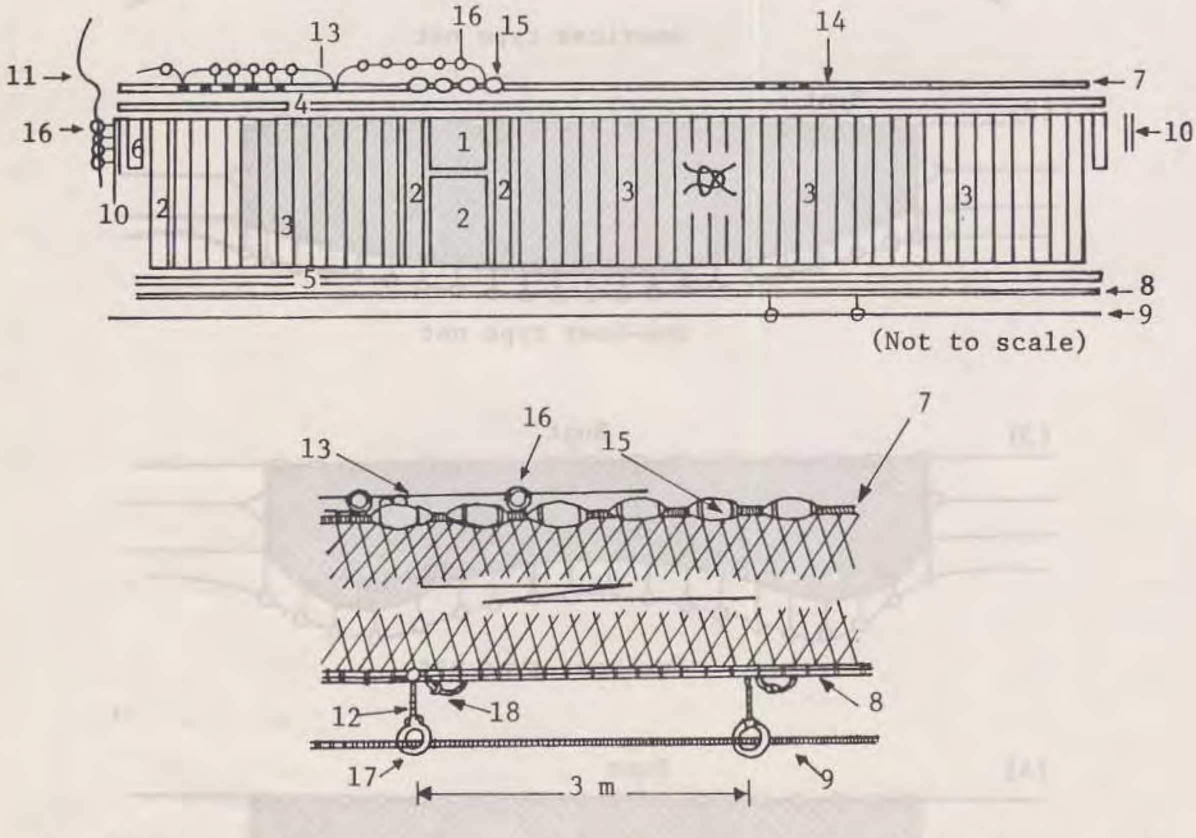


Fig. 29. Various net shapes and positions of the bunt

3. CONSTRUCTION OF PURSE SEINE NET

The length and depth of the net depend on the size of the fishing boat, the fishing method, and in the case of the fish school the detection method used. If the luring method is used, the net should not be too long. The mesh size used for a purse seine net depends on the fish to be caught, e.g. for sardine, mackerel, round scad, etc., a 1" to 1.5" mesh is suitable, however, for catching bonito, skipjack, etc., a 2.5"-3.7" mesh is suitable, and for catching anchovy, a minow net is required. The shape, construction and material of the nets used to catch fish in conjuction with coconut-leaf shelters, luring lights or by simply using traditional visual sighting are mainly the same (See Fig. 30 below).



1. Bunt or cod end;	7. Float line;	13. Auxiliary float line;
2. Net under cod end;	8. Sinker line;	14. Small float;
3. Main net;	9. Purse line;	15. Big float;
4. Upper selvedge net;	10. Side line;	16. Plastic ring;
5. Lower selvedge net;	11. Hand rope;	17. Purse ring;
6. Side selvedge net;	12. Breast line or Bridle;	18. Sinker

Fig. 30. Design of purse seine net.

4. FISHING OPERATIONS

There are two purse seine fishing methods used in Thailand:-

One is the fish school detection method and the other is the fish luring method.

1. Fish school detection methods

There are two fish school detection methods:-

a) Traditional visual observation

b) Modern method using fishfinder, sonar and radar, and in some developed countries, airplane and helicopter.

Usually fishermen like to search for fish schools in the evening before sunset and in the early morning or during twilight and in the night when the moon is waning. When a purse seiner arrives at a fishing ground, the masterfisherman will go up to the crow's-nest on the mast to look for a fish school. He gives directions to the steersman through a plastic pipe by signal (whistle, horn, or bell). On some purse seiners, the crow's-nest is fitted with a steering wheel so that the masterfisherman can control the vessel when searching for a fish school.

1.1 To find a fish school during the daytime

In the daytime we can find a fish school by looking for the following:-

a) Change of water colour

A fish school near the surface, seen from far away, will make the water appear coloured and the water around the school will show ripples distinguishing it from the surrounding water, especially in the case of schools of sardine, anchovy, mackerel, etc.

b) Jumping fish

Sometimes fish in the school are seen to be jumping, such as bonito and hardtail scad.

c) Flocks of birds

A flock of sea birds often accompanies a school of fish. Birds flying in a fixed direction are usually independent of a school below, but birds flying high as well as low in various directions are generally following a school. When the movement of a fish school in rapid, the birds are very active. The direction of their flight suggests the movement of the fish school. But when the movement of a fish school is slow, the birds fly slowly and circle high in the air. As soon as the fish school begins to come up to surface, the movement of the birds again becomes very active.

1.2 To find a fish school during night-time

At night-time when there is little moon light fish schools can be found by observing the plankton luminescence, caused by the swimming fish school. We call this "bioluminescence".

1.3 Modern method

This method takes advantage of fishing gear accessories or fishing equipment such as fishfinder, sonar and radar, etc. Some countries use airplanes or helicopters to find for example schools of tuna, bonito, skipjack, etc. Generally to find fish schools by using fishfinder and sonar, the fish school must be migrating below the surface and can be found at anytime of the day or night. However, when airplanes or helicopters are used, the school of fish must be swimming near the surface and can only be found in the daytime.

2. Fish Luring methods

There are six methods of luring to concentrate fish for purse seine fishing operations in Thailand today.

2.1 Luring by light raft (gas cylinder lamp)

2.2 Luring by light boat (generator)

2.3 Luring by underwater lamp

2.4 Luring by coconut-leaf shelter, called "payaw"

2.5 Luring by coconut-leaf shelter with light raft

2.6 Luring by mercury lamp and light raft.

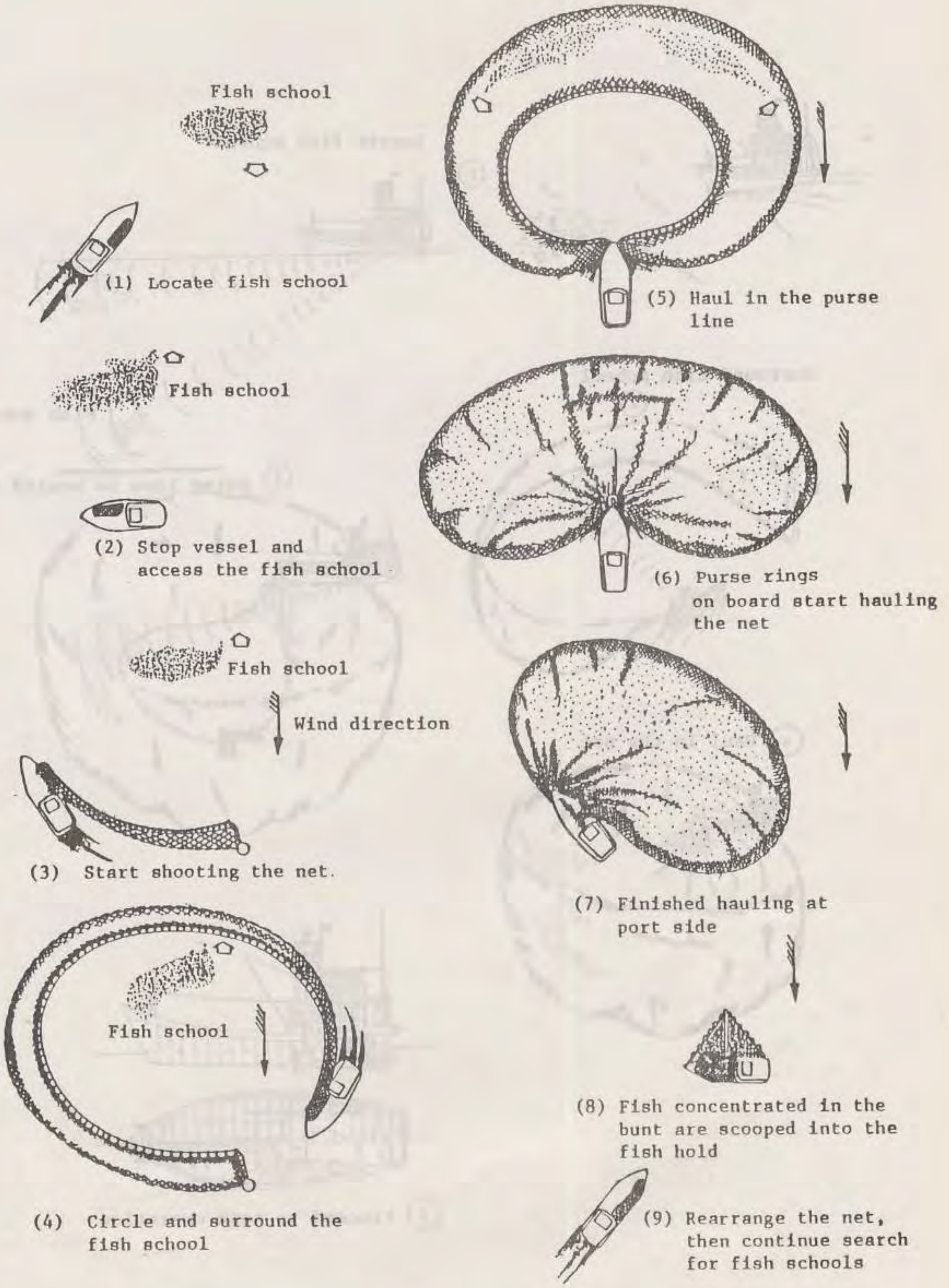


Fig. 31. Steps to a fishing operation with traditional visual observation

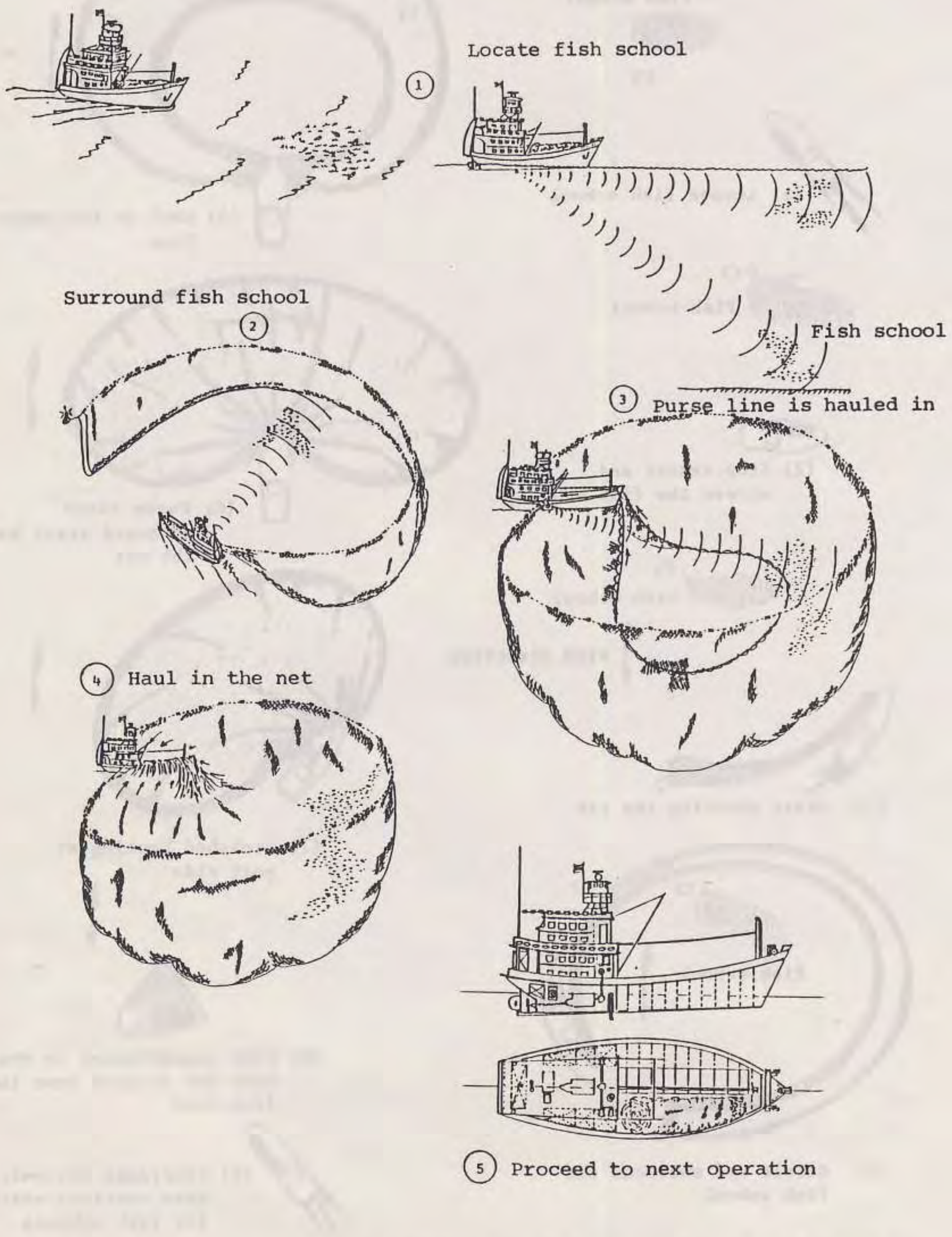


Fig. 32. Steps to a daytime fishing operation using sonar

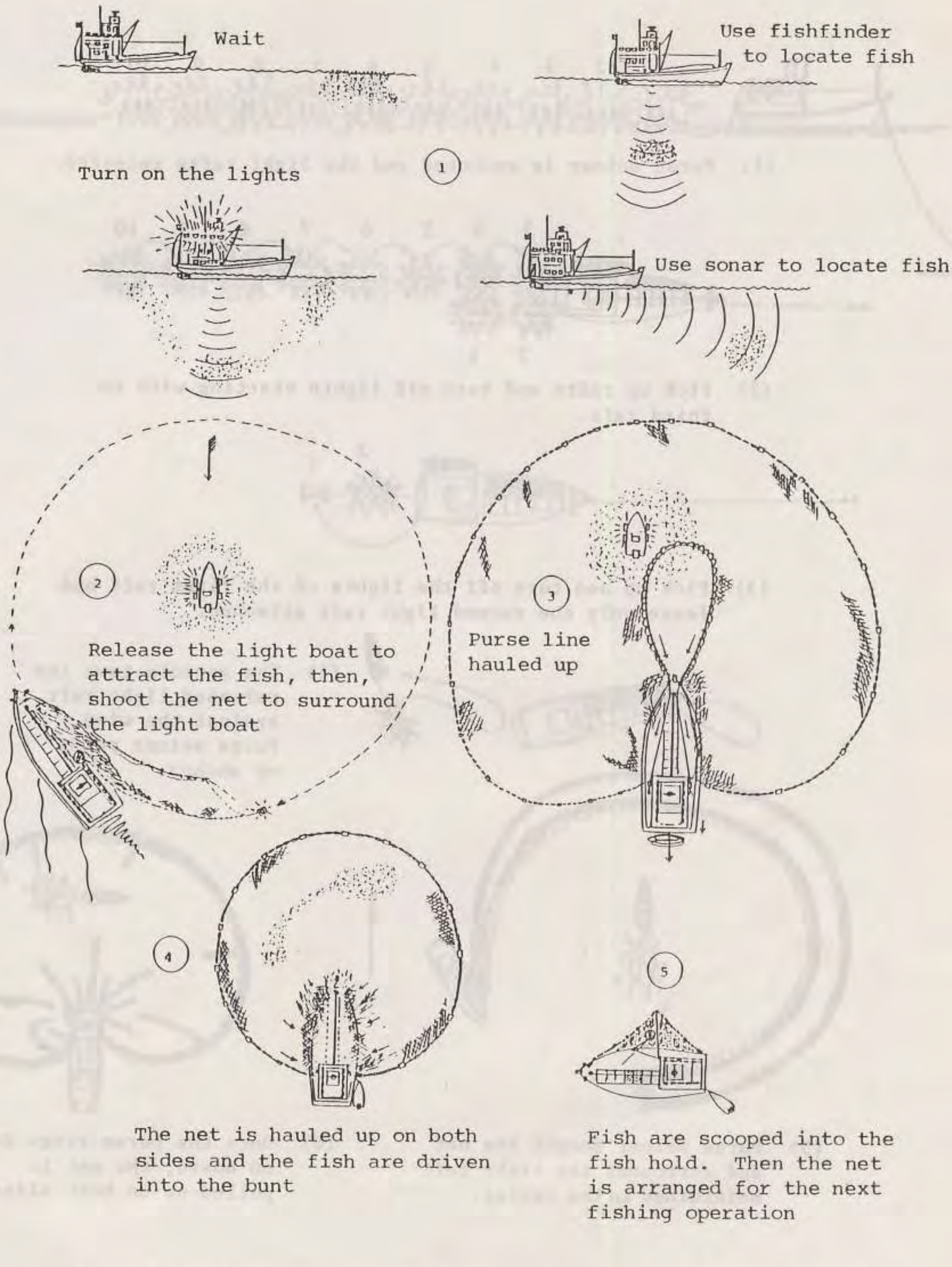
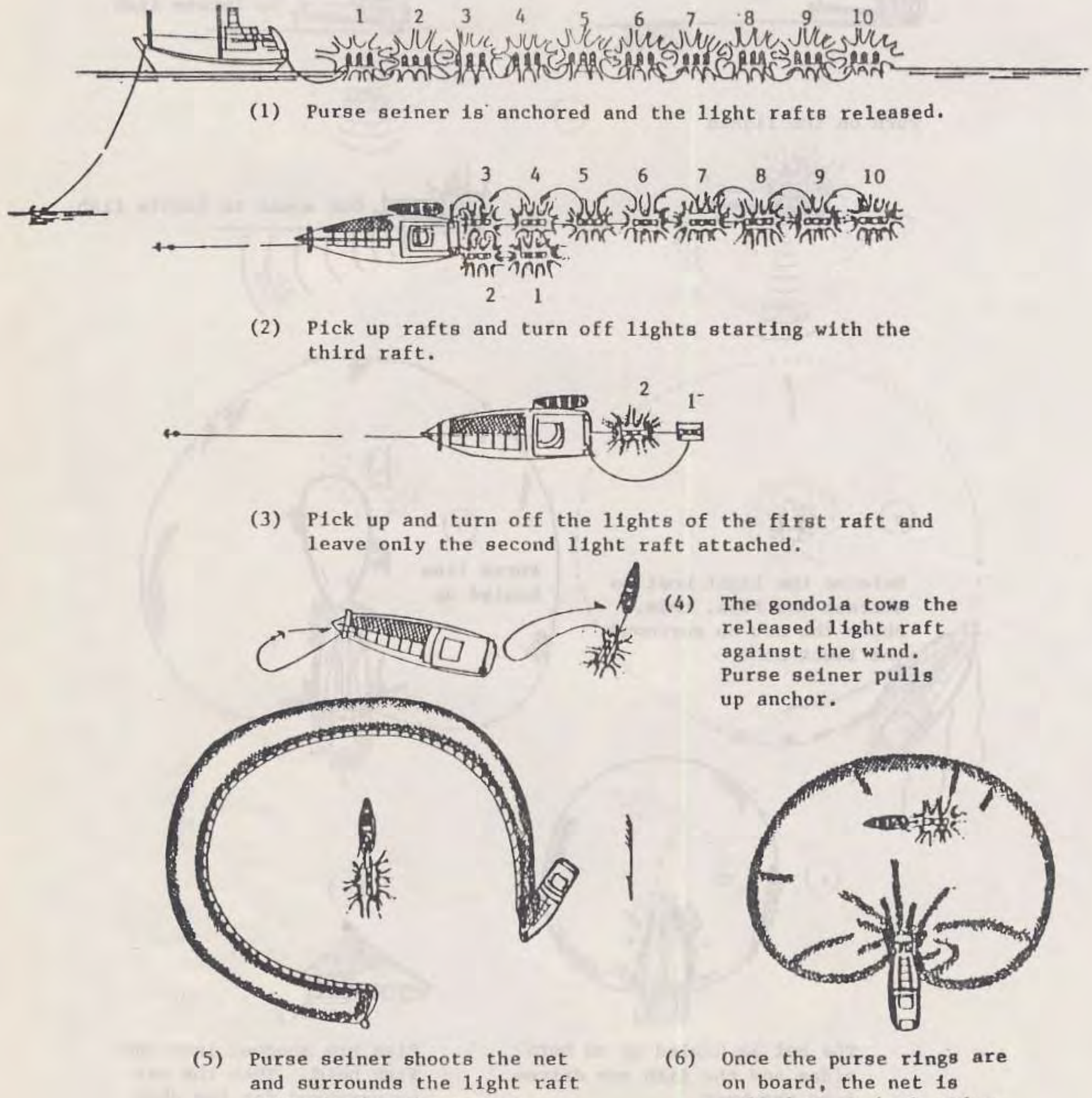


Fig. 33. Steps to a night-time fishing operation using fishfinder and sonar



(1) Purse seiner is anchored and the light rafts released.

(2) Pick up rafts and turn off lights starting with the third raft.

(3) Pick up and turn off the lights of the first raft and leave only the second light raft attached.

(4) The gondola tows the released light raft against the wind. Purse seiner pulls up anchor.

(5) Purse seiner shoots the net and surrounds the light raft maintained in the center.

(6) Once the purse rings are on board, the net is pulled-up on both sides.

Fig. 34. Steps to a fishing operation using light rafts

4.2 TRAWL

1. INTRODUCTION

It is difficult to establish exactly where and when trawls were first introduced into fishing practice. They are mentioned, however, as early as the 16th century in official documents published in England. To date, trawls have been known as a fishing gear that has a high catching efficiency and play an important role in the fisheries of the world.

Professor F.I. Baranov defined the difference between trawl and other fishing gear of the filtering class, as follows: "If the length of the fishing path of the gear exceeds the length of the gear itself by a few times (not over 5), then it is considered seine type gear, whether or not the gear in action reaches the surface of the water. If the length of the fishing path of the gear is several tens or even hundreds of times (up to 1000) longer than the gear itself, this is trawl type gear".

In more simple terms, a trawl is a form of fishing gear consisting of a net bag that is towed through a mass of water or along the bottom to trap any fish in its path.

2. CLASSIFICATION OF TRAWL

Considering the areas of operation and the position of the fishing gear in relation to the sea bottom when fishing, trawl fishing gear can be grouped into four major categories:

- Surface trawls (two-boat type);
- Mid-water trawls (one-boat and two-boat types);
- Bottom trawls (one-boat and two-boat types);
- Other towing nets (beach seine, boat seine, etc.).

<u>Surface trawl or floating trawl</u>

To catch small fish such as sardine and anchovy, surface trawl nets are sometimes used, because these groups of fish often appear near the surface and swim slower than the larger pelagic fish.

Mid-water trawl

To catch pelagic fish in the middle layers (middle layers here means the water layer in between the first few metres below the surface and the first few metres above the sea-bed), mid-water trawls are sometimes used. Usually mid-water trawling is carried out on the high seas. Mid-water trawls can be subdivided into one-boat and two-boat types.

The following are the main differences between mid-water and bottom trawling:

1. Mid-water trawling is aimed trawling. The search for and detection of fish schools, determination of their swimming depths, bringing the vessel to its shooting position, dragging through schools, and duration of drags, are all operations which are carried out according to readings of hydroacoustic instruments. All elements of the trawler's manoeuvres during fishing are determined by aimed trawling.

2. Because the mid-water trawl moves at a considerable distance from both the sea-bed and the sea surface, fish are able to escape by swimming in all directions. For this reason, the mid-water trawl nets are symmetrical (their top and bottom panels are equal) and designed without the over hanging squares characteristic of bottom trawl nets, or reverse over hangs.

3. The mouth area of a mid-water trawl and the towing speed exceed considerably those employed in bottom trawling, hence the increased resistance and increased power requirements of the main engine for towing mid-water trawls.

Bottom trawl

A variety of trawl nets exist and taking into consideration the fishing method and construction of gears used, this type of trawl can be subdivided into three groups:

1. Bottom beam trawl
2. Bottom otter trawl
3. Bottom pair trawl

Bottom beam trawl

The beam trawl was the forerunner of all trawl gear design as we know it today. The principle of this equipment was simple and consisted of a beam whose purpose it was to spread the netting which was held above the sea-bed by two metal or concrete shoes. Sometimes a heavy beam is supported by steel shoes at each end which run over the sea-bed; the head rope is connected to the beam, the ground rope being fastened loosely between the base of the shoes. The cod end is formed in the usual manner, the strap having a lazy line attached to aid recovery.

The towing bridle is formed by two or three ropes: one from each shoe, and another from the center of the beam. These come together and are shackled directly to the towing warp.

<u>Bottom otter trawl</u>

This kind of trawl net is basically a large bag made of netting which is drawn along the sea-bed to scoop up fish on or near the bottom. Depending on the manner in which the gear is constructed and rigged, its operating characteristic can be altered for use on various types of bottom and for many species of fish.

This net is a large bag-shaped net, wide at one end, the mouth leading to the body of the net which tapers to the closed end, where the fish that enter through the mouth are trapped in the "cod end".

The mouth is of an oval shape when viewed from the front with two wings stretching out to increase the area swept and to guide fish in the net's path down to the cod end.

Around the upper edge of the mouth runs the "head rope" to which a number of floats are fixed and around the bottom of the mouth is the "ground rope" which is in contact with the bottom and is weighted.

The combined effect of the floats on the head rope and the weighted ground rope keeps the mouth open vertically.

The ground rope may be weighted with a chain, lead, or merely wire when the net is being operated on a clear bottom; when used on a rough bottom, iron, wooden or rubber rollers are rigged to assist its passage.

The horizontal spread of the mouth is attained by the "otter boards" towed ahead of the net and set at an angle of attack to the towing direction, so providing the outward force necessary to spread the wings to which they are fastened. The otter board may be connected directly to the wings or separated from them by a length of wire or rope known as the "sweep-line". The sweep-lines are connected to the otter board by a backstrop and to the net by a bridle or "danleno" arrangement.

Bottom pair trawl

Two boats, each towing one warp, are used; the net mouth is kept open by the outward pull provided by the correct lateral spacing of the fishing boats, so that no otter boards are required.

By utilizing the combined towing pull of the two boats, and since no otter boards are needed, a larger net may be used than would be possible by one boat; alternatively, two boats of low horse power, which could not undertake single boat otter trawling, can combine to use this method efficiently.

As no otter boards are necessary, the arrangement of the gear is simplified, the warps being connected directly to the sweep-lines or bridles from each wing.

3. CONSTRUCTION OF TRAWL

According to the accepted classification, trawls belong to the class of filters, and to the group of dragged fishing equipment. The principle of trawling is the movement of a trawl net filtering the water through the mesh netting, neither permitting the fish to escape nor gilling them. Trawls can be mid-water, bottom, or semibottom. The construction of a bottom trawl will be given as an example.

3.1 The Sections of a Trawl net

A bottom trawl net is a horizontally asymmetric netting bag. The upper part is larger than the lower part, thus creating an overhang of netting, the square. The square is designed to prevent the fish from escaping upwards.

- The upper part of the trawl net consists of two upper wings, an isosceles trapezium-shaped square, baiting, upper panel of the lengthener, and the upper panel of the cod end.

- The lower part consists of two lower wings, belly, lower panels of lengthener, and cod end.

In a four-seam or six-seam net, the side baiting will be added. The details of the sections of a trawl net can be seen in Figs. 35, 36 and 37.

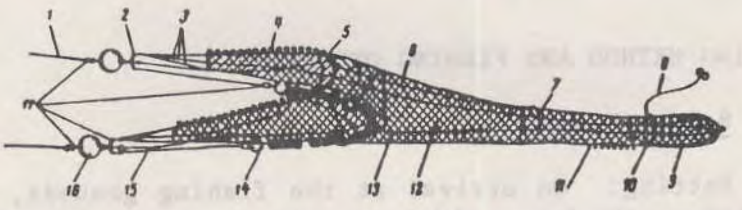
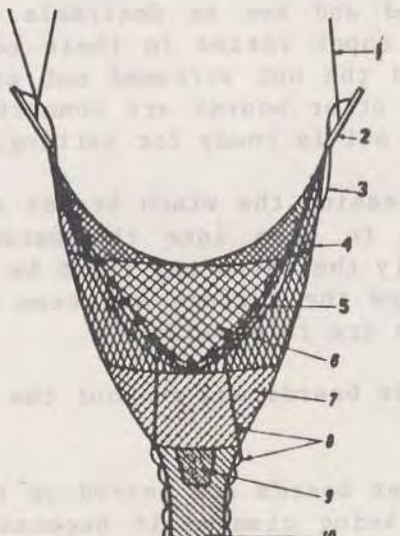


Fig. 35. A trawl rigged:

1 - sweepline;
2 - butterfly danleno;
3 - legs of mainlines and lastridge lines;
4 - float;
5 - quarter rope;
6 - lazy line of the fore splitting strop;
7 - fore splitting strop or fore halving becket;
8 - lazy line of the after splitting strop;
9 - cowhides;
10 - after splitting strop;
11 - chaffing pieces of hula skirt;
12 - body of the trawl net or belly and baiting;
13 - belly line and lastridge line;
14 - footrope with bobbins;
15 - footrope leg;
16 - metal bobbin;
17 - shackles.



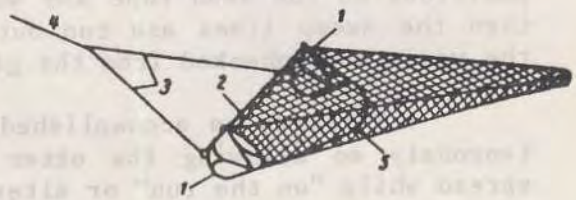


Fig. 37. Beam trawl:

1 - trawl heads;
2 - beam;
3 - bridles;
4 - warp;
5 - footrope.

Fig. 36. Otter trawl:

1 - warp;
2 - trawl board;
3 - quarter rope;
4 - wing;
5 - footrope;
6 - square;
7 - body (baitings and belly);
8 - belly lines;
9 - flapper;
10 - cod end.

4. FISHING METHOD AND FISHING OPERATION

4.1 Bottom beam trawl

Setting: On arrival at the fishing grounds, the beam trawls are hoisted on the booms which are then swung out. The same method is used for recovery. The operation is undertaken while the fishing boat streams along a straight course.

Hauling: When hauling, both nets are heaved in until they are at the boom tips. The cod ends are taken by the line attached to the cod end strap, and the catch is emptied out directly.

Beam trawl fishing grounds have shallow water and muddy bottoms. This kind of fishing is very famous in Nakhon Si Thammarat province and the south of Thailand. Fishing season is throughout the year.

4.2 Bottom otter trawl

Setting: When the gear is to be prepared, the boat streams along the desired course, into the wind and sea as desirable. The cod end is thrown out and the working ropes retied in their correct positions on the head rope and wings and the net streamed out astern, then the sweep lines are run out. The otter boards are connected to the warps and unhooked from the gallows, all is ready for setting.

This may be accomplished by releasing the winch brakes simultaneously so allowing the otter boards to drop into the water and spread while "on the run" or alternatively the warps may first be eased out until the otter boards are just below the surface and seem to be spreading satisfactorily before the warps are released.

All is now ready to set the otter boards and run out the warps to their required extent.

Hauling: When hauling, the otter boards are heaved up to the gallows and left hanging on the warps, being clamped if necessary to prevent slamming. The sweep lines are wound by winch to the ground rope. Then the ground ropes, wings and bellies of the trawl are also hauled up to the stern and the cod end is pulled to the fore deck for emptying.

4.3 Bottom pair trawl

Setting: When setting, the net is towed out by the bridles held at the gallows. The pull of one bridle is then transferred to the other boat by means of the heaving line and messenger, and the second boat then connects its warp to that bridle.

Both fishing boats then stream ahead together, paying out the warps evenly to their required extent, and fishing commences.

Hauling: Both fishing boats haul on their warps until the bridles reach the gallows. The fishing boats then converge until they are a safe distance apart, and a heaving line is used to transfer a messenger line fastened to the bridle end on one boat to the other. The first boat then disconnects the bridle from its warp so that the other may heave in the messenger on the winch through its second gallows block; when that bridle is hove up to the gallows, the net may be brought aboard and the cod end emptied in the usual manner for arrangement aboard.

4.3 GILL NETS AND ENTANGLING NETS

With many fishing gears made of netting it is found that fish sometimes hang in the mesh. In trying to swim through a mesh of netting which is a little smaller than the largest circumference of their body, they can get stuck or, in other words, "meshed". This can happen at the beginning of the dorsal fin of the fish but mostly it will be behind the opercula and the gills - i.e. they are 'gilled'.

The pressure of the mesh twine on the throat of the fish can cause the opercula to spread, and the net twine then hooks behind them so that the fish can go neither forward nor backward. By struggling to become free from the mesh the fish can further entangle itself. It may happen that small fishes can pass a mesh of a certain netting without difficulty, but bigger ones can be gilled, or gilled and entangled, and others, especially large ones, can be caught by entangling only, all in the same netting.

As a result of these observations, special gear has been constructed to catch fish by gilling. These are the so-called 'gill nets'. Other gear has been constructed to catch fish by entangling. These are the so-called 'entangling nets'. Gilling and entangling are two different principles of catching, but both can happen in the same fishing gear. On the other hand, gear used, e.g. for catching crabs by entangling, should not be called a gill net.

The structure of a gill net is the simplest among fishing nets. It is a single wall of net which consists of a number of pieces of netting joined together to form a rectangular shape or "fleet" of nets. It is provided with floats for buoyancy and with sinkers to enable it to stretch vertically when submerged underwater. It is necessary to distribute floats and sinkers in an even manner.

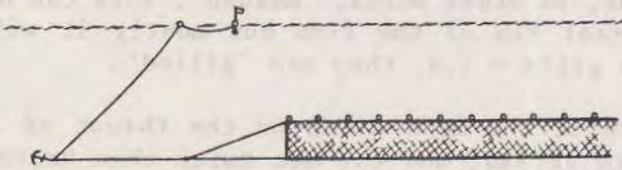
Several types of nets may be combined in one gear (for example, trammel net combined with gill net). According to their design, ballasting and buoyancy, these nets may be used to fish on the surface, in mid-water or on the bottom.

CLASSIFICATION OF GILL NETS AND ENTANGLING NETS

1. Set Gill Nets (anchored)

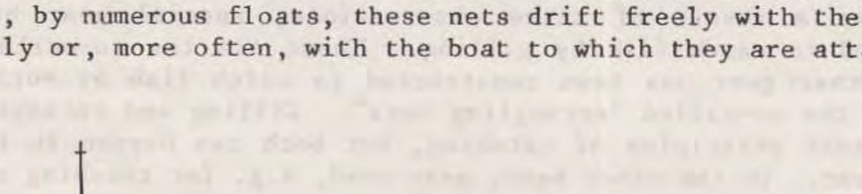
These nets are fixed to the bottom, or at a certain distance above it, by means of anchors or ballast sufficiently heavy to neutralize the buoyancy of the floats.

To give these nets a good contact with the bottom, which may be more or less rough, the leadline can be about 10 per cent longer than the float-line. These nets can be set in shallow water but also up to 150 metres in deeper waters (Icelandic cod nets are used down to 100 fathoms)



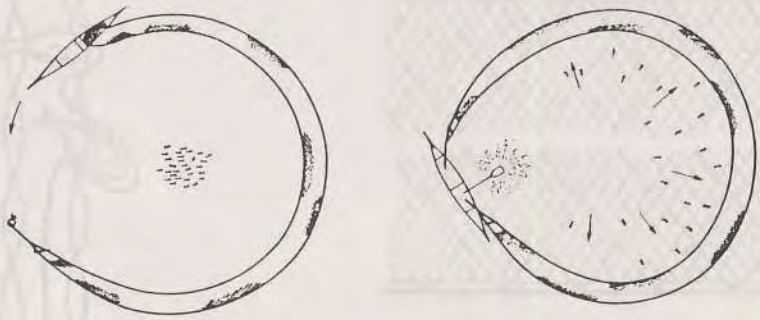
2. Drifting Gill Nets (Drift Nets)

Drift nets are especially used in sea fishing, particularly to catch herring, mackeral and sardines, but also for salmon and tuna and some other schooling fish. Kept on the surface, or a certain distance below it, by numerous floats, these nets drift freely with the current, separately or, more often, with the boat to which they are attached.



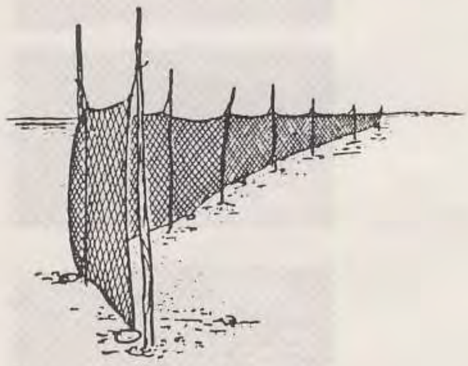
3. Encircling Gill Nets

This gear is generally used in shallow water with the float-line remaining at the surface. After the fish have been circled by the net, noise or other means are used to force them to gill or entangle themselves in the netting surrounding them. For frightening, a boat is usually placed in the middle of the shoal encircled by the gill net and then the fish are frightened by noises using sticks or oars striking the water. In Florida "cherry bombs" are regularly used to drive fish into the nets. Sometimes the net is set around a shoal not in the form of a circle, but more in the form of a spiral (coil). Sometimes not only are gill nets used for this purpose but also three-walled trammel nets and two-walled nets.



4. Fixed Gill Nets (on stakes)

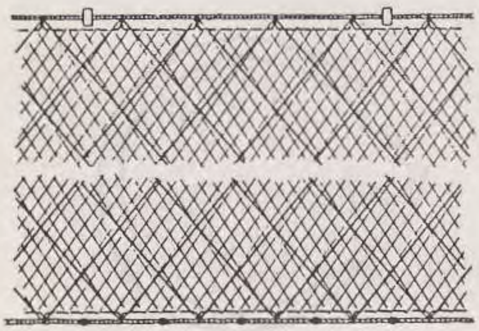
Used essentially in coastal waters, these nets are mounted on stakes driven into the bottom. The fish are collected at low tide (*no floats, no sinkers used**)



5. Trammel Nets

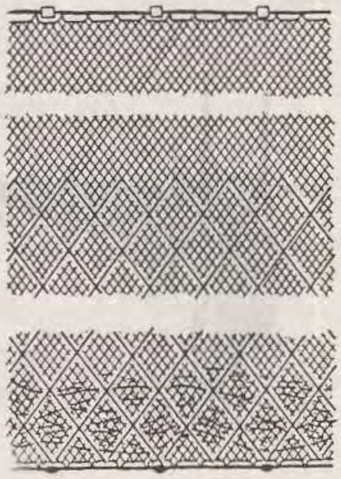
These bottom-set nets are made with three walls of netting, the two outer walls being of a larger meshsize (armouring) than the loosely hung inner netting panel (lint). The fish get entangled in the inner small meshed wall after passing through the outer wall.

Trammel nets are commonly operated to catch shrimps. Fishing operation is carried out in either day or night-time (1 hour). The water depth is between 3-10 metres. A trammel net for cuttle fish is set along the coast for 12 hours in the daytime.



6. Combined Gill Nets - Trammel Nets

This bottom set gear is made with a gill net, the lower part of which is replaced by a trammel net. It may catch bottom fish in the lower trammel net part, together with semi-demersal or pelagic fish in the upper gill net part.



FACTORS TO BE CONSIDERED IN SELECTING MATERIALS FOR GILL NET

1. Flexibility of netting cord;

The material of the netting cord is very important for gill net fisheries efficiency. In the past, fishermen used soft fibre made from natural materials such as cotton, silk, rummy, etc., but now they have been replaced with synthetic fibres such as nylon, vinylon, tetoron, etc. Among them, nylon is the best material for the gill net, because it posses good flexibility, high breaking strength, suitable elongation, good transparency, etc.

Most fishermen adopted very thin netting cords provided the breaking strength would allow, to give more flexibility to the cord during a fishing operation.

In special cases, fishermen use only one side twisting of the netting cord to have more flexibility. Spanish mackerel gill net operated in Thailand is one such example. (Ordinary type of netting cord consists of upper and lower twist).

Table 3. Catch ratio by kinds of netting cord

Fish Species and Country	Kinds of Netting Cord	Catch Ratio
Cod (Norway)	Cotton : nylon	1 : 3.2 - 4.4
Mackerel (Norway)	Cotton : nylon	1 : 1.2 - 1.3
Salmon (Japan)	Rummy : nylon multifilament	1 : 1.8
Salmon (U.S.A.)	Nylon Multifilament : nylon monofilament	1 : 2.3
Sardine (Japan)	Cotton : vinylon	1 : 1.8
Sardine (Japan)	Cotton : silk : nylon	1 : 1.03 : 1.44
King crab (Japan)	Cotton : vinylon	1 : 1.86

2. Tension of netting cord;

The degree of tension imposed on the leg of mesh is also closely connected with the efficiency of the gill net. Even if the number of meshes of the main net is the same, the shape of mesh will differ according to the hang-in ratio of the gear, and this also affects the tension of netting cord. Moreover, the tension of the legs of the meshes differs in accordance with the buoyancy of the float and sinking power of the sinker attached to the net. If the tension imposed on the leg of mesh is too high, good catch will be impossible.

3. Breaking strength of netting cord;

The breaking strength of the gill nets should be as high as possible so as to prevent damage while fishing. When the fish are gilled or entangled in the net, the fish have some momentum, so they may break the net and escape if the breaking strength is not high enough.

The gill nets require good flexibility and low visibility. Therefore, the thinner the netting cord used, the better will be the effectiveness, but thin netting cord ordinarily has low breaking strength.

When we are choosing the netting cord from many kinds of synthetic fibres, it is advisable to select one which has high breaking strength and the least thickness.

4. Elongation of netting cord;

The proper elongation of netting cord is necessary for gill nets to catch fish. Ordinarily, the proper elongation ratio at the breaking point is about 25 to 30 per cent.

The percentage ratio of elongation at breaking point in wet condition for several fibres used in fishing is listed in Table 4.

Table 4. Elongation ratios of different fibres

Kinds of Fibre	Ratio of Elongation (%) in Wet Condition
Nylon multifilament	20 - 27
Saran	18 - 33
Teviron	15 - 30
Tetoron	7 - 13
Polyethylene	10 - 40
Vinylon	19 - 30
Polypropylene	25 - 60
Cotton	8

5. Colour of the net and type of netting cord construction;

To make a good catch, it is preferable that the net has low visibility in the water.

Generally speaking, we can say that the colour of the net should be similar to the colour of the water of the fishing ground.

According to practical experience, sardine drift net which is operated at a depth of 50-60 metres in the daytime shows that dull grey is the best colour of netting cord to be used. Salmon gill net which is operated in the North Pacific needs greenish-grey colour, because the water transparency is very low and fishing operations are conducted at twilight. A blue colour net is good for catching flying fish, as the waters in which this fish migrates are highly transparent.

Recently, monofilament nets have been used as the material for gill net, especially in salmon fishing. Though this net has a very hard twine, the extreme transparency of the twine brings very good results to fishing.

6. Mesh size of the net;

Mesh size selection is a very important factor in designing gill nets. The mesh size of the net is closely related to its efficiency. The optimum mesh size should be chosen by considering the elasticity of the fish body, stress strain of netting twine, elongation of netting twine, momentum of fish, the shape of the fish body, etc.

7. Hang-in coefficient of the net;

The shape of the mesh is determined by the value of hang-in coefficient. Generally, the hang-in coefficient of gill net is about 25-45 per cent. On the other hand, trammel net or semi-trammel net has higher value of hang-in coefficient.

As explained before, there are four types of gill nets such as surface gill net, bottom gill net, etc. and the hang-in coefficient of the float and sinker line vary according to the type of gill net.

It is generally said that in surface gill nets, the float line side has 3-10% less hang-in coefficient than that of the sinker line. In mid-water gill net, the hang-in coefficient of both lines is almost the same. On the other hand, bottom gill net's float line has 3-10 per cent greater hang-in coefficient than that of its sinker line side.

In order to keep the expected mesh shape of any point in the surface gill net or bottom gill net, the hang-in coefficient of the float line and sinker line has to be adjusted. In the case of surface gill net, the amplitude ratio between surface wave and mid-water wave around sinker line is different.

In the case of bottom gill net, as the sea bottom is usually not flat, in order to keep the float line and sinker line the same length while in operation, different hang-in coefficient must be used on the lines.

8. Depth and length of the net;

The depth of surface gill nets and drift gill nets is usually large, whereas that of bottom gill nets is comparatively small.

In surface gill nets, the swimming layer of fish caught is distributed quite widely, so that the depth of net should be as great as possible.

In drift gill nets, when the net is pushed by the current under the water, tension is exerted on the net. However, a drift gill net does not take much water resistance even though the net is deep, since it is kept adrift in the water. Therefore, drift gill nets have greater depth than other types of gill nets and often measure as deep as 23 metres.

The length of the float line of gill nets usually measures 25-60 metres, according to the fishermen's preference.

9. Surplus buoyancy;

The buoyancy force of surface gill nets and drift gill nets should be greater than the total sinking force of the gear plus the additional weight of fish caught, since these nets are operated on the sea surface. In the case of entangling gill nets, the surplus buoyancy should be as small as possible.

Nets which are not fixed by anchor usually have a small amount of sinking force, whereas permanently set nets should have a relatively greater sinking power, since the net's bottom is subject to floatation by the current.

In some cases, drift gill nets are used to entangle the fish, and sometimes the sinkers are omitted.

The buoyancy of bottom gill nets is relatively small and the net has greater sinking force. In brief, we can say that the sinking force is 2 to 2.5 times greater than the buoyancy.

4.4 LIFT NET (STICK-HELD DIP NET)

FOREWORD

The stick-held dip net, which is one of the most typical types of lift net fishing has been widely operated in Japan since old times. The gear is suitable for small-scale fishing; it is easily operated at a lower cost and by smaller crews than some other types of gear such as purse seine, large set net, etc.

Furthermore, the merit of this fishing gear is that it can be carried out by many types of fishing boat which are also used for other kinds of fishing.

For example, pike mackerel is commonly caught by stick-held dip net from salmon gill net fishing boats during the salmon off season around the northern part of Japan. The operation is done at night with fish luring lamps to attract the fish.

In Thailand, catching squid by stick-held dip net began after 1978. Before the spread of this type of fishing, the squid had been caught mainly by trawl net or cast net fishing.

The squid cast net is one of the traditional fishing gears in Thailand. Although this gear is very effective for squid fishing, its size allows only a limited amount of catch.

With the advent of electric luring lamps, the squid cast net was replaced by stick-held dip nets whose number are increasing year by year. As mentioned above, stick-held dip net fishing is now an important fishing method in Thailand.

1. Outline of the stick-held dip net

1.1 Description of the stick-held dip net

The stick-held dip net is one of the many types of lift nets used for catching pelagic fishes such as sardine, pike mackerel, horse mackerel, squid, etc.

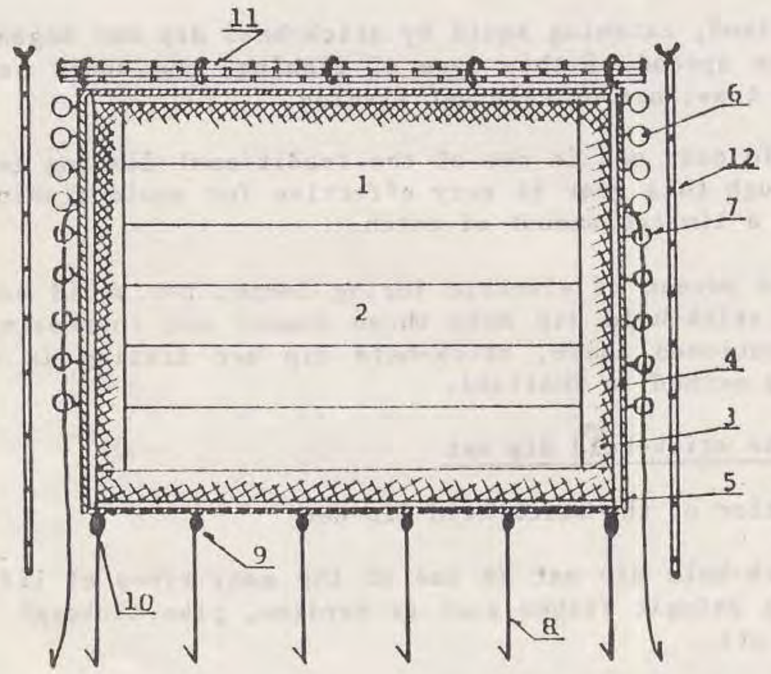
The net is composed of cod end, main net, side net and selvedge net. It is designed to scoop fish which are attracted by the fish luring lamp or bait. The net is also provided with a number of small sinkers on the sinker line of the net and heavier sinkers to which about six or more ropes are connected along the front end of the net for hauling purposes.

At the opposite end, the net is connected to a bundle of bamboo poles to keep the upper part of the net afloat on the sea surface. On each side of the upper part of the net end, some floats are attached for the purpose of preventing the escape of fish during hauling operations.

Two bamboo poles are used for the purpose of stretching out the net during operation. These are taken off from the net when the net is hauled toward the boat. Also a number of rings are attached to both sides of the net. Through these rings, some ropes are led for the purpose of pulling up the sides of the net immediately to prevent the escape of fish during hauling.

1.2 Operation method

Motorized fishing boats are now being used for operation of stick-held dip net. The net is set in fishing grounds where migratory schools of fish are mostly found.



1. Cod end
2. Main net
3. Side net
4. Selvedge net
5. Side rope
6. Float
7. Ring
8. Lift line
9. Small sinker
10. Heavy sinker
11. Bamboo pole
12. Bamboo pole

Fig. 38. Schematic view of the stick-held dip net

The operation is done at either side of the boat in order to make the operation easier and more convenient.

The stick-held dip net is mainly operated with fish luring lamps to attract the fish during night-time operations. When the gear is operated in the daytime, some bait is used to attract fish. With these luring devices, fish are made to concentrate on either side of the boat where the net is set.

Hauling lines are then pulled by using the line hauler until the front part of the net is hauled up to the sea surface to prevent the fish from escaping. The bamboo poles are taken off from the net or pulled with the net toward the boat so that it will be easier to scoop the fish caught.

The operation is done 20 to 80 times in a day by following the described procedure.

1.3 Fishing boat

As mentioned before, the fish most commonly caught by stick-held dip net in Japan is pike mackerel. Below is the description of the boat and the method employed in pike mackerel stick-held dip net fishing.

The fishing season for pike mackerel in Japan lasts five months, from August to December. During the rest of the year pike mackerel fishing is prohibited in Japan. Accordingly, there are no boats engaged exclusively in pike mackerel stick-held dip net fishing. Most boats engaged in this fishery are also used for salmon gill net fishing, skipjack pole-and-line or mackerel pole-and-line fishing, depending on the season.

The sizes of boats used vary from 10 to 300 GT. Therefore, there is no specific design of the boat but it should preferably have the following characteristics:

1) Shallow draft

The fish should be able to pass underneath the bottom of the boat to the side where the net is. Therefore, shallow draft is recommended.

2) Shallow freeboard

In order to operate easily, shallow freeboard is recommended.

3) Resistance against wind

At the relative position between the boat and the net should be maintained during a fishing operation, therefore, the boat should have resistance against wind.

4) Fish hold

The fish hold should be partitioned into small chambers. A fish hold with small chambers is required as fish caught at different times should be kept in different chambers.

Fishing equipment: The fishing boat should have certain equipment installed on board:

1) Fish luring lamps

The success or failure of this fishing method depends on the fish luring lamps. Therefore, the power of illumination should be large but within the regulation limit of 30 kw per boat. In general, the fish luring lamps are connected from 5 to 9 booms positioned 1.5 to 2.0 metres above the sea surface.

2) Winch and roller

A six-reel winch is provided for hauling the net towards the boat and two auxiliary winches are installed on both sides of the stern. To take up the net to the deck, rubber rod-shaped rollers are provided on the bulwark top.

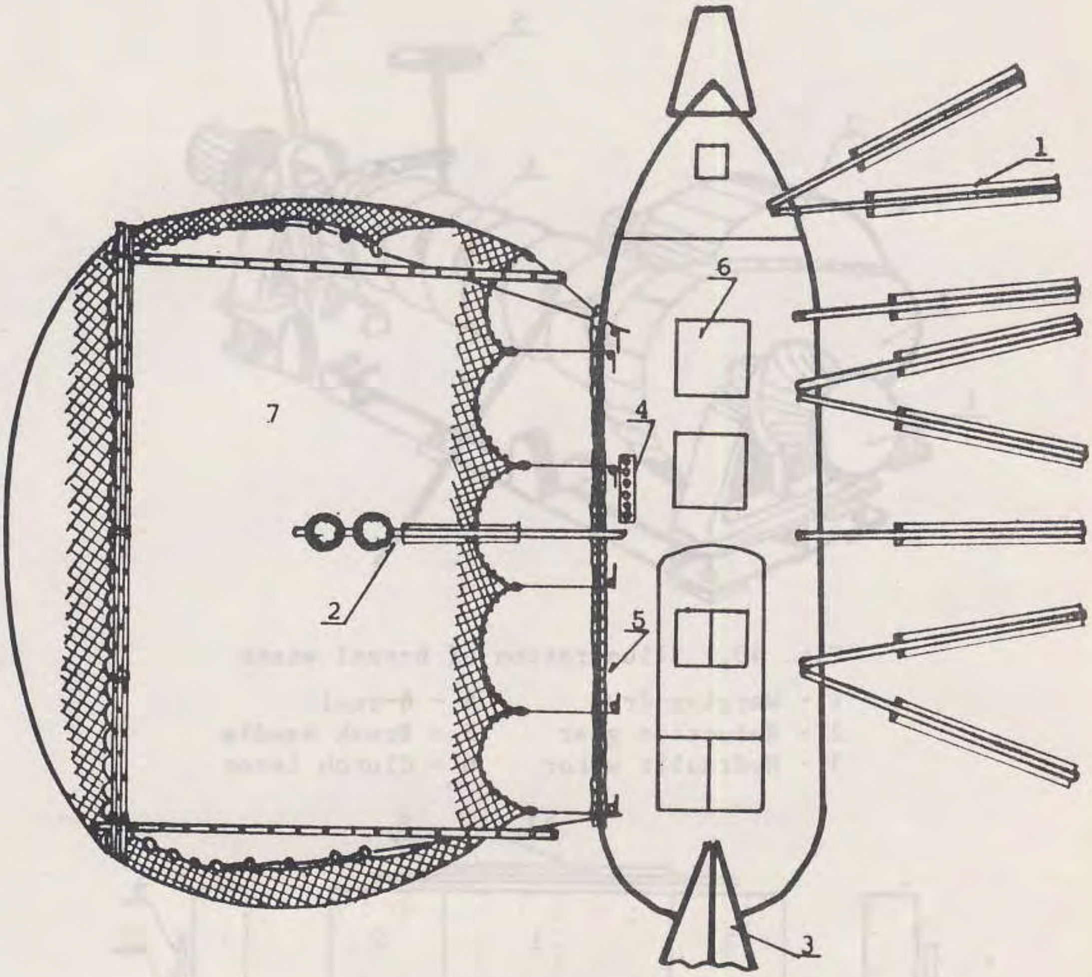


Fig. 39. Fishing boat of stick-held dip net

1 - Fish luring lamp (starboard side)

2 - Fish luring lamp (port side)

3 - Spanker

4 - 6-reel winch

5 - Roller

6 - Fish hold

7 - Net

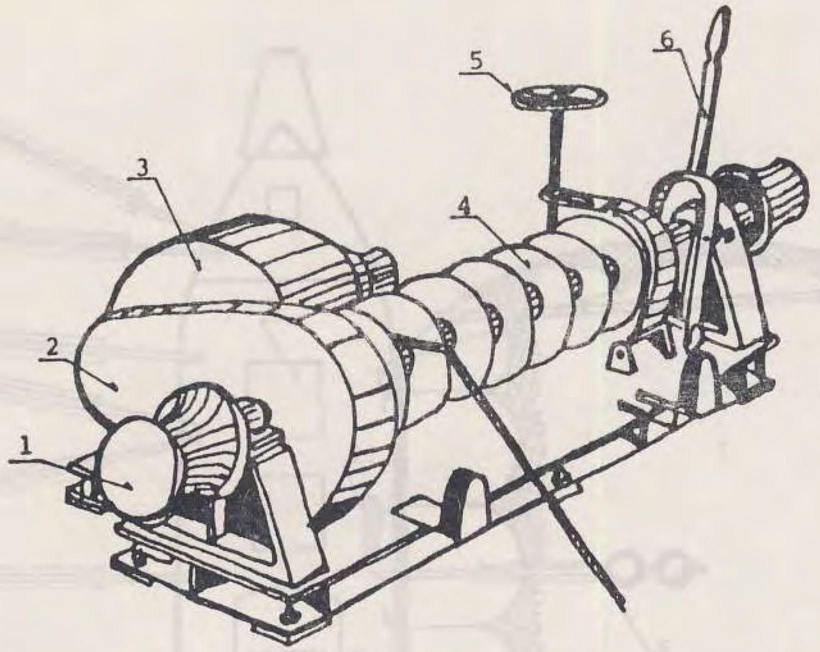


Fig. 40. Illustration of 6-reel winch

1 - Warping drum
2 - Reduction gear
3 - Hydraulic motor
4 - 6-reel
5 - Break handle
6 - Clutch lever

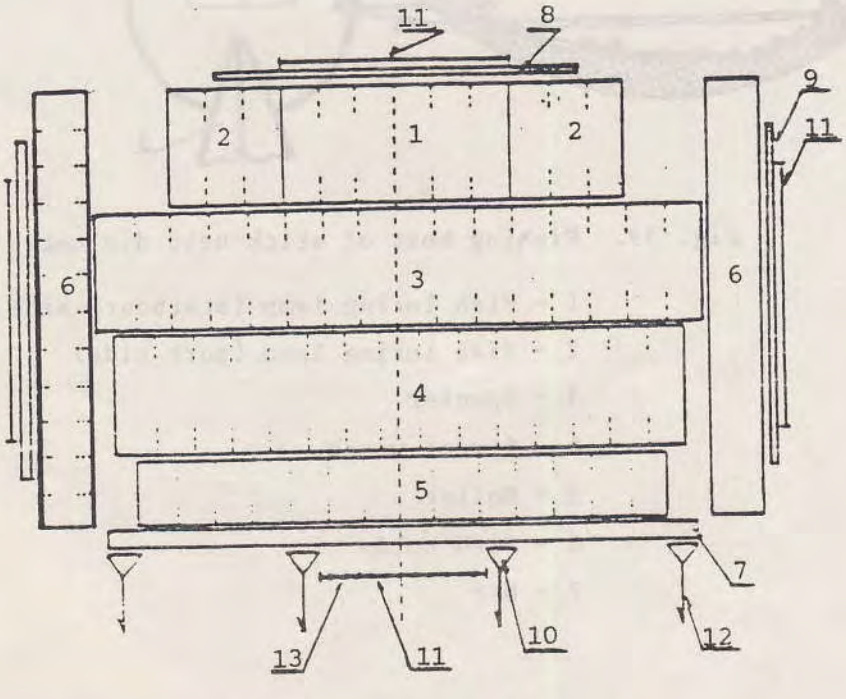


Fig. 41. Details of the net

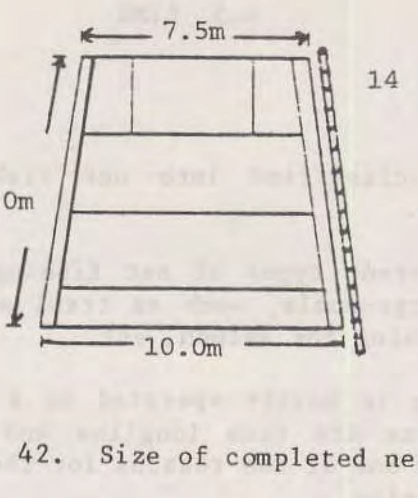


Fig. 42. Size of completed net

Scale : none

Particulars

No.	Name	Twine	Size of mesh	No. of mesh	Length	No. of sheet
1	End Vinylon	20's/15	2.3	100	7.5m	6
2	Sub - end	20's/12	2.3	100	7.5	3x2
3	Main 2nd	20's/9	2.3	100	7.5	16
4	Main 3rd	20's/9	2.3	100	7.5	15
5	Main 4th	20's/9	2.3	100	3.8	14
6	Side	20's/9	2.3	100	3.8	12x2
7	Lower brim	20's/15	4.3	15	40.0	1
8	Upper selvedge	20's/12	2.8	6	20.0	1
9	Side selvedge	20's/12	2.8	6	20.0	1x2
10	Triangle	20's/45	4.3	1 - 15		4
11	Side line	Vinylon 6mm dia S&Z				35.5m
12	Lift line	Vinylon 9mm dia				30m x 4
13	Sinker	Lead 220g/P'ce				100 P'cs
14	Pole	Bamboo 10 cm dia 11 m				2 P'cs

Fig. 43. Pike mackerel stick-held dip net (small type)

4.5 LINE

INTRODUCTION

Fishing is classified into net fishing, line fishing and miscellaneous fishing.

Of the different types of net fishing, there are many which are operated on a large-scale, such as trawl net fishing, purse seine fishing, gill net fishing for salmon, etc.

Line fishing is mostly operated on a small-scale in coastal waters; the exceptions are tuna longline and skipjack pole-and-line fishing. This may be one of the reasons for there being relatively few studies on line fisheries.

The construction of gear and the methods of operation vary according to the fishing ground, fishing season and fishermen's preferences, even for the same kinds of fishing.

Line fishing has certain advantages over other methods of fishing, but there are also disadvantages. On the advantage side, fishing grounds where line fishing is carried out are less likely to be limited by environmental factors. For example, operation of line fishing gear is possible in very deep-sea as well as in shallow waters, and in waters with strong currents and/or rough bottom. Furthermore, less damage is done to fish caught by line fishing, therefore preservation of freshness is good. On the other hand, a disadvantage of this type of gear is that the amount of catch is small because of the catching mechanism; one hook, one fish. Also, in most cases, a particular kind of bait is required for each species of target fish.

1. Line fishing gear

In comparison with the gear for net fishing, the line fishing gear is simple, being composed basically of a line and a hook. Other elements, such as pole, float, sinker, swivel and snap are added to the gear as required. The amount of catch is very much influenced by the efficiency of the gear, therefore the choice of material and the construction of the gear should be done carefully.

1.1 Hook

Hooks for line fishing exist in a variety of shapes and sizes. The materials of which hooks are made are mainly iron (galvanized or tinned for protection against rust), brass and stainless steel.

According to their shapes, hooks can be classified into three types: round, angular and long type. Besides, there are complex hooks, such as double and triple hooks, and hooks elaborately constructed as jigs for squid and for tuna pole-and-line fishing (Fig. 44).

A hook consists of five distinct parts, namely: head, shank, bend, point and barb (Figs. 45 and 46).

The function of the hook head is to allow the line to be fastened easily and securely to the hook. Fig. 46 shows different forms of hook heads.

A hook with a long shank can be handled easily; it is easy to place the bait on the hook and to remove the fish from the hook. Furthermore, a long shank prevents the line from being cut by the fish's teeth. However, the catching efficiency of such hooks is not high.

In order to prevent the captured fish from dropping from the hook, most hooks have a barb. In some cases when it is necessary to remove the fish from the hook quickly, as in the case of pole-and-line skipjack fishing, hooks without barbs are used.

The hook with the point bent inwards is the most suitable for use with bottom longline as it does not enter the fish's body very deeply and thus allows the fish to remain alive for some time after swallowing the hook.

The hook twisted in the bend part is convenient because the bait can be placed on the hook easily and its catching efficiency is high.

Double and triple hooks are used for troll fishing; these hooks are effective to prevent the fish from dropping from the hook.

Squid jigs vary in shape, colour and materials. Body parts are made of plastic, vinyl, rubber, cloth, wood, lead, etc.

Bonito and tuna jigs also vary in colour and materials of the lure part (body part). Generally fish skin and chicken feathers are used to conceal the hook.

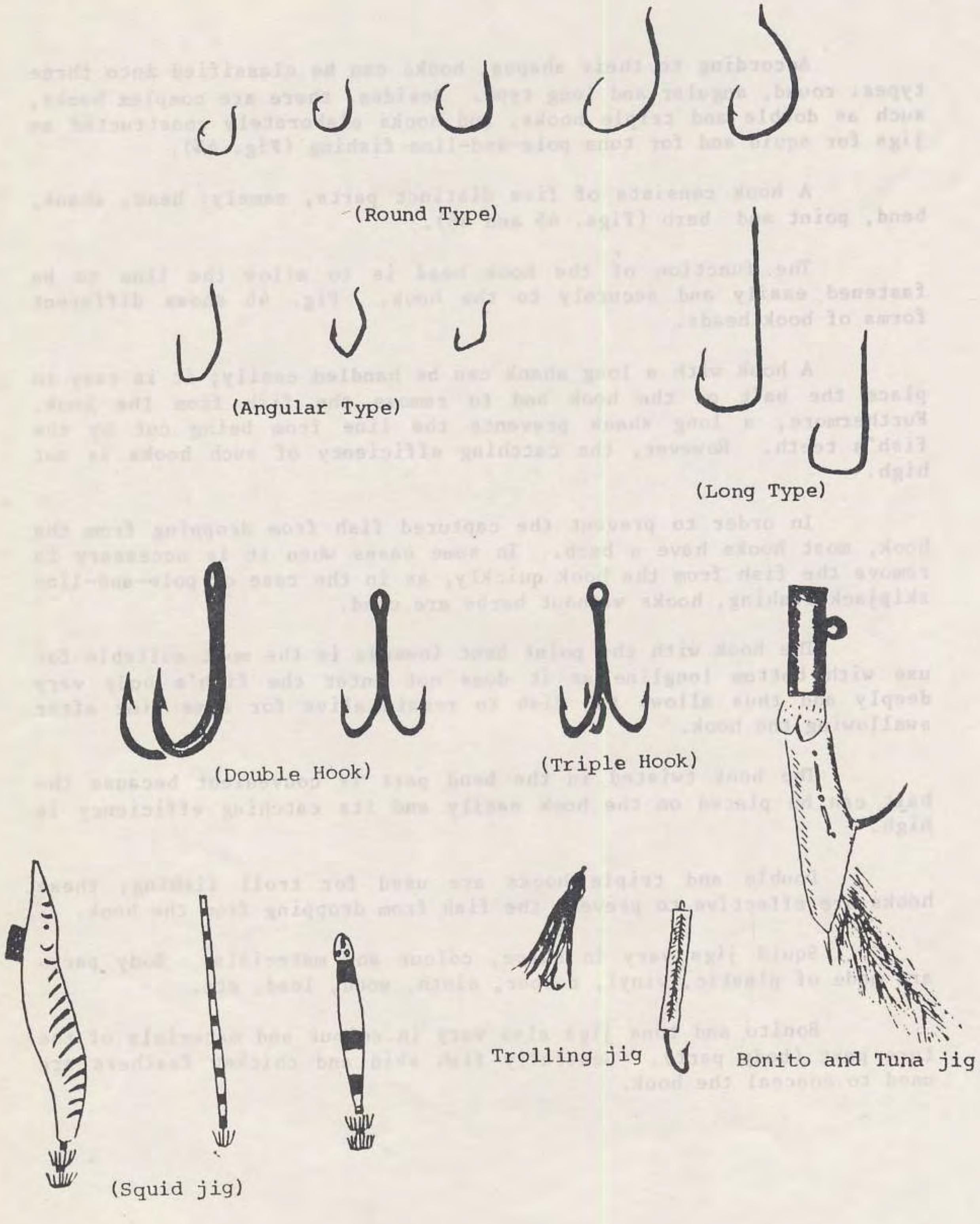


Fig. 44. Different types of hooks and jigs

Fig. 45. Parts of hook

1.2 Line

The material and thickness of the line depend on what kind of fishing it is used for. For example, in the case of tuna longline, the main line is 6 mm in diameter and it is made of vinylon, nylon, polyester, etc. Branch lines are somewhat thinner and are also made of nylon, vinylon, or polyester, whereas the hook line is made of steel wire. In the case of handline and pole-and-line fishing, the main line is not as thick as that of tuna longline. Nylon or polyethylene are used for both the main line and the hook line.

Generally, lines for line fishing should be as thin and as strong as possible, particularly branch lines and hook lines. Therefore, nylon monofilament is the best material for line fishing. Table 2 shows the standard of nylon monofilament.

1.2.1 Thickness of monofilament nylon line and the size of fish

Y. Ishida estimated the relation between the size of fish and the thickness (*go*[1] standard) of nylon line in the following way:

1) Spindle shape fish
$$N\ (go) = 6.2 \times W\ (kg)$$

2) Flat shape fish
$$N\ (go) = 4.2 \times W\ (kg)$$

N : *go* standard
W : Weight of fish (kg)

1/ *go* is the Japanese standard for thickness of monofilament nylon line. The metric equivalents of different *go* values are given in Table 5.

2. Classification of line fishing methods

Line fishing is classified according to the type of gear construction as follows:

- Line fishing
  - Handline
  - Pole-and-line
  - Longline
    - Drifting longline
    - Bottom longline
  - Trolling

Table 5. Strength of nylon monofilament line

No. of *go*	Diameter	Breaking strength	Knot strength
3	0.29 mm	4.2 kg	2.7 kg
5	0.37	7.3	4.1
7	0.44	10.7	5.9
10	0.52	14.4	8.0
12	0.57	17.0	8.1
16	0.66	21.9	10.4
18	0.70	24.0	10.9
20	0.74	27.1	12.2
24	0.81	30.7	13.5
28	0.87	36.4	16.6
30	0.90	38.1	17.8
35	0.97	41.4	19.8
40	1.04	46.9	21.5
50	1.17	56.9	27.6
60	1.28	65.1	28.4
70	1.38	74.5	30.0
80	1.47	82.0	35.0
100	1.65	101.0	47.0
120	1.81	115.0	57.2

2.1 Handline fishing

Handline gear is very simple. It is composed of the main line, branch lines, hook and lead. Some types of handline gear have several hooks; for example, a main line with an end-lead may have hooks on branch lines so that vertical longlines are formed. Fishing with a "Balance" which is a kind of pole, is also considered a variation of handline fishing. Handline gear is used to catch the fish dwelling in mid-water and near/on the sea bottom. Sea bream, mackerel, jack-mackerel and other bottom fish are caught by handline fishing.

2.1.1 Handline fishing for demersal fish

Fishing gear

The gear is shown in Fig. 47 and its specifications are given in Table 6.

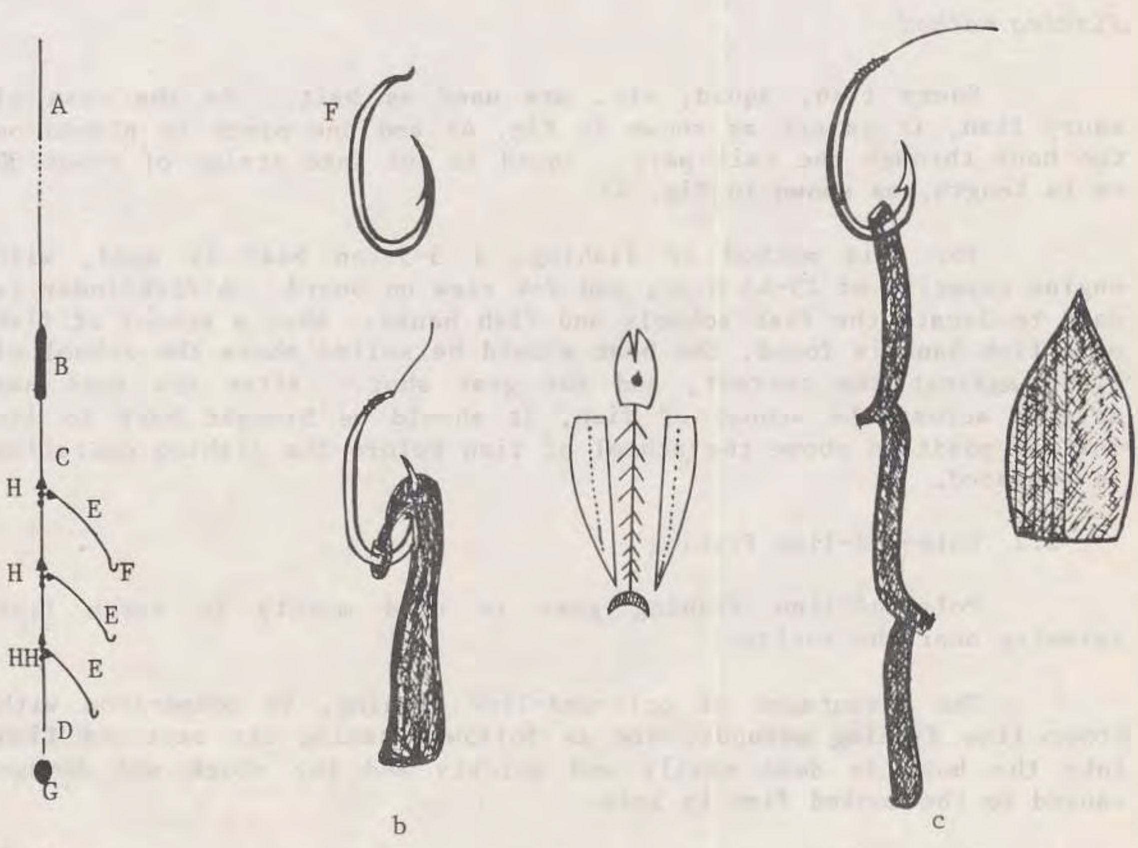


Fig. 47. a, b, c : Handline fishing gear and bait

Table 6. Specifications of handline gear for demersal fish

Mark	Name	Material	Dimensions		Amount
A	Main line 1	Wire #20		450-600 m	
B	- " - 2	Vinylon	48-ply	20 cm	
C	- " - 3	Nylon	30 *go*	40 m	
C	- " - 4	Nylon	20 *go*	2.3 m	
E	Branch line	Nylon	30 *go*	1.5-3.0 m,	12-15
F	Hook		23-25 *go*		12-15
G	Sinker	Iron	1 kg		
H	Two-way swivel				

Fishing method

Saury fish, squid, etc. are used as bait. In the case of saury fish, it is cut as shown in Fig. 47 and one piece is placed on the hook through the tail part. Squid is cut into strips of about 30 cm in length, as shown in Fig. 47.

For this method of fishing, a 3-5-ton boat is used, with engine capacity of 15-45 h.p., and 2-4 crew on board. A fishfinder is used to locate the fish schools and fish banks. When a school of fish or a fish bank is found, the boat should be sailed above the school of fish, against the current, and the gear shot. After the boat has drifted across the school of fish, it should be brought back to its initial position above the school of fish before the fishing operation is repeated.

2.2 Pole-and-line fishing

Pole-and-line fishing gear is used mostly to catch fish swimming near the surface.

The advantages of pole-and-line fishing, in comparison with other line fishing methods, are as follows; taking the captured fish into the boat is done easily and quickly and the shock and damage caused to the hooked fish is less.

Pole-and-line fishing on a large-scale is carried out mainly for skipjack and mackerel. Skipjack pole-and-line fishing is described below, as skipjack is an important species in commercial fisheries in tropical areas.

2.2.1 Skipjack pole-and-line fishing

Skipjack distributes widely in the warm waters of the world and is caught mainly by purse seine, pole-and-line and gill net.

A school of skipjack can be located by means of a fishfinder, trolling with lure and by visual observation. Skipjack form schools around drifting objects, whale sharks and baleen whales. Flocks of birds often circle above schools of skipjack and feed on the small fish. It is therefore possible to detect the presence of skipjack by spotting large drifting objects, whales, sharks or a circling flock of birds, all of which are easily observed by the naked eye.

When a school of skipjack has been found, the boat should approach the school and live bait fish be thrown from the bow to attract the school toward the boat.

2.3 Longline fishing

Handline and pole-and-line fishing are movable fishing operations made at the place where the school of fish is found. On the other hand, longline fishing is passive, that is, the gear is set at the place where the school of fish is expected to be found. Therefore the scale of gear is comparatively larger than the gear of handline and pole-and-line fishing.

Longline is classified into two types of fishing, one is drifting longline and the other is bottom longline.

2.3.1 Drifting longline

Drifting longline which has the largest size of boat, size of gear, etc., is commonly tuna longline.

Tuna longline fishing is operated in any waters between the latitudes of 40° South and 40° North. The number of units of gear used is different according to the size of the boat, but the construction of gear is almost always the same.

a) Tuna longline fishing with a small boat

Tuna longline fishing originated as a small-scale fishery in the coastal waters off Japan. Gradually, with the mechanization and modernization of fishing vessels, new fishing grounds have been developed and expanded from coastal waters to off-shore and pelagic waters.

Tuna longline fishing is still operated in coastal and off-shore waters on a small-scale with small boats of under 20 tons. Generally, tuna caught by small boats and preserved by means of ice and sea water is more expensive than tuna caught and frozen for long periods on board large vessels which operate in pelagic waters.

2.3.3 Bottom longline fishing

Bottom longline is used widely throughout the world. There are many types of bottom longline, but many of them are operated only on a small-scale, generally in coastal waters.

i) 10-ton boat

Gear is shown in Fig. 48.

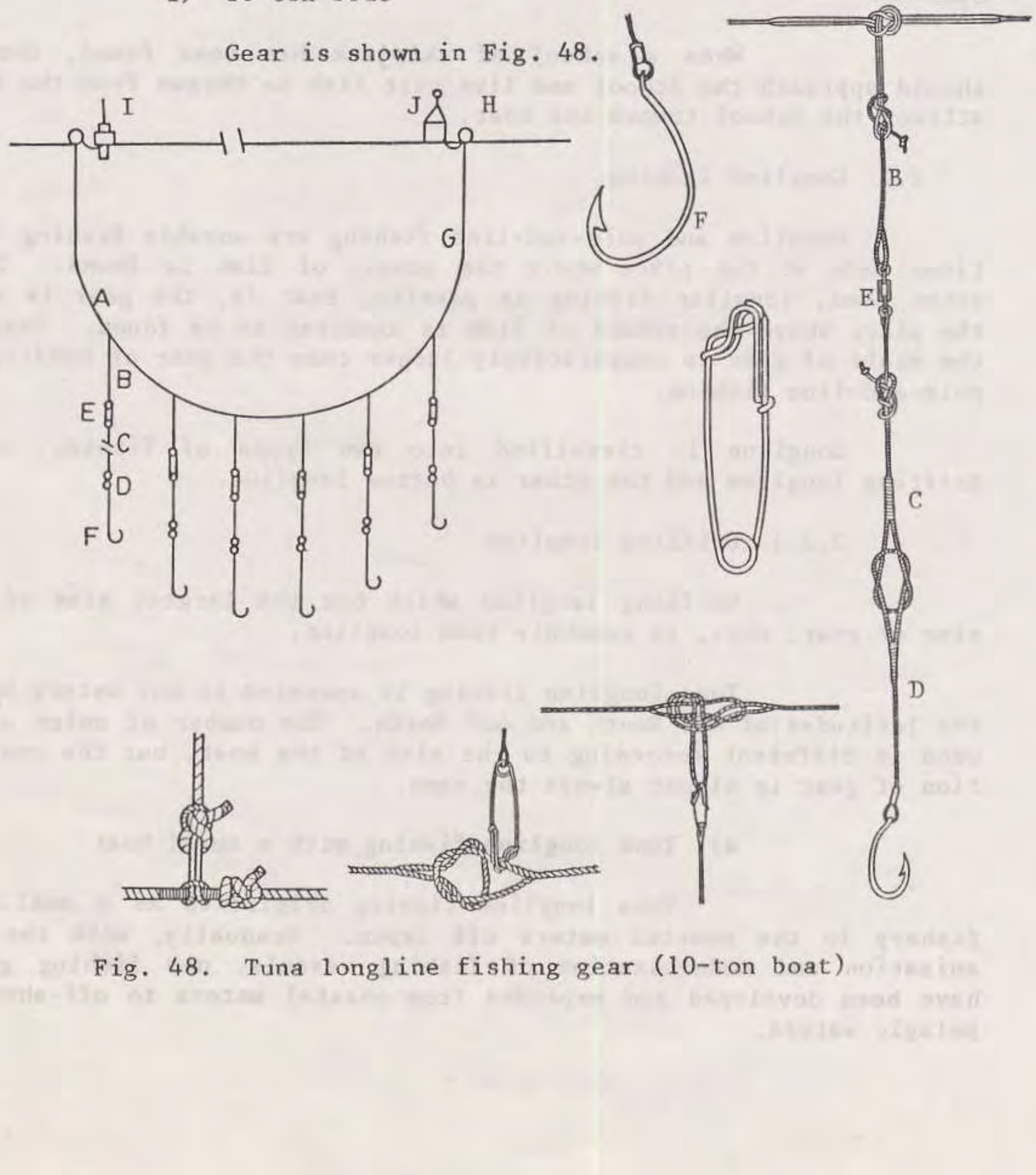


Fig. 48. Tuna longline fishing gear (10-ton boat)

a) Materials and structure of bottom longline gear

(i) Main line

Cotton and vinylon are widely used because these materials have high specific gravity which gives them high sinking speed and reduces the effect of current upon gear. Thickness is determined by many factors such as character of the bottom, speed of current, depth of water, size of fish, pulling power of fish, number of branch lines and size of the fishing boat. Generally, the thickness of the main line used by small boats (1-3 tons) in waters of less than 100 m in depth, is about 1.5 mm in diameter. Boats of 3-10 tons use a thicker main line whose diameter ranges from 1.5-2.2 mm.

When fishing is done in waters with a strong current, a main line thicker than 2.3 mm in diameter is used, regardless of the size of the boat. In most cases, length of one unit (basket) of main line ranges from 200-700 m.

(ii) Branch line

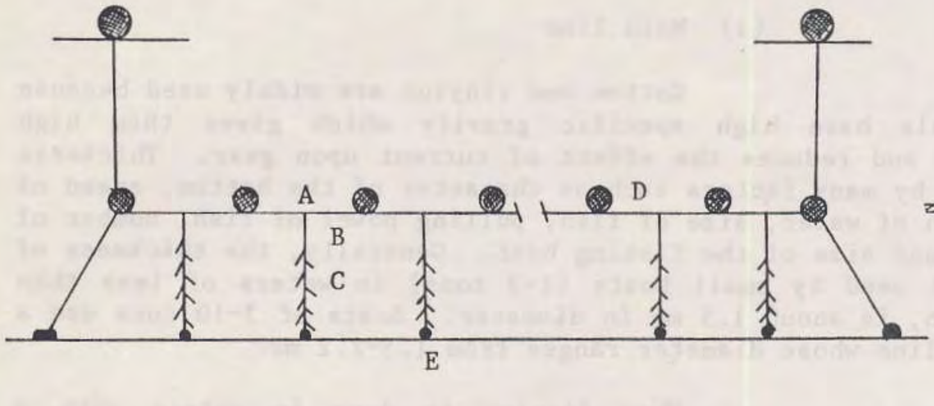
Branch lines should be moved by the current and have low visibility. Nylon with its high flexibility, good breaking strength, elongation and durability is the most suitable material for branch lines. The thickness and length of branch lines are determined by the size and power of the fish and the current speed. The length will also have to be chosen so as to allow for easy handling of the gear.

The length of branch lines and intervals between branch lines are determined by the size of the fish and density of the school. Generally, the length of interval between the branch lines is double or triple the length of a branch line.

b) Construction of typical type of vertical bottom longline

Fishing gear

Gear is shown in Fig. 49 and its specifications are given in Table 7.



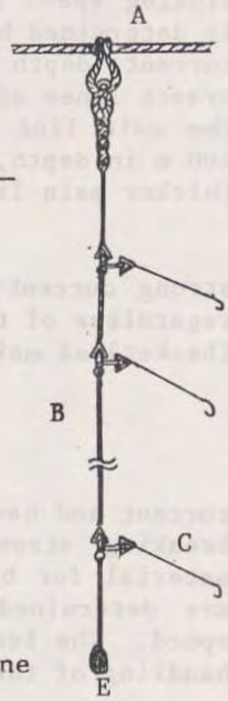


Fig. 49. Rockfish vertical bottom longline

Table 7. Rockfish vertical bottom longline

Mark	Name	Material	Size/Quantity	
A	Main line	Vinylon	ϕ 2.7 mm	960-2160 m
B	Branch line	Nylon	ϕ 0.6 mm,	15 m, 40-90 ps
C	Hook line	Nylon	ϕ 0.4 mm	0.8 m, 320-720 ps
D	Float	Glass	ϕ 9 cm	24 m intervals
E	Sinker	Stone		40-90 ps

Fishing method

Squid is used as bait in night-time operations and mackerel, saury, sardine, etc., are used in daytime operations.

Shooting is done just before sunrise; hauling begins from the starting point of the line as soon as shooting is finished.

2.4 Troll line fishing

Troll fishing gear is composed of a line, a trolling jig, and a diving board or splashing float whose function is to submerge or to move the jigs. The trolling jig moves like a small fish so that large fish are lured and captured. Boats used in troll fishing are generally small in size. Each boat tows several lines at a speed of 3 to 8 knots. The main species of fish captured by trolling are the pelagic ones, such as bonito, tuna, yellow-tail, etc.

2.4.1 Gear used for trolling

a) Diving board

There are many shapes of diving boards, but they all have basically the same function:

- to submerge the trolling jigs to the aimed depth,
- to move the jigs so as to simulate live bait fish,
- to indicate whether the fish are hooked; when this happens, the board comes up to the surface.

Some types of diving boards are shown in Fig. 50.

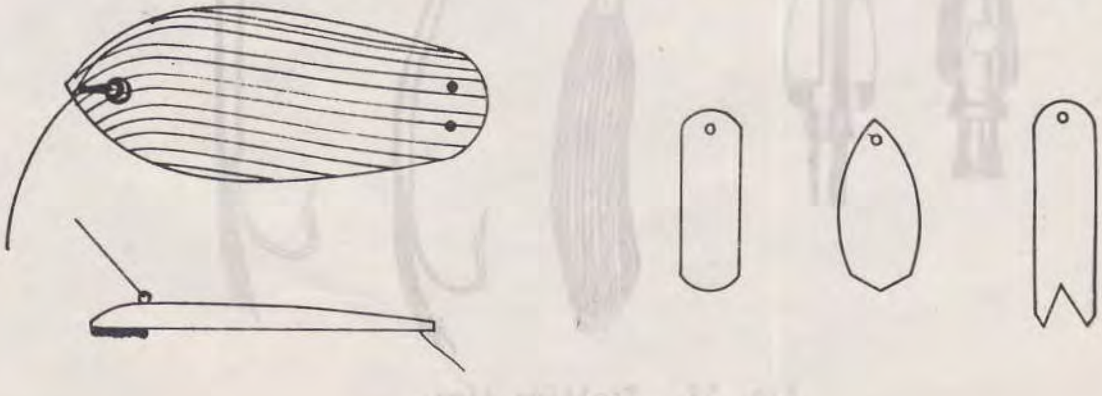


Fig. 50. Diving boards

b) Splashing float

There are many shapes of splashing floats; the purpose of these floats is as follows:

- to move the trolling jigs as if these jigs were real bait fish;

- to create waves and noise similar to those made by small fish;

- to indicate whether fish are hooked; generally, when fish are hooked, the float will submerge. Fig. 51 shows some splashing floats.

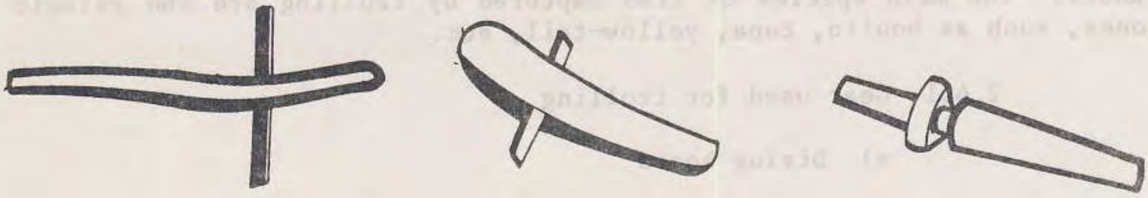


Fig. 51. Splashing floats

c) Trolling jig

The amount of catch by trolling is influenced by the type of trolling jig used. Selection of good jigs is very difficult. Some trolling jigs are shown in Fig. 52.

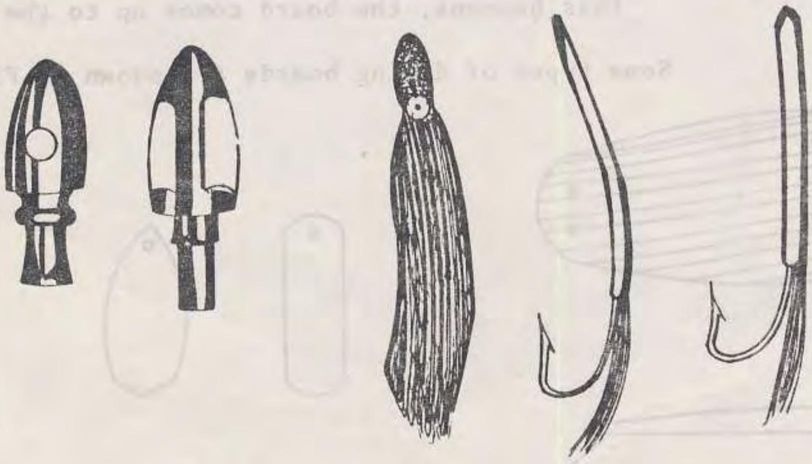


Fig. 52. Trolling jigs

2.4.2 Spanish mackerel trolling

Fishing gear

Gear is shown in Fig. 53 and its specifications are given in Table 8.

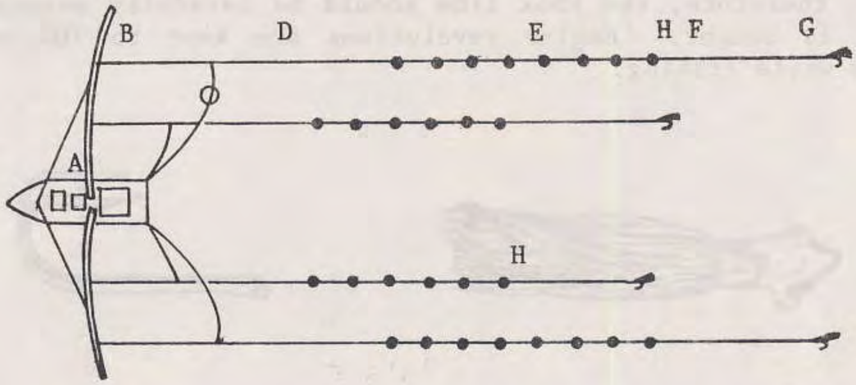


Fig. 53. Spanish mackerel trolling gear

Table 8. Spanish mackerel trolling gear

Mark	Name	Material	Size
A	Pole	Bamboo	10 m
B	Pole-tip line	Vinylon	ϕ 3.3 mm, 4-12 m
C	Messenger line	"	" "
D	Main line 1	"	" "
E	" 2	Wire with cotton	30 m
F	" 3	Stainless steel	4 m
G	Hook line	Wire	3 m
H	Swivel		

25 pieces of lead are attached along the main line 2 at intervals which become shorter the nearer they are to the hook. The weight of each piece of lead is 45 g.

Fishing method

Four pieces of some shiny, light-reflecting material, such as abalone shell, are inlaid in the head of the lure. (Fig. 54). This is believed to increase the effectiveness of the lure.

The teeth of spanish mackerel are sharp and can easily damage the line, therefore, the hook line should be carefully examined every time one is caught. Engine revolutions are kept to 70% of normal operation while fishing.

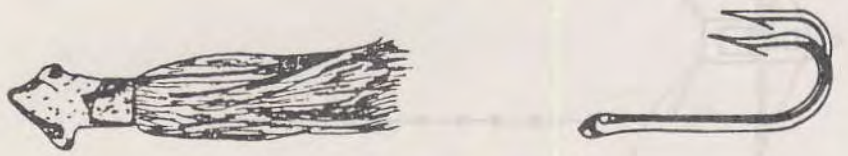


Fig. 54. Lure for spanish mackerel troll fishing

4.6 TRAP

INTRODUCTION

Trap fishing is broadly classified into set net fishing and pot fishing. Set net fishing is operated on a small- to large-scale, and set net is used to catch fishes migrating inshore. Pot fishing is generally operated on a small-scale, and pots are used to catch demersal marine animals.

The construction of pot fishing gear, i.e. the shape, size and the materials of gear vary from one fishing region to the next and according to target marine animals. In most pot fishing operations, bait it placed in the pots to attract marine animals, but non-baited pots are also widely used. Some species with a positive thigmotaxis tend to gather around the pots and use them as a hiding place; in such cases bait is not absolutely necessary.

1. CHARACTERISTICS OF TRAP FISHING

1.1 Pot fishing gear has high selectivity for species of marine animals.

Norman B. PARKS (1973) compared the catch obtained by using trawl net and pot.

The number of species caught by trawl gear and pots were 32 and 5 respectively. This means they were selective for certain species, particularly sabrefish. Furthermore, it was found that the mean fork length of sabrefish caught by pots was longer than that of sabrefish caught by trawl gear. This may be attributed to the fact that the larger sabrefish are stronger swimmers, which enables them to avoid or escape from a trawl net. Conversely, the large sabrefish are more avaricious, therefore they are attracted by baited pots and caught.

1.2 A marine animal captured in a pot is protected from predators such as sharks which cannot enter into the pot. Sometimes, however, it is observed that crabs, lobsters or other entrapped animals are eaten by octopus, because octopus can enter into the pot from which its prey cannot escape. In the case of line fishing or gill net fishing, it often happens that some of the captured marine animals are damaged by predators.

Fred W. HOPKINS and Alan J. BEADSLEY (1970) made the following observation on pot fishing.

1.3 Captured marine animals can survive several days in a pot, therefore the freshness of catch is very good.

1.4 While the fishing boat is in port because of engine trouble, stormy weather, etc., set-trap fishing gear continues operation at the fishing ground.

1.5 Operation of pot gear is possible in very deep-sea as well as in shallow waters.

1.6 If pots are lost on the sea-bottom, they continue unuseful fishing until the pot gear corrodes and breaks up.

2. CLASSIFICATION OF POT FISHING GEAR

Shoichi TAKEUCHI (1981) classified pot fishing gear by the shape of pot and by the target marine animals.

2.1 Classification of pot fishing gear by the shape of pot and its characteristics. (Fig. 55)

2.1.1 Truncated cone-shaped pot

A pot of this shape is stabilized on the sea-bottom. Most traps for catching crabs or shrimps in Japan are of this type. A crab pot usually has an entrance on its top part, while in the case of a shrimp pot the entrance is on the side.

2.1.2 Rectangular parallelepiped pot

In the United States pots of this type are used for catching *Chionocetes opilis*, *Poralithodes comtochatica* and *Anoplopoma fimbria*.

2.1.3 Semicylindrical pot

Such pots are used in many countries, mainly as lobster pots. In Thailand, large-sized semicylindrical pots with wooden frames are used for catching bottom fish.

2.1.4 Collapsible pot

Collapsible pots of any shape have a great advantage in that even a small fishing boat can operate many of them. Blue swimming crabs are caught by this type of pot in Japan.

2.1.5 Others

There are many other shapes of pots such as the hemisphere shape, drum shape, scoop shape and various irregular shapes.

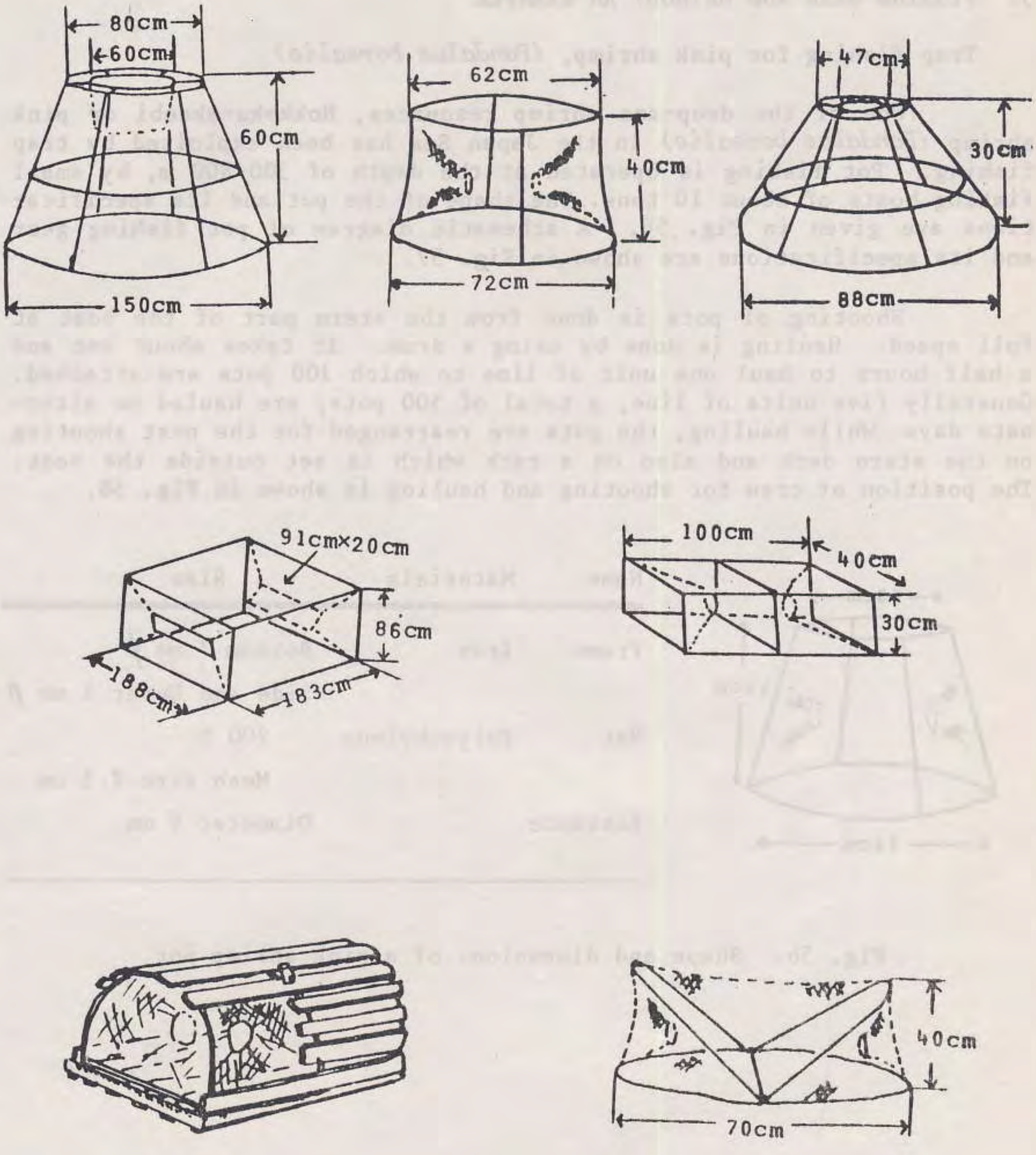


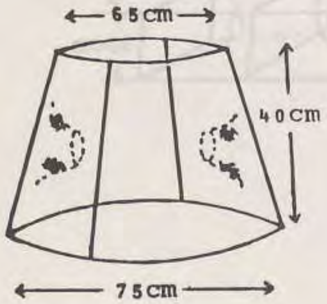
Fig. 55. Various pot fishing gear (TAKEUCHI, 1981)

3. FISHING GEAR AND METHOD: AN EXAMPLE

Trap fishing for pink shrimp, *(Pandalus borealis)*

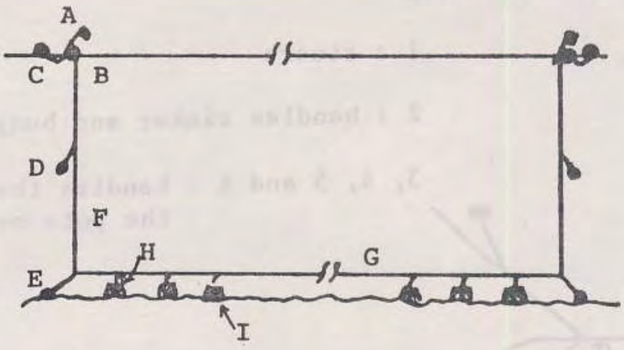
One of the deep-sea shrimp resources, Hokkoku-akaebi or pink shrimp *(Pandalus borealis)* in the Japan Sea has been exploited by trap fishing. Pot fishing is operated at the depth of 300-800 m, by small fishing boats of about 10 tons. The shape of the pot and its specifications are given in Fig. 56. A schematic diagram of pot fishing gear and its specifications are shown in Fig. 57.

Shooting of pots is done from the stern part of the boat at full speed. Hauling is done by using a drum. It takes about one and a half hours to haul one unit of line to which 100 pots are attached. Generally five units of line, a total of 500 pots, are hauled on alternate days. While hauling, the pots are rearranged for the next shooting on the stern deck and also on a rack which is set outside the boat. The position of crew for shooting and hauling is shown in Fig. 58.



Name	Materials	Size
Frame	Iron	Bottom 7 mm ø
		Side and Upper 5 mm ø
Net	Polyethylene	200 D
		Mesh size 2.3 cm
Entrance		Diameter 9 mm

Fig. 56. Shape and dimensions of a pink shrimp pot



Mark	Name	Materials	Size	Amount
A	Flag pole	Bamboo		2
B	Buoy	Glass or plastic	ϕ 30 cm	2
C	"	" "	"	2
D	Sinker	Stone	10 kg	2
E	"	"	20 kg	2
F	Buoy line	Polyethylene	ϕ 20 mm	Depth x 1.5 m
G	Main line	"	ϕ 24 mm	1000 m
H	Branch line	"	ϕ 10 mm	5 m x 100

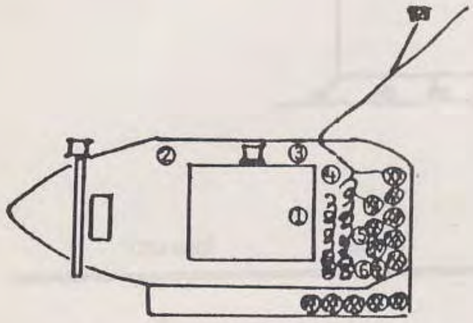
Fig. 57. A schematic diagram and specifications of trap fishing gear

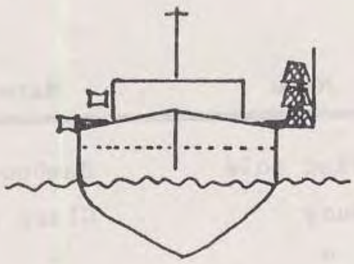
Position of crew for shooting

1 : steers

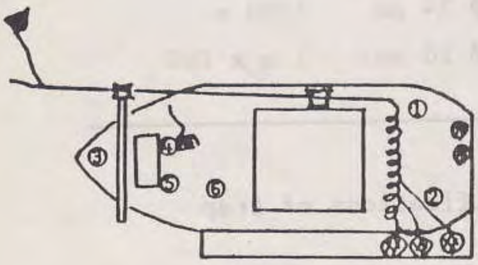
2 : handles sinker and buoy

3, 4, 5 and 6 : handles the pots - hands the pots over one by one





Position of crew for hauling



1 : handles main line

2 : joins the pots to main line and arranges them

3 : removes the pots from main line and opens pot mouth

4 : takes the catch out

5 : sorts out pink shrimp and others

6 : receives the empty pot, places bait inside and hands it over to 2

Fig. 58. Position of crew for shooting and hauling gear

4.7 TRAP (SET NET) FISHERIES

INTRODUCTION

In waters along the coastlines, where a warm and cold current meet, plankton are produced, providing abundant food for small fish. Bigger fish from both cold and warm currents gather in such places to feed.

Japan is one of the countries with warm and cold currents along its coastline. Thus, the coastal waters of Japan are very rich in fish migrating from north to south or south to north. Moreover, the topography of the country is very varied with gulfs, bays and coves. The situation is very favourable for set net fishing because of the moderate coastal current, the variety of topographic features of the coastline, the seasonal migration of fish, and the moderate meteological stimulation which induces the fish schools from offshore areas to shore by variation of the sea conditions with depressions.

The set net method of catching fish consists essentially of leading fish into a situation or enclosure from which they cannot escape, or from which the route for escape is not readily apparent. The same catching principle appears in other fishing gear, such as fish pots, traps, weirs, stream racks, and barricades. However, because they are usually made of materials other than textile fibres, they differ from the set net as defined here.

There are two types of set nets. One is to catch fish by guiding them, while the other is to fish by straining. *Choko-ami* (pound nets) and *Otoshi-ami* (trap nets) belong to the guiding type, while *Masu-ami* (hoop nets) and fyke nets use the straining method.

The set net gear consists mainly of a leader and a trap net. When putting up a set net, a leader net is fastened near the mouth of the trap and led toward the shore after the main parts of the trap net have been moored to the sea-bed. As fish encounter the leader net they usually move towards deep water following the leader. Thus, this leads the school of fish through the entrance into a huge enclosure the play ground of the net. Fish are then guided through the funnel from the heart into the next chamber or a pot which has a net bottom. *Choko-ami* and some *Otoshi-ami* which are called floating trap nets, are held in water by stakes or pilings and rigid floating frames, while the so-called deep trap nets are held in position and in shape entirely by anchors or sand bags and buoys. Some deep trap nets have a top of webbing except for the heart, and this can be used in waters of considerable depth, by adjusting the length of buoy lines and/or anchor ropes.

The fyke net is used extensively in some river fisheries, as it is best adapted for use in a fair current, and under such conditions it is sometimes used without any wing or leader. A typical fyke net is a long bag mounted on one or several hoops. The hoops serve a double purpose; they keep the net from collapsing, and they form the attachment for the base of net funnels which prevent the fish from escaping easily. The catch is removed from the last pocket. The hoop net is like a fyke net in its construction. Usually this type of net has no wing and is used in lake fisheries.

Set net fishing is operated by securing the gear on the seabed as mentioned above. This method of fishing takes advantage of the fact that fish usually migrate for spawning and mating to a certain area and for a certain period. As a school of fish comes inshore, a set net is placed in its path and is kept there for the period of migration. The set net fishing operation is conducted by hauling the bunt of the net at certain times, such as in the early morning and in the late evening. In the past, set net fishery had declined due to its characteristic "passive" fishing method. There is a big difference between a "passive" fishing method and an "active" one, such as trawl and purse seine fishing, where great effort is made to detect and pursue fish.

Recently, however, set net fishing has been re-evaluated and is carried out again, especially since the onset of the oil crisis, because it conserves energy, manpower and marine resources. Also, it provides a supply of very fresh fish preserved with ice only, because of the short distances from fishing grounds to fish markets.

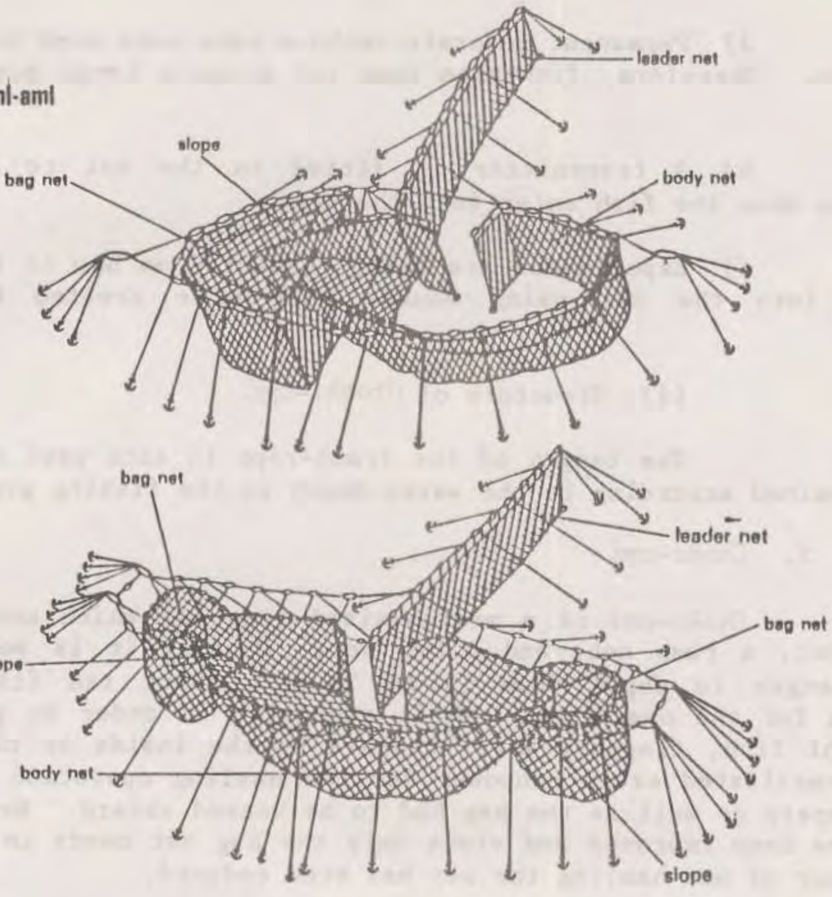
THREE COMMON TYPES OF SET NET

The most advanced as well as most widely used type of set nets are large set nets known as *Otoshi-ami* and the pound nets which are in use in Japan called *Choko-ami* and *Masu-ami*

1. *Otoshi-ami* (large-size trap net)

Otoshi-ami is set in waters with a depth range from about 15 to 100 metres. Ten to thirty fishermen are engaged in the operation, depending on the scale of the gear used. *Otoshi-ami* is mainly used for catching sardine/anchovy, squid/cuttlefish, barracuda, mackerel, horse mackerel, hairtail, herring, yellowtail, tuna, salmon and trout, etc. which migrate along the coast.

Otoshi-ami



While the gear is in operation, only the bag net is hauled; this reduces the labour required. However, *Otoshi-ami* is a passive fishing gear. So, the management of this fishery is not very stable since the fishing depends on the migration of fish. In recent years, various improvements, mentioned below, have been introduced in order to make this fishery more stable and profitable.

a) Nets and ropes made of synthetic fibres began to be used instead of natural fibres. When natural fibres were dominant 60-80% of the net parts had to be changed every season.

b) Winches were installed on vessels for net hauling. Recently, ball-roller, the new net hauler, has been effectively used, thus saving man-power.

c) The submerged net is nowadays inspected by aqualung divers.

d) Permanent concrete anchors have been used for the last few years. Therefore, fishermen need not prepare large quantities of anchors.

e) A transmitter is fitted to the net to inform the fishermen when the fish enter into the net.

f) Experiments are being conducted on how to induce fish schools into the net using sounds underwater created by fishing devices.

(1) Structure of *Otoshi-ami*

The length of the frame-rope in each part of the gear is determined according to the water-depth in the fishing ground.

2. *Choko-ami*

Choko-ami is a medium-sized trap net which consists of a leader net, a ramp net, and a bag net. Usually it is set in water which ranges in depth from 15 to 30 m. About ten fishermen are required for the operation. Until recently, in order to prevent the escape of fish, flappers were attached on the inside of the bag net. This necessitated extra manpower for the hauling operation since both the flappers as well as the bag had to be heaved aboard. Nowadays, the nets have been improved and since only the bag net needs to be hauled, the number of men hauling the net has been reduced.

The leader net should be set at right angles to the shore to achieve maximum effect. As the shape of the net will be deformed by the current, the bag net should be set along the current direction to minimize this deformation.

One of the variations of *Choko-ami* is shown in Fig. 61.

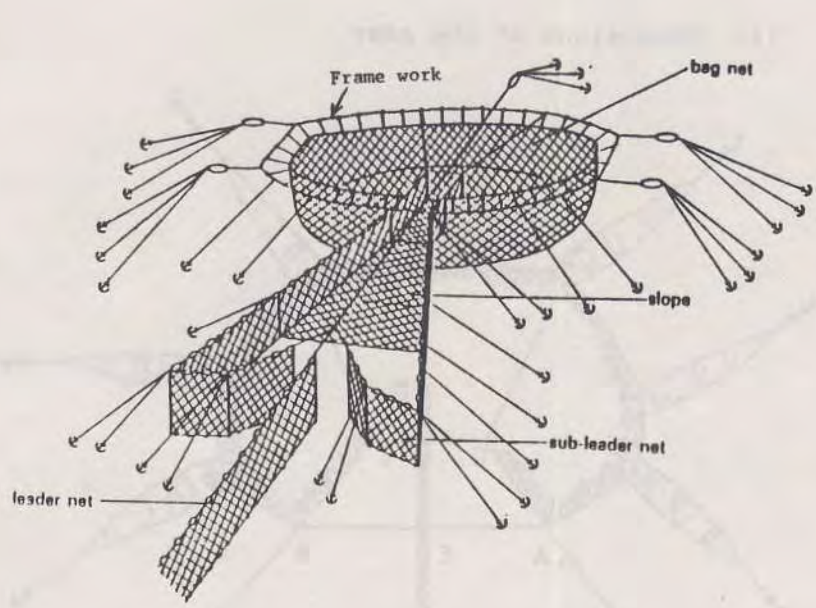


Fig. 61. *Choko-ami*

3. *Masu-ami*

Masu-ami is a small type of pound net. In the past, a pound net was square or hexagonal in shape. However, the net employed nowadays is octagonal in shape. The number of attached nets (bag nets with a funnel) has increased as the design developed.

This gear can be set in inshore waters or inlets, and also it can be set in shallow waters where fairly swift currents are flowing. The size of the net varies with the locality. The length of the main net and that of the leader net are calculated on the basis of the water depth, as in the table below:

Water depth	Length of main net	Length of leader net
less than 15 m	75-90 m	75-90 m
15-22 m	105 m	225 m
23-30 m	180 m	300 m

(1) Dimensions of the gear

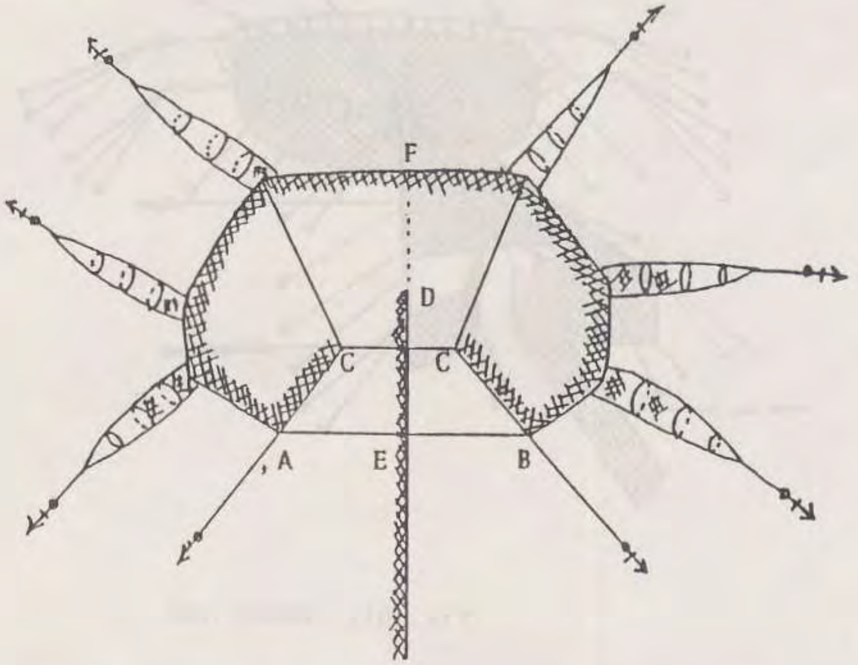


Fig. 62. Structure of some *Masu-ami*

AB (outer entrance) :	water depth	length
	less than 15 m	18-30 m
	less than 30 m	36 m

CC (inner entrance) : 70-80% of AB

Depth of the main net after hanging : 2 times the water depth

EF (width of the net): 100-200% of the water depth

DF: 30% of EF

AC or BC (length of winkers): 1.5-3 m shorter than DE

Hang-in percentage: 50% for main net, 30% for winkers or leader net

Pocket net (bag net with funnel): 9-13 m, generally a few bamboo or plastic hoops are attached to the net to hold the pocket net open. Diameter of a hoop is 1.5 m, hang-in percentage ranges within 30-40%.

Masu-ami exists in many shapes and sizes. Three common variations are shown in Figs. 62 and 63.

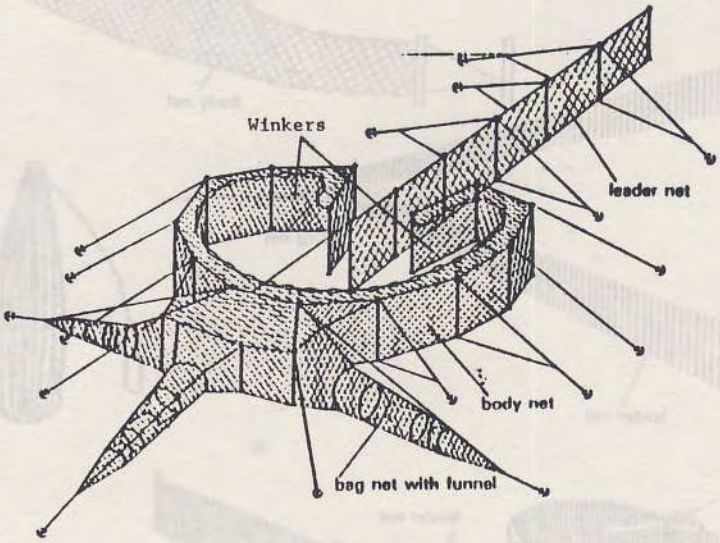


Fig. 63. A three-pocket net type *Masu-ami*

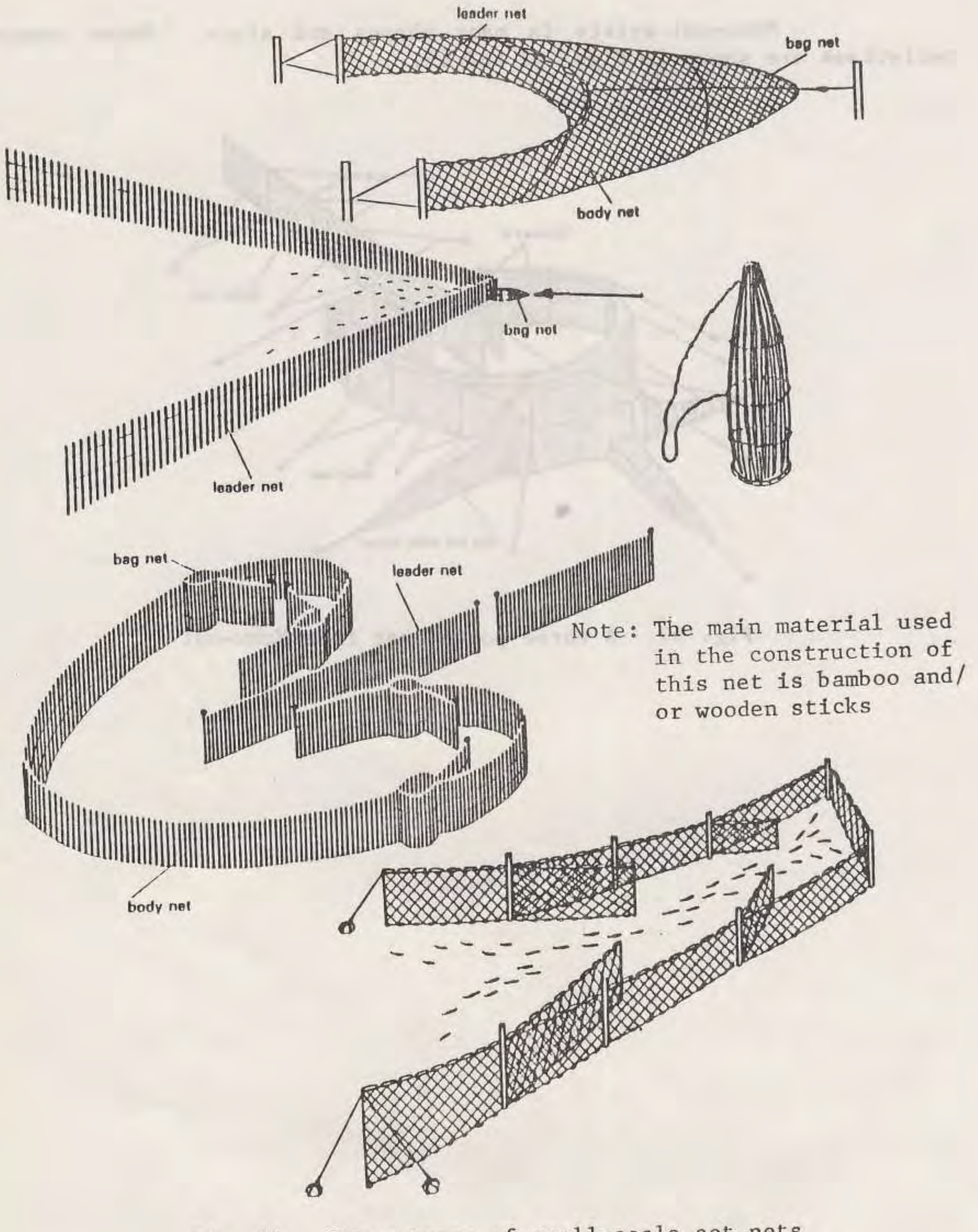


Fig. 64. Other types of small-scale set nets

The above small-scale set nets are still operated in shallow waters, in some lakes, and river fisheries.

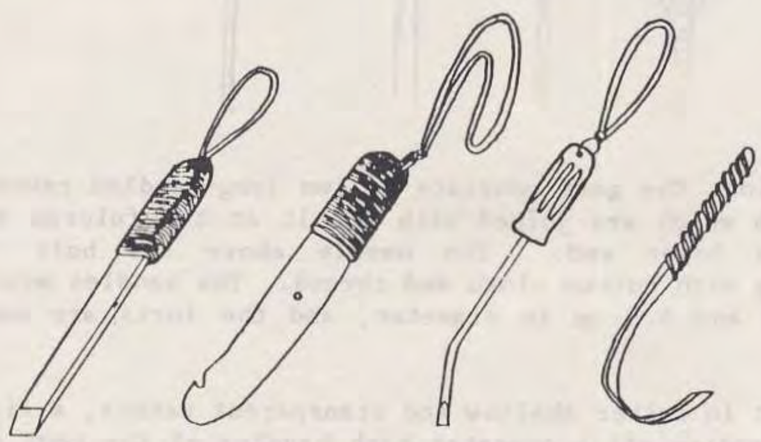
4.8 OTHERS

1. SPATULA

Construction and Operation: The gear is designed for diver's to use in collecting shellfish adhered to rocks, and there are many variations as illustrated. Generally, they have two parts: iron spatula and wooden grip. The iron part, usually 20-25 cm long and 2-3 cm wide, is thinly edged or armed with teeth at the head. The wooden grip, coupled with the iron part, measures 10-15 cm long. There are also all-iron types.

Species: Abalone, top-shell, oyster, etc.

Fishing grounds: Along all the coasts of the country.



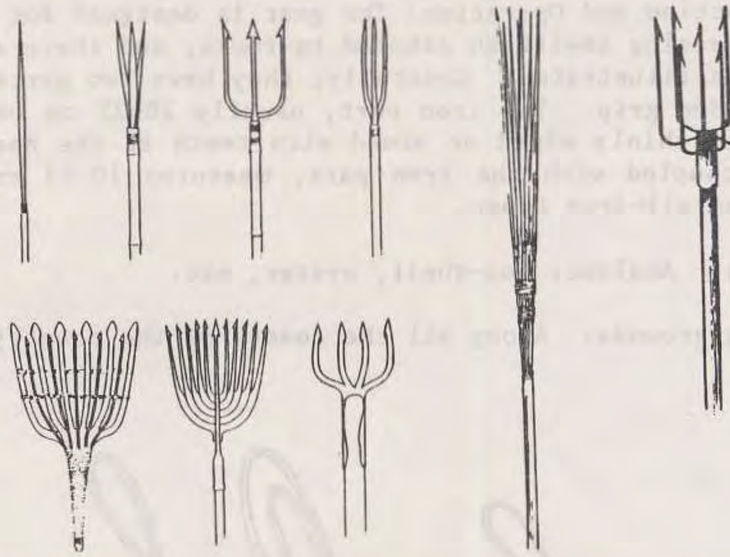
2. SPEARS

Construction: The gear consists of a metal spear and a handle made of bamboo, wood or iron. The spear is barbed so as to catch fish securely.

Operation: Fishermen use these types of gear for spearing fish. In fishing for large species in clear fresh water such as salmon and trout, they can be aimed at directly by the unaided eye, but in the case of small fishes such as ayu-fish, minnow, carp, flatfish, abalone or sea-cucumber the fisherman's aim is aided by a pair of water goggles, or glasses.

Species: Salmon, trout, ayu-fish, minnow, carp, flatfish, abalone, sea-cucumber, etc.

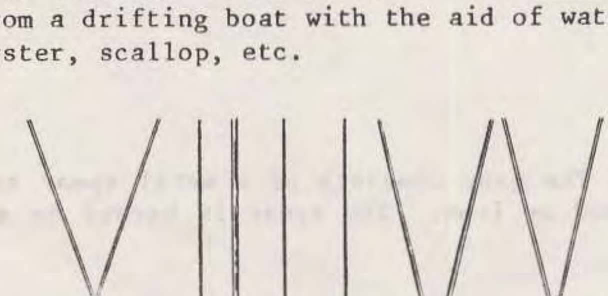
Fishing grounds: Rivers, lakes and shallow seas.



3. TONGS

Construction: The gear consists of two long-handled rakes with 3-5 iron teeth which are joined with a bolt at the fulcram some 30 cm above the lower end. The handle above the bolt is coiled manifoldly with cotton cloth and thread. The handles measure 2.1 m in length and 4.5 cm in diameter, and the forks are each 9.1 cm long.

Operation: In rather shallow and transparent waters, a fisherman on a boat standing still operates both handles of the tool and plucks off shellfish from the rocks on the sea-bottom. Sometimes, it is operated from a drifting boat with the aid of water glasses.
Species: Oyster, scallop, etc.



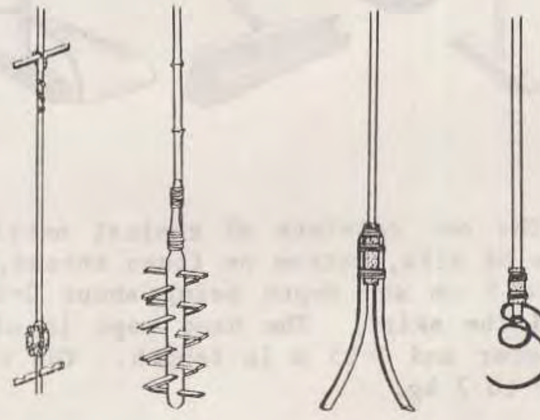
4. SEA-WEED TWISTERS

This gear greatly varies both in shape and size by locality and according to the seaweeds to be collected. The 'Makka' in the Hokkaido area, to be explained below, is one of such twisters for harvesting seaweed (Laminaria).

Construction of a 'Makka': A Makka is a combination of bent iron plates, an oak shaft, a willow handle bar and their accessories.

Two arched iron plates, each 1.7 m long 1.2 cm thick, are fastened back to back at one end by iron rings. The oak shaft measures 6-7 m long and 3 cm across, the willow handle bar 70 cm long, 3 cm across both ends and 7 cm across the middle. The lengthy shaft is attached to the bent-plates.

Operation: A fisherman on a stationary boat operates the handle bar and twists off sea-weed growing on the sea bottom.

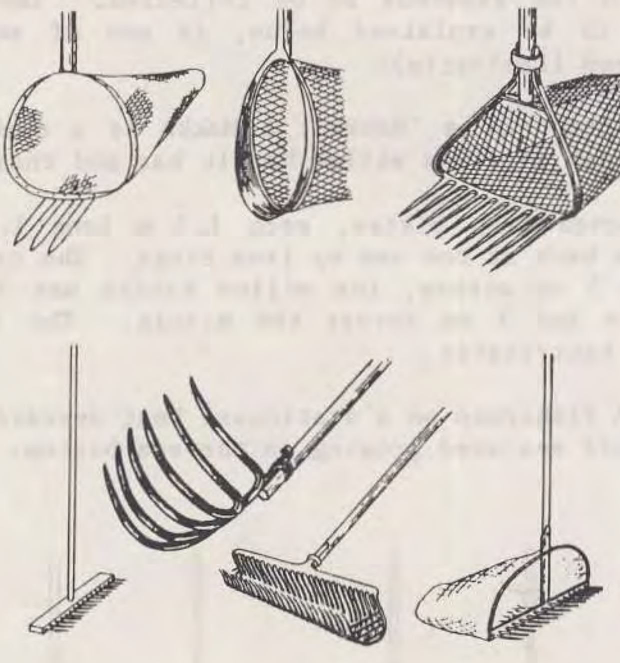


5. RAKES

Construction and Operation: Fishing tools of this category are designed for collecting algae attached to rocks or shellfish hiding or embedded in sand or gravel and have many variations as illustrated.

The handling of these tools differs with their structure. Some are used by a fisherman on foot just like those on the land, some are operated by a fisherman on a boat holding a long handle, and the others are towed by a boat or hauled by means of a wheel on a boat.

Note: As a whole, they are of small-size with little economical importance, except those for collecting shellfish.



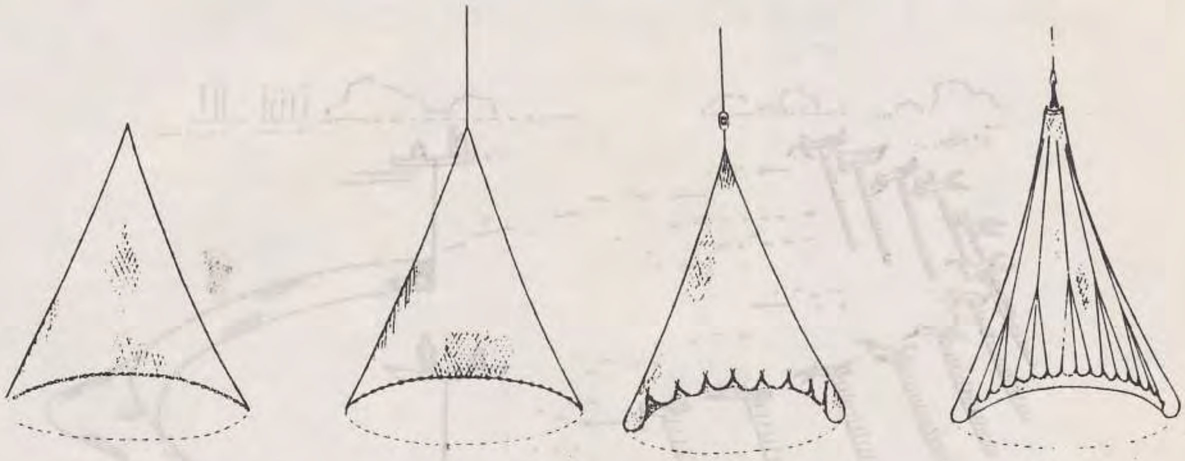
6. CASTING NET

Construction: The net consists of conical netting and hand rope. Netting is made of silk, cotton or linen thread, mesh size varying from about 1 to 5 cm and depth being about 2-5 cm. Sinkers are attached around the skirt. The hand rope is of cotton or linen, 5-8 mm in diameter and 7-15 m in length. The total weight of net varies from 4.5 to 7 kg.

Operation: The net is cast into the water from the beach, boat or water itself in such a way as to cover a group of fish and entrap them. Then the hand rope is carefully lifted to spread the skirt. Fish are caught up in the pocket of the net. According to the surrounding conditions, such as distance, depth and others, the method of casting should vary so as to make such shapes as round, temple-bell, umbrella and triangle. This requires skill and experience to a great extent.

Species: Ayu-fish, minnow, salmon, carp, crucian carp, perch and mullet.

Fishing grounds: Fresh waters and shallow sea waters throughout the country.



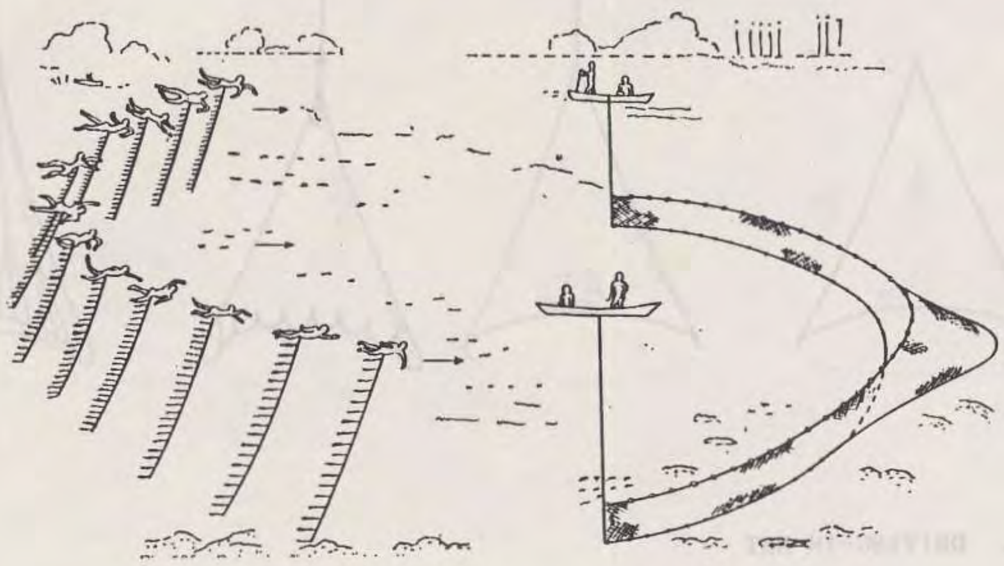
7. DRIVING-IN NET

Construction: The net consists of two wing nets of 20-40 m and a bag or pocket net in the center. This cotton net varies from 50 to 100 m in length and from 3 to 5 m in breadth. The mesh size varies according to the species to be caught, but it usually measures 3 to 5 cm in a stretched condition.

Operation: This fishery is operated by 20-100 fishermen with 3-10 boats. A group of fishermen swimming in the water drive those fish sheltering themselves between rocks into the net by means of scare ropes which are fastened to their bodies. The ropes are usually made of cotton or palm fibres, and palm leaves are fastened thereto. Fish are entangled in the wing nets, or driven into the pocket, or sometimes they are speared by divers.

Species: Coastal fish.

Fishing grounds: Coastal waters of the Islands where trawling and seining cannot be operated.

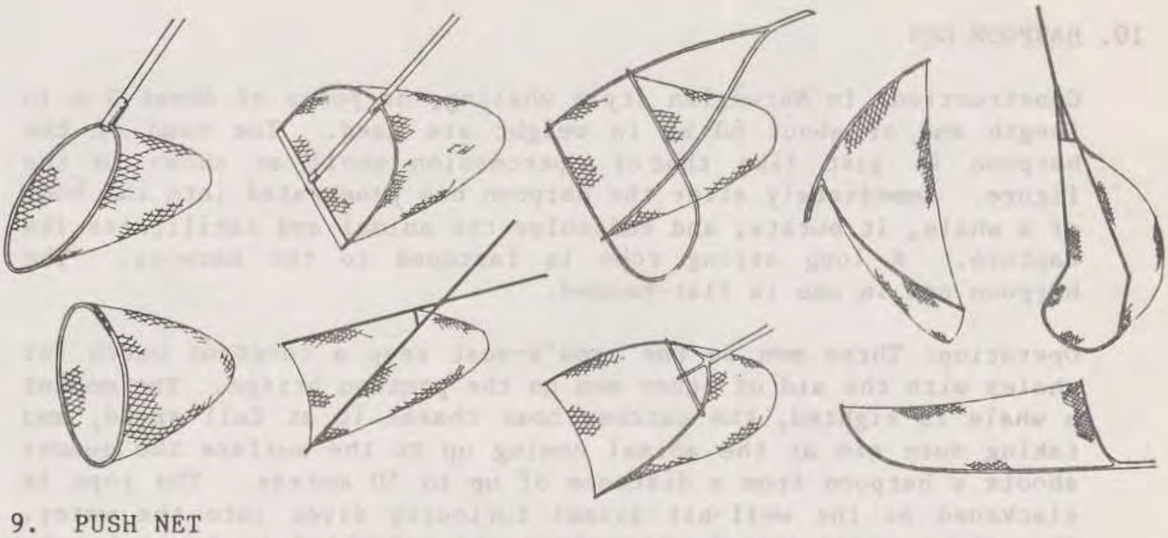


8. SCOOP NETS

Construction and Operation: The scoop net includes the many other hand nets regularly used in all parts of the world. Their shape depends on the form of the frame. The most common form for small nets is a round frame with a net bag attached. They can be more or less of circular form. The filtering bag can be either stretched flat or allowed to hang in the form of a bag. The round scoop nets can be without a handle, like those operated by women and children as a device for collecting small fish. Very often, catching by scooping demands rapid action for successful results. Therefore the scooping implement must be able to be guided easily through the water; that is, it must not be swollen and bulky in form and, when lifted, the water must run out quickly to leave the filtered catch behind. This, therefore, requires that the scooping gear be plaited as lightly as possible and be not too large.

Species: Small fish, shrimp, squid, etc.

Fishing ground: Rivers, lakes and shallow seas.

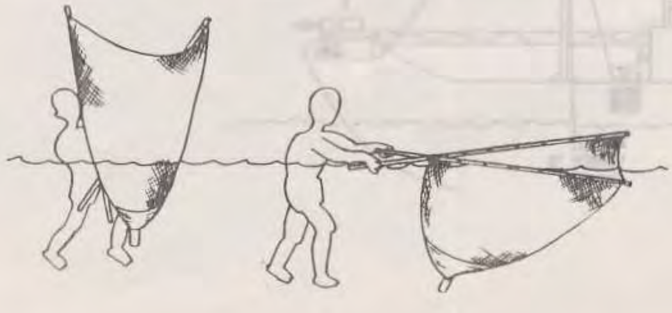


9. PUSH NET

Construction and operation: Push net resembles a large spoon and can be operated by one fisherman. The skis at the end of the two poles are made of wood or coconut husks. The fishing is carried out in the day-time, in waters 0.10-1.50 m deep. The fisherman attaches the net to the poles, gets into the water and starts wading, pushing the net in front of him. From time to time he raises the net and picks up small shrimps, planktonic shrimp or any other catch.

In large-sized gears, the net has three distinct parts: the upper and the lower part, and the cod-end. The ends of the ground rope are fastened to the poles which hold the net. The head rope hangs along the length of the poles. The poles are either bamboo or trunks of pine trees, 6-15 metres long. Two poles are tied so as to form an inverted V-shape, ending in wooden or iron skis which slide along the sea-bed, fishing is operated from an engine-driven boat. At the end of a fishing operation, the cod-end is hauled by means of a rope attached to it, emptied, and lowered for the next round of fishing.

Fishing ground: Shallow seas and coastal areas.



10. HARPOON GUN

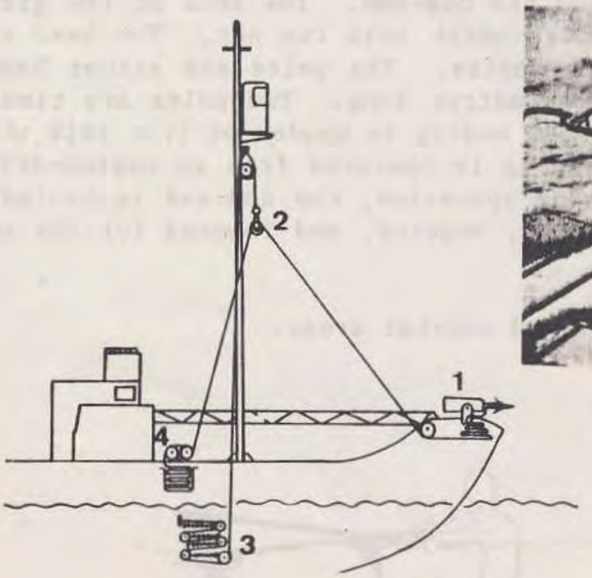
Construction: In Norwegian style whaling, harpoons of about 2 m in length and of about 60 kg in weight are used. The head of the harpoon is just like that of a percussion shell as shown in the figure. Immediately after the harpoon has penetrated into the body of a whale, it bursts, and enfeebles the animal and facilitates its capture. A long strong rope is fastened to the harpoon. The harpoon now in use is flat-headed.

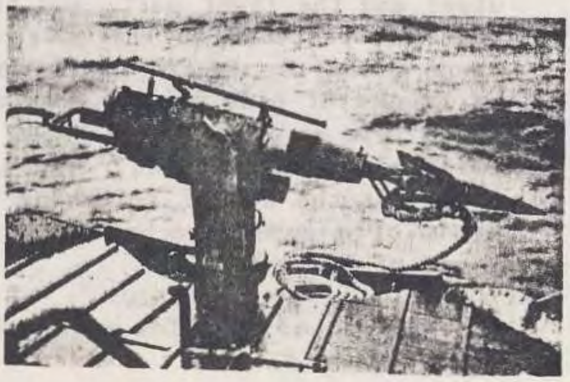
Operation: Three men in the crow's-nest keep a constant watch for whales with the aid of other men on the pontoon bridge. The moment a whale is sighted, the catcher boat chases it at full speed, and taking sure aim at the animal coming up to the surface the gunner shoots a harpoon from a distance of up to 50 metres. The rope is slackened as the well-hit animal furiously dives into the water. Then the wounded animal when tired and enfeebled is towed to the catcher. In cases where the first harpoon fails to tell or mises the mark, a second harpoon is shot.

Whaling season: During summer season.

Species: Blue whale, fin whale, sei whale, hump back whale, sperm whale, etc.

Whaling grounds: Coastal waters around Japan, the Northern Pacific and Antarctic Oceans.



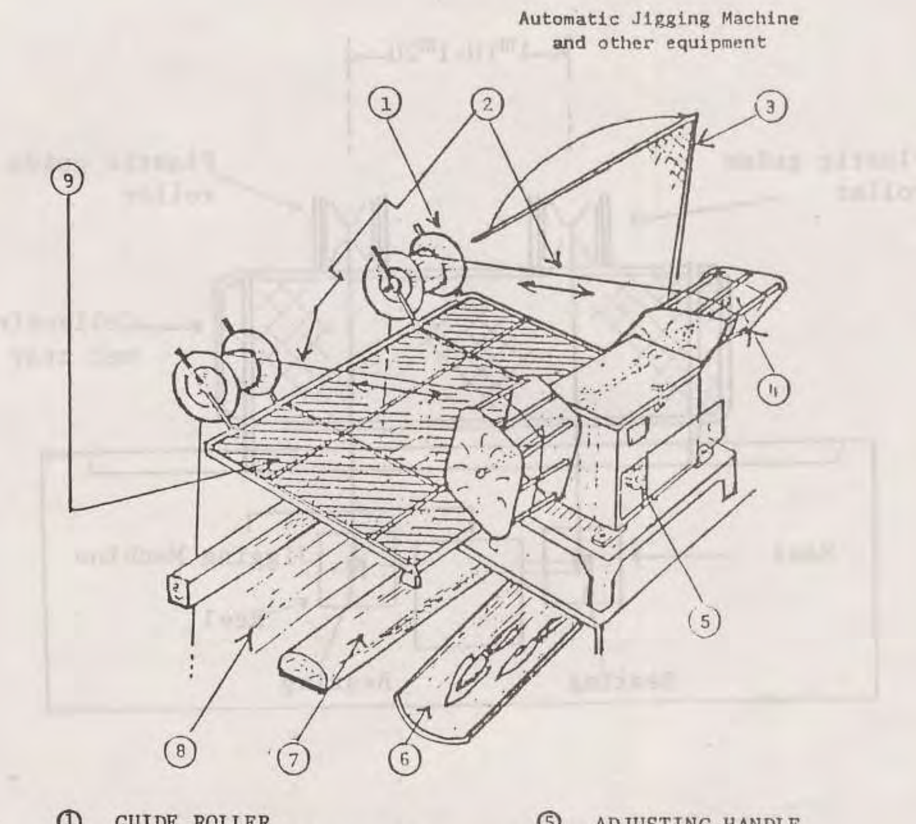


V. FISHING DEVICES AND EQUIPMENT

5.1 HAULING DEVICES

1. Automatic jigging Machine and Hand Jigging Gear

To carry out more effective operations and to save labour on board, the machine in Fig. 65 was invented.



① GUIDE ROLLER
② FISHING MONOFILAMENT LINE
③ POSITION LIFTED UP GUIDE ROLLER
④ REEL
⑤ ADJUSTING HANDLE
⑥ FISH SHOOT
⑦ BULWARK TOP
⑧ FISHING PLATFORM
⑨ COLLECTING NET TRAY

(Fig. 65)

The typical layout is shown above, two pieces of fishing monofilament line with jigs (artificial bait with hooks) go down into the sea and come up from the sea automatically, driven by an electric motor.

The Guide Rollers are made from plastic and the distance interval between two guide rollers is from 1,110 to 1,120 millimetres (See Fig. 66). This distance interval (1,110-1,120 mm) is also the same as the distance between the two axis bearings connected to the electric motor of the machine (See Fig. 66)

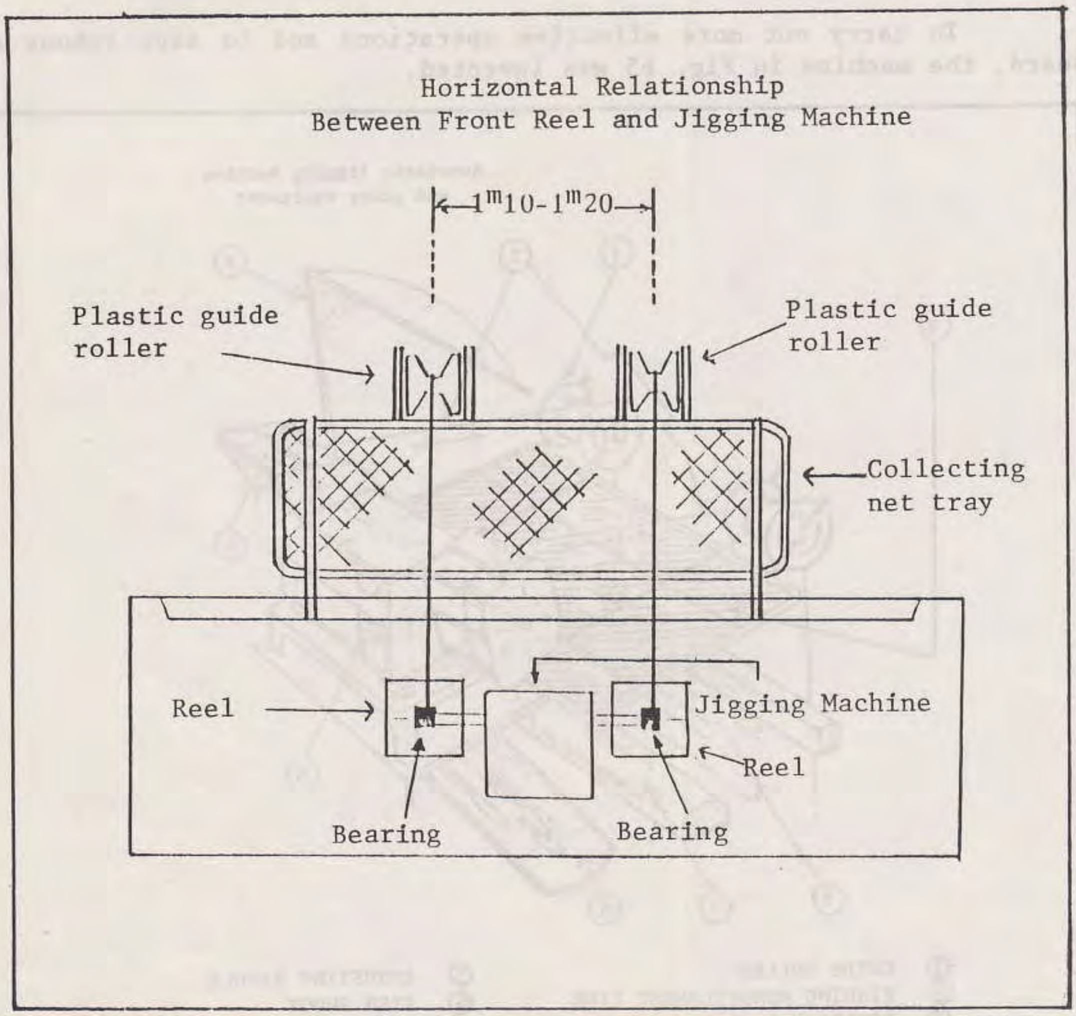


Fig. 66

The position of the two reels (④ in Fig. 65) is vertically higher than that of the guide rollers (See Figs. 67 & 68)

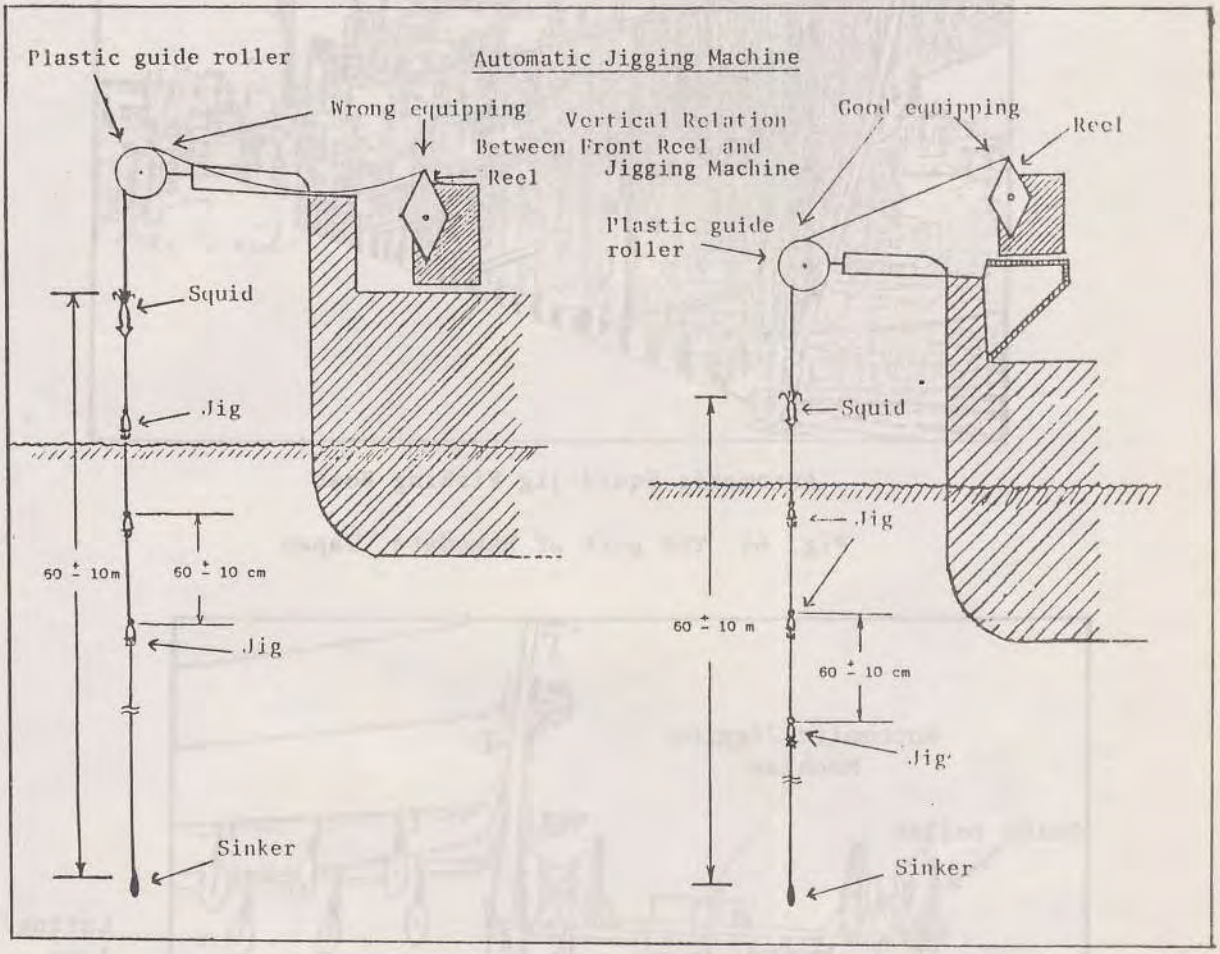
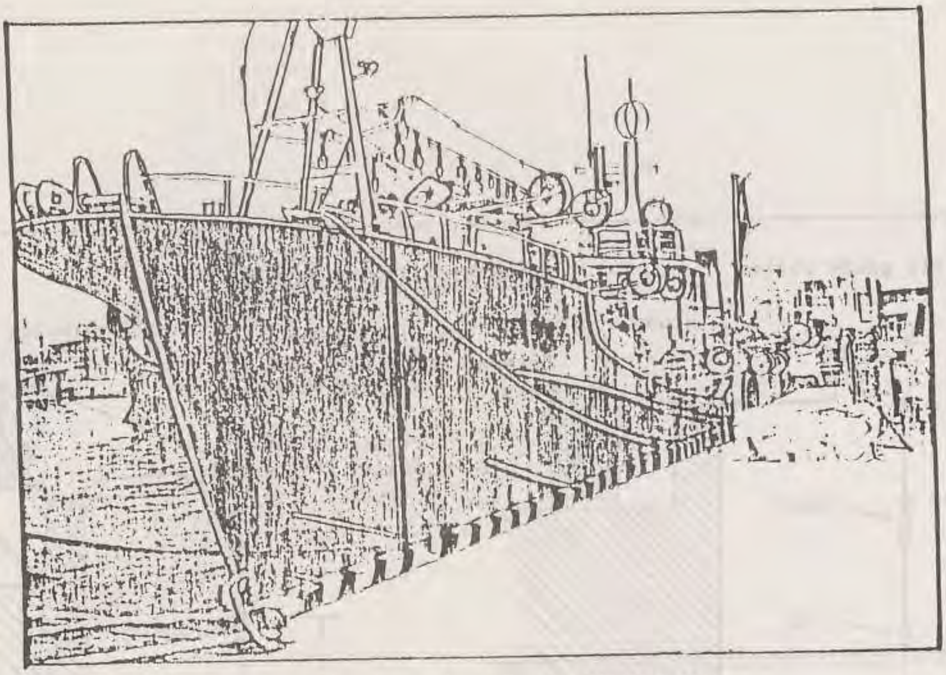


Fig. 67 Fig. 68

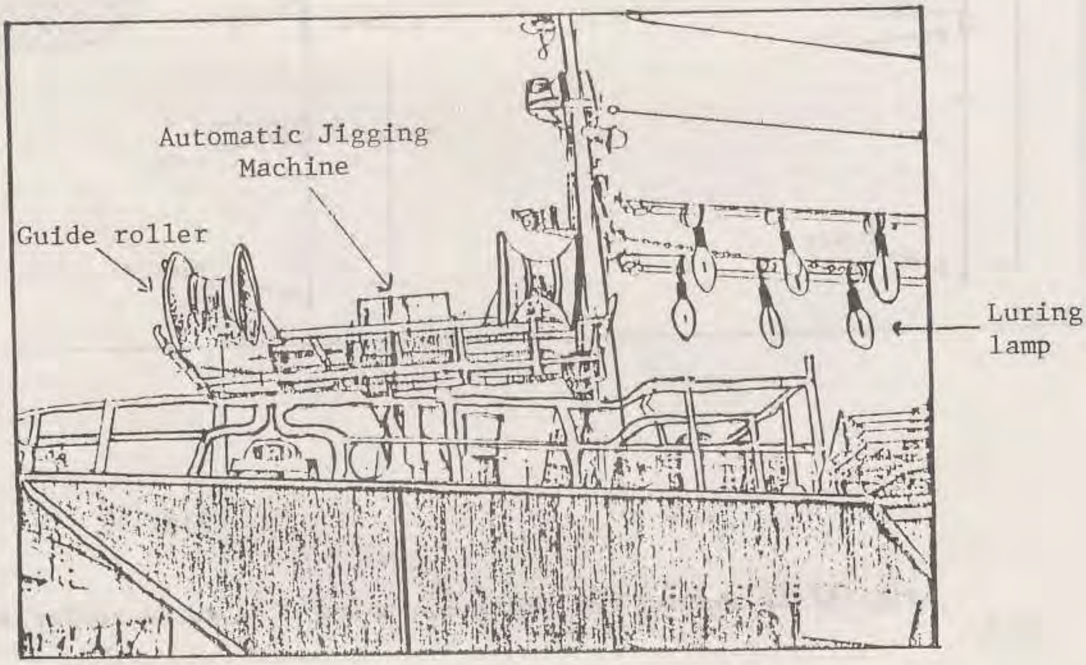
Fig. 67 is showing the wrong equipping of a guide roller and a reel.

Automatic Jigging machines are installed near the bulwark of a fishing boat, as in Figs. 69 and 70.



Automatic Squid-jig Fishing Boat

Fig. 69 The port of Hakodate, Japan



Automatic Squid-jig Fishing Boat.

Fig. 70 The port of Hakodate, Japan

On the other hand there are various hand jigging reels, Fig. 71 shows one type of hand jigging reel for squid fishing.

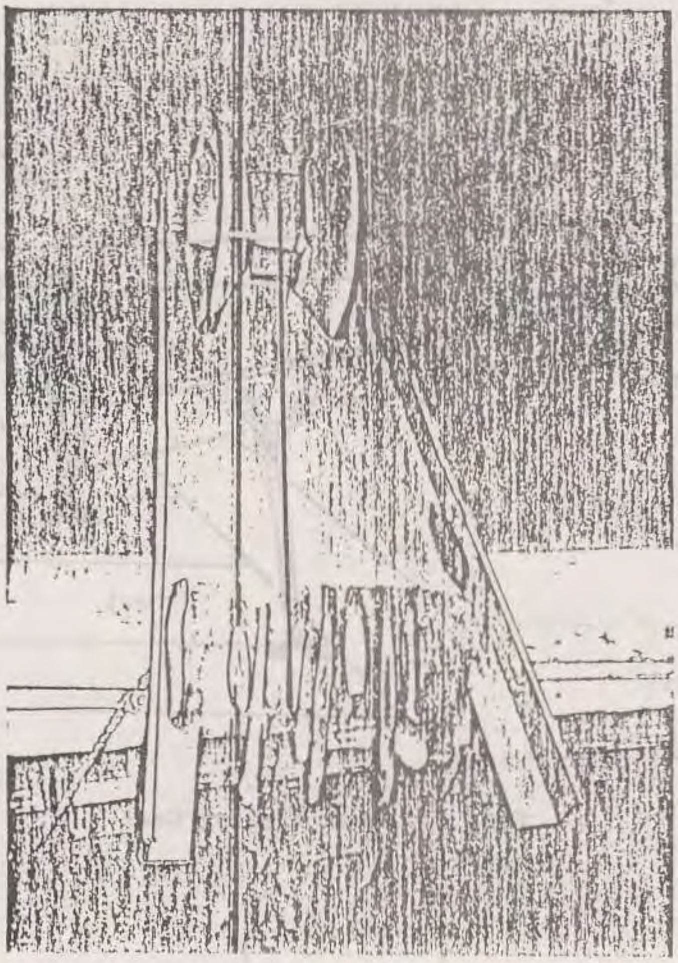


Fig. 71 Hand jigging reel

This type of hand jigging gear is suitable for ultra-small-scale fishing because an automatic jigging machine will cost about 3,500 to 4,000 U.S. dollars, but hand jigging gear only 35 U.S. dollars. The construction of hand jigging gear is shown in Figs. 72 and 73.

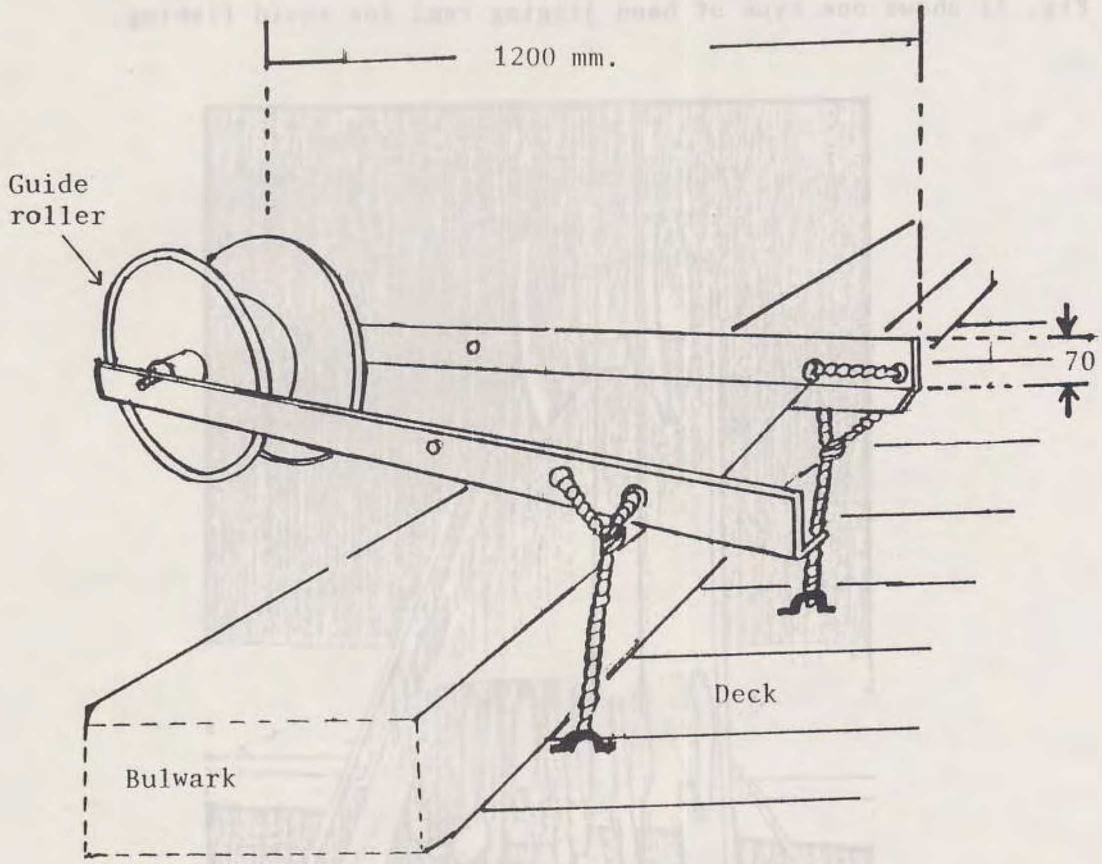


Fig. 72 Hand Jigging Gear

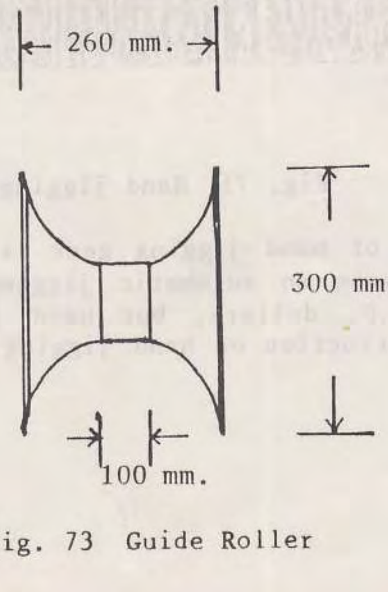


Fig. 73 Guide Roller

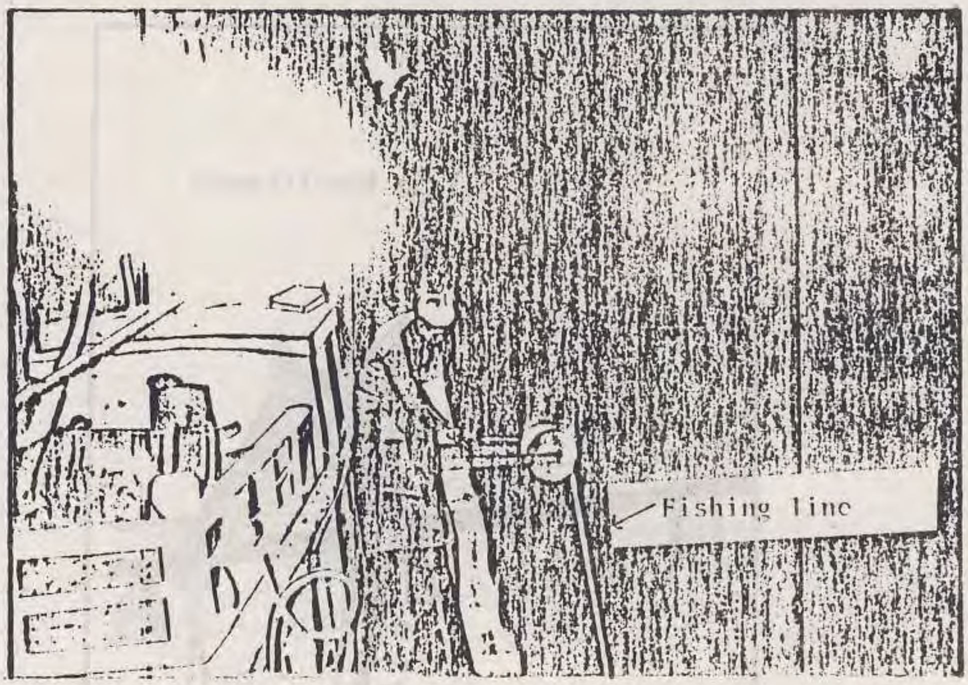


Fig. 74 Fisherman Jigging

Fig. 74 shows an ultra-small-scale fisherman fishing with hand jigging gear in the bay of Hakodate, Japan and Fig. 75 shows a squid caught with artificial bait.

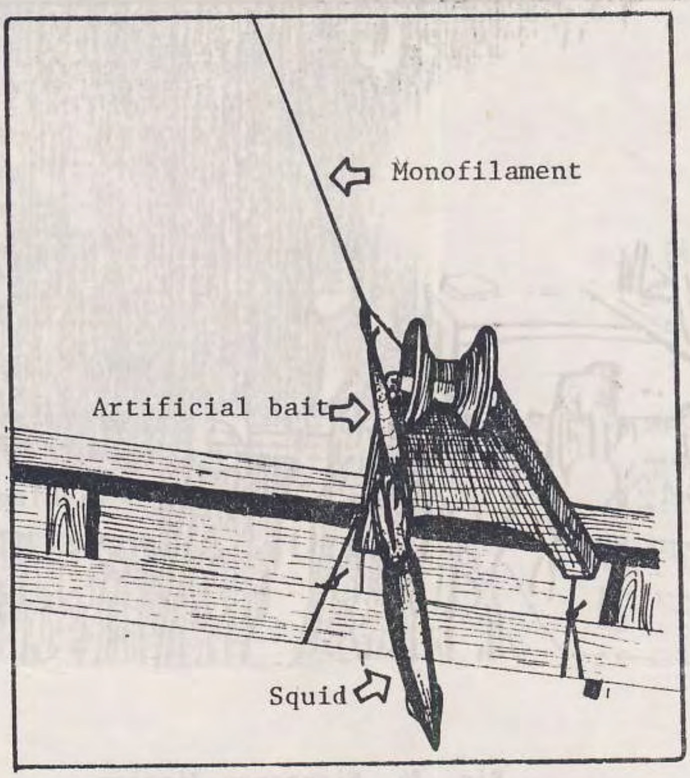


Fig. 75

2. Line Hauler

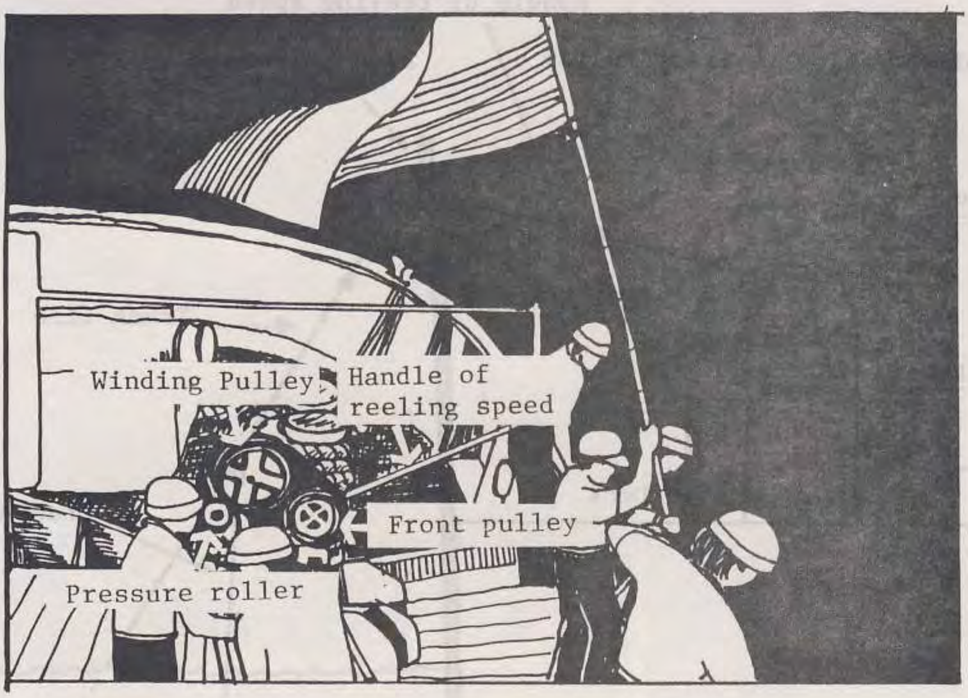


Fig. 76 Hauling longline at night M.V. PAKNAM in the South China Sea

Line haulers are designed primarily as hauling devices for tuna longline. A Japanese tuna longliner shoots 200 to 300 baskets of trunk lines, total length of the continuous lines reaches 60,000 to 100,000 metres. Without the haulers, it would be impossible for a tuna longliner to finish hauling the lines in half-a-day.

The line hauler of M.V. PAKNAM under fishing conditions is shown in Fig. 76. In this photograph one can see the Handle of Reeling Speed, Front Pulley, Winding Pulley and Pressure Pulley (also see Fig. 77), a fisherman who is handling the line hauler and 2 trainees. The principle dimension of the line hauler manufactured by IZUI IRON WORKS CO., LTD. Model 2S-60 is shown in Fig. 78. The driving power of a hauler is hydraulic.

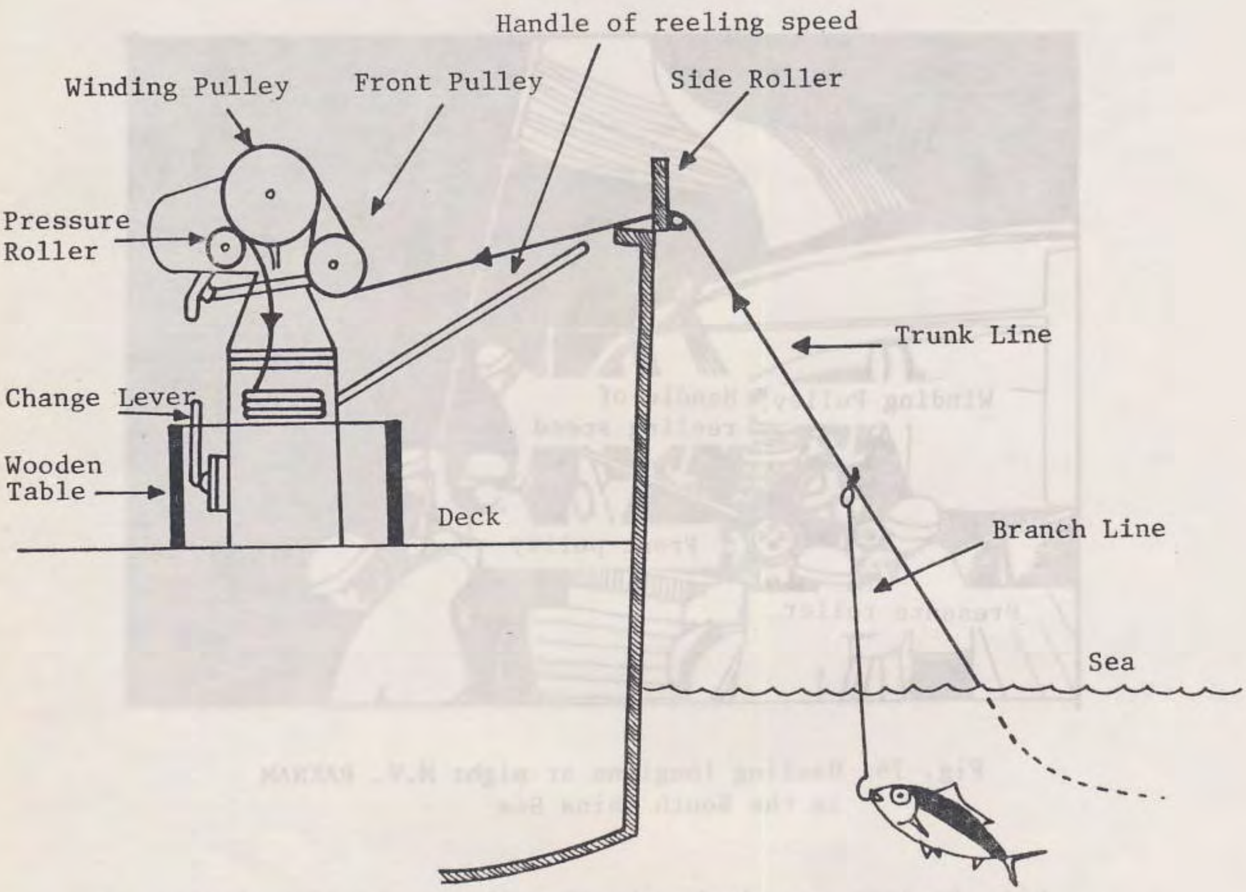


Fig. 77 Line Hauler and Longline

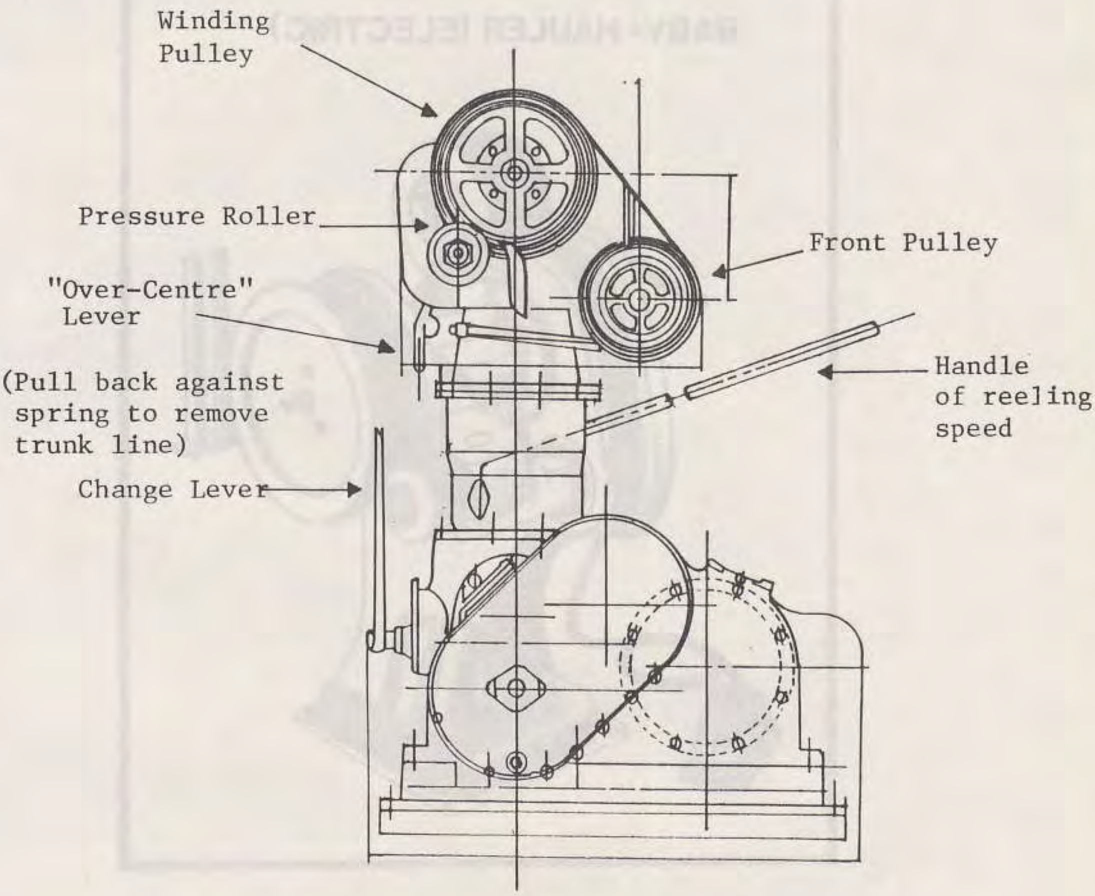


Fig. 78 Line Hauler installed on M.V. PAKNAM
Hauling speed 193 metres/min

On the other hand, there is another type of line hauler for small-scale fishing, this hauler is very small and called Baby Hauler, Fig. 79. This is an electric hauler driven by DC-24 voltage and 125 watts, hauling power 50 Kilograms and its weight is only 23 Kilograms.

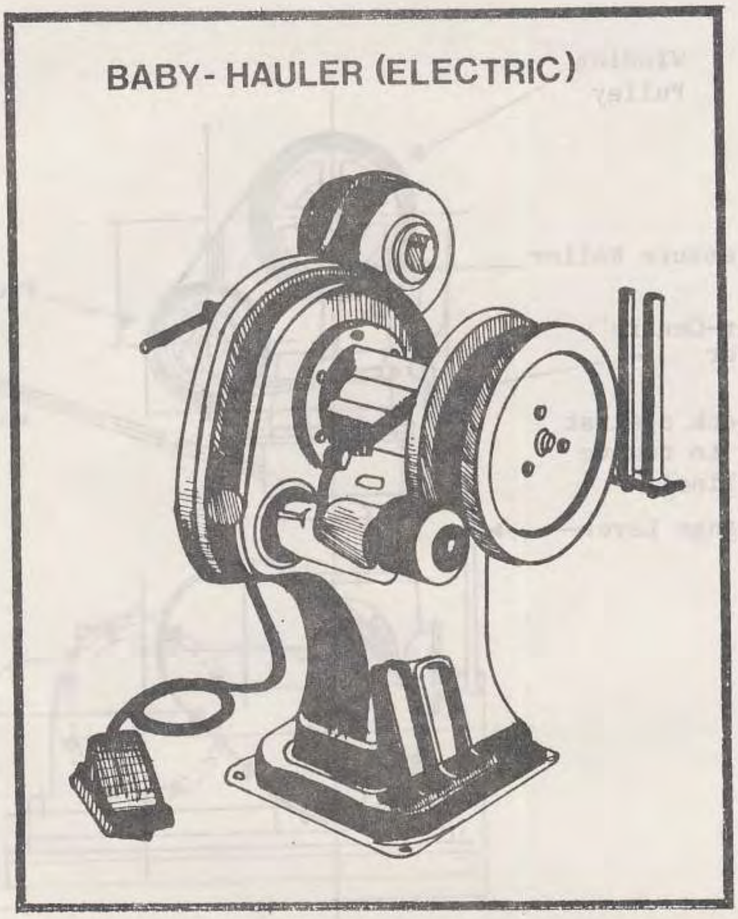


Fig. 79 Baby Hauler, Yamashita Fishing Tackle Co., Ltd.

Both line haulers (Figs. 78 and 79) can be used not only for tuna longline but also for bottom longline, vertical longline to catch demersal fish and also for pot fishing to catch crab and shrimp.

For ultra-small-scale fishing, a manual reel is introduced here in Fig. 80. This fishing reel was designed by a fisherman, made from wood and a steel bar to catch both pelagic and demersal fish.

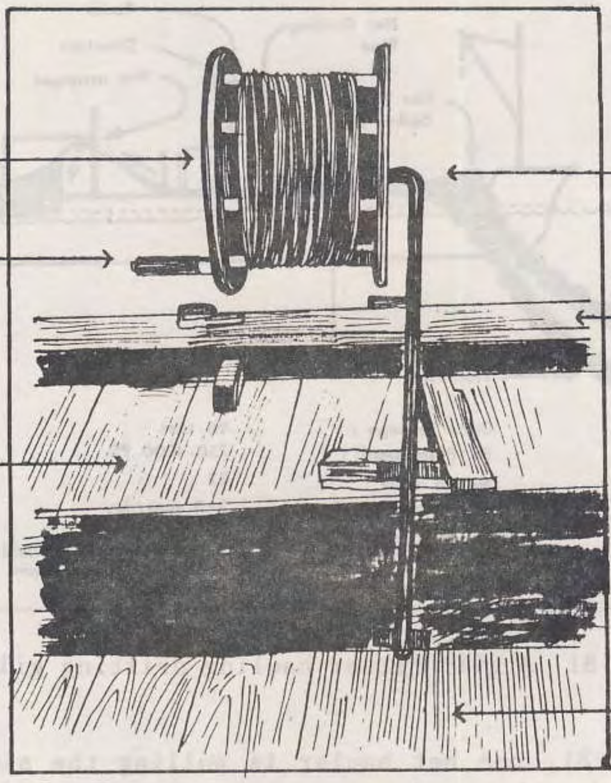


Fig. 80 Manual Reel

3. Drifting gill net hauler

A gill net hauler for Salmon or Squid is introduced here. The gear arrangement for gill net hauling is shown in Fig. 81.

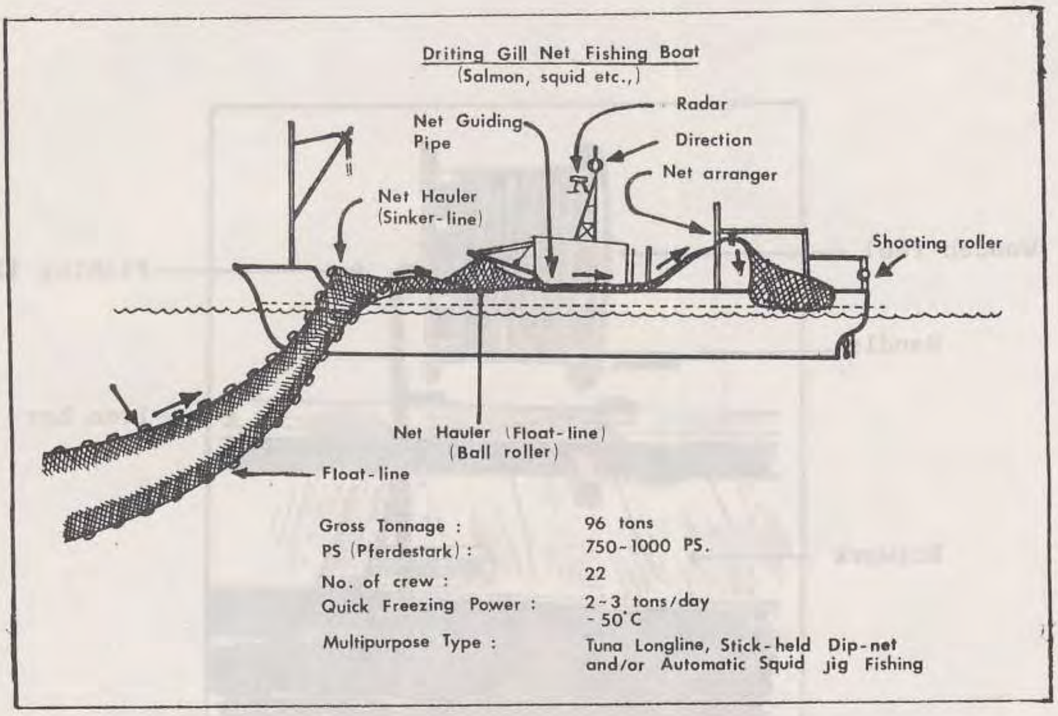


Fig. 81 A gill netter hauling drifting gill net

In Fig. 81, one net hauler is pulling the sinker line of the net onto the deck and, another is pulling its float line over the port side of the boat. Fig. 82 is showing a net hauler for sinker-line and Fig. 83 for the float-line of drifting gill net, and both of them are driven by hydraulic power. During hauling, the gill net is sent back to the stern deck of the boat through a net guiding tube and a net arranger to prepare for the next operation (See Fig. 81). A net guiding tube is shown in Fig. 84.

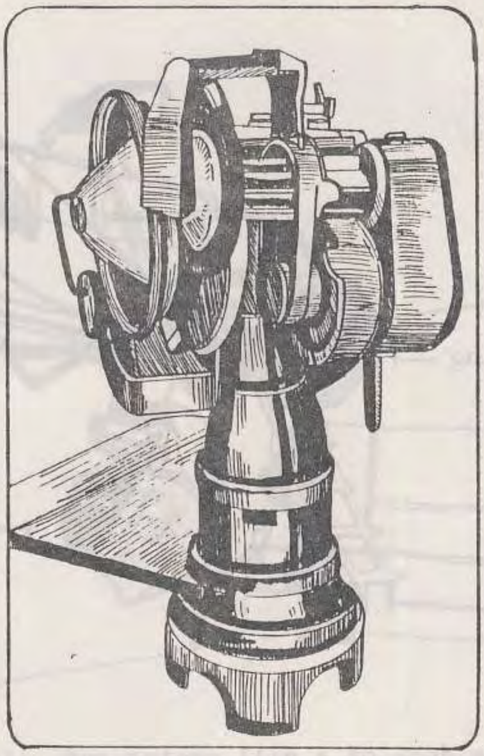


Fig. 82 Net Hauler for Sinker-line of gill net

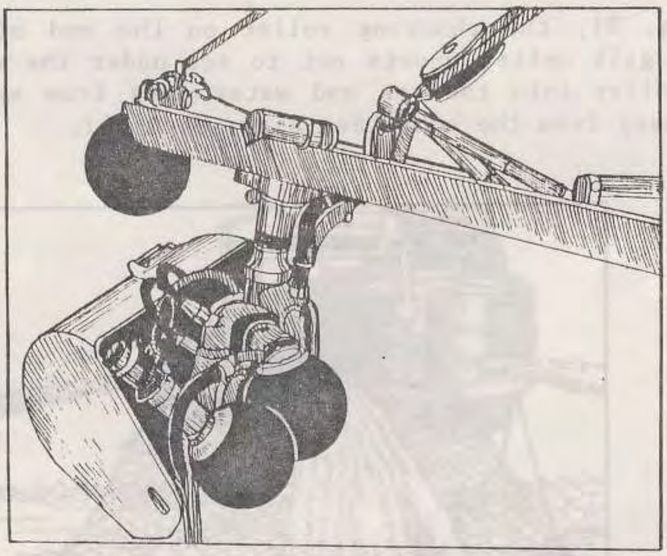


Fig. 83 Net Hauler for Float-line of gill net

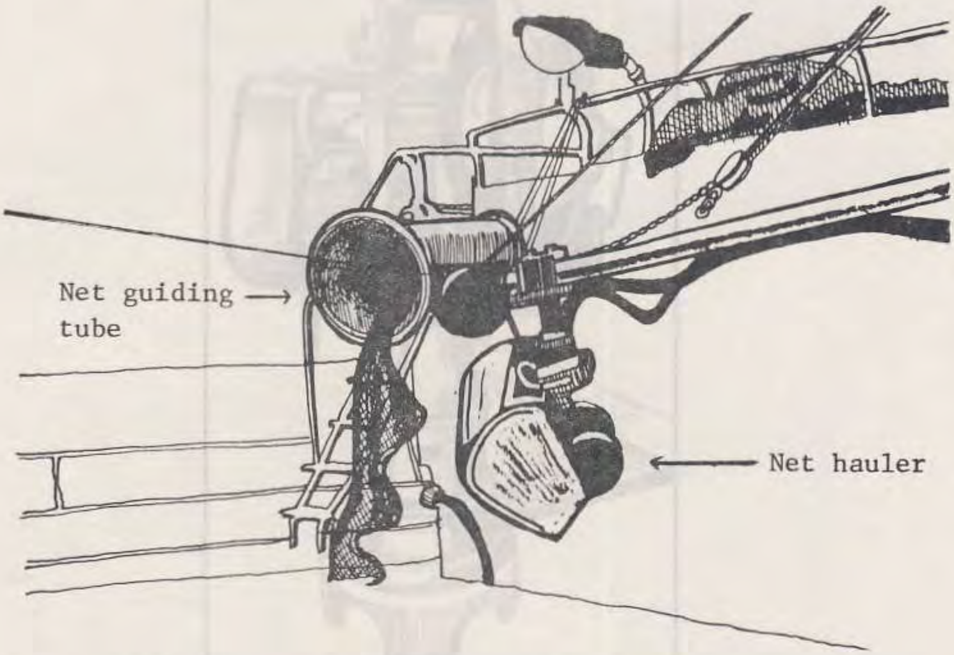


Fig. 84 Fore deck of a gill netter and, its net guiding tube and net hauler for float-line

In Fig. 81, the shooting roller on the end of the boat is shown, when a gill netter shoots net to set under the water, the net runs on the roller into the sea and water jets from sprinklers push the gill net away from the boat (See Figs. 85 & 86).

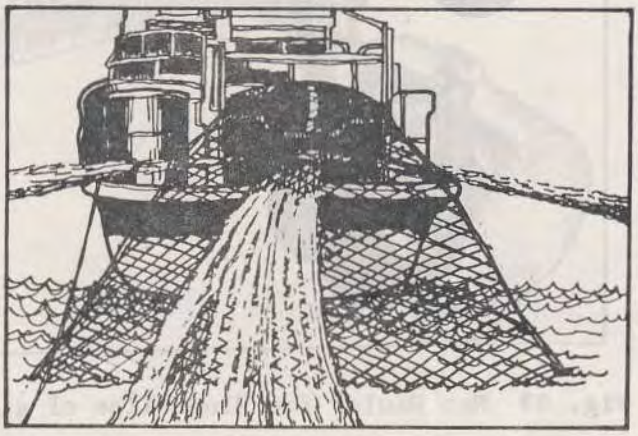


Fig. 85 Sprinklers for water jets and a shooting roller of a gill netter

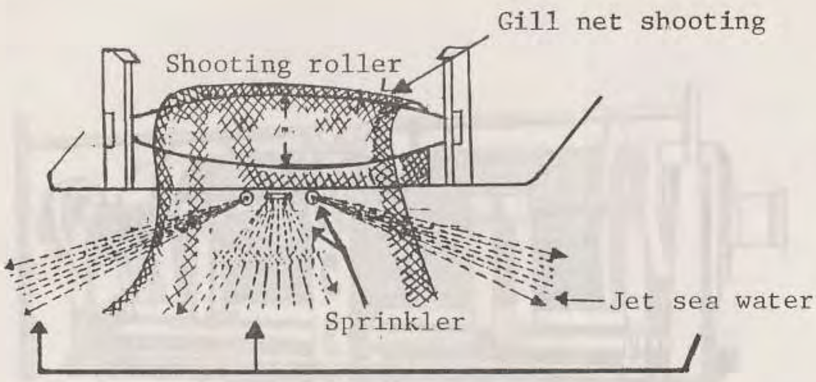


Fig. 86 Sprinklers and a shooting roller

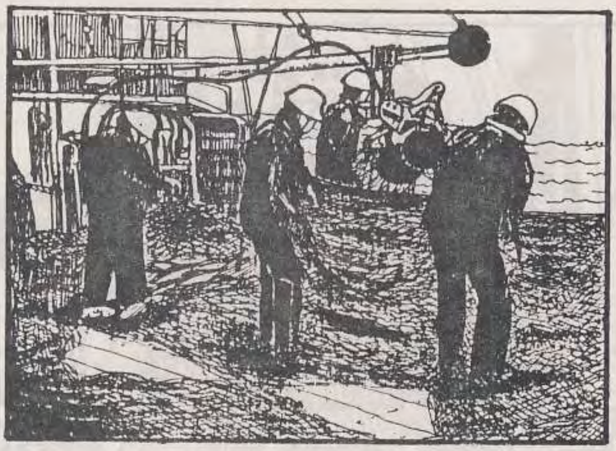


Fig. 87 Hauling Salmon gill net

4. <u>Trawl Winch</u>

A type of trawl winch is shown in Fig. 88 mounted on a Japanese deep-sea trawler. Trawl warps are reeled on main drums. During fishing the warps run from the main drums of the winch through gantry blocks into the sea, and they are pulled up from the sea through gantry blocks onto the main drums of the winch (See Fig. 90).

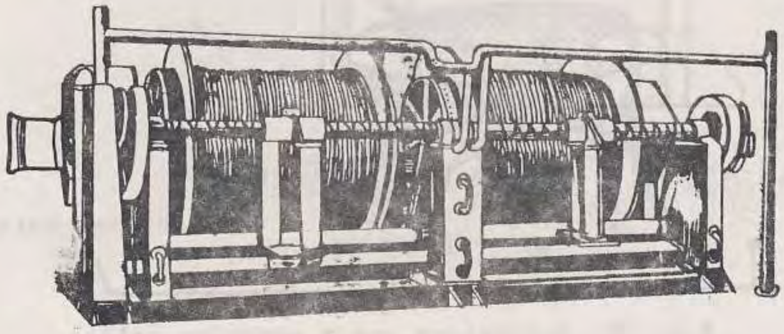


Fig. 88 Trawl winch of a deep-sea trawler

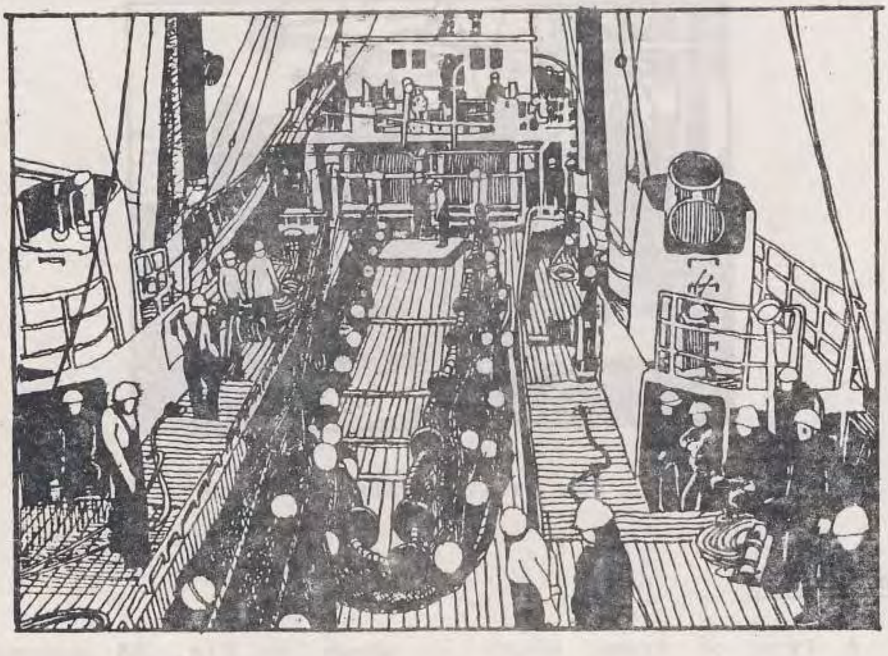


Fig. 89 A deep-sea trawler hauling the net

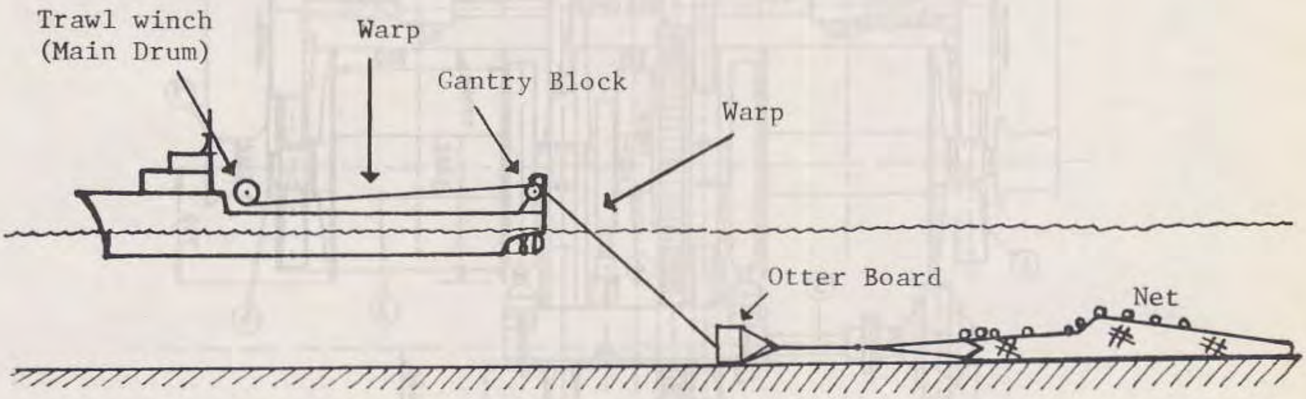
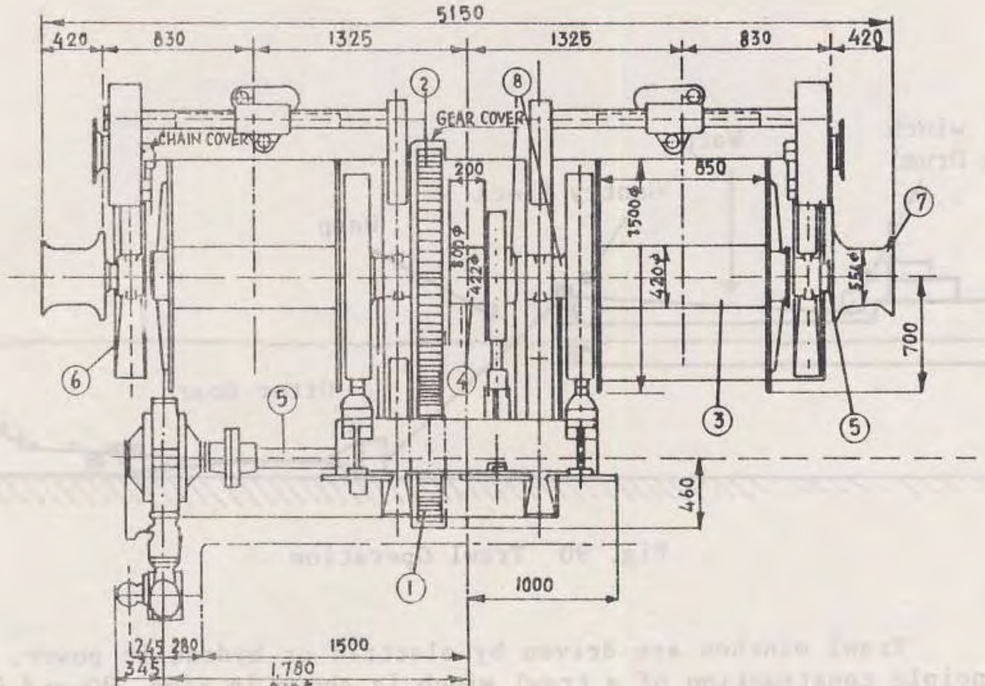


Fig. 90 Trawl Operation

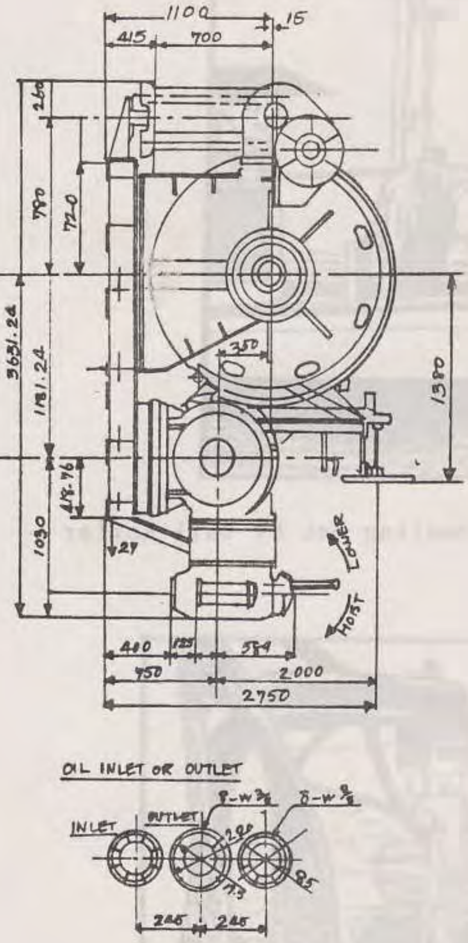
Trawl winches are driven by electric or hydraulic power. The principle construction of a trawl winch is shown in Figs. 90 and 91 as installed on M.V. PAKNAM, the fishery training vessel of SEAFDEC. The speed of hauling warps of this trawl winch is 60 metres a minute, lifting load 7.5 tons and revolutions of the main drums 26.3 per minute, driven by hydraulic power. This trawl winch is employed in fishing operations in both shallow and deep-sea (depth 300 metres) fishing grounds.

In Fig. 89, a trawler is hauling up its trawl net in a fishing ground. If the dimension of the trawl net is large in size, a powerful trawl winch should be mounted on the boat.



No.	Name	Material
1.	Clutch	Cast steel, steel
2.	Warping Drum	Cast iron
3.	Bearing	Cast steel
4.	Shaft	Steel
5.	Cod end Drum	Cast steel, steel
6.	Main Drum	Cast steel, steel
7.	Gear	Cast steel
8.	Pinion	Cast steel

Fig. 91 Front view of trawl winch of M.V. PAKNAM



PARTICULARS		
Main Drum	Lifting Load	6 ton
	Lifting Speed	60^m/min
	Point of Design	794 mm (Dia meter)
	Stowing Capacity	18 mm^t x 2800 M
Cot Drum	Lifting Load	11.0^t
	Lifting Speed	30^m x min
	Stowing Capacity	28 $mm^{\emptyset}$ x 50 M
Warping Drum	Lifting Load	6^t
	Lifting Speed	30^m/min
Type of MYD. Motor		MA 10
Type of Cont. Valve		E 14
MYD. Motor R/M		50.5
Main Drum R/M		24.5
Type of MYD.Pump x R/M		(G19 x 210R/M) x 2

LIST OF GEAR					
Name	Modul	No.of Teeth	P.C.D	Width of Teeth	Type of Teeth
Pinion	16	54	864	170	20°Star
Wheel	16	110	1760	170	Do
GEAR RATIO 1 : 2.04					

Fig. 92 Side view of trawl winch of M.V. PAKNAM

For small-scale trawlers, there are different net haulers as shown in Figs. 93 and 94. These hauling devices called "Ball Rollers" consist of 2 rubber balls, driven by hydraulic power. A "Ball Roller" is used not only for trawl operation, but also for hauling gill nets, etc.

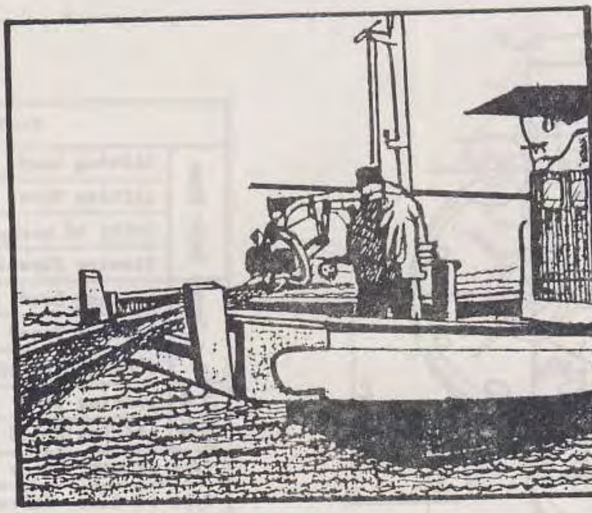


Fig. 93 A small-scale trawler hauling net by Ball Roller

Fig. 94 A small-scale fisherman hauling a trawl net by Ball Roller

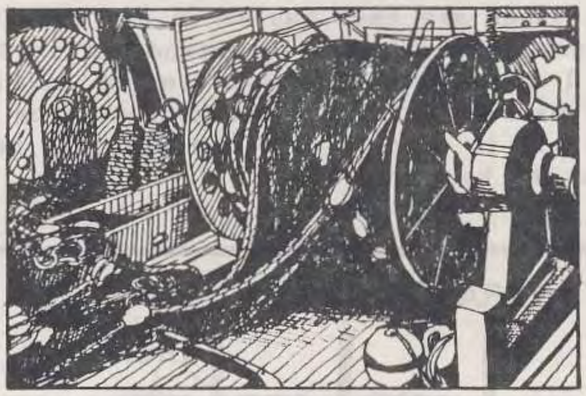


Fig. 95 Net Reel

Another type of hauling device for trawl is shown in Fig. 95 and called Net Reel. This reel hauls both warps and net on the main drums, it is very convenient for small-scale trawlers. Its capacity is 500-3000 Kg with 100 metres per minute.

5. Hydraulic wire-rope reel for stick-held blanket net

Stick-held blanket nets are used to catch Pacific saury, sardine, anchovy and bait fish. A stick-held blanket net extends from the boat into the sea largely to catch pelagic fish species attracted by luring lights (See Fig. 96).

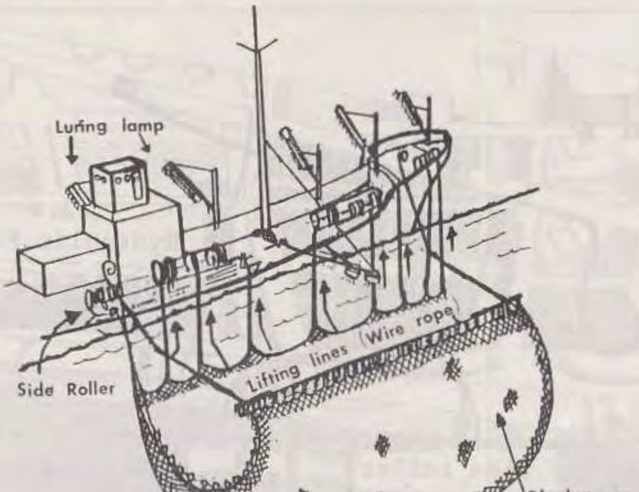


Fig. 96 Stick-held Blanket Net

The lifting lines are best hauled in by "Hydraulic wire-rope reel" for speed. One type of reel is introduced in Fig. 97. This hydraulic reel has 3 drums and winds 3 pieces of lifting line (wire rope) at the same time when hauling a blanket net from the sea. If a blanket net is very big in size, 2 or 3 reels should be mounted on a boat to lift it into the boat.

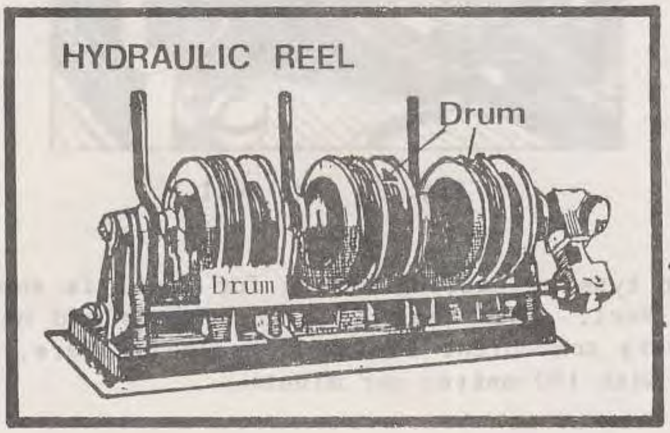


Fig. 97 Hydraulic Reel

Fig. 98 shows a set of hydraulic reels mounted on a Japanese fishing boat to catch pacific saury.

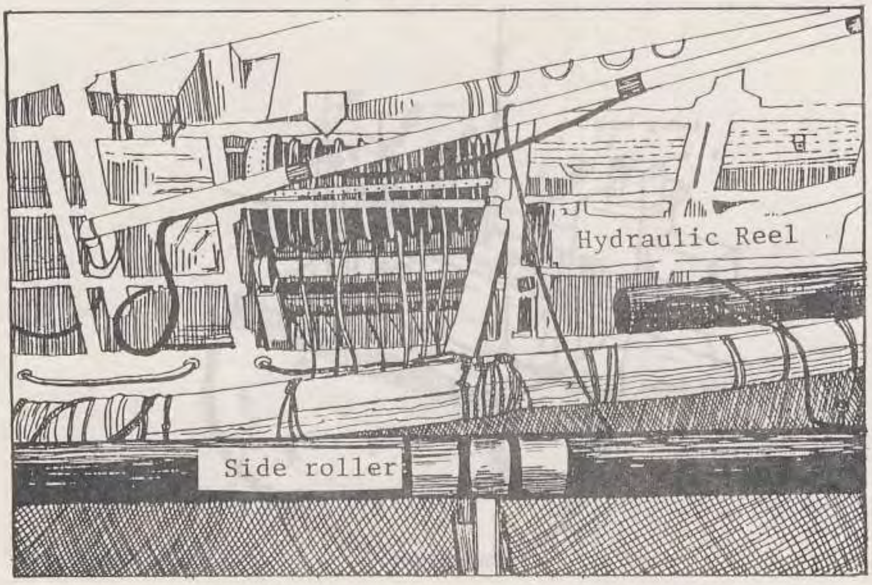


Fig. 98 Hydraulic reel mounted on a boat

After hauling all the lifting lines the blanket net is pulled up by hydraulic Side Roller (See Figs. 98 and 99).

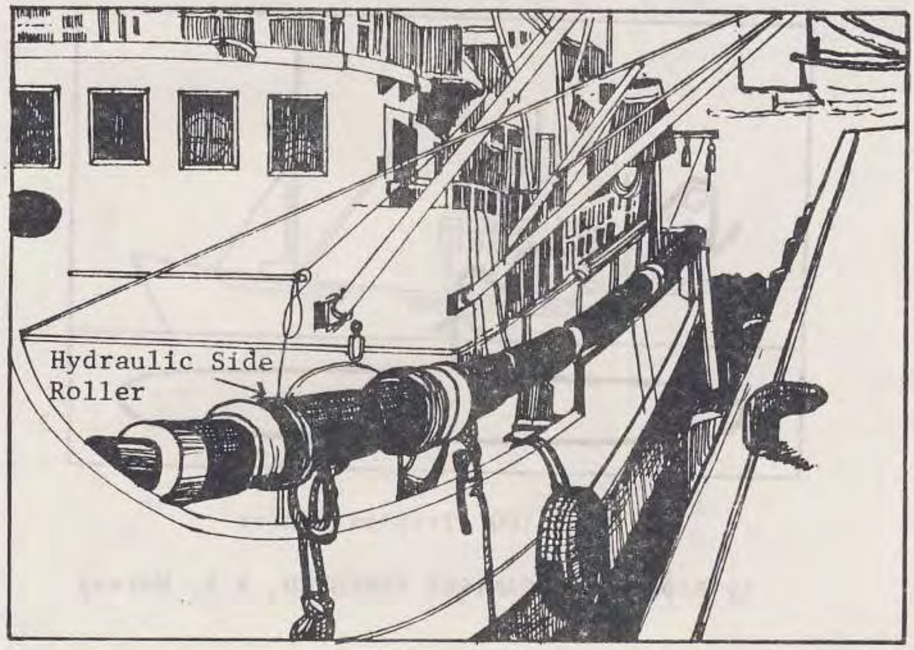


Fig. 99 Astick-held blanket net fishing boat (Pacific saury boat, about 60 tons)

6. Tripliex Roller of Purse Seine

Modern purse seines are so large and so efficient that net hauling equipment is a vital part of a purse seiner's outfitting. It is impossible to haul in a large-scale seine by hand. The major type of net hauler on purse seiners is the power block driven by hydraulic power. But recently another type of purse seine net hauler was invented in Norway, it is called "Triplex Hauler". To haul the net after having been pursed, 3 rollers combined are working together to pull up the net into the boat from the sea (See Figs. 100 and 101).

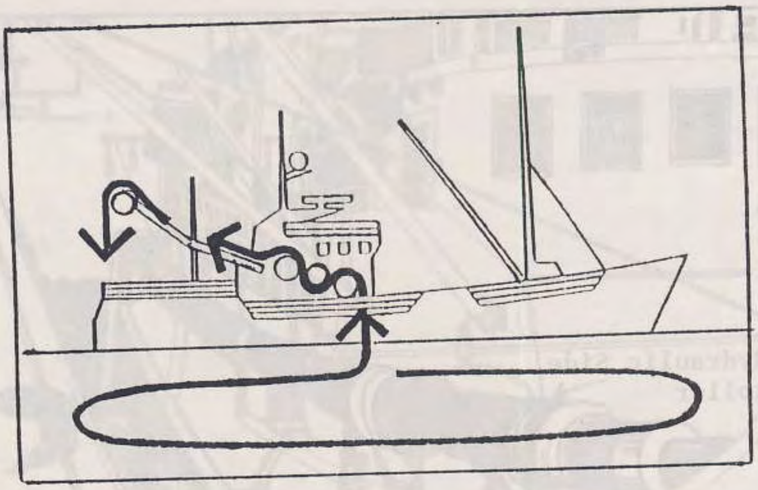


Fig. 100 Triplex Hauler

By BJØRSHOL MEKANISKE VERKSTED, A.S. Norway

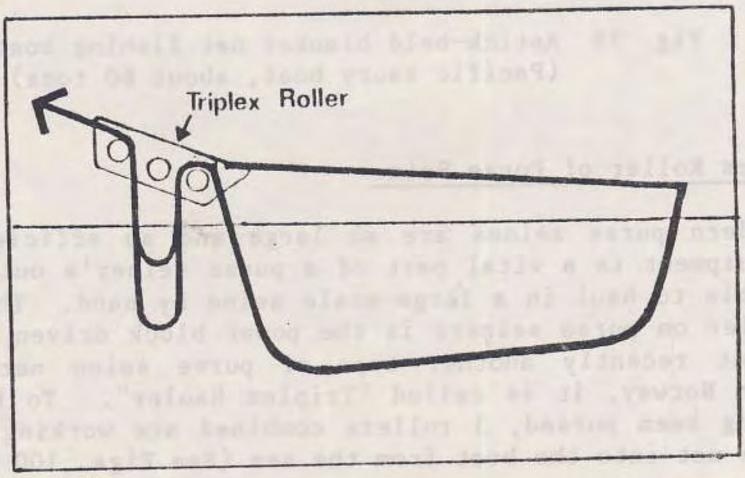


Fig. 101 Triplex Hauler

By BJØRSHOL MEKANISKE VERKSTED, A.S. Norway

Working system of triplex roller is shown in Fig. 102

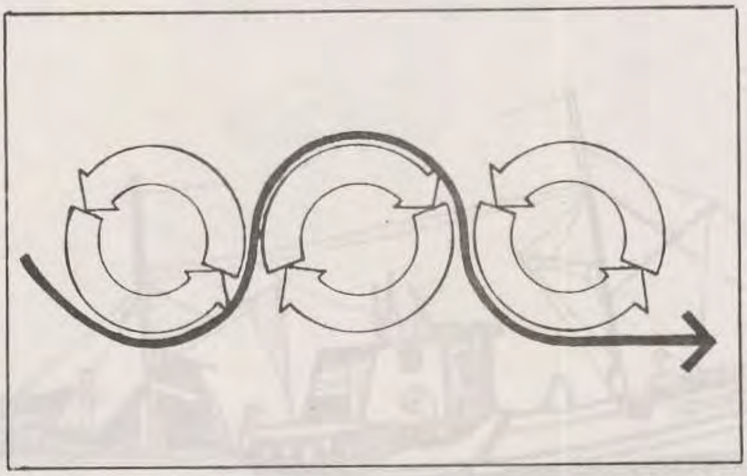


Fig. 102 Working System of Triplex Roller

Its prominent advantage lies in that it reduces the number of crew required on board a fishing boat and it makes work safer at sea and is mounted lower on a boat than a conventional power block net hauler (See Figs. 103 and 104) which helps the boat maintain good stability.

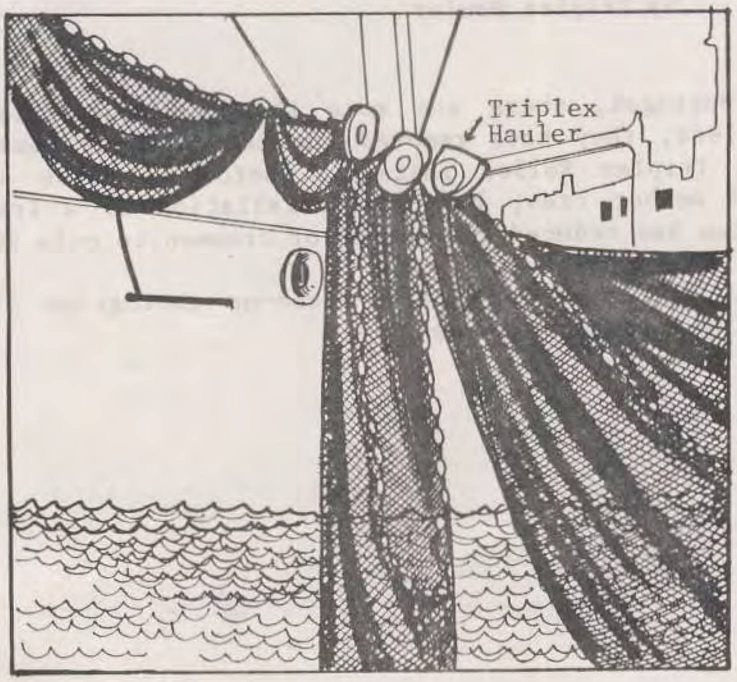


Fig. 103 Hauling purse seine net by Triplex Hauler

(BJØRSHOL MEKANISKE VERKSTED A.S. Norway)

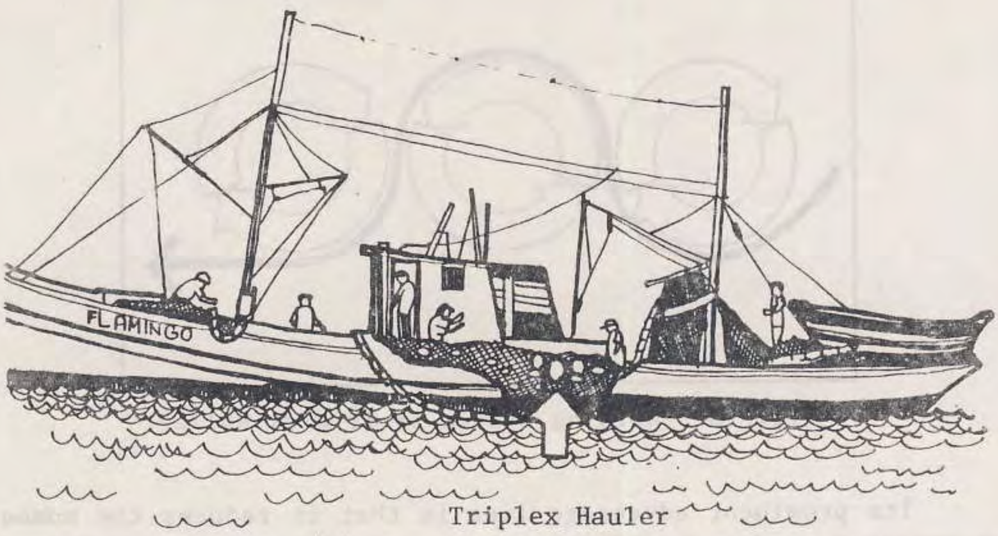


Fig. 104 A portuguese purse seiner hauling in its seine net by Triplex Hauler

In Portugal, there are more than 130 purse seiners using Triplex Rollers, they have removed the conventional power block and installed a Triplex Roller instead. Before a purse seiner there needed a 50 member crew, but the installation of a Triplex Roller hauling system has reduced the number of crewmen to only 20.

Fig. 105 is a copy of a close-up photograph of a Triplex Hauler hauling a purse seine net.

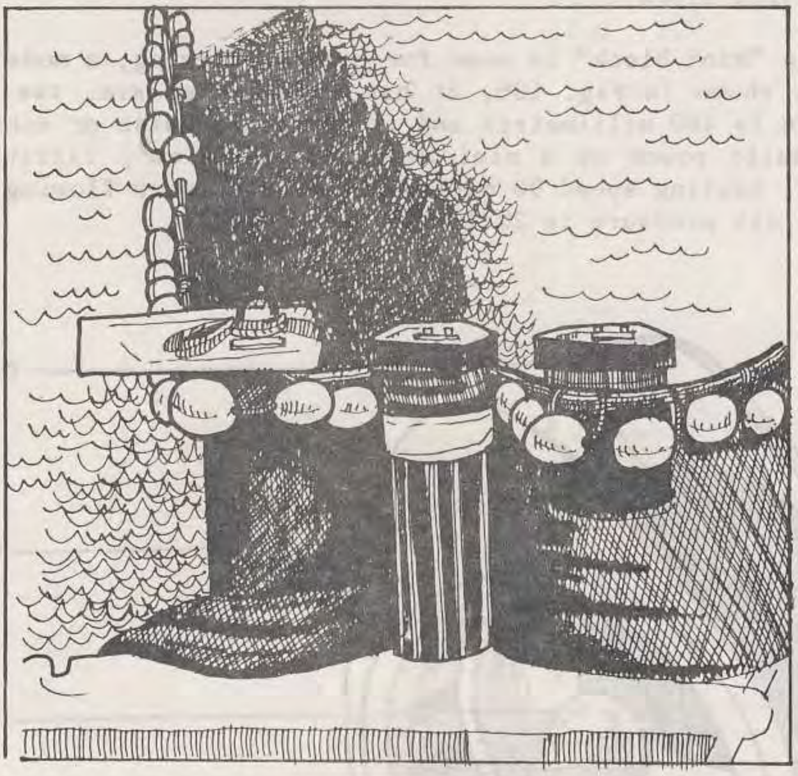


Fig. 105 Triplex Hauler under hauling conditions

By NICHIMO CO., LTD. Japan

7. Multipurpose hauling devices for small-scale fishing boats

Small-scale fishing boat's operations are quite different from large-scale ones. Large-scale fishing boats are able to catch fish in large quantities, and target fish species are few and their fishing grounds are very far from the shore. On the other hand the small-scale fishing boats are operating in the vicinity of the coast and their aim is to catch a wide variety of species of fish, from pelagic ones to demersal ones and, local fishery regulations have been restricting fishing to specific fishing areas, fishing seasons and fishing gear.

Thus small-scale fishing boats will have various kinds of fishing gears, so the installation of multipurpose hauling devices on them is recommendable.

For instance, a hauling device or equipment on board could be applicable to longline, gill net, trawl, etc., here are some outlines of multipurpose hauling devices.

7.1 Mini Block

A "Mini block" is used for coastal fishing, a model of a "Mini Block" is shown in Fig. 106, it has a rubber sheave, the diameter of the sheave is 480 millimetres and it turns clockwise or anti-clockwise. The Hydraulic power of a mini block is 70 Kg/cm^2, lifting force 106 Kilograms, hauling speed 90 metres per minute (when flowing quantity of hydraulic oil pressure is 20 litres per minute).

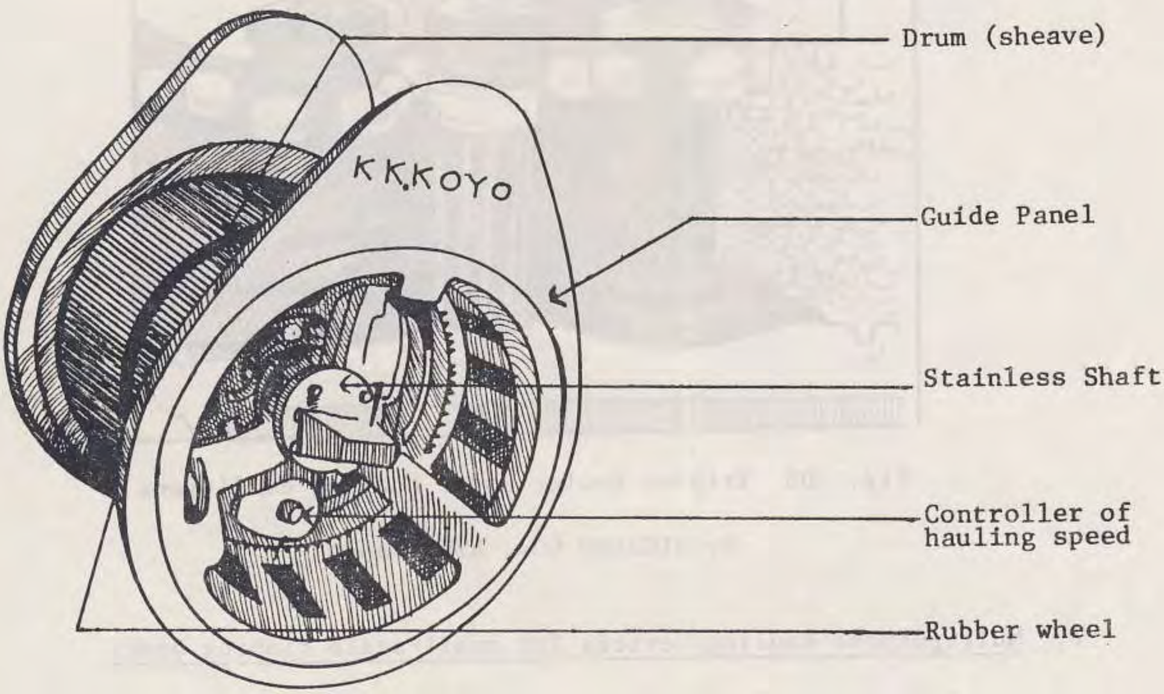


Fig. 106 Mini Block for gill net and longline

KOYO Fishing Machinery Co., FUKUSHIMA Pref, Japan

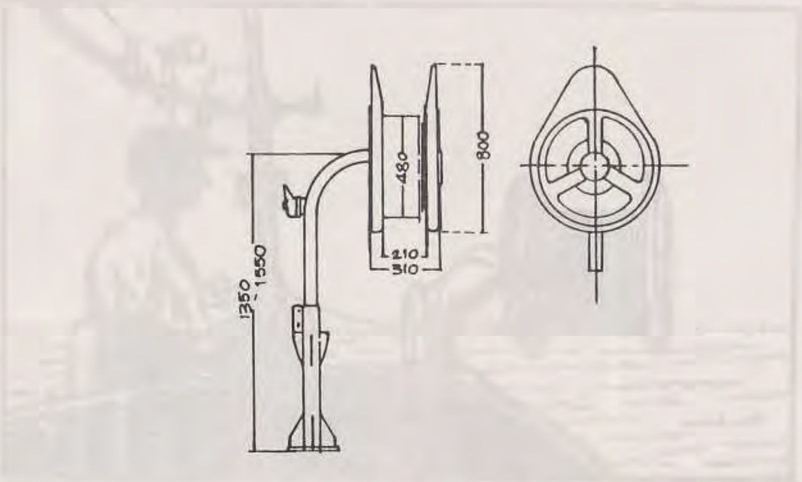


Fig. 107 Side view of Mini Block

KOYO Fishing Machinery Co., FUKUSHIMA Pref. Japan

Fig. 107 is showing a side view of a Mini Block, it is a very compact hauling device and capable of hauling gill net (See Fig. 108) and longline (See Fig. 109).

Fig. 108 A fisherman hauling gill net with a Mini Block mounted on the stern deck of his boat

Photo by KOYO KK & NICHIMO CO., LTD.

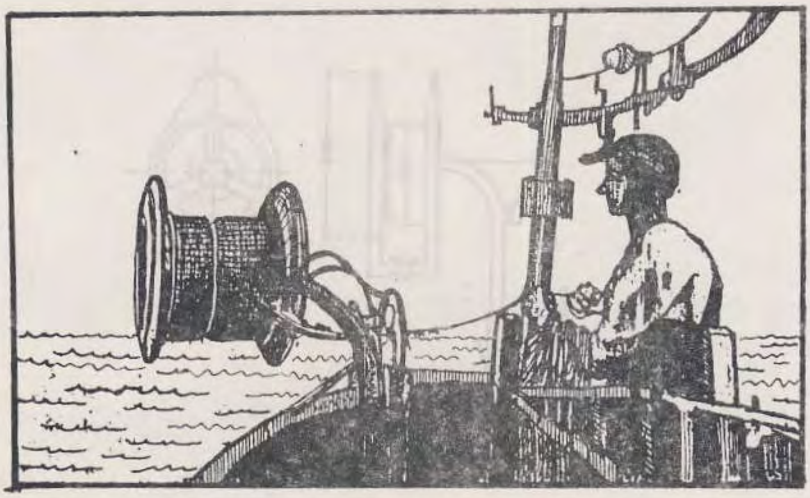


Fig. 109 A fisherman hauling longline with a Mini Block mounted on the fore deck of his boat

Photo by KOYO KK & NICHIMO CO., LTD.

7.2 Cone Roller

Cone Rollers are used for purse seine, gill net, longline, stick-held blanket net, stationary trap net (set net) and trap-cage net, etc. Figures 110 to 113 show various Cone Rollers.

Fig. 110

Photo by AWAKUME CO., LTD. TOKYO, JAPAN

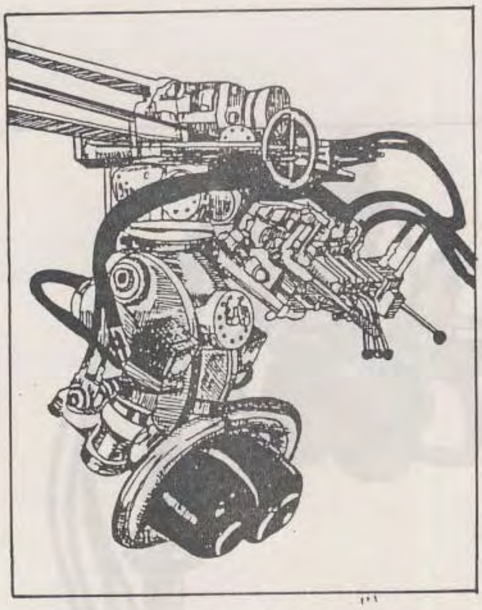


Fig. 111 Net hauler

Photo by AWAKUME CO., LTD. TOKYO, JAPAN

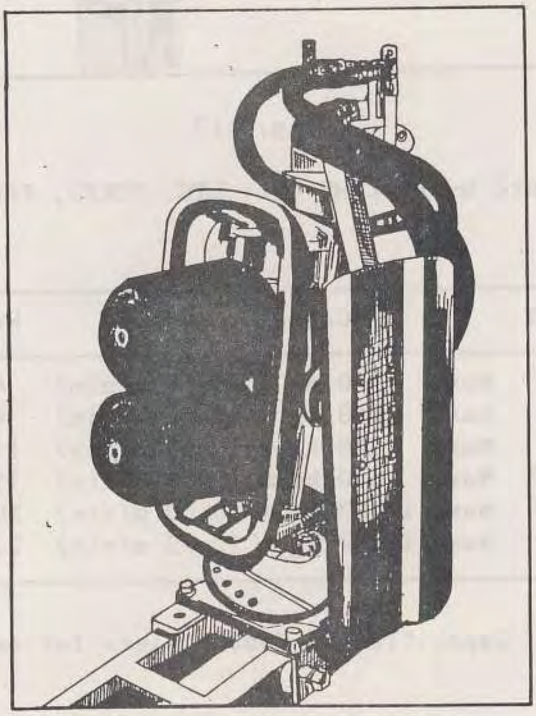


Fig. 112 Net hauler

Photo by AWAKUME CO., LTD. TOKYO, JAPAN

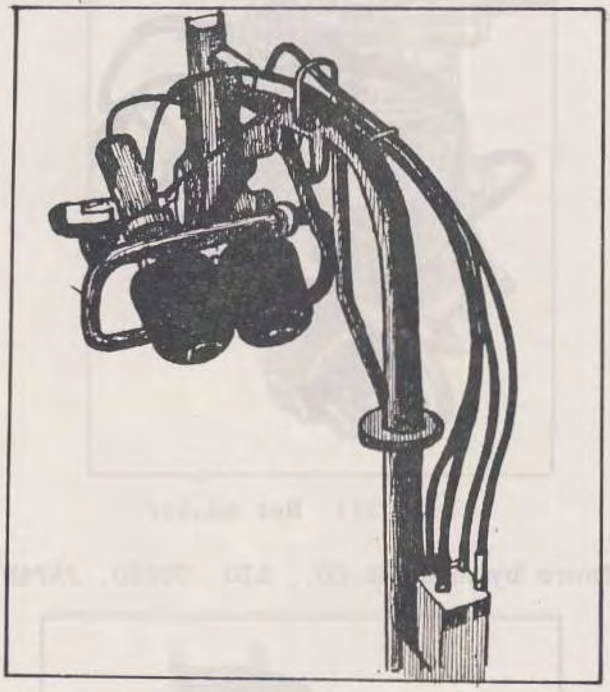


Fig. 113

Photo by AWAKUME CO., LTD. TOKYO, JAPAN

Model	Capacity	Weight
S-1	Max. 100 kg x (0-60 m/min)	40 kg
S-2	Max. 150 kg x (0-60 m/min)	45 kg
S-3	Max. 300 kg x (0-60 m/min)	110 kg
S-3.8	Max. 500 kg x (0-60 m/min)	150 kg
S-4.5	Max. 1,000 kg x (0-60 m/min)	200 kg
S-5	Max. 1,500 kg x (0-60 m/min)	235 kg

Fig. 114 Capacities of Cone Rollers for each Model

The capacities of some Cone Roller models are shown in Fig. 114.

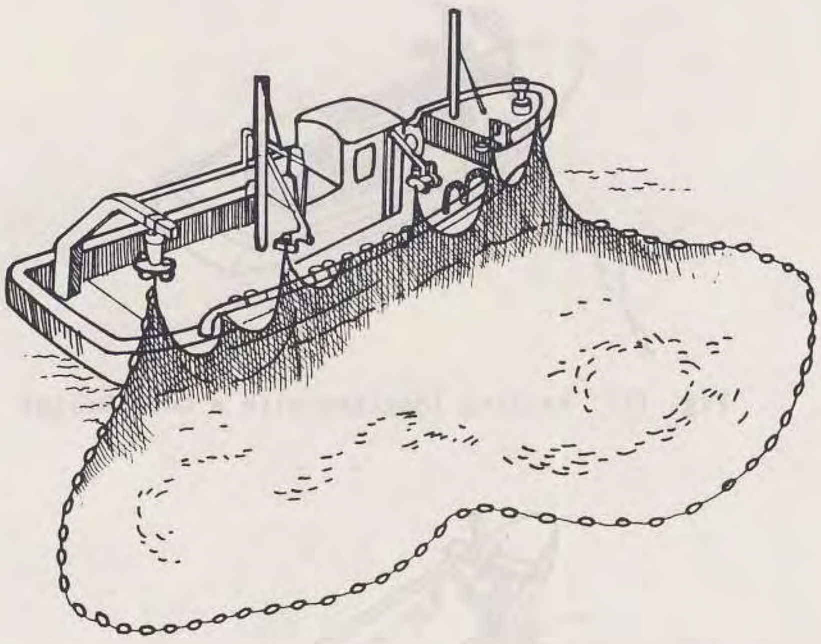


Fig. 115 Hauling small-scale purse seine net with Cone Rollers

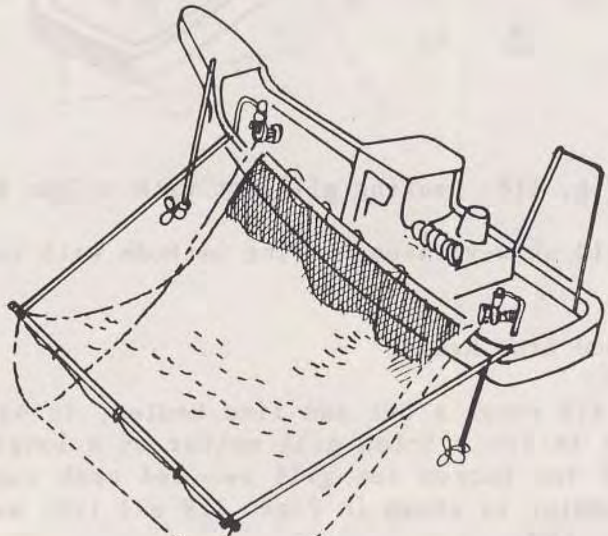


Fig. 116 Hauling stick-held blanket net with Cone Rollers

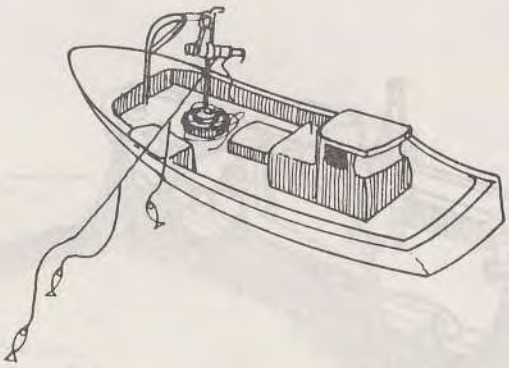


Fig. 117 Hauling longline with a Cone Roller

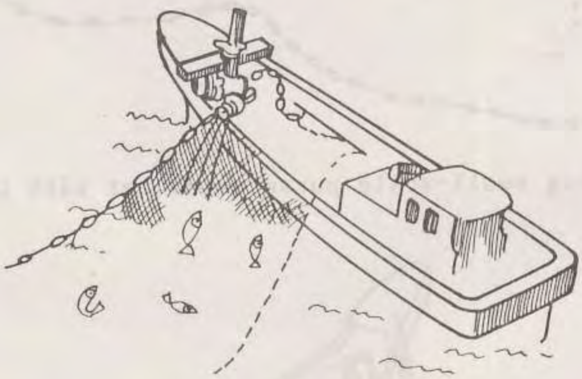


Fig. 118 Hauling gill net with a Cone Roller

Figs. 115 to 118 show various hauling methods with Cone Rollers.

7.3 Net and Line Hauler

Fig. 119 shows a net and line hauler, it has a long drum with a ditch. This is for a 5-ton gill netter or a longliner. This hauler is mainly used for bottom set gill net and crab cage-net fishing. A model of the hauler is shown in Figs. 119 and 120, manufactured by IZUI IRON WORKS CO., LTD.

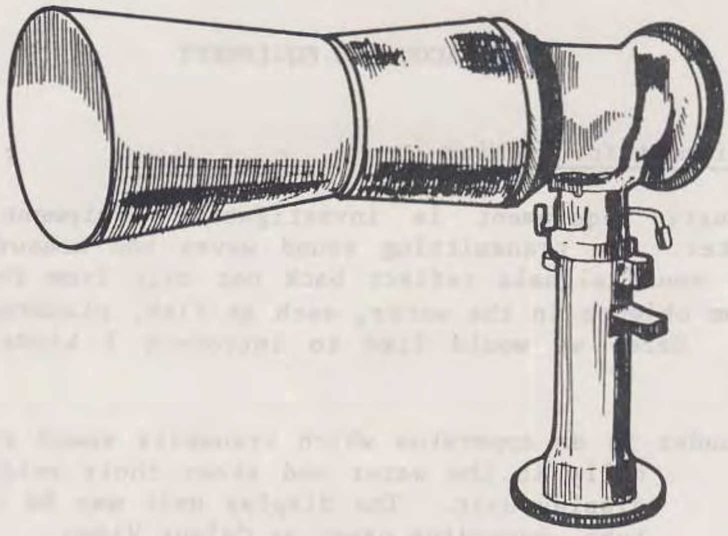
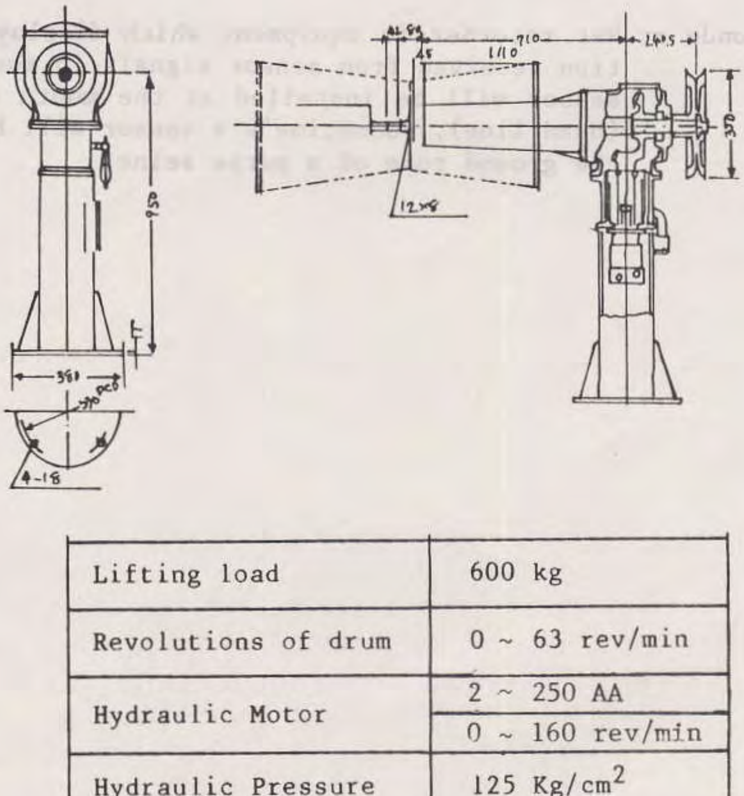


Fig. 119 Net & Line Hauler

IZUI IRON WORKS CO., LTD



Lifting load	600 kg
Revolutions of drum	0 ~ 63 rev/min
Hydraulic Motor	2 ~ 250 AA
	0 ~ 160 rev/min
Hydraulic Pressure	125 Kg/cm^2

Fig. 120 Dimensions of Net & Line Hauler Model SE-2
IZUI IRON WORKS CO., LTD.

5.2 ACOUSTIC EQUIPMENT

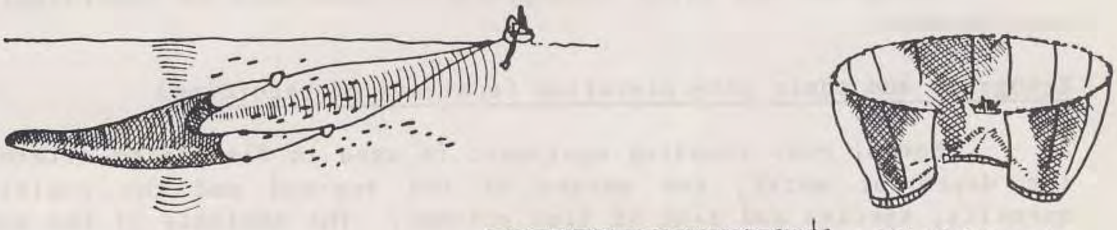
Acoustic equipment for fishing

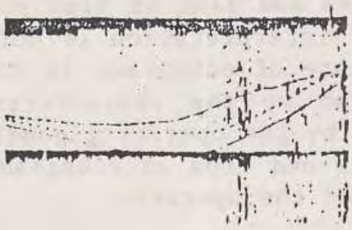
Acoustic equipment is investigative equipment which uses sound in water. By transmitting sound waves and measuring the echo return time, sound signals reflect back not only from the sea bottom but also from objects in the water, such as fish, plankton, sediments, waste, etc. Here, we would like to introduce 3 kinds of acoustic equipment.

1. Echo sounder is an apparatus which transmits sound signals vertically in the water and shows their echo return on a display unit. The display unit may be a cathode ray tube, recording paper or Colour Video.

2. Sonar is an apparatus which transmits sound signals horizontally in the water (in a more or less horizontal direction). Same display units as echo sounder.

3. Net sonde or Net recorder is equipment which displays the information received from sensor signals in the sea water. A sensor will be installed at the mouth of a trawl net (head line). Sometime's a sensor will be installed on the ground rope of a purse seine.





◀ NET SONDE marks on echogram: NET-SONDE aids fishing at 100–120 m depths with a 250 m deep net. Otherwise the net is frequently damaged by bottom obstacles.

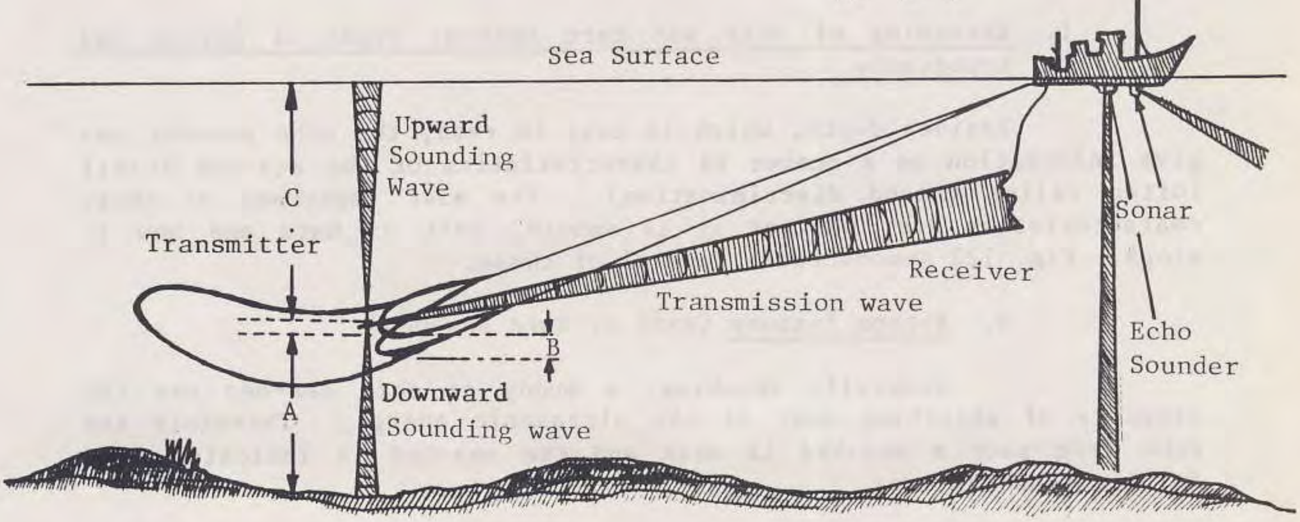


Fig. 121

Echograms and their interpretation (analysis of recording) of echo sounder.

Echograms and their interpretation (analysis of recording)

Normal echo sounding equipment is used in fishing to determine the depth of water, the nature of the sea-bed and the position, quantity, species and size of fish present. The analysis of the echograms and their interpretation is not always easy and straightforward, because the nature of echograms is determined not only by the type of target, but also by the characteristics of the respective acoustic instruments and by the operating conditions. The amount of information that can be obtained from an echogram depends essentially on the skill and experience of the operator.

1. Recording of soft and hard bottom; types of bottom and topography.

Besides depth, which is easy to read, the echo sounder can give information on a number of characteristics of the sea-bed itself (often called ground discrimination). The most important of these characteristics are, whether it is smooth, soft or hard and how it slops. Fig. 122 demonstrates several of these.

a. Bottom feature (soft or hard sea-bed)

Generally speaking, a muddy or soft sea-bed has the property of absorbing most of the ultrasonic energy. Therefore the echo from such a sea-bed is weak and the sea-bed is indicated in a faint and narrow line.

On the other hand, the reflection from a hard bottom is strong, making the bottom echotrace dense and with a long tail. Differences of bottom trace in appearance will facilitate recognition of the bottom feature, soft or hard see Fig. 122.

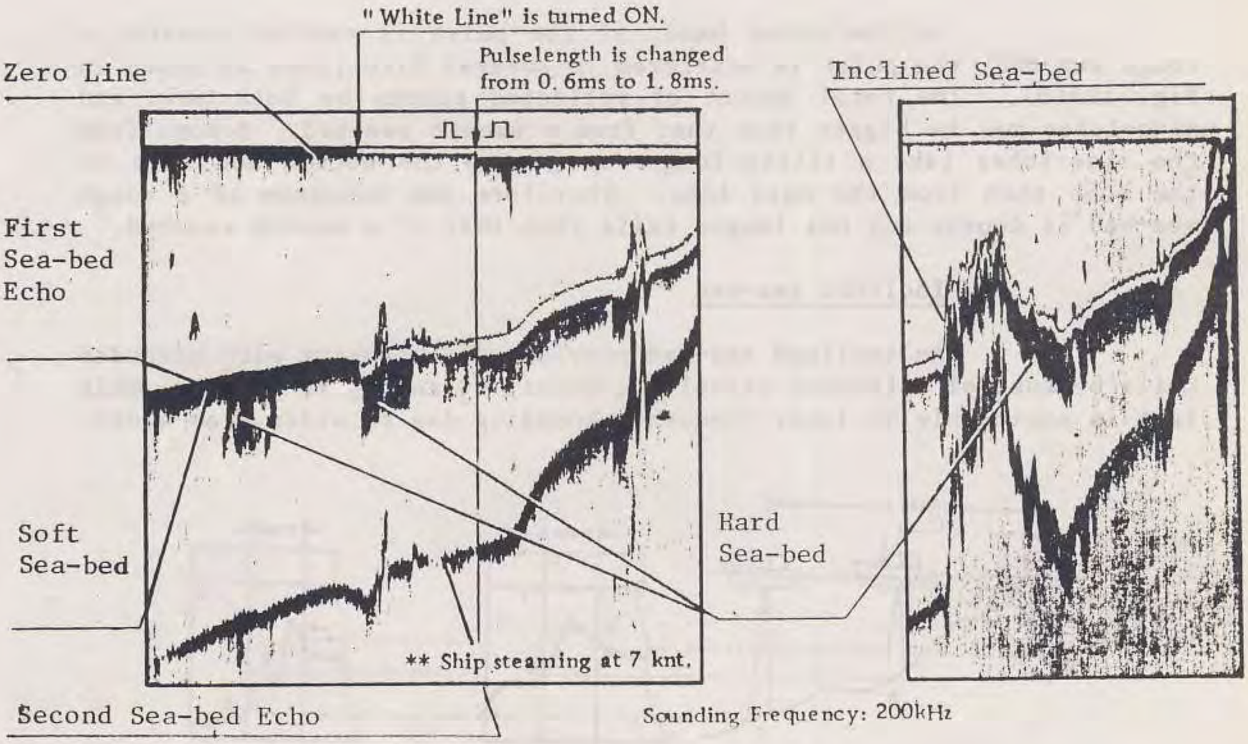


Fig. 122

b. Smooth or rough sea-bed

If the echo sounder transmits the sounding pulse towards a perfectly smooth sea-bed, only the echo from the main-lobe which strikes the sea-bed at a right-angle is received and most of the echoes from the side-lobes do not return to the ship as shown in Fig. 123(a).

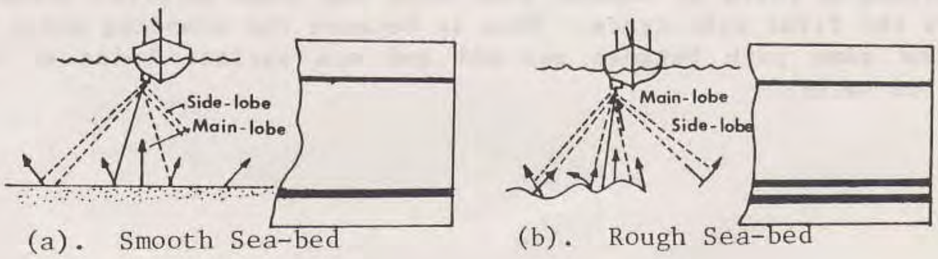
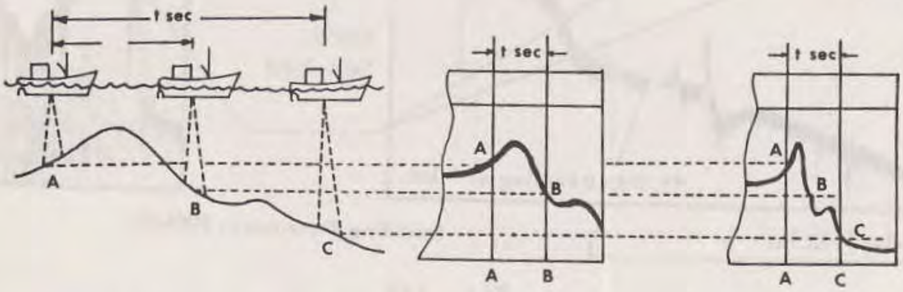


Fig. 123

On the other hand, if the pulse is emitted towards a rough sea-bed, the pulse is scattered in several directions as shown in Fig. 123(b). The total amount of reflected echoes by both main and side-lobes may be bigger than that from a smooth sea-bed. Echoes from the side-lobes take a little longer to get to the bottom and back to the ship than from the main lobe. Therefore the echogram of a rough sea-bed is denser and has longer tails than that of a smooth sea-bed.

c. Inclined sea-bed

An inclined sea-bed provides the echogram with extended tails because of different travelling paths, d_3 and d_4 in a beam. This fact is noticeable in lower frequency sounding due to wider beam-width.



(a). Slow Speed (b). Fast Speed

Fig. 124

d. Echoes and multiple reflection

In a comparatively shallow depth sounding, too high a setting of the amplifier gain and a stiff sea-bed cause a second or sometimes a third or fourth echo with the same interval between them below the first echo trace. This is because the sounding pulse travels in the same path between sea-bed and sea surface twice or more in shallow water.

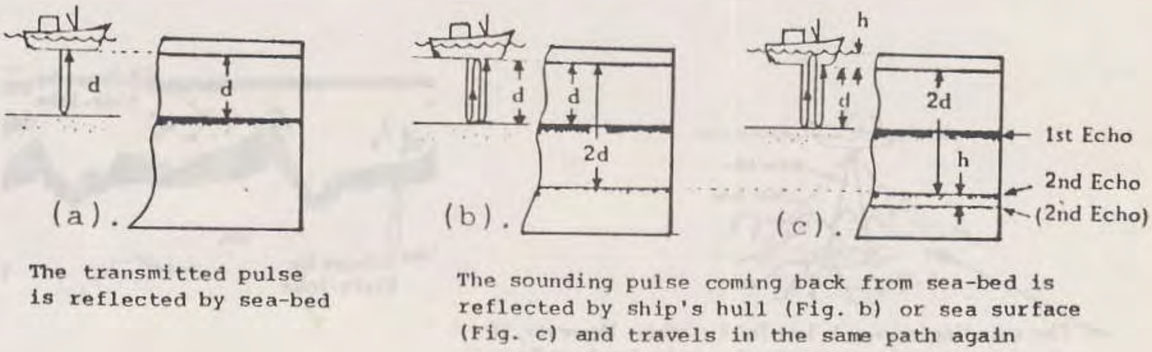


Fig. 125

e. Sea-bed consisting of two kinds of layers

When the sea-bed comprises of two layers one composed of hard and the other of soft materials, the sea-bed indication becomes wider blackening and there sometimes appears quite a peculiar recording of second echoes.

Fig. 126

f. Shallow and craggy sea-bed

The shallow and craggy sea-bed may sometimes be marked as shown below when sounding beamwidth is wide (low frequency) and amplifier gain is set high.

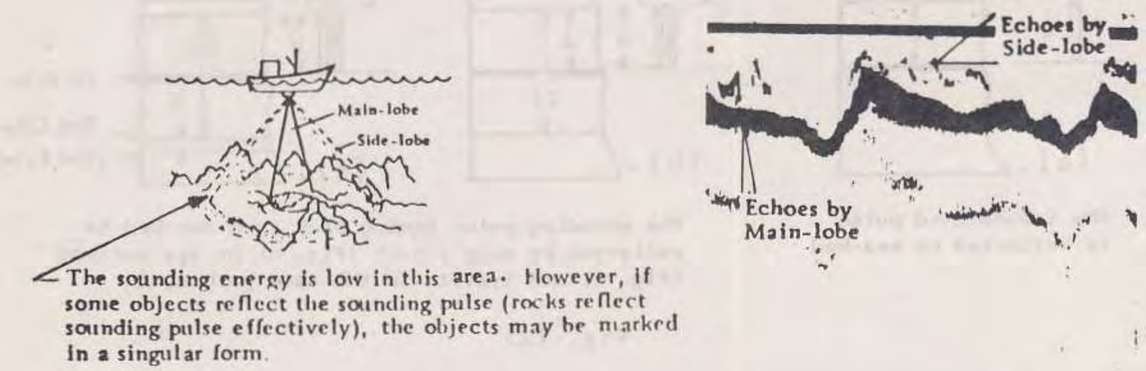
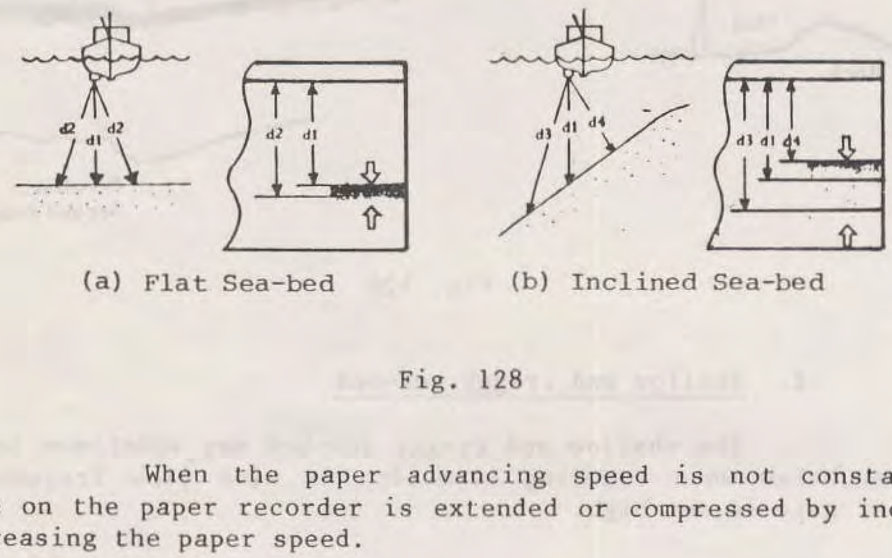


Fig. 127

g. <u>Sea-bed trace at different ship's speed</u>

The sea-bed appears on the recording paper as if it is very much diminished in size in the paper advancing direction. This is based on the relation between ship's speed and paper advancing speed. At a constant paper advancing speed, the echo trace varies in appearance with the change of ship's speed as shown below.



(a) Flat Sea-bed (b) Inclined Sea-bed

Fig. 128

When the paper advancing speed is not constant, the picture on the paper recorder is extended or compressed by increasing or decreasing the paper speed.

(a) Fast speed (b) Slow speed

Fig. 129

2. Fish echo

Fish echoes will generally be plotted between the transducer and the first echo from the sea-bed. Usually a fish echo trace is weaker than a sea-bed echo trace because the reflection surface of fish is smaller and their reflection property is weaker than that of the sea-bed. The blackness of the fish recording largely depends upon the grouping density and shoal size.

Fish echoes are sometimes plotted in the midst of surface noise, but it is possible to identify the fish echoes because surface noise is weaker than fish echoes in density and moreover, it can be eliminated by using TVG for easier recognition of the fish echoes. However, too high a setting of TVG will cause the fish echoes to disappear as well. Proper setting of the TVG is very important.

a. Recording of a fish school

A fish school is generally recorded in a continuous solid block built up by a series of echo traces. If the boat passes directly over the school, the leading edge of working indicates the actual depth of the fish school.

In most cases, dense school echograms with long tails are seen on the recorder and sometimes they extend upto the bottom echo. The lengths of these tails are related to the density and width of the school. Namely, the denser the school, the longer the tail.

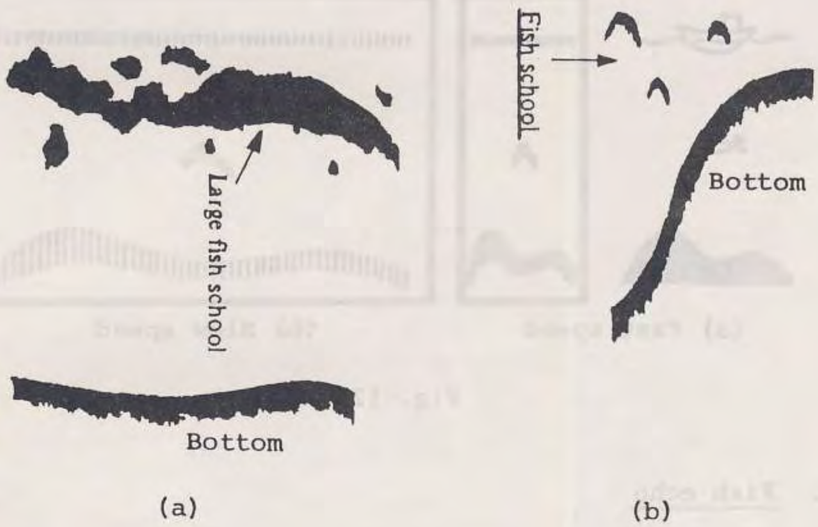


Fig. 130

b. Recording of large single fish

A large single fish just below the ship is recorded in a crescent (arc) form. The following show the reason why the fish appears in a crescent shape.

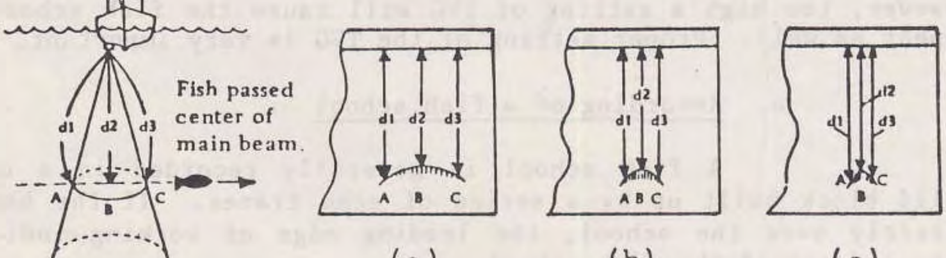


Fig. 131

If the ship is stopping, the echo sounder starts to detect the fish when the fish reaches point A. The distance from transducer to fish is referred to as "d_1". Next, the fish moves to the points B, then C. The distances from transducer to points B and C are referred to as "d_2" and "d_3" respectively. The distances "d_1" and "d_3" are greater than "d_2", so the echo trace appears in a crescent form as shown in Fig. 131(a). When the fish is moving at a faster speed, a shorter and sharper crescent is traced as shown in Fig. 131(b) and (c). The same result is given when the ship cruises over a stationary fish.

Sonar operation in fishing

There are 5 important factors which affect the sonar's efficiency:

1. The sea - poor or good condition;
2. The fish - slow or fast swimming (behaviour);
3. The sonar and its installation - good or bad;
4. The ship - noisy or quiet;
5. The operator - knowing his job or not.

Mid-water fish school detection by sonar

Immediately a fish school is detected the ship should approach the fish school at a low speed in a straight direction. This may avoid the fish scattering because of the noise and make sonar control easier. With a continuous increase in tilt angle in relation to the ship's speed, the signal will always appear on the screen.

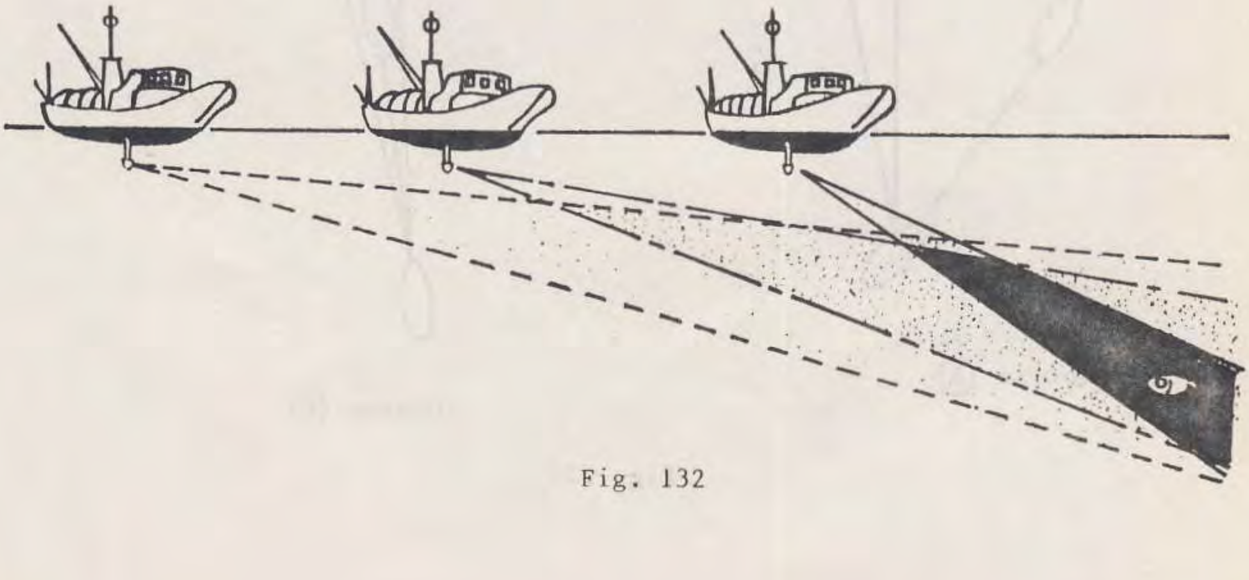


Fig. 132

It is more complex when the ship goes around the fish school, in this case both train and tilt angle are engaged. It is inconvenient for the operator to use tilt controls at the same time and there is more chance of loosing the target. Once the ship has moved completely around the fish school the wake will block the fish school from the sound beam, therefore, it is best to avoid this manoeuvre.

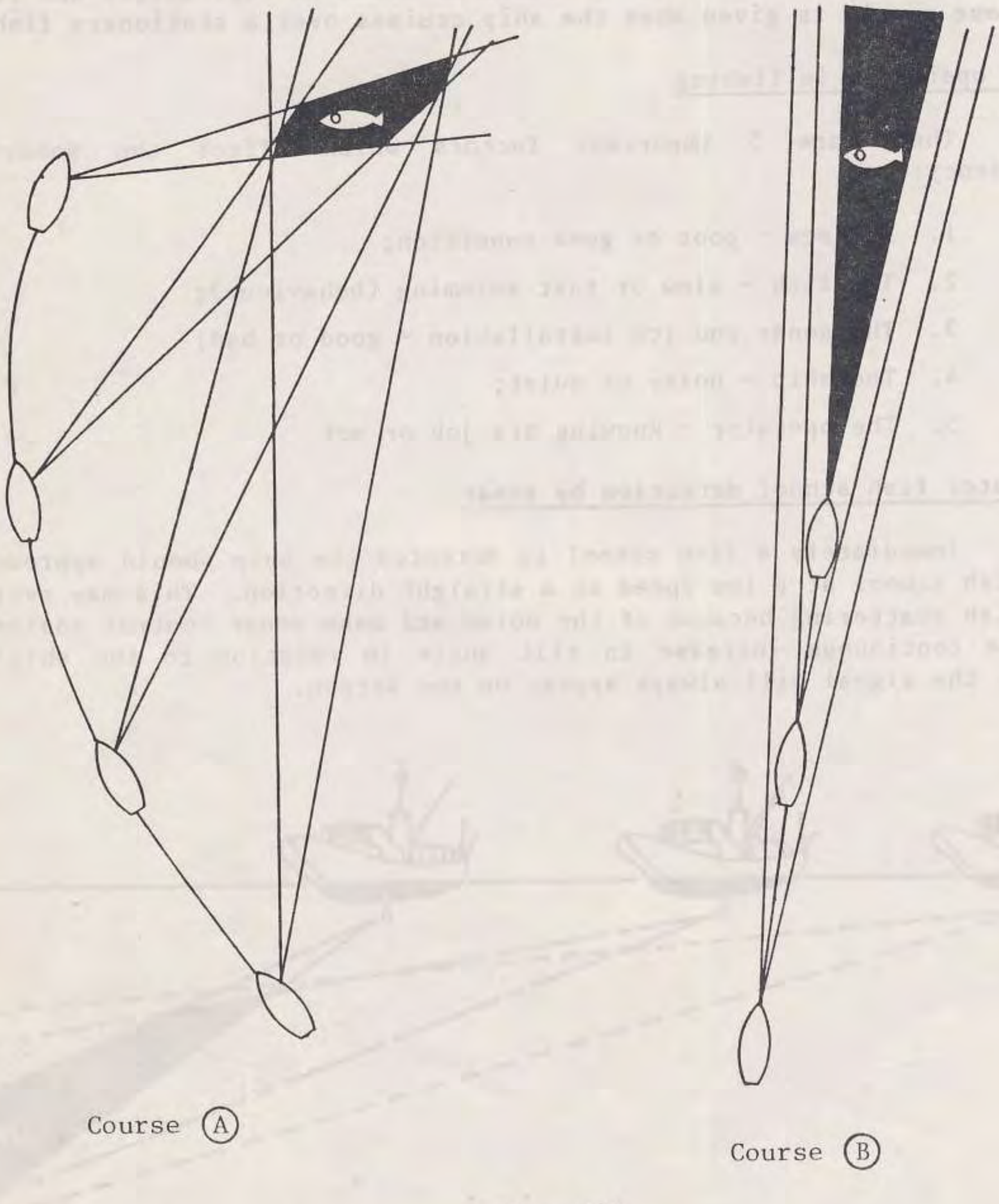
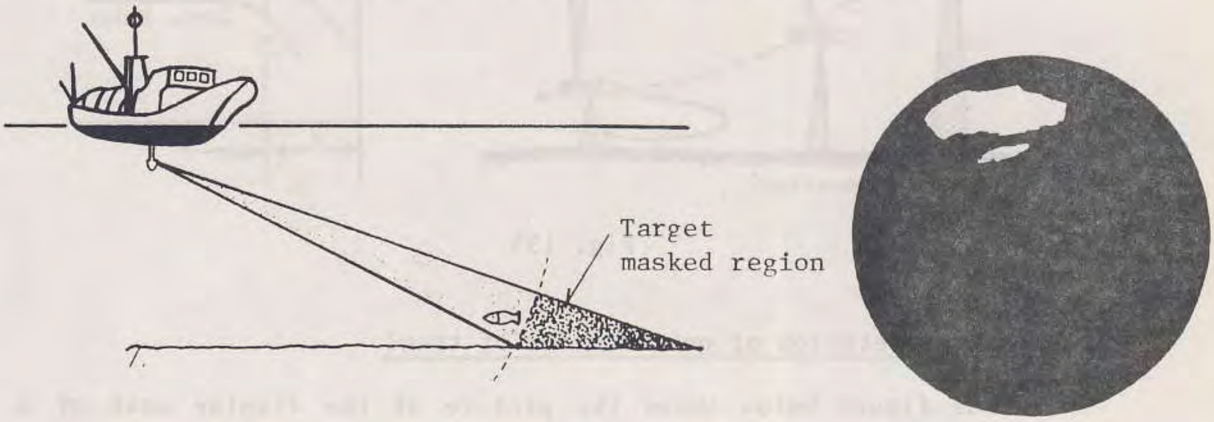


Fig. 133

Bottom fish detection by Sonar

This method of detection is similar to mid-water fish detection but there is the problem of bottom reverberation which occurs when the beam angle intersects the sea bottom. Bottom reverberation is stronger than fish echoes. If fish stay in the zone of the bottom reflecting area, their echoes will be hidden. While the ship is far from the fish and the tilt angle is rather high, one has to remember the distance and direction of the fish shown on the indicator, before it is masked by bottom reverberation during the approach.



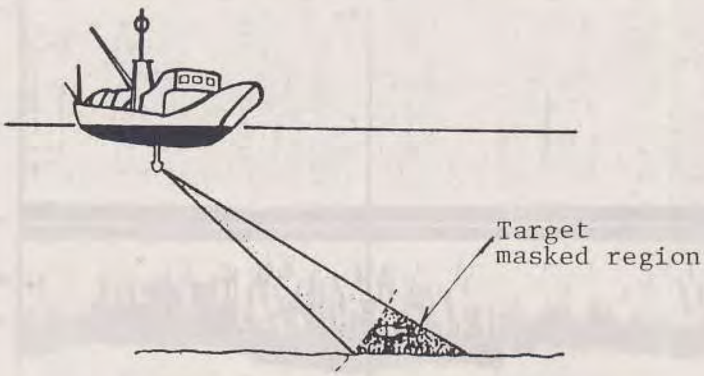


Fig. 134

Net sonde for trawling

For use in trawling, the net sonde has been developed to measure the fishing depth and the opening of the trawl as well as recording the fish which enter the trawl. The distribution in front of the trawl can also be observed with this instrument.

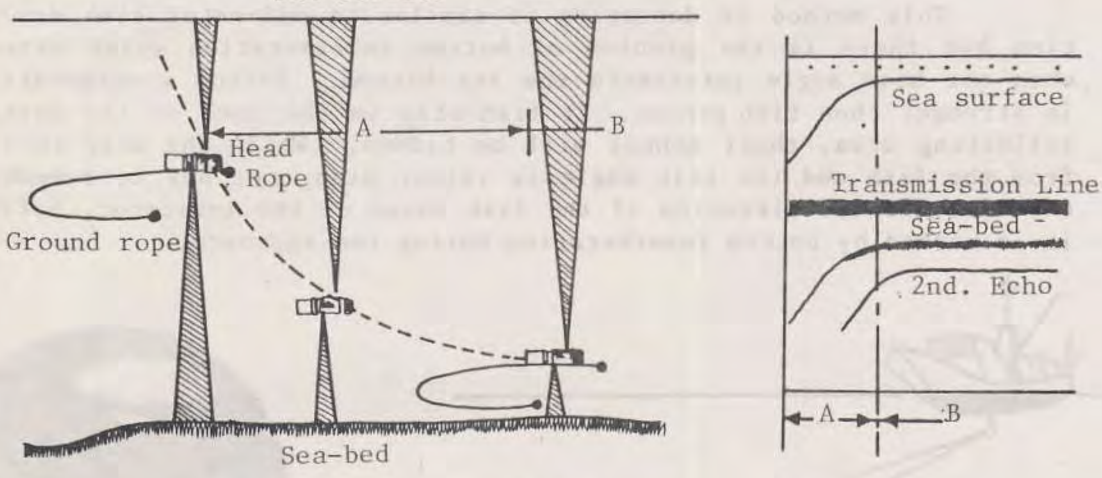


Fig. 135

Picture interpretation of net recorder of trawl

The figure below shows the picture of the display unit of a net recorder during a trawl operation.

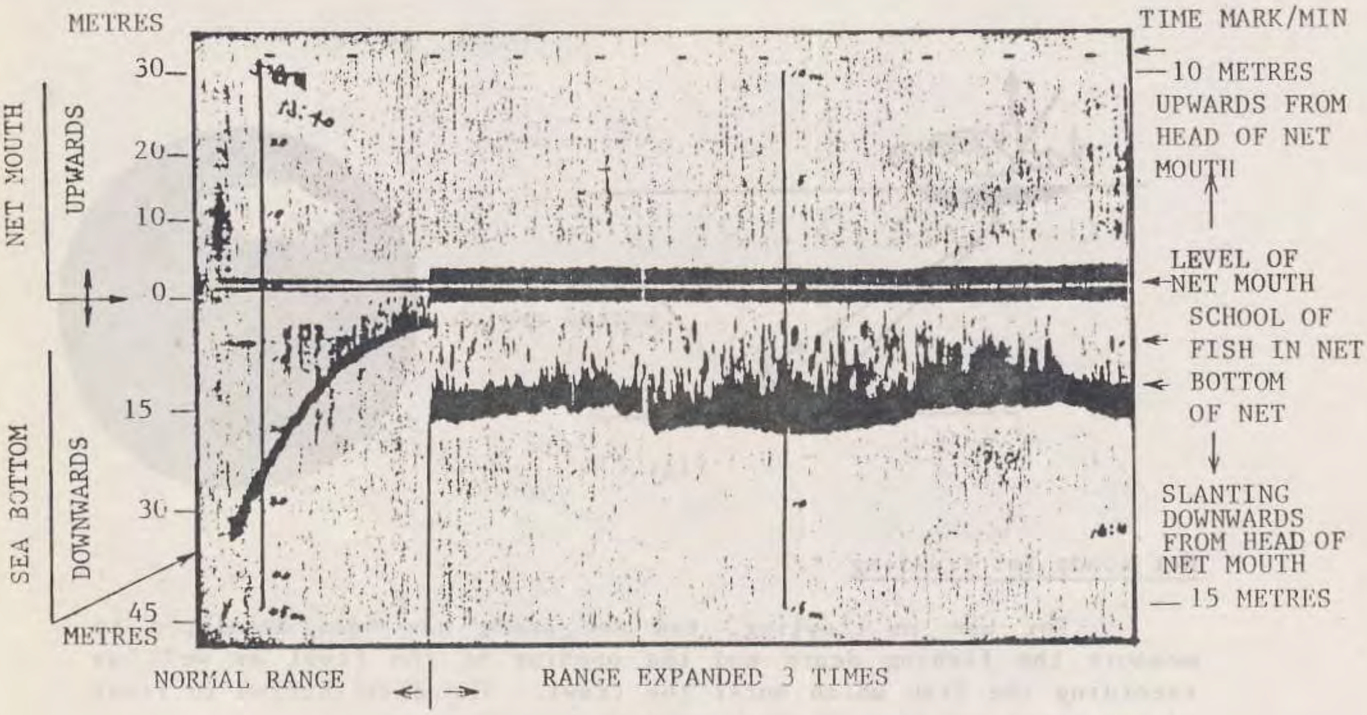


Fig. 136

Net Sonde for Purse Seine

This kind of net sonde may be used in conjunction with an echo sounder. usually the transmitter is installed on the bottom of the middle length of the net (when there is only one transmitter). The position of the transmitter denotes the location of the net bottom. The purse seine can adjust the speed of net hauling to control the depth of the net bottom by observing the position of the transmitter on the metre indicator or as shown on the display unit of the echo sounder as in the figure below.

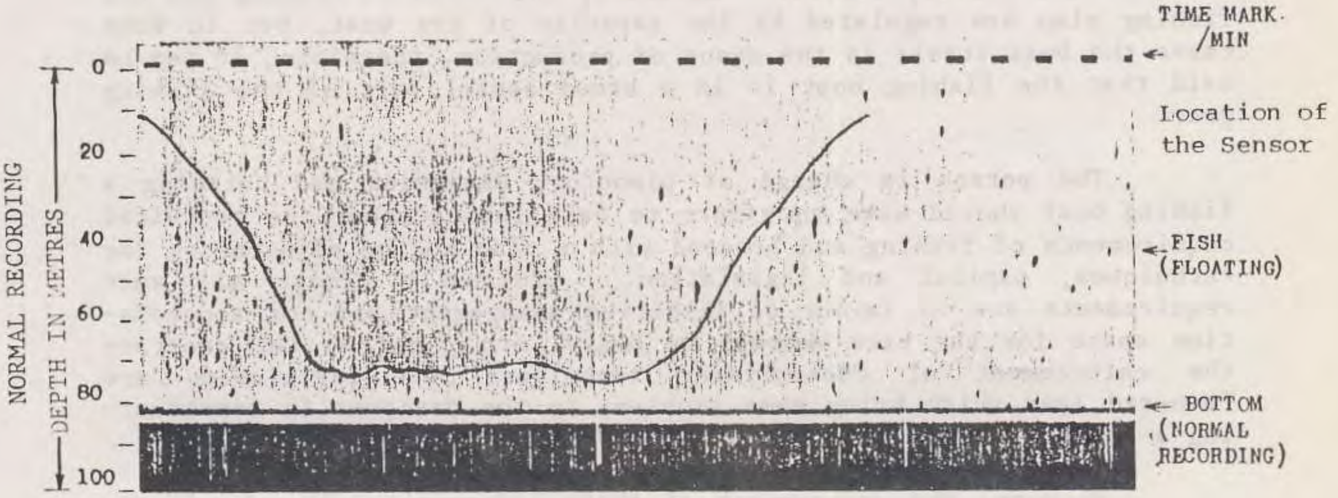


Fig. 137

VI. FISHING BOATS

1. INTRODUCTION

There are many kinds of fishing boats, i.e. from big fishing boats such as the mother boat of a whale fishery to very small boats such as coastal non-engined boats which are operated by only one fisherman. Various kinds of fishing boats can be found in the world but, every kind, even small fishing boats, are used for a particular type of fishing, so the capacity of the boat depends upon the kind and scale of the fishery itself. Sometimes, the scale of fishing and the fishing plan are regulated by the capacity of the boat, but in both cases the boat itself is the means of production, therefore, it can be said that the fishing boat is in a broad sense, part of the fishing gear.

The person in charge of planning, designing and building a fishing boat should make an effort to take into account the technical requirements of fishing and proceed with a plan making adjustments for techniques, capital and legislation. Ordinarily almost all such requirements are in favour of fisheries management and the accomodation space for the crew members on board, etc., and on the contrary the enforcement of enterprising techniques and legislation are favoured less which bring some problems to the designer in constructing a fishing boat.

However, the arrangement of these informative elements is the key point of fishery management and for future application, careful consideration of this is indispensable.

It needs to be emphasized that the fishing boat is one of the means of fulfilling the fishing itself, therefore, the boat should be selected and constructed to meet the fishing objectives.

Unnecessary luxury articles and useless instruments should be excluded from the point of view of the essential objectives of fishing.

Recently the development of modern fishing boats has progressed remarkably not only in hull and engine construction but also in the preservation of the catch facilities, communication means, navigation instruments, fishing apparatus, etc. Consequently, ship builders are quite naturally being expected to have a full knowledge of all parts of a fishing boat when new boats are planned to be built.

Throughout the world various different types of fisheries are conducted and their future development presents many difficulties, since fishing boats are indispensable to fisheries so the technical development of fishing boats is essential to fisheries expansion.

Actually, the fishing boat is the most valuable item of fishing gear, therefore the vigorous attempts at improvement and investigation of boat efficiency are very important to fisheries management as well as to shipbuilding.

The Definition of a fishing boat

In simple terms, a fishing boat is a boat engaging in fisheries. It can be engaged in the activity of catching marine or inland fishery products, aquaculture management or such activities as investigation, guidance, training and inspection.

The law of fishing boats (e.g. in Japan) could be defined as follows:

1) Those boats which mainly engage in fisheries such as trawl boats, whale catchers, tuna longliners, bonito angling boats, danish seiners, etc.

2) Those boats which have special facilities such as those for the preservation of catch or processing like the mother boats of whale fishery, Northern Pacific salmon fishery, etc.

3) Those boats which mainly carry some of the catch from fishing ground to port. There are sometimes subordinate carrier boats with purse seine fishing when it is operated on a big-scale.

4) Those boats which mainly engage in, surveys, research, guidance, training or in inspection activities having fishing facilities. These boats mainly belong to fishery governments, fishery research institutes, fishery schools and fishermen's cooperative associations.

Kinds of main engine

Steam engines, diesel engines, semi-diesel engines, gasoline engines are used in fishing boats. Among them all diesel engines are the most popular.

2. COMMON AND TECHNICAL TERMS FOR VARIOUS PARTS OF A FISHING BOAT

A ship can float, trawl from A. to B., carry men and materials. The dictionary says that a ship is "a large vessel for use on water ....", and that is precisely what it is. A vessel is a container and a ship is nothing more than a container which moves about on the water, but the dictionary specifies "a large vessel".

A boat is not a ship. The difference between a boat and a ship is quite vague, but as a rule of thumb you may say that a boat can normally be hoisted into a ship, whereas a ship is too large to be hoisted into another ship. There is one exception to this rule, submarines are called boats, although they are major vessels.

In general everybody knows what a boat is, but if you want to know in more detail you have to study common and technical terms relating to the various parts of the boat.

Roughly speaking the main body of a boat can be divided into three parts, fore part, mid-ship part and after part and can be divided bilaterally by a center line to the port side which is on the left and starboard side which is on the right when you stand at mid-ship and face the fore part or stem. Direction on a boat is divided into 8 sections on the horizontal or on deck, foreward is ahead, behind is astern, perpendicular from both sides are abeam, between ahead to abeam on the port side is the port bow, on starboard side is the starboard bow, the sections between astern to abeam on both sides are port quarter and starboard quarter.

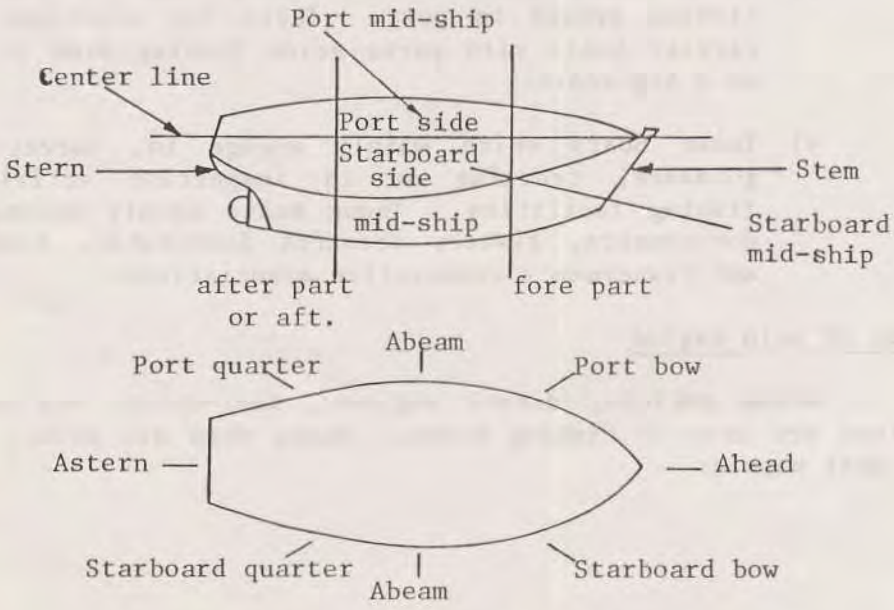


Fig. 138 Section and Direction of boat

The actual shell of the boat is called the "hull" the "stem" is the sharp edge for cutting through the water and the "stern" is the other end which does not normally have to cut through the water. The common terms for various parts of the hull and compartments are as follows:

"Beam" -the width of a ship.

"Decks" -the flat or horizontal surfaces upon which you walk.

"Ship sides" -up and down or vertical surfaces of the hull.

"Bow" -the ship sides which curve inward toward the stem.

"Quarter" -the ship sides which curve toward the stern.

"Waterline" -the line between the wet and dry part on the ship sides.

"Free board" -the distance from the waterline to the deck.

"Draught" -the distance from the waterline to the deepest part of the bottom.

"Compartments" -the rooms in the hull.

"Bulkhead" -the wall which divides the hull into compartments.

"Transverse Bulkhead" -the wall across the ship.

"Longitudinal Bulkhead" -the wall along the centerline.

If a hole was made in a boat's bottom and there were no compartments, flooding would soon spread throughout the hull and the ship would sink quickly. However, if the ship has compartments, the flooding can only spread as far as the bulkhead of the hold compartment and the vessel does not sink. Theoretically, if a ship has enough compartments, it should be unsinkable.

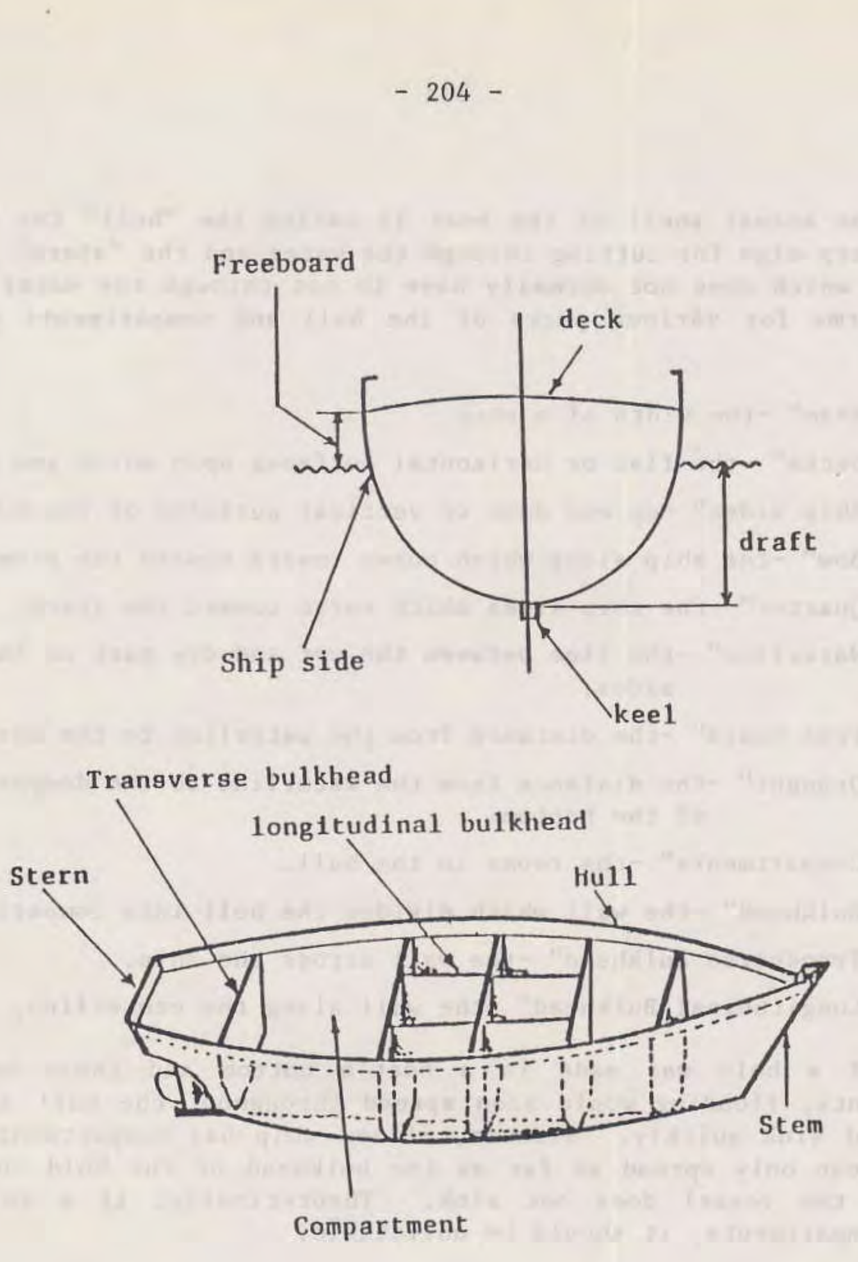
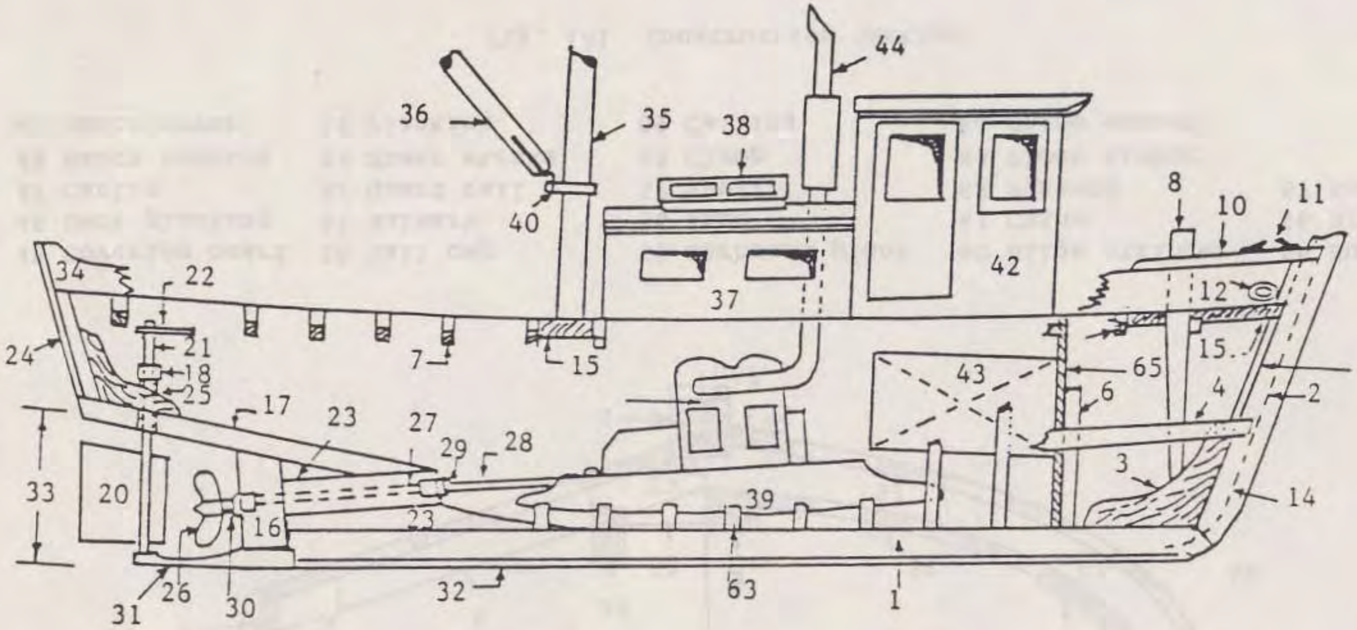


Fig. 139 General boat structure

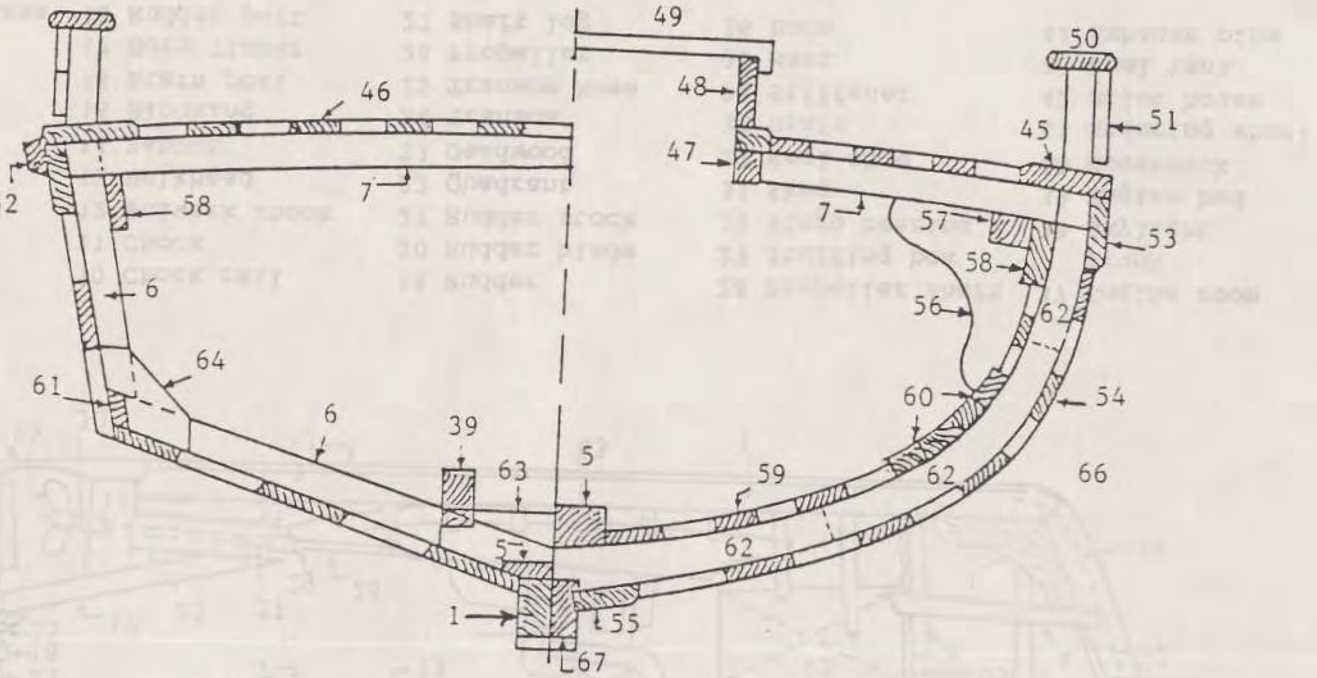
3. CONSTRUCTION DRAWING

Usually a construction drawing has to include three views; profile plan and body plan view, to show the general arrangements of the vessel and deck and under deck layout to help in outlining the requirements for the construction work. These drawings are prepared to show the overall construction details of the hull. The scantling dimensions and fastenings required are clearly detailed in the contruction drawing.



1 Keel
2 Stem
3 Stem knee
4 Breast hook
5 Keelson
6 Frame
7 Deck beam
8 Bitt
9 Anchor windlass
10 Chock rail
11 Chock
12 Bulwark chock
13 Bulkhead
14 Rabbet
15 Blocking
16 Stern post
17 Horn Timber
18 Rudder port
19 Rudder
20 Rudder blade
21 Rudder stock
22 Quadrant
23 Deadwood
24 Transom
25 Transom knee
26 Propeller
27 Shaft log
28 Propeller shaft
29 Stuffing box
30 Stern bearing
31 Skeg
32 Keel shoe
33 Draft
34 Stiffener
35 Mast
36 Boom
37 Engine room trunk
38 Skylight
39 Engine bed
40 Gooseneck
41 Steering wheel
42 Pilot house
43 Fuel tank
44 Exhaust pipe

Fig. 140 Construction Profile



45 Covering board	50 Rail cap	55 Garboard plank	60 Bilge stringer	65 Bulkhead
46 Deck planking	51 Bulwark	56 Knee	61 Chine	66 Bilge keel
47 Carlin	52 Guard rail	57 Shelf	62 Futtock	67 Keel shoe
48 Hatch coaming	53 Sheer strake	58 Clamp	63 Floor timber	
49 Hatch cover	54 Planking	59 Ceiling	64 Chine gusset	

Fig. 141 Construction section

4. FISHING BOAT CHARACTERISTICS

The necessary characteristics of fishing boats are almost the same as those of ordinary passenger boats or cargo boats. A fishing boat should have a specific function different from other boats such as those related to processing and preservation facilities, etc.

Accordingly, fishing boats have the following characteristics: speed, steering, durability, navigation range, construction, engine, preservation facility, fishing machinery, fishing facilities, etc.

1) Speed

A fishing boat is required to be able to reach a high speed e.g. when searching and tracing a fish school, to transport the catch keeping it fresh over a certain period of time. A 700-ton whale catcher has a maximum speed of 18 miles per hour and a 300-ton tuna longliner has a maximum speed of 12 miles per hour and a 100-ton trawler of 11 miles per hour.

Care should be taken because a fishing boat may not be efficient if it has a much too high powered engine for its requirements.

On the contrary fishing boats sometimes require dead slow speed in fishing operations such as tuna longline fishing and this must also be viewed as a fishing boat characteristic.

2) Manoeuvring and engine

The fishing boat is required to have good manoeuvring ability especially when tracing and detecting fish schools, operating fishing gear, etc. To facilitate fishing operations the rudder should work efficiently, a turning circle should be small, starting, stopping, moving ahead or astern should be simple, swift and sure, the rotation of the engine should be smooth at all speeds.

For instance, bonito fishing boats must move at the same speed as the bonito school when angling and changing of the engine's speed should be smooth when the tuna longline (about 15 kilometres) is taken up while proceeding at slow speed ahead otherwise fishing efficiency may be affected considerably. For this reason, some of the big fishing boats have converted recently to variable pitch propellers.

3) Resistance

A fishing boat is required to be fully resistant against the strong forces of the wind, waves, etc. For this purpose, the fishing boats should be constructed with good stability, full buoyancy and limited rolling and pitching.

4) Navigational distance

The distance only depends upon the environmental condition of a fishery such as the movement of the fish schools, size and location of fishing ground, etc. Therefore navigational distance is important. Tuna longline fishing boats, for instance, must navigate long distances, for example, from the Pacific to the Atlantic via the Indian Ocean without any stops.

5) Construction

The construction of a fishing boat should be strong because it may encounter severe sea conditions, and must endure the vibration caused by engine operation.

6) Propulsion of engine

Preferably the engine is small in size although it must be powerful enough. Usually diesel engines are employed on fishing boats because they can be smaller in size than a steam engine. Both high speed and low speed engines are suitable for fishing boats.

Steam engines can stand severe running and are durable but are rather large in size. On the contrary high speed engines such as automobile engines have recently started to be used with the benefits of simplifying handling.

7) Preservation and processing facilities

Fishing boats ordinarily have to carry the catch back to the port. In order to keep the fish fresh, the ice keeping room, cold room or freezing room must be well isolated from the outside. Processing machines for example for canning and fish meal plants are also included among the equipment when necessary.

8) Fishing machinery

Naturally a fishing boat should be equipped with fishing apparatus, such as angling machine, line hauler, net hauler, trawl winch, purse winch, power block. There are so many different types of equipment but the choice depends upon the target species.

5. BASIC CALCULATIONS FOR DECIDING THE ELEMENTS OF A BOAT

1) Speed of boat

L.B.D., coefficient of form, displacement, body shape under draft line, trim, selection of the engine, etc. are elements which affect the speed of the boat. Ordinarily a ship builder can estimate navigational speed and maximum speed approximately from past experience. The navigational speed uses three-quarters of B.H.P.

The necessary horse power is decided according to the size of boat and speed of boat. One simple way of calculation is by application of the Admiralty coefficients:

$$C = \frac{\Delta^{\frac{2}{3}} V^3}{IHP}$$

2) Fuel and lubricating oil

Normal consumption of fuel oil is based on the following factors:

Necessary consumption of oil

= Rate of fuel consumption x Number of Horse power x Time consumable

Rate of fuel consumption

Diesel engine 0.22 (Kg/HP/hr)

Number of horse power to maximum continuous horse power for navigation (to & from): 70 to 80 per cent for fishing: 50 to 80 per cent (depends upon operative condition) Time consumable.

Calculation summing up the time required going to and returning from the fishing grounds, plus operation in the fishing ground, etc.

Weight of oil

Heavy oil	920 kg/m^3
Light oil	840 kg/m^3
Lubricating oil	900 kg/m^3
Coal	780 kg/m^3

Necessary quantity of lubricating oil

Diesel engine 0.03 x fuel oil

3) Fresh water, provisions and hand luggage

Water:

20 litres/day/person for sea fishery

20-30 litres/day/person for off shore fishery

30 litres/day/person for coastal fishery

Provisions: 1.7-2.0 kg/person/day

Hand luggage is 100 kg/person/average trip

4) Ice

The quantity of ice is less than 70 per cent of expected amount of catch.

Weight of ice	136 kg (0.3 m x 0.57 m x 1.15 m)
Weight of flake ice	625 kg/m^3

5) Weight of catch

Unit weight in fish storage:

Fish	835 kg/m^3
Fish with flake ice	760 kg/m^3
Freezing	665 kg/m^3
Fish box	33 kg/mid-size box 67 kg/large-size box
Freezing box	28 kg/mid-size box 58 kg/large-size box

6) <u>Load condition</u>

Table 9. Load Condition of Fishing Boats.

	Light load	Departure	Leaving fishing ground	Arrival
Hand luggage	100%	100	100	100
Ice	-	100	100	100
Live bait	-	-	100	100
Fish store	-	0	100	100
Fuel tank	-			
Main	-	100	40	10
Subordinate	-	100	100	50
Lubrication tank	-	100	70	50
Water tank	-	100	40	10
Ready cold water	-	0	100	100
Provisions	-	100	40	10
Fishing gear	-	100	100	100

6. FISHING BOAT ENGINES

The main kind of fishing boat engine is the diesel engine. Fifty years have passed since diesel engines began to be employed on fishing boats.

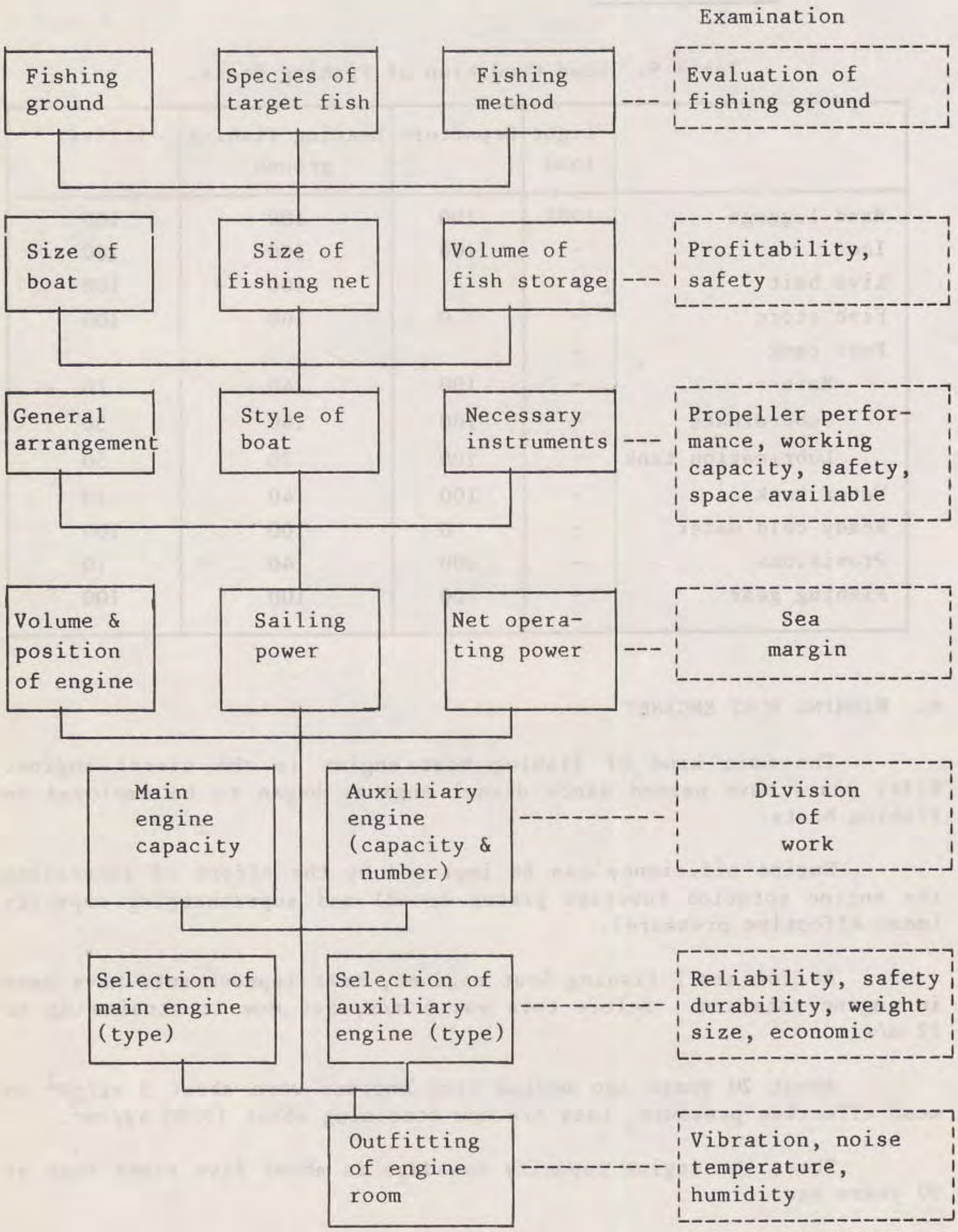
Engine efficiency can be improved by the effort of increasing the engine rotation (average piston speed) and supercharging capacity (mean effective pressure).

As for small fishing boat engines, most improvements have been in engine rotation. Before this was 6 m/s, but now it attains up to 12 m/s.

About 20 years ago medium size engines were about 5 kg/cm^2 in mean effective pressure, they are now attaining about 15-20 kg/cm^2.

Thus, the engine capacity nowadays is about five times that of 20 years ago.

Decision Process When Selecting an Engine



7. PRINCIPAL FISHING BOAT DIMENSIONS

The principal dimensions are length, breadth and depth of boat. These are the most important elements in deciding the boat's capacity, so these dimensions L, B, D should be carefully examined before building the boat.

Length

a) Length over all, LOA. or Loa.

This is the horizontal distance from stem end to stern end.

b) Length between perpendicular, Lpp or L

This is the horizontal distance from fore perpendicular (FP) to after perpendicular (AP) at the designed load waterline level, LWL. The center of Lpp of the body is called mid-ship.

Breadth (Extreme breadth) B

This is the horizontal distance of breadth at the widest part of the boat.

Depth, D

This is the vertical distance from the base line to freeboard deck at the mid-ship section.

Draft, (Draught, d)

Moulded draught (d) is vertical distance between load waterline and the base line.

Freeboard

Freeboard is the vertical distance between freeboard deck line and full load waterline. That is to say the freeboard could be obtained by subtracting draught (d) from depth (D). Big freeboard means big reserve buoyancy, which means increased safety for the boat.

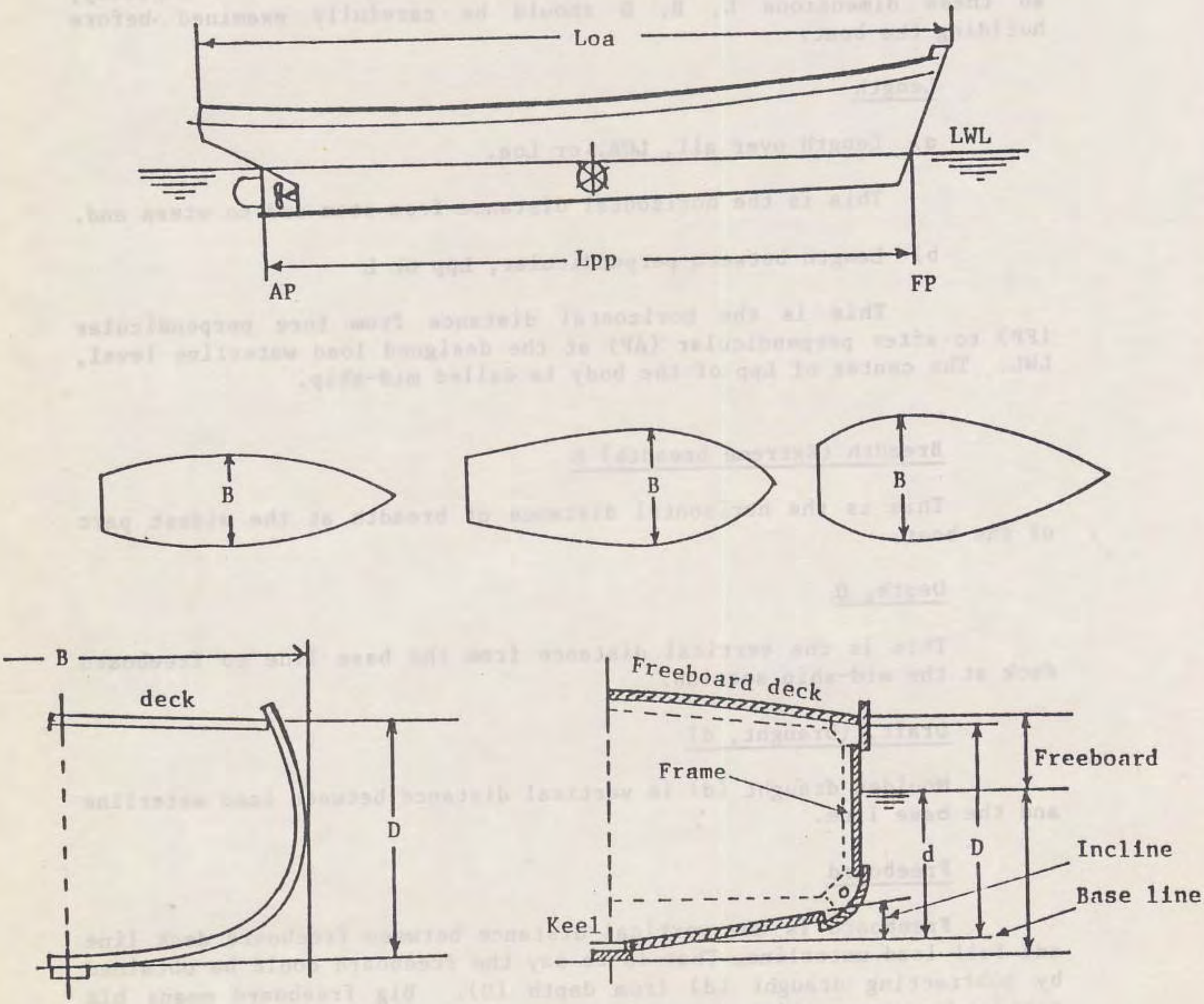
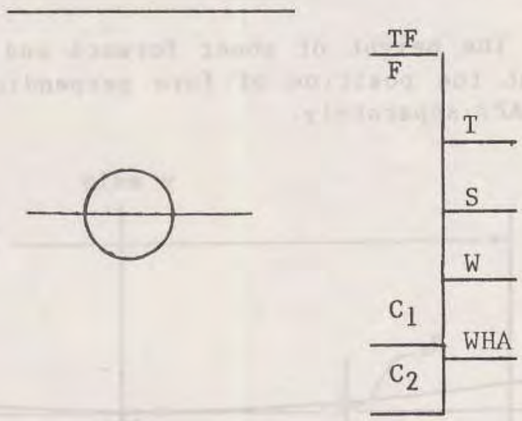


Fig. 142 Principal boat dimensions

The indications shown as an example would be found marked on the side of the boat's body.

Freeboard deck line

Full load waterline

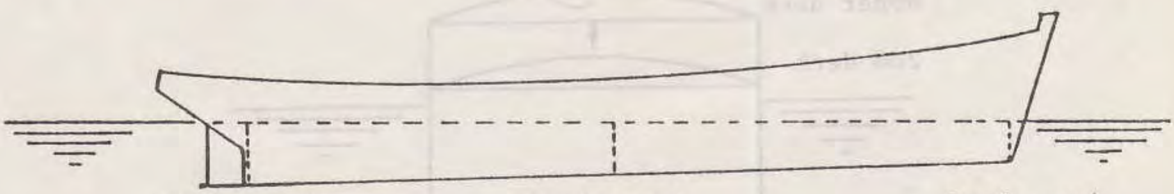


TF	:	Tropical fresh water full load waterline.
F	:	Summer fresh water full load waterline.
T	:	Tropical full load waterline.
S	:	Summer full load waterline.
W	:	Winter full load waterline.
WNA	:	Winter North Atlantic full load waterline.
C_1	:	Passenger boat full load waterline.
C_2	:	Passenger and cargo full load waterline.

8. VESSEL TERMINOLOGY

Trim

The difference between draft of bow and draft of stern is called trim. Trim by stern means the boat has a deeper draft in the stern than the bow.

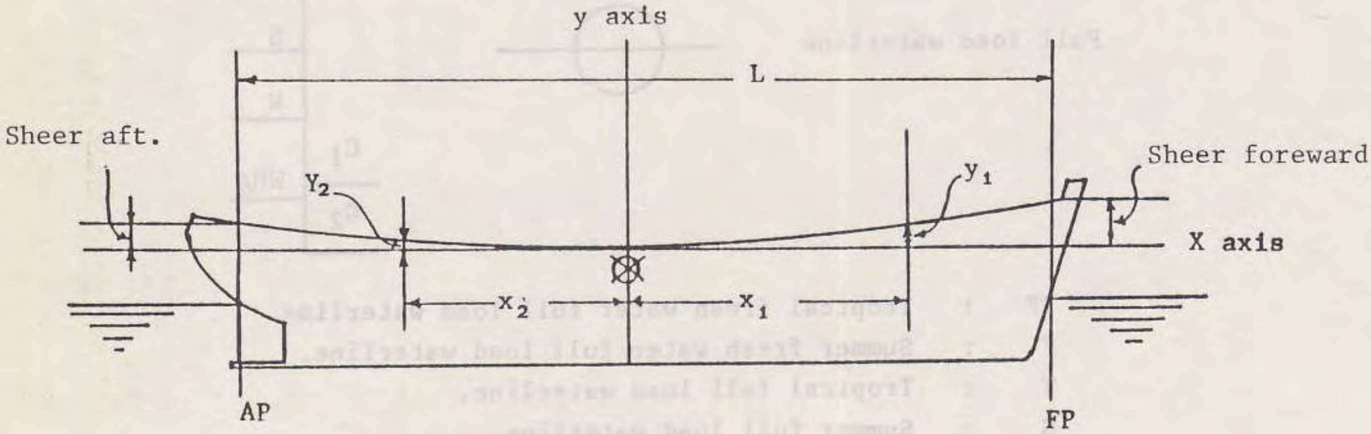


Draft mark (aft. or stern, after) — Draft mark (mid-ship) — Draft mark (bow or stem, foreward, fore)

Sheer

The word "sheer" in boat terminology means bend of freeboard deck sideline.

The height of sheer forward and that of sheer aft. are calculated at the position of fore perpendicular (FP) and after perpendicular (AP) separately.



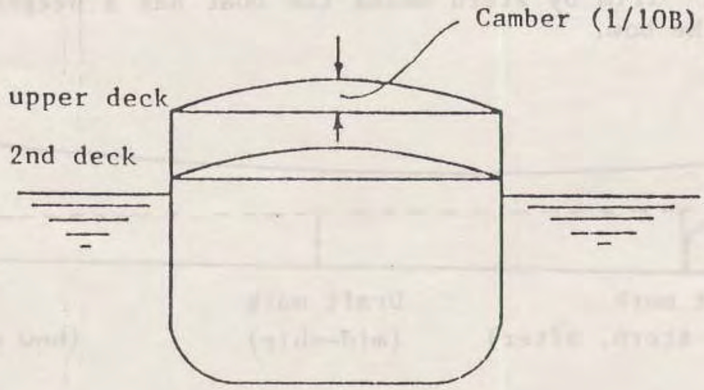
$$Y_1 = (6.664L + 203.2) \times \left(\frac{x_1}{L}\right)^2 \text{ (cm)}$$

$$Y_2 = (3.332L + 101.6) \times \left(\frac{x_2}{L}\right)^2 \text{ (cm)}$$

Here, L is length of boat.

Camber

The camber is the curvature height of the deck beam at centerline of boat body.



4) Coefficient

Following the symbols shown here are several coefficients expressing the condition of boat shape denoted in the succeeding formulae.

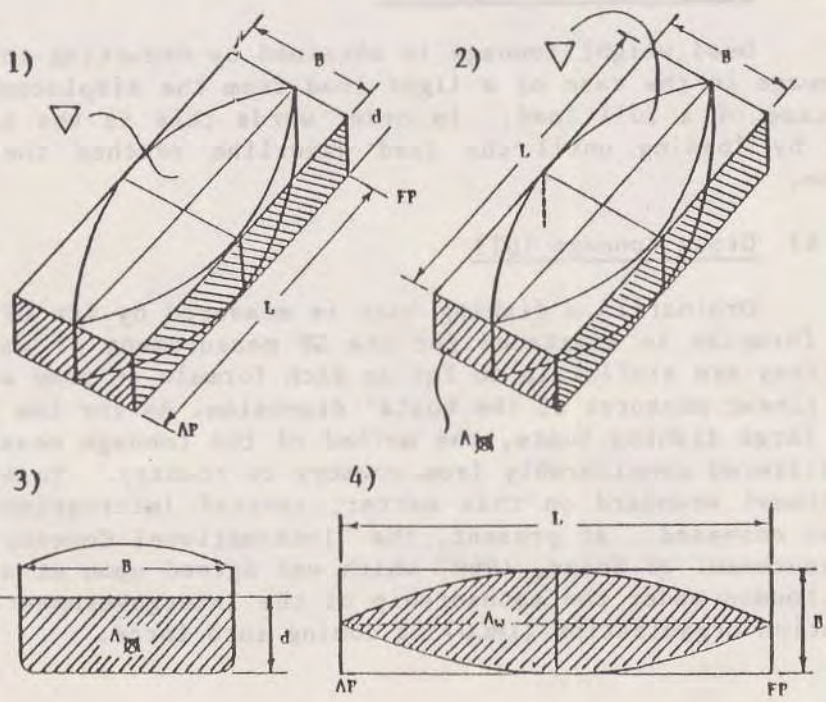
- L : length of boat
- B : breadth of boat
- d : draft
- A_w : horizontal area of boat at waterline
- $A_{\otimes}$: section area of boat under waterline at mid-ship
- ∇ : displacement (Volume)

(1) Block coefficient, C_b $\quad C_b = \dfrac{\nabla}{L\ B\ D}$

(2) Prismatic coefficient, C_p $\quad C_p = \dfrac{\nabla}{A_{\otimes}\ L} = \dfrac{Cb}{C_{\otimes}}$

(3) Mid-ship coefficient, $C_{\otimes}$ $\quad C_{\otimes} = \dfrac{A_{\otimes}}{B\ d}$

(4) Water plane coefficient, C_w $\quad C_w = \dfrac{Aw}{L\ B}$



9. MEASUREMENT OF SMALL FISHING BOAT TONNAGE

1) Net tonnage (NT)

(1) Net volume of space (m^3) is obtained by deducting the space volume of the following from the total volume of space (m^3):

Crew's room, anchoring room, chart room, balast tank, steering gear room, engine room, auxiliary engine room, store room, i.e. all the rooms above the deck.

Net tonnage = (net volume of space) x 0.353

(2) In the case of the length of boat being less than 24 metres net volume of space (m^3) is obtained by deducting 1/5 of the total volume of space.

Net tonnage = (net volume of space) x 0.353

2) Displacement tonnage (Δ)

The displacement of a boat is expressed by the weight of (unit = 1 ton) the boat and varies according to the quantity of fuel, water, crew. This is called displacement tonnage and is the weight of the boat. Ordinarily in the case of a fishing boat the displacement is bigger than the gross tonnage.

3) Dead weight tonnage (DW)

Dead weight tonnage is obtained by deducting the displacement tonnage in the case of a light load from the displacement tonnage in the case of a full load. In order words this is the total weight of load by loading until the load waterline reaches the full load waterline.

4) Gross tonnage (GT)

Ordinarily a fishing boat is measured by its GT. There are several formulae in existance for the GT measurement of small fishing boats. They are similar in so far as each formula in some way combines several linear measures of the boats' dimension. As for the GT measurement of large fishing boats, the method of the tonnage measurement has always differed considerably from country to country. To establish an international standard on this matter, several international meetings have been convened. At present, the "International Convention on Tonnage Measurement of Ships, 1969" which was agreed upon at a conference held in London under the sponsorship of the Intergovernmental Maritime Consultation Organization (IMCO) is coming into force.

(1) International formula for the GT measurement of fishing boats of more than 24 m in length.

The gross tonnage of a ship shall be determined by the following formula:

$$GT = KV$$

Here, V = Total volume of all enclosed spaces of the boat in cubic m.

$$K = 0.2 + 0.02 \log_{10} V$$

Enclosed spaces are all those spaces which are bound by the boat's hull, by fixed or portable partitions or bulkheads, by decks or coverings other than permanent or movable awnings. No break in a deck, nor any opening in the ship's hull, in a deck or in a covering of space, or in the partitions or bulkheads of a space, nor the absence of a partition or bulkhead, shall preclude a space from inclusion in the enclosed space.

(2) Current practice for GT measurement of small fishing boats.

For the measurement of GT, 100 cubic feet (or 2.83 cubic metres = 1000/353 m^3) of enclosed space is considered as 1 gross ton. Since GT is measured for the volume of all enclosed spaces above upper deck as well as under the upper deck, a formula for measurement of GT is summarized as follows:

If, a = Volume of enclosed space under upper deck, and

b = Volume of enclosed space above upper deck, then

$$GT = (a + b) \times 0.353 \quad \text{(metric system)}$$

$$\text{or } GT = (a + b) \times 1.0 \quad \text{(British system)}$$

Replies to an FAO questionnaire from Australia, Japan, Korea, New Zealand, Singapore and Taiwan clearly indicate that both (a) and (b) are measured for GT in every country.

Formula for measurement of enclosed spaces under upper deck (a)

A. Method based on cubic number

This is a method based on the cubic number of a boat, which is a product of L.B. and D. Since a boat is designed in a form which is streamline not cubic, a coefficient is multiplied by the cubic number to derive the actual volume of the hull of a boat. Thus, a formula commonly in use is:

GT of a = L x B x D x C x 0.353

coefficient G = volume of enclosed sp./L x B x D

B. Moorson Method No.2

This method is adopted only in South Viet Nam and Thailand. A particular feature of this method is then in the formula for measurement of GT, periphery (P), which is the measure around the section of hull at the mid-length, is used. The formula in use in these countries is:

$$GT = \frac{(P + B)^2}{2} \times L \times C$$

In South Viet Nam, P is directly measured, whereas in Thailand P is indirectly derived from the following formula:

$$P = (B + 2D) \times C_b$$

where, C_b (Block coeff.) = 0.85 for displacement hull; 0.90 for flat boat hull.

In both countries, the metric system is used for the measurement of dimension, and C is defined as follows:

	Wooden boat	Steel boat
South Viet Nam	0.060	0.064
Thailand	0.058	0.070

The value C_b is commonly fixed in Thailand and is rather large. This does not seem realistic if the formula is for a variety of boats. Therefore, it is advisable to avoid using C_b and replace it by a general coefficient such as K instead.

C. Thames method

This method is used in Hong Kong and only L and B are used as parameters in the formula as follows:

$$GT = \frac{(L-B) \times B \times B/2}{94}$$

In Hong Kong the British system of measurements is used. Enclosed space above upper deck (b).

There are several countries which do not have any provision for the measurement of enclosed space above upper deck. This matter has to be agreed among the countries concerned in order to keep an international comparability for GT. Although it seems more reasonable to include enclosed space above upper deck, which space is to be included and which space is not to be included needs to clarified.

For example, at present Japan excludes from GT measurement the following enclosed space above upper deck:

a. Space used to accommodate steering equipment, mooring equipment and anchor winch.

b. Engine casing, wheel house and galley.

c. Space used for ventilation and for skylight and toilet.

d. Companion ways and small hatch ways.

It is likely that at present the same exemptions are not always made in each country.

(3) Standardization of the measurement in the case of small boats below 24 m length.

Definitions of L, B and D.

Even if the same formula is used by all countries, different GT will be obtained for the same boat if the definition of L, and B and D differs among the countries. IMCO therefore considers that this is the right time to make the best use of the definitions given in the paper for solving the problems before us.

The following specific dimensions were suggested by FAO for the formula:

Length Loa; Overall length: horizontal distance between extreme ends of the boat;

Breadth Boa; Overall breadth: extreme width of the boat measured to outer surface of the hull;

Depth D min; Minimum depth: Minimum vertical distance at side measured from the top of deck beam to the keel line plus the minimum thickness of decking.

Coefficient C

Once the formula and the definitions of L, B, and D are decided, a suitable C has to be sought in each country by means of actual measurement of GT for a reasonable number of fishing boats since the shape of fishing boats differs to some extent from country to country.

Besides this, the shape of fishing boats differs according to the type of fishing gear employed. Somewhat different coefficients may therefore have to be sought even in the same country.

For the determination of Coefficient C, how to measure actual volume of enclosed space, how many boats should be chosen for such a measurement, how to derive C based on such a measurement, etc., have to be worked out in consultation with naval architects.

Table 10. Coefficient K in International Formula of GT Measurement

V	K	V	K	V	K	V	K
10	0.2200	45,000	0.2931	330,000	0.3104	670,000	0.3165
20	0.2260	50,000	0.2940	340,000	0.3106	680,000	0.3166
30	0.2295	55,000	0.2948	350,000	0.3109	690,000	0.3168
40	0.2320	60,000	0.2956	360,000	0.3111	700,000	0.3169
50	0.2340	65,000	0.2963	370,000	0.3114	710,000	0.3170
60	0.2356	70,000	0.2969	380,000	0.3116	720,000	0.3171
70	0.2369	75,000	0.2975	390,000	0.3118	730,000	0.3173
80	0.2381	80,000	0.2981	400,000	0.3120	740,000	0.3174
90	0.2391	85,000	0.2986	410,000	0.3123	750,000	0.3175
100	0.2400	90,000	0.2991	420,000	0.3125	760,000	0.3176
200	0.2460	95,000	0.2996	430,000	0.3127	770,000	0.3177
300	0.2495	100,000	0.3000	440,000	0.3129	780,000	0.3178
400	0.2520	110,000	0.3008	450,000	0.3131	790,000	0.3180
500	0.2540	120,000	0.3016	460,000	0.3133	800,000	0.3181
600	0.2556	130,000	0.3023	470,000	0.3134	810,000	0.3182
700	0.2569	140,000	0.3029	480,000	0.3136	820,000	0.3182
800	0.2581	150,000	0.3035	490,000	0.3138	830,000	0.3183
900	0.2591	160,000	0.3041	500,000	0.3140	840,000	0.3184
1,000	0.2600	170,000	0.3046	510,000	0.3142	850,000	0.3185
2,000	0.2660	180,000	0.3051	520,000	0.3143	860,000	0.3168
3,000	0.2695	190,000	0.3056	530,000	0.3145	870,000	0.3187
4,000	0.2720	200,000	0.3060	540,000	0.3146	880,000	0.3188
5,000	0.2740	210,000	0.3064	550,000	0.3148	890,000	0.3189
6,000	0.2756	220,000	0.3068	560,000	0.3150	900,000	0.3190
7,000	0.2769	230,000	0.3072	570,000	0.3151	910,000	0.3191
8,000	0.2781	240,000	0.3076	580,000	0.3153	920,000	0.3192
9,000	0.2791	250,000	0.3080	590,000	0.3154	930,000	0.3193
10,000	0.2800	260,000	0.3083	600,000	0.3156	940,000	0.3194
15,000	0.2835	270,000	0.3086	610,000	0.3157	950,000	0.3195
20,000	0.2860	280,000	0.3089	620,000	0.3158	960,000	0.3196
25,000	0.2880	290,000	0.3092	630,000	0.3160	970,000	0.3197
30,000	0.2895	300,000	0.3095	640,000	0.3161	980,000	0.3198
35,000	0.2909	310,000	0.3098	650,000	0.3163	990,000	0.3199
40,000	0.2920	320,000	0.3101	660,000	0.3164	1000,000	0.3200

V = Volume in cubic metres. Coefficients K at intermediate values of V shall be obtained by linear interpolation.
(extract from: N. Fujinami *et al.* Measurement of gross tonnage of small fishing vessels, IPFC/IOFC/ST 26, Nov. 1971)

Test calculation of GT by different countries

A test calculation was made using four different formula, namely those of, Japan (based on cubic numbers), Hong Kong, South Viet Nam and Thailand. Dimensions of a Japanese wooden purse seiner TOSHIN MARU No. 1 as described were used:

	According to Japanese practice	According to Vietnamese practice	According to Thai practice
L	17.70 m	17.50 m	19.80 m
B	4.40 m	4.40 m	4.52 m
D	2.04 m	2.04 m	2.13 m
P	8.30 m	8.30 m	8.30 m
C_b	0.56	-	0.85 m
	(loaded condition)		

(i) Japanese Formula

$$GT = \frac{L \times B \times D \times 0.56}{2.83} = 30.90$$

(ii) South Vietnamese Formula

$$GT = \left(\frac{P + B}{2}\right)^2 \times L \times 0.06 = 43.00$$

(iii) Thai Formula

$$P = (B + 2D)\, C_b = 7.50 \quad \text{Here, } C_b = 0.85$$

$$GT = \left(\frac{P + B}{2}\right)^2 \times 2 \times 0.058 = 41.50$$

(iv) Hong Kong Formula

$$GT = \frac{(L - B) \times B \times \frac{1}{2}B}{94} \text{ (in ft)} = 48.2$$

(taken from: N. Fujinami *et al.* Measurement of gross tonnage of small fishing vessels, IPFC/IOFC/ST 26, Nov. 1971)

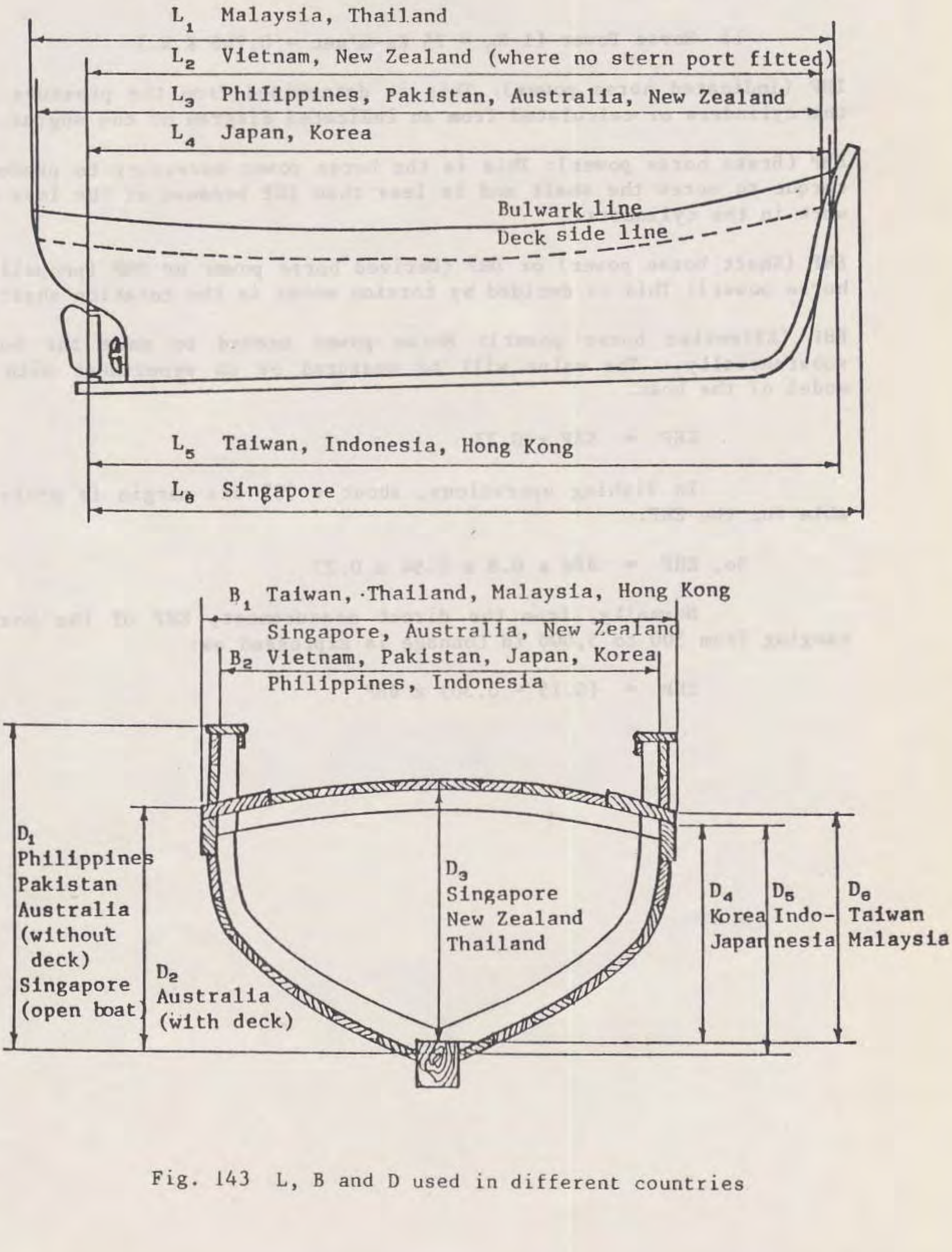


Fig. 143 L, B and D used in different countries

10. SPEED OF BOAT

1) Horse Power (1 H_p = 75 Kg-m/sec = 0.746 K.W.)

IHP (Indicated horse power): This is determined from the pressure in the cylinders or calculated from an indicated diagram of the engine.

BHP (Brake horse power): This is the horse power necessary to produce torque to screw the shaft and is less than IHP because of the loss of work in the cylinders.

SHP (Shaft horse power) or DHP (Derived horse power or PHP (propeller horse power): This is decided by torsion meter in the rotation shaft.

EHP (Effective horse power): Horse power needed to move the boat substantially. The value will be measured by an experiment with a model of the boat.

$$EHP = SHP \times 0.23$$

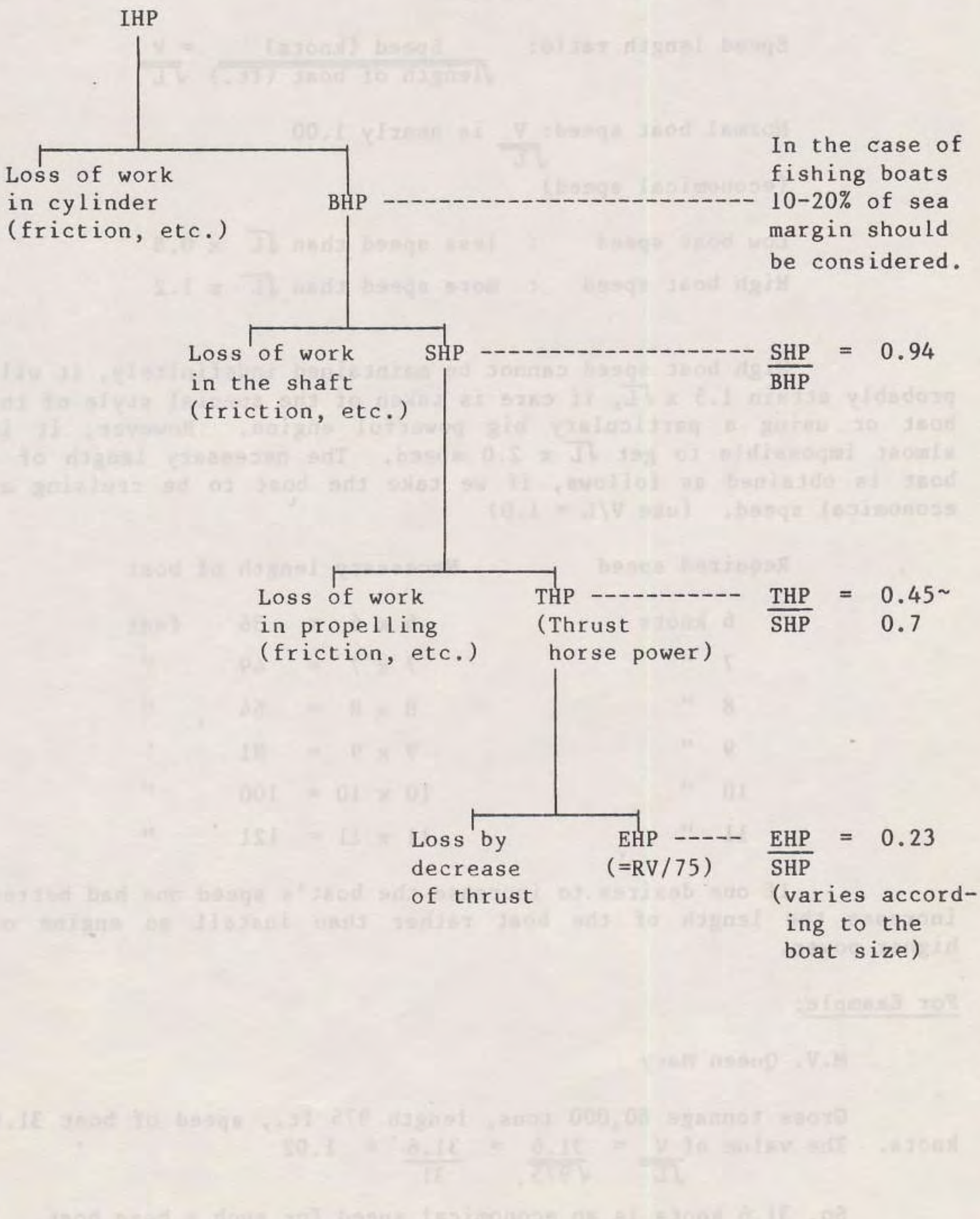
In fishing operations, about a 20% sea margin is preferable for the EHP.

$$\text{So, } EHP = BPH \times 0.8 \times 0.94 \times 0.23$$

Normally, from the direct measurement, EHP of the boats ranging from 300 to 5,000 in tonnage is expressed as:

$$EHP = (0.15 - 0.30) \times BHP$$

Diagram


IHP
Loss of work in cylinder (friction, etc.)
BHP
In the case of fishing boats 10-20% of sea margin should be considered.
Loss of work in the shaft (friction, etc.)
SHP
SHP/BHP = 0.94
Loss of work in propelling (friction, etc.)
THP (Thrust horse power)
THP/SHP = 0.45~0.7
Loss by decrease of thrust
EHP (=RV/75)
EHP/SHP = 0.23 (varies according to the boat size)

2) Relation between speed and length of boat

$1 \text{ knot} = 1852 \text{ m/hr}$

Speed length ratio: $\frac{\text{Speed (knots)}}{\sqrt{\text{length of boat (ft.)}}} = \frac{V}{\sqrt{L}}$

Normal boat speed: $\frac{V}{\sqrt{L}}$ is nearly 1.00

(economical speed)

Low boat speed : less speed than $\sqrt{L} \times 0.8$

High boat speed : more speed than $\sqrt{L} \times 1.2$

High boat speed cannot be maintained indefinitely, it will probably attain $1.5 \times \sqrt{L}$, if care is taken of the special style of the boat or using a particulary big powerful engine. However, it is almost impossible to get $\sqrt{L} \times 2.0$ speed. The necessary length of a boat is obtained as follows, if we take the boat to be cruising at economical speed. (use $V/L = 1.0$)

Required speed	Necessary length of boat	
6 knots	6 x 6 = 36	feet
7 "	7 x 7 = 49	"
8 "	8 x 8 = 64	"
9 "	9 x 9 = 81	"
10 "	10 x 10 = 100	"
11 "	11 x 11 = 121	"

If one desires to increase the boat's speed one had better increase the length of the boat rather than install an engine of higher power.

For Example:

M.V. Queen Mary

Gross tonnage 80,000 tons, length 975 ft., speed of boat 31.6 knots. The value of $\frac{V}{\sqrt{L}} = \frac{31.6}{\sqrt{975}} = \frac{31.6}{31} = 1.02$

So, 31.6 knots is an economical speed for such a huge boat.

3) Relationship between speed and horse power

Example: M.V. Takachiho-Maru, Gross tonnage 50 tons, length 76 ft.
$\sqrt{L} = \sqrt{76} = 8.72$

Table 11. Relationship Between Speed and Horse Power

	Speed (knot)	Horse power H.P.	Necessary horse power for increasing 1 knot	$\frac{V}{\sqrt{L}}$
Low speed	6	12	–	0.69
	7	29	17	0.80
	8	52	23	0.92
Normal speed	9	86	34	1.03
	10	130	44	1.15
High speed	11	198	68	1.26
	12	310	112	1.38
	13	498	188	1.49

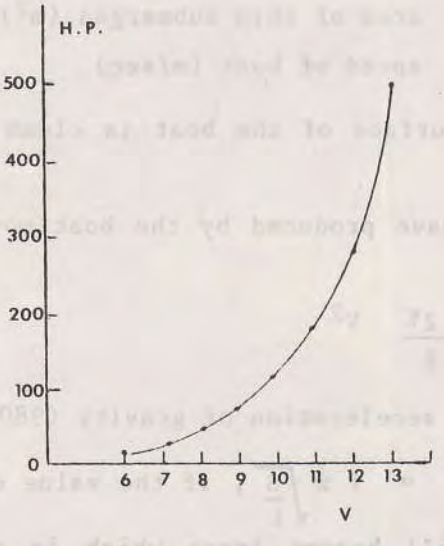


Fig. 144 Relationship between speed and horse power

The horsepower required to increase speed by 1 knot will become greater according to the number of knots increased. It is impossible from the figure of V - HP to get the speed to be more than 13 knots whatever we do to increase the horse power. Because the value of $\frac{V}{\sqrt{L}}$ will be more than 1.5

4) Approximate calculation from speed to horse power or the opposite

Boat resistances are classified as; frictional resistance R_f, wave making resistance R_w, eddy making resistance and air resistance. The following formula is realized.

$$F_f = p\lambda \{1 + 0.0043\ (15 + t)\}\ AV^{1.82}$$

Here:

Rf : Frictional resistance (Kg)

t : water temperature (°C)

p : specific gravity of water (1.025 in sea water)

λ : frictional coefficient

A : area of ship submerged (m^2)

V : speed of boat (m/sec)

Usually, if the surface of the boat is clean the value of λ is from 0.13 to 0.16.

The length of a wave produced by the boat moving foreward is denoted as:

$$S = \frac{2\pi}{g} V^2$$

g : acceleration of gravity (980 cm/sec)

As; $\frac{V}{\sqrt{L}} = \sqrt{\frac{g}{2\pi} = \frac{S}{L}} = f \times \sqrt{\frac{S}{L}}$, if the value of $\frac{V}{\sqrt{L}}$ becomes large, the length of wave will become large which is accompanied by big wave making resistance. Approximate calculation formula between speed and horse power is denoted in the following formula:

$$\text{I.H.P.} = \frac{\Delta^{2/3} V^3}{C} \quad \text{or} \quad V = \sqrt[3]{\frac{\text{IHP} \times C}{\Delta^{2/3}}}$$

Here:

C : admiralty coefficient (about 60-100)

Δ : displacement tonnage

V : speed (knots)..... normal speed

I.H.P. : indicated horse power

II. PARTICULARS OF FISHING BOAT

i. Trawler

1) Trawlers in general

As the trawlers go out fishing for a long period of time and they continue their fishery operation even in stormy weather towing bulky netting, it is recommended that they have a steel hull, strong structure and solid fishing equipment.

In addition to the requirements for general high sea fishing boats, trawlers must meet the following design and structural conditions:

(1) Hull and fishing facilities must be strongly constructed.

(2) The shape of boat must be fit for trawling operations.

(3) Stability must be great; sea worthiness must be excellent; and oscillation must be little.

(4) The boat should have good buoyancy and big towing power, and at the same time it must be easily manoeuvrable during fishing.

(5) The trim is not easily changed.

(6) The boat must have enough and complete storing facilities for the catch.

(7) The boat should have such special features as great rise of floor and large sheer; namely, large warp of the side line of the upper deck.

2) Shipbuilding regulations

The fishing boats, (shown later) are regulated according to the shipbuilding regulations of each country. The purpose of the regulations is to improve the buoyancy of fishing boats by adjusting the characteristics of boats to expedite fishing operations. The trawlers, for instance, must follow the stipulations and regulations in Japan as follows:

(1) Any trawler shall be a steel vessel of 1st class over 200 GT.

(2) Its dimensions shall be over L x B x D = 30,000

(3) It shall be equipped with an exclusive oil tank durable for more than 2,000 miles, and its maximum speed shall not be less than 11 kt.

(4) The adequate balancing, if the boat is around 40 m in length, will be:

L/D = less than 10.5

L/B = less than 5.8

B/D = more than 1.75

3) Types of fishing boats

The trawler is one type of fishing boat, and each type of fishing vessel has its own particular elements for the purpose of fishing. They of course depend upon the necessity of fishing specialities which are defined by the kind of fishing, i.e. aiming for pelagic fish or demersal fish, movable gears or unmovable gears, etc.

Fishing boats are classified as follows:

Trawling	:	Stern trawler, two-boat trawler, danish seiner, small trawler, shrimp trawler, etc.
Seining	:	One-boat purse seiner (Tuna, mackerel, sardine.....) Two-boat purse seiner (Tuna, sardine......)
Gill netting	:	Salmon gill netter, flying fish boat, tuna gill netter, etc.
Hand lining	:	Cod hand line boat.
Trolling	:	Trolling boat.

Longlining : Bottom longliner (Sharks, red fish....)
surface longliner (tuna, mackerel.....)

Mother ship or Factory ship -

: Salmon mother ship, king crab factory ship, fish meal factory ship, whale factory ship.

Others : Carrier boat, lamp boat, angling boat, pole-and-line boat, fisheries inspection boat, oceanographic research boat, fisheries research boat, refrigerated fish carrier, etc.

4) Trawler's main elements

(1) Generally speaking, a trawler has a long L, a narrow width B and big draft D. The block coefficient C_p should be as small as possible, and aft draft be as deep as possible. Longer L benefits maintaining high speed, narrow B is also good for high speed but not for stability. Deep D is good for dragging net power and also for good stability. The position of center of gravity G is better placed lower in many cases. When dragging a trawl net at slow speed the resistance involved for the boat and the net will increase more than usual, the propeller should be big in size to enhance dragging thrust for the net. From this point of view, a low speed rotated engine and pitch propeller are preferable.

(2) Characteristics

Table 4. Characteristics of Trawlers (a., b., c. and d.)

a. Value of ratio

L	L/B	L/D	B/D
40 M	5.5 - 5.8	9.7 - 10.3	1.7 - 1.9
45	5.6 - 6.0	10.5 - 10.9	1.7 - 2.0
50	5.8 - 6.2	10.8 - 11.6	1.7 - 2.1
55	5.8 - 6.2	11.2 - 11.8	1.7 - 2.2
60	5.8 - 6.2	11.4 - 12.0	1.8 - 2.3

b. Coef. of form for trawlers

Coef.	Light load	Full load
C_b	0.52 - 0.62	0.58 - 0.67
C_p	0.61 - 0.68	0.66 - 0.72
$C_{\boxtimes}$	0.85 - 0.92	0.88 - 0.93

c. Value of KG/d

L	Light load	Full load
40 M	0.75 - 0.83	0.68 - 0.76
50	0.72 - 0.80	0.65 - 0.74
60	0.72 - 0.80	0.64 - 0.73

d. Characteristics under different conditions

Condition	∇	d	F_{bd}	KG	GM	θ (Range of stability	GZ (Max)	θ x GM (degree at Max)
Light load	827 T	2.985 M	2.317 M	3.970 M	0.568 M	67.0°	0.412 M	36.0°
Full L. at departure	1224	3.964	1.338	3.647	0.783	81.1	0.401	35.2°
Full L. at arrival	1161	3.832	1.470	3.891	0.539	64.9	0.298	31.4°

The value of Gross ton/L x B x D is between 0.24 to 0.30

Stability: Generally the position of the center of gravity should be as low as possible, draft should be deep. Although the initial stability is not so great, dynamical stability should be big providing a big draft.

5) Fishing machinery

The machines and fishing apparatus are namely trawl winch, gallows roller (center & side), gallows, top roller, fish tackle, etc.

Trawl winch (electric or oil pressure)

Size of boat	Capacity	Motor
200 gross ton	3.0 ton x 14.5 * 40 m/min	* 50 PS
300 - 500	4.5 x 21 ~ 42	75
600 - 1,000	5.0 x 14 ~ 31	90
1,500	5.0 x 14 ~ 48	120

$* \text{PS} = \frac{3000 \times 40/60}{75} = 26.6$ (Loss of work and sea margin should be taken into consideration).

ii. Two-boat trawler and medium trawler

1) Introduction

The two-boat trawler and medium trawler are typical Japanese trawl net boats developed from the conventional design of the small trawler which has carried out fishing by sailing or rowing and hauling the net by hand for over a hundred years. These kind of trawl boats number more than twenty thousand.

Two-boat type trawlers operated in the East China Sea are mainly of 75, 95 and 130 gross tons. Medium trawlers are a little smaller than the two-boat type, mainly from 15 to 100 gross tons.

12. INSTALLATIONS ON FISHING BOATS

1). Equipment and Installation

General arrangements of fishing boats are shown in Figure 16. Major equipment and installations found on board a fishing vessel are as follows:

(1) Steering gear: rudder, steering machines, steering engines.

(2) Mooring arrangements: anchor chain, windlass, fairleader, mooring pipe, bitt, bollard, capstan.

(3) Life saving appliances: life jackets, life buoys, life rafts, life buoy flares, life boat, boat davit.

(4) Cargo gear: derrick, cargo winch.

(5) Piping arrangements: ballast, bilge, air, sanitary-water, freshwater, sounding, scupper, hydrant.

(6) Fire extinguishing appliances: fire alarm, fire extinguishers.

(7) Ventilation and lighting arrangements: natural ventilation, mechanical ventilation, lighting, air conditioner.

(8) Engine room arrangements: main engines, auxiliary engines, electricity generators, pumps, shafting, propeller, etc.

(9) Electrical installations, motors, switch boards.

(10) Radio installations: wireless telephone, direction finder, radar, loran, facsimile, radio buoy, etc.

(11) Navigational instruments: gyro compass, magnetic compass, track recorder, draft gauge, pressure log, electric thermometre, clear view screen, helm indicator, etc.

(12) Fishing gear: trawl winch, net hauler, line hauler, etc.

2) Electronic equipment

Since the introduction of the radio direction finder at the begining of the 20th century, other important radio equipment has been developed. This includes Radar, Loran, Decca, Omega, etc., all of which are widely used in fishing boats today to ensure safe navigation and to contribute to the efficiency of fishing operations.

Fish finding techniques by means of acoustic devices such as: fishfinder, sonar, net monitoring devices are also rapidly developing and are widely used throughout the world.

(1) Radio direction finder

A radio direction finder (RDF) consists of a loop antenna and a radio receiver. Almost any radio with a loop antenna can be used as a RDF. For example, when a loop-equipped table model or portable radio is rotated 360 degrees, the signal picked up will be minimal at two points. This is due to the directional characteristics of the loop antenna. By taking the bearing from two or three radio stations located at known positions we can provide a point intersection on the sea chart.

A ship or a radio buoy transmitting radio signals can be located by using a RDF. This is very useful in rescue work because the ship in distress which is sending emergency or distress signals can be located. Ocean going ships larger than 1600 G.T. must install RDF in accordance with an International Convention "SOLAS".

On the other hand, RDF is used not only as navigation equipment but also for finding fishing grounds because the fishermen can know the direction of other boats which are sending information about fish catch or fishing grounds or finding fishing gear.

(2) Radar

The term "Radar" is derived from Radio Detecting and "Ranging". By this function, it is possible to detect the presence of objects and to determine their velocity, direction and range (distance). In addition, a rough analysis can be made by some types of radar systems on the composition of the detected object. Radar aids a number of ships to navigate in an area of poor visibility, because with radar the objects can be seen on the screen through the dark, as well as through rain and fog.

Main uses of Radar

a. Following the sailing route of one's ship and those of other ships.

b. Confirmation of ship's position.

c. Prevention of collisions.

(3) Loran

Loran is an abbreviation for Long Range Navigation and is classified into two systems (Loran A and C systems). The Loran system in based on the principle that the radio wave goes through the air with a known constant speed.

(4) Decca

The Decca navigation system was introduced for practical use in 1948. This system consists of three to four shore radio stations arranged to form a chain. The first chain of stations was established in England in 1948 and was followed by chains in other European countries such as Germany, France, Sweden, Spain and Italy. In the East, most of Japan is already covered with Decca system service areas. If the Decca chain in set up in the Southeast Asian area, it will be of great help to every ship operating in the region.

The principle of the Decca navigation system is a hyperbola navigation system like the Loran A and C systems. A three coloured LOP is printed on a chart, called the "Decca chart". The point of intersection will be obtained by reading two or three figures indicated on the receiver. This gives the ship's position.

(5) Fishfinder (Echo-Sounder)

A fishfinder is used to measure the depth of the ocean and to detect fish shoals. This apparatus is designed to radiate sound waves through the water, and the reflections from the bottom and fish shoals are sent back to a recorder and the return time is processed electronically and recorded on paper or displayed on CRT (cathode-ray tube). The principle is the same as in radar.

(6) Sonar

The term Sonar stands for Sound Navigation and Range, and it includes all underwater acoustic systems used for the detection and location of underwater objects, though, recently the term Sonar has been used for an echo-sounder for horizontal detection in a narrow sense. The Sonar records or displays the reflected wave from an object under the water on recording paper or a cathode-ray tube (CRT) by scanning the transducer horizontally. Recently, most sonar have been designed for either horizontal or vertical use.

(7) Net monitoring system

For successful trawling, it is important to know the net mouth performance under towing. This system gives information concerning both the net mouth height and the fish shoals entering the net and records it on recording paper or displays it on a CRT.

(8) Other equipment (Omega, Facsimile, Satellite Navigation system)

These items of equipment have already been installed on some deep-sea fishing boats.

A variety of electronic equipment is being employed on fishing boats. However, the most suitable equipment should be chosen considering the purpose of use and economical investment, otherwise the equipment will be a useless possession.

VII. FISHING GROUNDS

1. INTRODUCTION

When the subject of fish detection and luring methods is described it is better to divide it between before and after the end of World War II. Until the end of World War II, to detect a school of fish all fishermen depended mostly upon their experience, fortune and instinct like an animal. In those days, what was important for them was live information, that is, a certain fishing vessel operated at a certain time in a certain area and got some catch. In 1945 the Second World War came to an end and thereafter the world industrial situation changed from the aims of military affairs to the aims of peaceful affairs to assist the world's population. By a process of trial and error, the industries have continually improved and developed to their present condition, and the fisheries industry has also been developed in order to supply enough protein for mankind. Nowadays, in addition to the former means, namely, visual observation, experience and instinct: reflection from the scales of sardine and so on and information from electronic devices help with fish detection. With the advance of fishing technology and methods, it is essential for fishermen to understand the factors influencing fish habitat, behaviour, and biological conditions as much as possible. Those factors consist of environmental conditions of fishing grounds and so on. Such knowledge, experience, and technology in fish detection of a skillful and experienced masterfishermen is not easily passed on to unskillful fishermen. A skillful masterfisherman has to have a talent for collecting and analysing the information involved to reach a decision whether to operate or not. Therefore, it takes over 15 to 20 years to become a full-fledged skipper after graduation from a fisheries institute. Recently, anybody who is going to engage in fishery can get the information on good fishing areas from numerous papers and reports issued from fisheries research institutes, etc. At a fishing ground a skipper should investigate good fishing possibilities as widely as possible and aim to catch as many fish as possible which are expected to have a high market value. When schools of fish can be found with the naked eye from on board a vessel, some skillful crew with good eye sight will suffice. However, if not, it is necessary to install suitable fish detection devices such as fishfinders, sonars, and sometimes radars. It is a fact that fishing vessels operating in the right waters at the right time can obtain a good harvest. Therefore, it is very important to know the fish path, fishing ground and period of fish migration.

2. FORMATION OF A FISHING GROUND

Environmental conditions of fishing grounds

It is known that changes in environment act as a stimulus to fish. Specifically, fishes and marine animals meet instinctively the changes in environment to live in suitable waters, and they move en mass or separately to the best habitat for their environmental adaption. Moreover, there is no difference in the feeding and spawning environment on one occasion, and there is a difference on another, also they are destined to seasonally move around looking for the appropriate environment on each occasion.

Especially in regard to the feeding environment, marine animals will migrate due to changes in external environment such as seawater temperature, salinity, disolved oxygen, PH, impurity, tide and current of seawater, sea-bed topography and materials, and also food. Fishermen always chase a school of fish with consideration of its movement in a fishing ground. However, they have to estimate the profit to be realized from fishing economically. As a prerequisite to a fishing operation, they must study the current, current rips and condition of the seawater mass for the above reason.

It is necessary to understand the fundamental conditions of existance of an aimed fish species. Also the fishermen should consider economical factors like amount of fish to be realized during fishing operations for fisheries management. Moreover it is necessary to understand the scientific basis of fish detection methods, fishing strategy, selection of fishing gear and fishery management.

Fishing technology will be improved when the order of nature in distribution and gathering is understood. Scattering of fish schools involves fisheries management. It is essential to understand the living conditions of fish as mentioned above and also to study how fish gather around current rips. The study on current rips was carried out over a long period and as a result, it was ascertained that a good fishing ground will appear at the front of current rips.

Fishermen can expect a good fishing ground for tuna and skipjack by following current and seawater mass in the deep-sea, and also they can find clues to detect a fishing ground for Sardine, Saury Skipjack, Mackerel, Squid, Yellowtail, etc. offshore. Waters where a warm current and cold current meet are typically good fishing grounds.

A. Physical/Chemical Conditions

Water temperature, salinity, turbidity, current, topography and bottom materials are considered to be physical and chemical conditions of fishing grounds. Among them, water temperature exerts a significant influence on the migration of fish. According to the fish species, optimum water temperature is determined, as shown in (Fig. 145) salinity is also one of the main physical factors. It is low in the waters where fresh water flows from the land, and in regions with much rain. On the other hand, it is high offshore and in the waters where water evaporates quickly. In addition, the vertical variation of salinity is very complicated. When the daily behaviour of fish is observed, it is seen that their behaviour is closely related to the

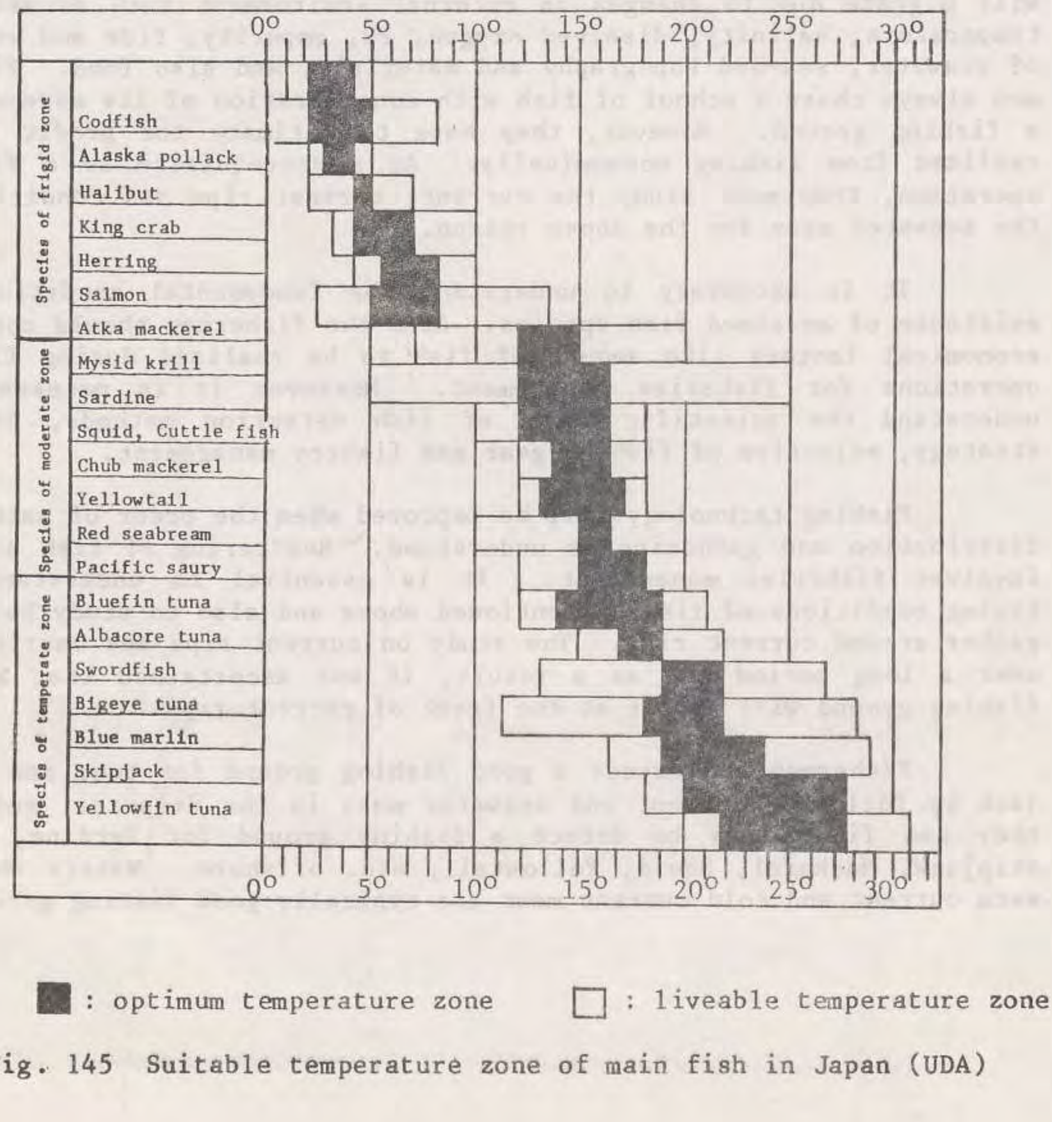
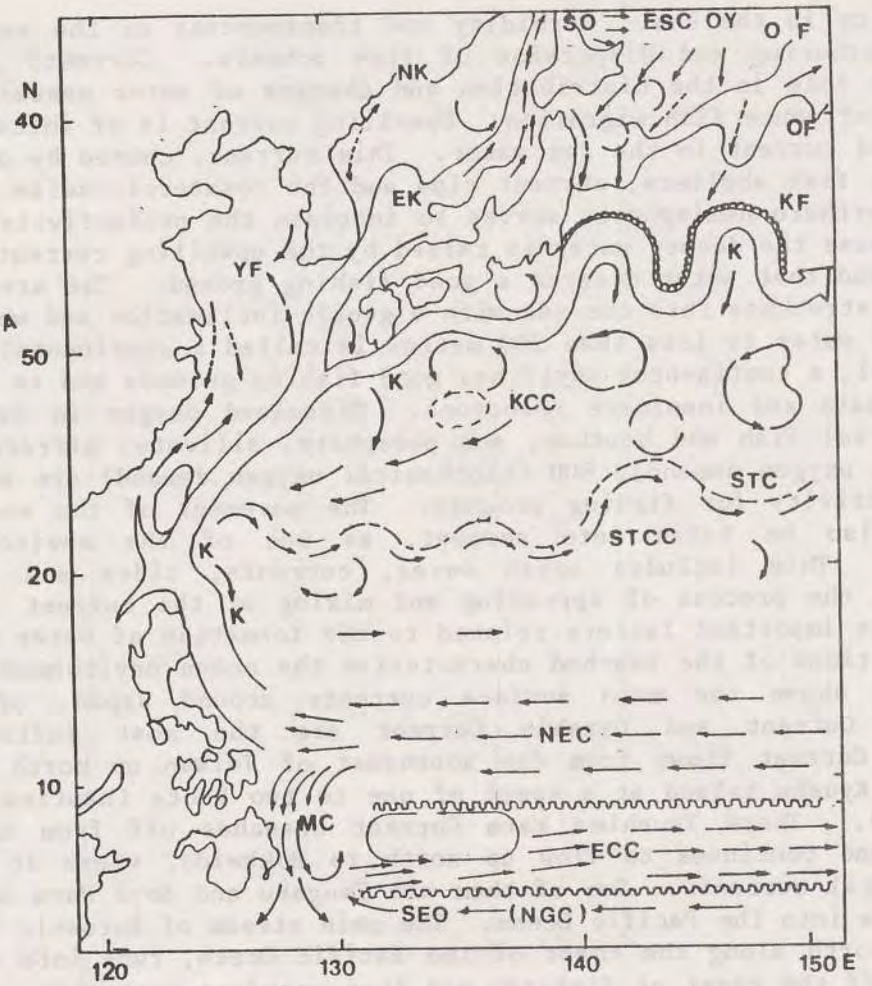


Fig. 145 Suitable temperature zone of main fish in Japan (UDA)

luminousity in the sea. Turbidity and transparency of the sea water affect gathering and dispersion of fish schools. Currents play an important role in the distribution and changes of water masses, which in turn influence fish migration. Upwelling current is of influence as a vertical current in the sea water. This current, caused by offshore currents, fish shelters, current rips and the counterclockwise current in the northern hemisphere, serves to increase the productivity of the sea, because the deeper water is raised by the upwelling current to the surface and that water creates a good fishing ground. The area where the land stretches into the sea with a gentle inclination and where the depth of water is less than 200 metres is called a continental shelf. In general, a continental shelf has good fishing grounds and is rich in both animate and inanimate resources. Dissolved oxygen in essential for demersal fish and benthos, and phosphate, silicate, nitrate. COD (chemical oxygen demand), BOD (biochemical oxygen demand) are an index of productivity for fishing grounds. The movement of the sea water should also be taken into account, as one of the environmental factors. This includes ocean waves, currents, tides and so on. Moreover, the process of spreading and mixing of the current is also one of the important factors related to the formation of water masses. The conditions of the sea-bed characterize the ocean environment, too. Fig. 146 shows the main surface currents around Japan, of which Kuroshio Current and Oyashio Current are the most influential. Kuroshio Current flows from the southeast of Taiwan up north to the south of Kyushu island at a speed of one to two knots (nautical miles per hour). There Tsushima Warm Current branches off from Kuroshio Current and continues to flow up north to Hokkaido, where it splits into several currents. Two of them are Tsugaru and Soya Warm Currents which flow into the Pacific Ocean. The main stream of Kuroshio Current goes up north along the coast of the Pacific Ocean, runs into Oyashio Current off the coast of Kinkazan and then meanders eastwards. On the other hand, Oyashi Current is a cold current rich in nutrient salts with low salinity. It goes down south along Chishima island, and after it runs into Oyashio Current off the coast of Kinkazan, part of Oyashio Current turns to be an undercurrent flowing down south.



Li	Liman current	KCC	Kuroshio Counter-current
EK	East Korean current	NEC	North Equatorial current
ESC	East Sakhalin current	MC	Mindanao current
O'F	Oyashio front	JC	Japan Sea current
YE	Yellow Sea current	TG	Tsugaru current
STCC	Sub-tropical counter-current	OF	Okhotsk front
SEC	South Equatorial current	K	Kuroshio current
NK	North Korean current	TS	Tsushima current
SO	Soya current	STC	Sub-tropical convergence
OY	Oyashio current	ECC	Equatorial counter-current
KF	Kuroshio front	NGC	New Guinea current

Fig. 146 Distribution of main surface currents around the islands of Japan (UDA).

B. Biological conditions

Live bait for fish are considered to be a biological condition. Plankton, which are bait for fingerlings, are brought and gathered in current rips by ocean currents. They are drawn up from the undercurrent to the surface by upwelling currents, and there they breed rapidly by photosynthesis. Plankton play an important part in gathering fish schools, for they contribute to the production of fish as part of the food chain between animals. Fish migrate along tidal currents of suitable water temperature. They move for feeding or spawning, and sometimes stay. This migration is much related to the formation of fishing grounds. Some fish live in limited areas where they migrate vertically according to the daily periodical change of the luminousity in the sea and shift to the deep-sea during the spawning season. These areas have biologically suitable conditions for fish so good fishing grounds are formed there.

C. Pattern of a typical fishing ground

Roughly speaking, fishing grounds are divided as follows according to their formation:

(a) Continental shelf fishing ground

(b) Current rips fishing ground

(c) Upwelling fishing ground

(d) Bank fishing ground

(e) Tidal fishing ground

(a): The whole of the continental shelf belonging to Japan covers an area of some 300,000 km^2, which is equivalent to 80% of her territorial area. Rivers bring nutrient salts into some areas of the continental shelf. The quantity of these salts accounts for a half of those produced in the sea. Since the depth of water is relatively shallow, upper and lower waters mix and nutrient salts are spread. There is also more sunlight penetrating into the water, therefore, these environmental conditions help plankton with their photosynthesis which results in the increase of organic substances. Most of marine animals spawn in the waters of a continental shelf, and after hatching juveniles grow up to be fingerlings, feeding on photoplankton which breed owing to abundant organic substances, or on zooplankton which feed on photoplankton. Fish gather to feed on these fingerlings, therefore, these waters are rich in marine organisms and a good catch can be expected, for the food cycle develops the productivity of the fishing ground. The waters of the continental shelf in the North Pacific and the East China Sea are good fishing grounds for trawling. This is because abundant plankton and benthos breed in this area where the sea-bed composed of much sand and mud is relatively smooth, inclines gently, and is rich in nutrient salts. This area presents good fishing conditions for trawlers, since it is suitable for the spawning and growth of demersal fish. Offshore water meets coastal water around the continental shelf. The branch from offshore water often gets into coastal water through the influence of the distribution of low atmospheric pressure (depression) and geographical features. This relation between coastal and offshore waters influences the gathering and dispersement of fish. For instance, this is considered a fishing condition for coastal stationary net (set net) fishing. The shape of a bay and the state of the insobaths affect the formation of fishing grounds for set net fishing, which is much influenced by the thrust of offshore water. Fishing grounds for purse seining are available around fronts of coastal water where coastal water meets offshore water, since migrating fish such as sardines, horse mackerels, bonitos, mackerels, and tunas feed and spawn there. Thus, in general a fishing ground is not fixed, as it is easily affected by sea conditions. The conditions of a fishing ground determines the kind of fishing available. For example, pole-and-line, longline, and bottom gill net fishing are operated in fishing grounds where the sea-bed consists of rocks and trawling is not carried out, even if fish abound there.

(b): A good fishing ground is found at current rips such as the Sanriku fishing ground where different current systems and water masses meet. These fishing grounds are called current rip fishing grounds. Since at current rips, both water systems are different in water temperature, salinity, water colour, etc., and they touch each other discontinuosly, the fish schools from one water system can hardly migrate to the other. There are Kuroshio Current Front, Oyashio Current Front and subtropical convergence at the current rips. Moreover, turbulance and mixed currents cause an up-and-down eddy of the sea water, and as an ascending water mass of thick density brings nutrient salts upwards, fish schools gather there to feed on fingerlings. For example, in the region, fishing grounds for bonito are distributed along the warm water belt of 20°C to 24°C. Fish schools of bonito and skipjack tend to gather in the water where the cold water belt and the temperature front arise due to isotherms centered on the 22°C line that juts north. Schools of pacific saury also seem to go down south along with the southern end of Oyashio Current (cold current) in these waters. Then the location of current rips changes, according to the direction and meandering of the Kuroshio Current, it presents two fishing grounds; one is near the coast and the other offshore. In the years when the Oyashio Front develops well, extending offshore from adjacent water to Sanriku, the schools of pacific saury gather there, and therefore, the area turns out to be a good fishing ground for saury fishing. On the contrary, when Oyashio Current flows down south drastically and the Oyashio Front appears from the north to the south along the coast of Sanriku, it is said that fish schools of pacific saury go down south rapidly so the catch is poor. In the case of chub mackerel fishing, the conditions of the fishing ground off the coast of Hachinohe are closely influenced by the cold current from the Oyashio current system, particularly by the strength of its branch stream. A strong Oyashio Current has a tendency to bring chub mackerel down south fast. In addition, there is a good fishing ground for bluefin tuna around the current rips. In winter a good fishing ground suitable for operating set net, pole-and-line, and longline fishing for albacore, is formed at the current rips caused by cold and warm currents around the Midway islands to the east of Nojimazaki. It is thought since feeding habits of spotlined sardine are different from those of chub mackerel, they can share a habitat in the same fishing ground. Spotlined sardine live in a mixed water area of cold and warm currents and migrate up north to water 10°C - 17°C in temperature which is influenced more by the water of the Oyashio Current system, where a fishing ground is formed. During the spawning season, they migrate to the coastal area where the water of the Juroshi Current system is influential. Chub mackerel migrate closer to the water of the Oyashio Current system during their feeding season, and this area becomes a good fishing ground. During the spawning season, they approach closer to the Kuroshio Current and spawn in the shallows. Thus, though both species share one habitat, one prefers a warm current and the other a cold current, and even though their feeding habits are different they are caught in the same fishing area. In western Japan, the strength and the outstretch of warm and cold currents form some important fishing grounds for horse mackerel, mackerel, and sardine. The main fishing grounds for spotted mackerel and horse-scad mackerel are found in the Kuroshio Current branch area on the continental shelf to the northeast of the Taiwan shelf due to the strength and the outstretch of warm and cold currents in the South of the East China Sea. The coastal water of the continent of China touches Kuroshio Current branch water in the area West of the East China Sea off the coast of Bahrain. Therefore, the water area is regarded as one of the main fishing grounds for horse mackerel and chub mackerel. In the fishing ground off the west coast of Saishu island, the end of the warm current of the Yellow Sea touches the bottom current of the Yellow Sea. Fishing grounds to the east of Tsushima, off the west coast of Goto, and off the coast of Shimane are formed on the rips of the meander of the Tsushima warm current and the coastal water to the South of Korea or the cold water off the coast of Shimane. The Satsunan fishing ground is formed by the complex water mass that consists of the coastal water of the Kyushu and Okuma branch stream of the Kuroshio Current flowing eastwards off the coast of Yakushima and Tanegashima islands.

(c): In the cold bottom water with high density organic remains are decomposed by bacteria, and they are accumulated as nutrient salts. However, when they are brought up by an upwelling stream to the surface, photosynthesis takes place and organisms are yielded, which helps the production of plankton. Fish then gather in these waters owing to the oforementioned productivity, and then a good fishing ground is formed. This kind of fishing ground is called an upwelling fishing ground, and is found off the coast of Peru and Chili, where anchovy are caught in the coastal area and horse mackerel and tuna offshore. A large cold water mass often comes out in the Sea of Eushu. As the water at the center contains many nutrients and the temperature is low, a tuna fishing ground is formed in the north of the water mass, one for albacore in the south, and one for skipjack at the current rips between the water mass and the main Kuroshio Current. Lots of species gather at a fish shelter. This is because some turbulance of the sea water and eddying currents arise around rises such as banks and shallows, and marine organisms breed there. There are many fish shelters in and around the ridge extending from Tonan to Ogasawara, where skipjack inhabiting the bank form schools. A good fishing ground for chub mackerel is formed in Zenisu, a fish shelter to the south of Izu Peninsula.

3. SELECTION OF FISHING GROUNDS

Fish concentration cannot be expected in the waters where there is a constant stream, in other words, these waters do not make good fishing grounds.

A key indication of a good catch or a good fishing ground is a remarkable difference in the sea conditions such as seawater temperature, current and wind force and direction.

In a period when there is little difference between maximum and minimum seawater temperatures, the fish school activity is so low that a poor catch can be expected. In rising and descending periods of seawater temperature, fish school activity is so lively that a good catch can be expected.

Good fishing grounds are mostly formed under the following environmental conditions in the optimum temperature zone of the fish:

(1) Boundary of watermasses, Line of convergence, Current rips

(2) Zone of upwelling, Area of divergence

(3) Eddies, Turbulent mixing, Riging, Dome, and Entrainment

According to Kitahara's Law (Kitahare-1918, Uda 1983, 1985), in a boundary of watermasses (oceanic front), marine animals concentrate, and good fishing grounds are formed. It is said that an indication of an oceanic front are the current rips which appear on the sea surface. In Nathanson's Law (1906) it says that a zone of upwelling generally is productive of marine life. As many kinds of marine life gather in these waters, a good fishing ground is necessarily formed there.

Around places such as channels, straits, peninsulas, capes and months of rivers, the back-eddy system develops easily due to the topography and forms a rich feeding area. This can then become a good fishing ground for mackerel, squid, yellowtail and so on.

In the existence of ripping (thermoanticline), a fishing ground for under layer fish occurs. An example of this is the tuna fishing ground in the tropical Pacific Ocean. This remarkable situation appears when an upwelling by a watermass under layer reaches the enphotic zone where photosynthesis is progressive.

This means that an under layer cold watermass projects toward the upper layer forming a knoll, and ripping means the above will occur forming a mountain chain.

Around a river mouth, inlet, bay, edge of continental shelf, island and fish bank, a watermass is rich in nutrient salts. This phenomenon is called entrainment, and the entrainment contributes to forming optimum conditions for good fishing and/or fish cultivation. (See Fig. 147)

An eddy along an oceanic front provides a rich feeding ground rich in plankton, live food, and small fishes for fish schools. Also a path of fish migration is formed around a rich feeding area.

In the northern hemisphere, a counter-clockwise eddy shows a cold eddy. There is an optimum temperature zone for certain fish on the edge of an upwelling in a cold eddy, i.e., pacific saury, whales, squid in the pole front and albacore tuna in the Kuroshio front.

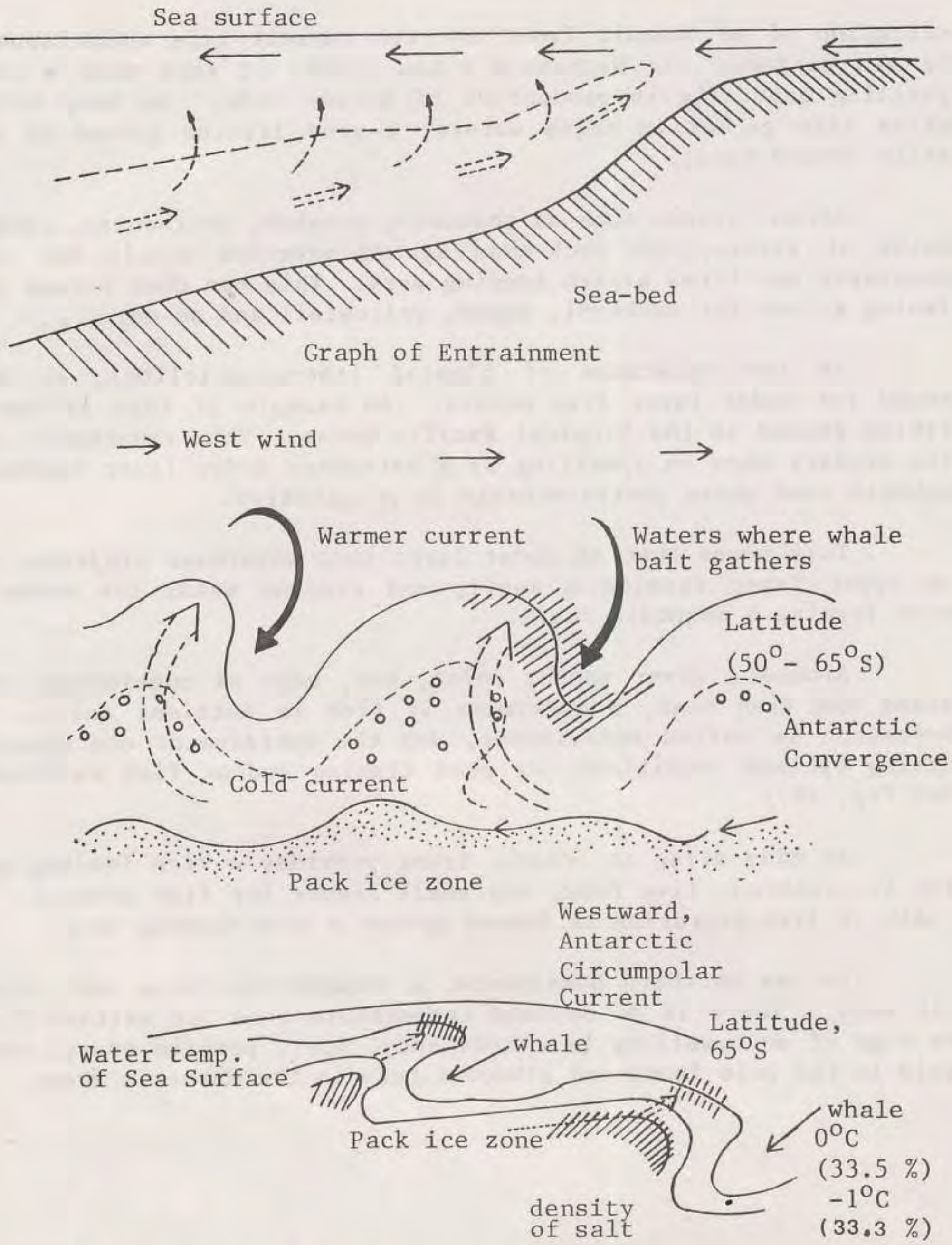


Fig. 147 Whale fishing ground in the Antarctic Ocean (NASU)

In the southern hemisphere, when a clockwise eddy appears along the antarctic convergence current, it forms a good whale fishing ground between the current and pack ice zone. (NASU 1959, See Fig. 147)

4. FISHING ACTIVITIES IN FISHING GROUNDS

Fishing is often said to be a sort of gamble since fishermen cannot always be sure of a good catch due to uncertain capture, and difficulties in forecasting how long and what kinds of a fish species will stay even if the forecasting on the migration of a certain school of fish is made based on past experience to some degree.

Fisheries is an industry which pursures the following three factors; whether fishermen can get a good catch, can sell it, and can make a profit from it. Therefore, the main concerns of fishermen are the above three factors. Generally speaking, fishing grounds in fisheries activities mean waters which can supply a good catch, and a commercial fishery can be made from them.

Seawater is always moving sometimes at a certain speed and in a certain direction and sometimes not i.e., at an uncertain speed and an uncertain direction. In the former condition, the formation of a fishing grounds is unlikely, on the other hand the waters in the latter condition are likely to create a fishing ground with current rips, eddies, and upwelling because seawater is mixed between the upper layer water and the bottom, plankton, lavae and fry are transported by these water streams, and as lavae and fry eat plankton fish species also can be enticed to these waters.

Current rips are caused by the collision of currents with different characteristics. Current character is mainly due to temperature, colour, and nutritient salts in the water.

A fishing ground is defined as the waters where a good amount of fish dwell and also where commercial fisheries can be conducted because a profitable catch can be taken from the area.

Fishermen who deal with fish schools as an objective should study the laws of distribution, gathering and scattering of fish schools. This is because if fish do not form a school a good catch cannot be expected, and when they find a school of skipjack fishermen cannot catch the skipjack with their fishing poles without the skipjack chumming well to the live bait thrown from the fishing boat. In such a case, it is better to use another fishing gear such as purse seine.

Moreover, it is very difficult to catch fish by means of any fishing gear even if there is a marketable fish in a fishing ground when the sea conditions such as rough sea, strong current are not convenient for fishing activities.

Essentials for fishing activities are as follows:

(1) Experienced crew who are knowledgeable of fishing activities and navigation.

(2) A fishing boat with all the necessary equipment installed.

(3) Appropriate fishing gear in both size and amount to catch targeted species.

As fishermen do not carry out fishing activities unless a certain fish is marketable, it can be said the economic value of fish forms a fishing ground due to the interest of the fishermen.

For example, fishermen intend to catch fish which they did not recognize the value of before because of new market demands for chemical materials from marine resources such as special fish oil, vitamins and insulin.

After the matter of fish value, the accessibility of fish schools should be considered and their vulnerability should be taken into account also.

Availability of fish schools is regarded as a combination of factors, namely, accessibility, vulnerability, abundance and concentration of fish school.

The availability declines with a deep swimming fish school, thin and wide fish school and fast moving fish school due to the weather conditions at sea. Therefore, catch rate is regarded as availability by fishing effort.

To study fish schools is to understand relationships between different fish behaviours, including, spawning, distribution, migration and variations in size of fish schools, and sea condition with regard to the living environment of fish schools.

A person involved in fisheries must study and understand the fish and the sea, specifically, what fish want, how fish act and the relationship between the fish and the condition of the sea which varies moment by moment.

To study fishing grounds, it is necessary to consider the following factors:

(1) How fish schools are distributed, move, and are caught.

(2) Why fish schools gather and also disperse at a certain time and in certain waters which is the principle of the formation of fishing grounds.

(3) Fluctuations in annual catch;

Why the fluctuations in annual catch are caused.

(4) Fluctuations in abundance;

Why the size of fish schools varies in a certain period and in certain waters.

(5) What fish resources exist, how accurately fish-stocks (amount of units of fish schools) can be estimated and what per cent of the stock humans catch (Catch, catch rate, catch per unit effort, fishing intensity).

(6) Optimum catch, maximum sustainable catch;

The amount of the fish-stock that can be caught, how to prevent overfishing, and fishery regulations (protection of fry and spawning fish).

(7) How to prevent the kinds of pollution which affect fisheries resources and how to create the formation of an optimum environment for fish farming.

(8) Standards of good and poor catch can be set when the value of a fishing ground can be evaluated.

Principles of distribution, gathering and scattering of fish schools

Those who engage in fisheries are interested in where, when, how to find a good fishing ground, how fishing conditions vary, what elements bring good or poor catches annually and to what extent catch can be improved.

Fishermen have continuously endeavoured to understand the above factors, combining their long years of experience and all the data collected at sea under various weather conditions.

To carry out a smooth fisheries operation, the following matters should also be taken into consideration:

(1) When, where and how a useful fish school is formed in a certain ground.

(2) Whether a certain fish is marketable in a certain fishing ground.

(3) Whether the waters are accessible to fishermen.

(4) Whether the stock of fish is vulnerable to fishing activities.

(5) How to obtain optimum catch or maximum sustainable catch, while respecting the laws of resources conservation.

(6) Coordination and fishery management to prevent overfishing and water pollution are very important in conserving resources.

5. FISH DETECTION AND LURING METHODS

Fishing activities are carried out in the order of fish detection, fish aggregation and fish capture, respectively. Usually gathering fish work precedes capture work except for the trawl fishing method where a fish school is frightened and caught after or while it is detected by means of fish finders and/or sonar.

Fish aggregation is very important to raise the efficiency of capture. Therefore, men who are concerned with fishing activities must continue to make an effort to catch fish efficiently as well.

Fish detection and luring methods are classified as one type of fishing method.

1. Fish detection method

Fish detection includes the following;

(1) by naked eye and/or binoculars from on board the vessel i.e., purse seiner,

(2) by naked eye and/or binoculars from an aircraft i.e., bigger purse seiner,

(3) by fishfinder/sonar on board the vessel i.e., most fishing vessels,

(4) by scope of distribution of seawater temperature information by satellite.

Satellite is an effective means to find a good fishing ground in huge waters though this is not a direct method of fish detection. Fishermen can get information to investigate, evaluate and decide on a fishing ground as the distribution of seawater temperature clearly shows current rips on the scope. Superficially this method is very useful in spotting a good fishing ground.

Furthermore, as it also shows the variations in environmental fishing conditions from hour to hour fishermen can carry out efficient fishing activities, while coping with the variations.

2. Fish luring method

After the detection of fish or spotting of a fishing location, fishermen aim to gather and concentrate the fish school, while chumming, luring, attracting, driving, trapping, frightening them and blocking their movements as a first step in catching them efficiently.

The following methods are used in fish luring:

(1) Attraction methods can be divided into three types.

a. By means of artificial lights

In this method, lights are used which take advantage of fish behaviour as fish are attracted to lights, the typical fishing methods using this are pacific saury stick-held dip net, Mackerel pole-and-line, Mackerel/Horse mackerel/Sardine purse seine, Squid angling and lift net fishing.

b. By means of food and/or bait

This method is one to gather fish by scattering food and/or bait during the day or night. The fishing methods which do this are Mackerel/Skipjack pole-and-line fishing, Horse mackerel stick-held dip net, lift net, Sardine purse seine and Yellowtail *domesticate fishing.

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* Domesticate fishing

This fishing method is where fishermen try to induce and concentrate fish by scattering lots of food for a certain period in a certain place where fish are gathering. They manage to prevent the gathered fish from escaping and then they can concentrate on catching the fish by means of hooks and/or nets.

The target fish of this fishing method are yellowtail, mullet and rockfish. Usually, this fishing is carried out around a natural and/or artificial reef because areas where fish are easy to gather appear there.

c. By means of artificial reef V-FAD (fish aggregating devices)

This fishing method is one to induce fish to artificial shelters, reefs, octopus pots, all barrel-shaped baskets, dolphin shelters and FADs like artificial reefs and payaos.

(2) Aggregation with driving method

This fishing method is one to frighten, drive and gather fish with the help of ropes, nets, divers, poles and so on. It can be divided into tuck-net (drive-in net) and encircling gill net.

(3) Aggregation with blocking method

This method is one to induce the fish to a place where nets or bamboo fences are put to block the fishes path. Set nets, electric screens, weirs, fish pounds and flashing lights are included in this method.

6. EXPLOITATION OF FISHING GROUNDS AND THEIR MAINTENANCE

With the recent increase in the construction of large-size fishing vessels, the modernization of their equipment and the introduction of improved observation apparatus, the size of fishing grounds has been magnified.

It is of vital importance in the development of fishing grounds to have excellent fishing boats and well-trained crews, knowledgeable of the overall practical techniques, oceanography and the science of fisheries resources plus the study of various factors of oceanographic observation and judgement. The current rips, water temperature, salinity and transparency in off-shore fishing grounds as well as the water temperature in the middle and lower layers are very important factors for the purpose of fishing operations. For example, the introduction of acoustic detectors for fishing has revolutionized fishing operations. The development of the echo sounder has also clarified the actual status of the sea floor which was previously unknown to fishermen. As a result, fishing, which was formerly operated by watching only the condition of a fish shoal on the surface, has now developed to be more vertical and at the same time more effective.

Fisheries resources in boundless areas appear to be inexhaustible at first sight, but if they are left to aggressive exploitation by the latest mechanized fisheries operations without regard to the proper conservation measures to be taken to protect the resources, all fishing grounds will be laid waste. Furthermore, unrestricted catch of spawning fish and fingerlings or young fish will destroy the actual stocks. Therefore, preventive measures against overfishing on both a national and international level are absolutely necessary for the maintenance and preservation of fishing grounds in general. This is the reason why various international conventions and national laws have been established all over the world.

In order to improve the optimum utilization of fisheries resources research and studies should be intensified along the lines of the development of fishing grounds on the one hand and their maintenance and preservation on the other.

VIII. FISH BEHAVIOUR AGAINST GEARS

1. INTRODUCTION

Quite different fishing gear may be used to catch the same species of fish under different fishing conditions and even, sometimes, in the same fishing ground. In the Sea of Japan sardines are caught mainly by drift net because they disperse widely in low-density schools. Northwest of Kyushu they do not school at the surface by day, but at night purse seiners using light attraction devices take sardine which swim slowly in dense schools within easy reach of the surface. Off the Pacific coast of Central Japan the sardines school near the surface by day and two-boat purse seiners operate.

Light attraction is most effective where the transparency of the water is high and the temperature not too low. Sight appears to be the most important sense, especially when moving. Man's range of visibility in the sea by day, though dependent on transparency, is 5 to 6 m. Judging from their eyes, fish may have almost the same visual capacity as man.

2. BEHAVIOUR AND ILLUMINATION

Observations were made of sardine behaviour in the southern part of the Sea of Japan. Before dawn when the illumination was low, the schools were at a depth of 50 to 90 m. Immediately before sunrise when the light intensity was 10^{-1} to 10^{-2} lux at the depth of the fish, the schools rose rapidly to the surface into an intensity of not more than 10^2 lux. Guided by echo sounders fishermen shoot their nets and make good catches at this time.

After sunrise, with the further increase of light, the schools descended into deeper water remaining at light levels between 10^1 and 10^3 lux and forming dense schools at 40 to 70 m. Towards dusk, as the illumination decreased the sardines again moved up. Fishing is again good at this time. Later the sardines descended again and from the echo sounding traces the schools appeared to disperse.

3. REACTION OF SCHOOLS TO DRIFT NETS

3.1 Visibility of the net

With drift nets the twine should be invisible to the fish, hence the wide use of monofilament nylon. With bag nets, however, the leader net has the function of guiding the fish and it should be as visible as possible.

3.2 Sound

Sounds produced by netting may also influence fish so that the twine of gill nets should be as thin as possible to reduce the noise level and turbulence. While a drifting net will tend to make rather little noise, for a bottom gill net noise may be a serious factor; in a leader net vibration could be advantageous.

3.3 Diurnal changes in catches of drift nets

A survey was conducted in the sardine drift net fishery at the end of May in the Sea of Japan (Niwa, 1952). The catch was minimal from 15.00 to 18.00 built up slightly from 18.00 to 19.00 and was maximal from 20.00 to 23.00. After a fall lasting an hour another peak occurred from 24.00 to 01.00 and thereafter the catch decreased hour by hour until another increase at dawn. These catches are in accordance with the behaviour described in relation to illumination, i.e. an ascent towards evening when the fishing is good at depths of about 50 m. At night the fish disperse, but move up to the surface again at dawn.

3.4 Colour of drift net

In a fishing test of drift net colour (Nomura, 1961) in the southern Sea of Japan a large net 75 m. x 20 m. was divided into 60 different coloured panels each measuring 7.5 x 2 m. The colours used were (in order of brightness measured at 50 m.) White (W), Yellow (Y), Green (G), Blue (B), Orange (O), Purple (P), Red (R), Grey (G_y), and Black (B_k). The catch of sardines in the panels on each of 11 days was recorded. The catch in each panel on a particular day was compared horizontally with the adjacent panel to the right and the adjacent panel below. No attempt was made to use the numbers of fish but only whether the catch was higher or lower than in the adjacent panels. In this way each coloured panel could be allotted a score.

The combinations (+) (+) and (-) (-) are higher scores than the combinations (+) (-) and (-) (+). As each panel was similarly compared with its neighbour to the right and below for each day, box indicator (+) (+) means better catch in darker net, and (-) (-) means poorer catch in brighter net. So, the result indicates that the darker the colour of netting the better the catch during the daytime. This effect was not found in night-time fishing.

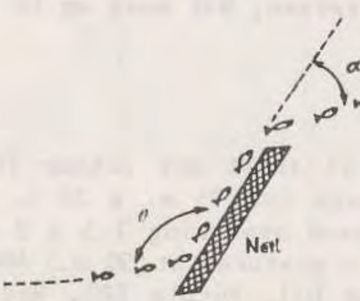
Another test by Koike (1958) in the salmon drift net fishery compared the catch between cutch-brown and blue-green nets and between cutch-brown and grey nets. In both tests cutch-brown nets were less efficient. In the fishing grounds of the North Pacific the water has a low transparency and is dark grey. It appears., therefore, that a net similar to the colour of the sea water is best.

3.5 Echo sounding observations

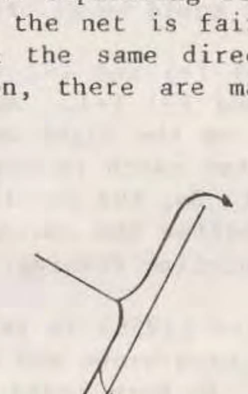
By comparing the distribution of fishes within a net and echo sounding records before and after shooting, it is possible to deduce the behaviour of sardines as the net is shot. There is a drop in the number of schools above the depth of the corkline after shooting which suggests that the fish move downwards as the nets are shot.

4. BEHAVIOUR OF FISH TO GILL NET SPREAD UNIFORMLY IN WATER

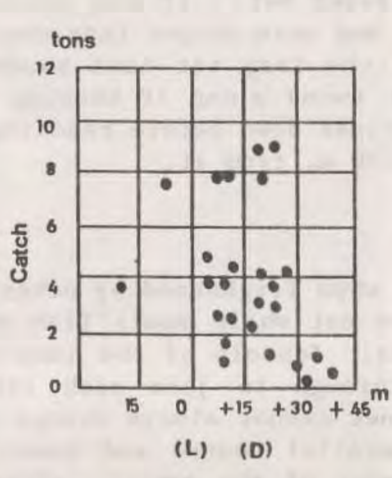
What is the reaction of a fish school to a gill net hung uniformly in the sea? Fish can to some extent recognize a gill net in the daytime by means of their eyesight. Experiments were carried out to find the effect of a gill net on the behaviour of a fish school when one was set in their swimming course, assuming the net is a kind of obstacle.



When the fish came towards the net at the angle θ, some were gilled and some went on swimming along the net and turned at the end of the net in the angle α as the figure indicates. When θ is 90°, fish swim along a net after separating right and left, in this case the gilling efficiency of the net is fairly high, and it seems that they continue swimming in the same direction as the figure shows. However, in this condition, there are many factors to disturb the schooling fish.



On the other hand, it is considered that when θ is about 45° or 135°, the gilling efficiency of a net is highest as fish are more accessible to the net. An experiment has been made with fishfinders to know the behaviour of sardine schools to a sardine gill net consisting of cotton twine, 20 count, 4 yarns, 43 mm in stretched mesh size, 18 metres in completed depth, with 30-40 pieces of netting, each of which measures 30.3 metres. During the daytime fish swam approximately 30-45.7 metres below the water surface and the net-hanging ropes were 45.7-60.6 metres long. Denoting D, the depth of fish swimming and L, the length of net-hanging rope, the figure indicates the relationship between L-D and the amount of fish caught, obtained



from the recording papers of fishfinders. In consequence it was found that L was generally 7.6-30.3 metres longer than D, and few fish were caught when the length of the net-hanging rope was equal to the depth of the swimming fish or shorter than it. The images of fish appearing on the recording papers of the fishfinders indicated that fish swimming above the float line dispersed when the gill net was spread, and those swimming below the sinker line became dense when the net was set. That is to say, fish tend to swim deeper when a net is set in the sea.

5. BEHAVIOUR OF FISH IN AND AROUND TRAP NETS

Leader nets are set to lead fish into a trap net of which about 15,000 are to be found in Japanese coastal fisheries, mainly catching yellowtail (*Seriola quinquerdiata*). Formerly, the leader net was generally of straw material with a mesh of 35 to 45 cm, far larger than the girth of the fish. Fish may swim 300 to 3000 m along the leader net. Most of the information on fish behaviour has been obtained by diving and indirect methods on the leader net rather than on the main part of the trap net.

5.1 Sardines

If in large schools, sardines move along the leader net, sometimes at some distance from it. The distance swum along the net is generally greater if the current is against them. Schools swimming offshore near the surface move down immediately to about 10 m. when they encounter the leader net.

5.2 Yellowtail

Large schools generally move more slowly than small ones before they reach the leader net. If the schools encounter reefs or anchore ropes they sink and swim deeper than usual. Observations from the tops of hills near the trap net have shown that after a school meets the leader net it swims along it keeping about 15 m. away from the net, then suddenly sinks down before reaching the mouth of the net at a distance of 70 to 150 m. from it.

5.3 Other behaviour

Schools of fish when frightened by other fish may swim through the meshes of the leader net while small fish may even pass back and forth through the meshes. Schools of the same species on either side of the net may pass through to join each other. A large school approaching the leader net cannot always change direction sufficiently rapidly to take up a parallel course and some fish may pass through the meshes. The remainder of the school, after some disorientation, will finally swim through the meshes and join up again. Schools of tuna may pass in either direction along the leader net while sardine schools usually go one way.

Formerly, when a trap net was constructed of straw netting with a large mesh, yellowtail would sometimes escape through the meshes. Tuna, which are usually wary of approaching netting, might then follow the yellowtail.

Schools of fish after entering a trap net disperse into smaller schools. This may reduce the escape rate from the net.

Salmon fishermen use leader nets of cotton or manila twine with a small mesh. The fish swim close to the net and occasionally become enmeshed. However, with a net of straw material with 6 to 8 mm. diameter twine and 30 cm. mesh the schools move along it at a distance of 1 to 1.5 m. and rarely pass through the meshes.

Table 12. Relative value of catch in different bag net positions

Kinds of fish	Position of bag	Net A I	Net A II	Net A III	Net A IV	Net B I	Net B II	Net B IV	Net B V
Bream	Number of catch (ratio)	1	2.45	2.45	1	1	1.6	1.6	1
	Amount of catch (ratio)	1	3.50	3.50	1	1	1.8	1.8	1
Perch	Number of catch (ratio)	1	3.2	3.2	1	1	1.7	1.7	1
	Amount of catch (ratio)	1	4.0	4.0	1	1	2.0	2.0	1
Flat fish	Number of catch (ratio)	1	3.8	3.8	1	1	2.2	2.2	1
	Amount of catch (ratio)	-	-	-	-	1	2.5	2.5	1
Shad	Amount of catch (ratio)	-	-	-	-	1	2.5	2.5	1
Crab	Amount of catch (ratio)	1	0.6	0.6	1	1	3.4	3.4	1
Cuttle fish	Amount of catch (ratio)	-	-	-	-	1	1.5	1.5	1

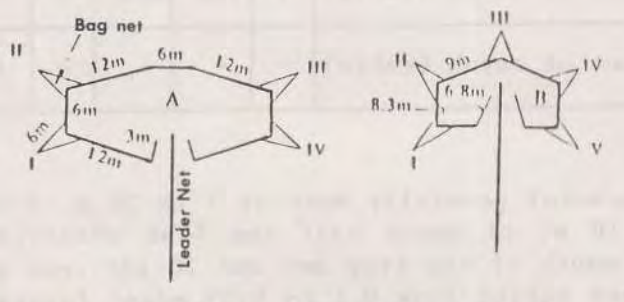
Horse mackerel generally move at 5 to 20 m. from the net at a depth of about 10 m; of about half the fish observed, 30 per cent passed into the mouth of the trap net and 20 per cent swam out again. The swimming speed varied from 0.1 to 0.55 m/sec (average 0.27 m/sec) entering the net and from 0.05 to 0.35 m/sec (average 0.20 m/sec) when swimming out.

5.4 Catching positions in bag nets

About 4,000 small bag nets or "Masu-ami" are now operated along the coast of Japan. Miyamoto (1954) plotted the position of capture of fish within these nets. These are shown in Table 12, the results indicate that more fish were caught on the seaward side.

Table 13. Relative value of catch of fish in nets of different materials

Bag net and colour	Bream	Perch	Shad	Flat-fish	Sharp-tooth eel	Eel
Cotton tarred (black)	1	1	1	1	1	1
Cotton cutched (brown)	1.5	1	-	-	-	-
Cremona cutched (brown)	2.1	1.5	-	-	-	-
Cremona (white)	2.6	1.5	1.3	2.4	0.17	0.17
Nylon (white)	3.5	2.8	1.4	2.4	0.17	0.17
Nylon (blue)	4.2	2.8	-	-	-	-



Plan of "masu-ami" nets used for experiments

5.5 Colour of bag nets

Miyamoto also used materials such as cotton, nylon and cremona for bag nets. The relative catch with these nets is shown in Table 13. The coastal fish such as bream, perch, shad, yellowtail and flatfish were taken better by the lighter coloured nets and nocturnal species such as the eel and sharp-toothed eel by darker nets. Crab and shrimp were not affected.

IX. FISHERY OCEANOGRAPHY

1. OCEANOGRAPHY AND MARINE FISHERIES

Dairy farming, breeding of livestock and poultry husbandry are being developed all over the world. Marine fishery has also a great role to play in this development. It is worthwhile to make every effort to increase the effectiveness of the marine fisheries, since the seas can produce, at least theoretically, enough animal protein to cover the vital need of a world population ten times larger than the present population. Here the word "theoretically" refers to two practical points:

(1) The sea products must be preserved in an appropriate way, that is, without damaging their significant proteins.

(2) It is necessary to strive for an even distribution of the said sea products all over the world, especially to the areas presently short of animal protein.

The sea products are used mainly as food for humans. However, especially in industrialized countries, more and more fishmeal is used in feed for poultry and cattle. This is reasonable product use, since the animal protein remains in the meat of poultry and cattle. On the other hand, the use of fish as fertilizer means waste.

The effectiveness of the marine fisheries is increasing. However, too great a portion of this production is used to add variety to the diet of the well-fed nations. Because of this uneven distribution and consumption of sea food, the need for additional animal protein from the sea fisheries will remain larger than an even distribution would imply.

Whether for the benefit of the nations without an adequate animal protein diet or in the interests of the well-fed nations, it is necessary to make the world fisheries not only:

a. rational as far as the economic yield is concerned, but also

b. more appropriate from the point of view of fish population dynamics.

(a) The fisheries may be considered economically rational if they are conducted in such a way as to ensure the maximum production of fish of the highest possible quality, in a form which can be marketed with minimum expense because of the minimum expenditure of effort and material involved. This means, among other things, that one has to know where, when and how to organize the fisheries. This actually leads the fisherman and his advisors to several practical problems, the basic ones being: How to find the largest fish concentrations? And how can fish be caught with minimum expenditure of effort and monetary resources?

(b) It would be rash to consider the tasks and potentials of fishery oceanography without taking into account population dynamics, the knowledge of which provides the continuity of fisheries with a solid basis. Under natural conditions (Fig. 148), assuming that a dynamic equilibrium has been reached, all increments to the stock by growth and recruits are balanced by losses due to natural mortality. Fishery causes additional losses. Fishing will result in a shift of the age composition of the fish caught towards younger specimens. Thus a new stage of equilibrium of the usable stock must be reached in spite of the fishing. One of the central goals in all fishery management is to find the stage of dynamic equilibrum, between the four factors affecting the usable stock, which will give the maximum yield.

Fig. 148 Upper part: dynamic equilibrium of the usable fish stock under natural conditions. Lower part: effect of fishing upon the dynamic equilibrium.

Potential extinction of the stock is reached if the specimens which are capable of reproducing under average conditions cannot ensure the maintenance of the stock. Every educated fisherman must be interested not only in the immediate yield of his own efforts, but also in the conservation aspect of fishery. He must be wary lest the really valuable species are caught to such an extent as to permit the dominance of valueless fish.

Science can assist and support the fisherman in various ways. In the General Scientific Framework for World Ocean Study, recently prepared for the Intergovernmental Oceanographic Commission by the Scientific Committee on Oceanic Research of the International Council of Scientific Unions, there is a significant statement on this subject:

Marine science supporting the marine fisheries is of direct economic value in two ways:

(1) For those fish populations being substantially exploited, it can provide both the basis of more efficient catching operations, and the basis of maintaining the populations at levels which will produce maximum yields year after year.----With the rapid increase of the world's fisheries, additional fish populations are being utilized to the point where such conservation management, based on scientific understanding, is required.

(2) For the populations that are little used, or not used at all, research on their habits and their reactions to the changing sea can provide the basis for developing means to catch them cheaply, so that they can be exploited economically in large volume. Such little-used fish stocks occur not only in distant waters but also near the coasts of major fishing nations.

Physical oceanography and maritime meteorology, which are scientifically closely related to it are assisting marine fisheries already and the significance of this assistance is bound to increase in the future. In the practical tasks and in the more sophisticated problems as well, the fisherman is convinced that the weather and sea do affect the yield of his fishing. It is obvious that in most respects the casual relationship between weather and fish behaviour, resulting in a good or poor catch, cannot be direct. The great ocean fisheries are affected by changes in the oceanic current systems, in the temperature distribution and in other physical and chemical conditions, all these being weather-dependent.

On the basis of long experience, advanced skill and good luck, some fishermen have learned how to make instinctive use of the correlations, casual or otherwise, between weather and fish behaviour. But this is not enough. All fishermen need to know how the oceans function, how the food web in them is built, how all the living things in the oceans are linked in their reproduction, aggregation and migrations to the ocean. In the interest of our fishermen and of the starving nations we must learn to understand the ocean itself in its dynamic complexities as the basis for understanding the even more complex processes of life going on in it. Practical predictions for fisheries can be based upon such understanding only. It is only because of the youth of marine science that profitable relations between physical oceanography and marine fishery have not yet been more numerous. Nevertheless, we have every reason to be optimistic in this respect. The fishing industry is already presenting new urgent problems to the marine scientists.

The basic problems which at present confront oceanographers and marine ecologists in this respect are, according to Nikolsky,

(1) those of the dynamics of populations and biomass of fish stocks, and

(2) those of fish migration and group behaviour.

The dyamics of populations and biomass of fish stocks are basically related to the solution of such problems as the principles which govern the individual development of fish, their growth and the principles of intraspecific and interspecific relationships. Thus one may divide schematically basic fish ecology into the following two groups (which are not fully independent):

(1) the factors affecting the individual development of fish, and

(2) the factors affecting their migrations and group behaviour.

The knowledge of both these factor groups is of great economic significance. Mastery over the factors of the first group will lead to the following achievements:

- The improvement of forecasts of the yield of commercial fishery, most useful for the successful planning and administration of fisheries.

- The development of methods of improving the productivity of the commercially catchable fish and of increasing the value of marine fisheries products.

The factors of the second group, that is, those affecting the migrations and group behaviour, are obviously related, according to a statement by Nikolsky (1963), to such problems as the protective and migratory significance of shoaling, the biological significance of the noises emitted by fish, the role of various sense organs and of the behaviour of fish, etc. The solution of these problems is of importance to the consideration of such practical matters as the improvement of fishery technological methods of searching for fish schools, increasing the effectiveness of fishing gear, and the development of new means of capture.

Summarizing this kind of reasoning a FAO working group recently gave the following useful definition:

"Fishery oceanography is the study of the living resources of the sea, using those aspects of oceanography (including marine biology, physical oceanography, marine chemistry, maritime meteorology, and marine geology) that affect their abundance, availability and exploitation.

2. FISH AND THEIR ENVIRONMENT

We have to base our consideration upon the unity of an organism and its environment, since the dynamics of the abundance of a species is the result of the interaction between the organisms and their environment (Fig. 149, A). Between them there does not exist a stable balance, since the environmental factors are bound to vary, and since the adaptive properties of the organisms also fluctuate. It is always important to remember that the ecological approaches must be based upon physiologically correct premises. As emphasized by Nikolsky among others, the form, the function and the mode of life of an organism are inseparably related. Therefore, the study of the mode of life of the organism is only possible if it is based upon a knowledge of its structure and the function of its organs, that is, upon its physiology.

The environment consists of:

(1) biotic and

(2) abiotic or "physical" interrelationships.

The extremely variable biotic interrelationships again are either interspecific, like the relationships with food organisms, predators, parasites, etc., or intraspecific, that is, interrelationships between specimens of the same age, males, parents and descendants, etc.

Our figure shows how the physical interrelationships consist of numerous factors, which we shall deal with in detail.

The connection between an organism and any particular component of its environment is never isolated from the connections with other environmental components. This complexity of the causes and their effects makes the investigation of the relationships between the environment and the organism (the fish) most difficult. Furthermore, the effect of the environmental factors always depends upon the condition of the fish as well, that is, upon the state of maturity of its gonads, upon its state of nourishment, upon its fat content, etc. (Fig. 149, B).

In spite of this actual complexity of the interrelationships, the ecologist is in reality frequently forced to investigate for the most part separately the various environmental factors, with their effects, instead of approaching all the factors and their effects simultaneously. One always has to bear in mind that this separation is unrealistic and subjective. Nevertheless, this approach is often the only practical one and, fortunately, in spite of its limitations relatively successful in many cases.

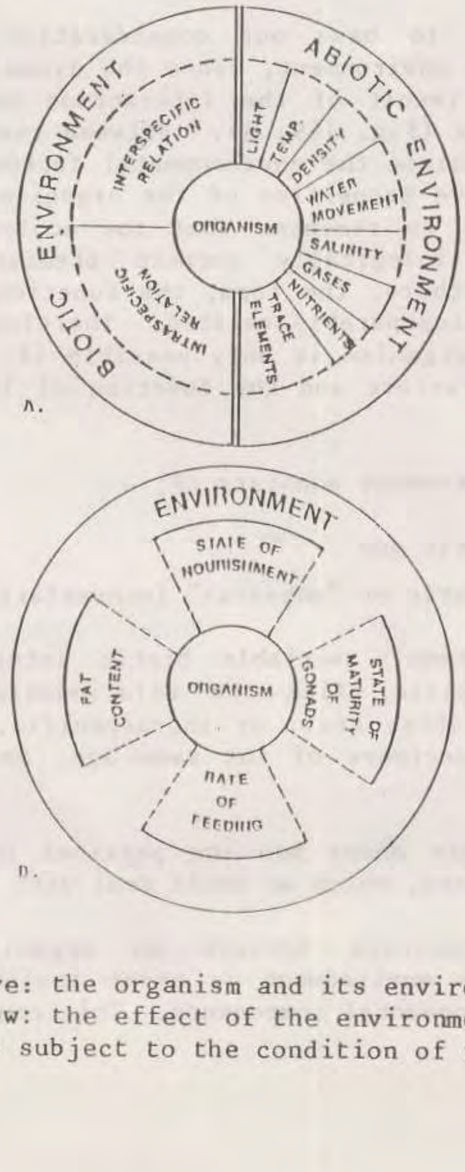


Fig. 149 A. above: the organism and its environment.
B. below: the effect of the environmental factors subject to the condition of the organism.

3. ENVIRONMENTAL FACTORS

Let us now return to the abiotic or physical environmental factors. Their significance on the life of fish and other marine organisms is enormous. This means that the problems routinely dealt with in the framework of physical oceanography are fundamental to fishery biology. This is an established fact, regardless of the difficulties encountered in the practical application of the results.

3.1 Light

It is logical to start the consideration of physical environmental factors with the light, which plays a very great direct role in the life and in the behaviour of fish.

The incidental light, affected at different depths by the content of suspended particles in the water, produces its effect:

(1) upon the conditions of hunting for food in fish which orientate themselves by means of the visual organs, and

(2) upon the conditions for protection from predators.

It appears from various observations and experiments that every species has a particular optimum light intensity at which activity is at a maximum. The diurnal cycle in the behaviour of fish is related to the degree of marine illumination, as we shall see later on. The annual cycle of light intensity determines to some extent the maturation of the gonads and the changes in the metabolism of the fish.

For most fish light is an essential direct environmental factor, not to speak of the significance of light in connection with the primary productivity of the sea. Furthermore, the amount of incidental light is more or less directly related to the temperature, which for its part plays the role of a dominant environmental factor.

3.2 Temperature

Temperature affects the fish both indirectly and directly in numerous ways. In this context one has to observe that the body temperature of most fish differs from that of the surrounding water by not more than 1°C. Therefore they must be affected by the changing temperatures of their environment more than homothemal animals. This fact manifests itself in the metabolic rate, which must be closely correlated with the changes of the surrounding temperature. This also explains how a change in water temperature frequently acts as a stimulus to the onset of spawning and migration.

Especially the stenothermal fish, which are adapted to a narrow range of temperature fluctuations only, are seriously affected by temperature changes, e.g., the mortalities of cold-water fish may by caused directly by rising temperatures, although usually the temperature causes the mortality indirectly, acting through changes in the oxygen content of upper waters and so changing the respiratory conditions. Similarly, temperature changes also bring about changes in the degree of toxicity of various substances to the fish. For instance, the higher the temperature of water, the stronger the toxic effect of CO_2 dissolved in sea water.

Nearly all fish species seem to have specific optimum temperatures which they prefer, provided that the temperature is not accidentally connected with some adverse factors. One has to remember that fish search for and select a certain optimum combination of physical and biotic conditions in the environment. Therefore, in spite of its great significance, temperature alone is not always the only decisive factor.

A further complication is brought about by the fact that the environmental requirements change during the various stages of growth and even seasonally, e.g., the optimum spawning temperature of the Atlantic herring is in spring $6.5 \pm 2.8^{\circ}C$ and in autumn $11.2 \pm 2.1^{\circ}C$. With a thorough knowledge of these optimum temperatures, with their limits and fluctuations, forecasts of temperature distributions can be used for predicting the seasonal abundance of catchable stocks.

The temperature range which a fish species prefers can be considered to a certain extent a species characteristic. The fish of arctic and antarctic waters have evolved a certain type of metabolism which enables them to feed successfully at very low temperatures. The activity of these fish decreases if the temperature rises to exceptional values. On the other hand, if the temperature drops much below the optimum, the feeding rate of the Baltic herring is reduced abruptly, as shown by Nikolajev (1958) (Fig. 150).

Concerning the apparent and indirect effects of temperature one should observe, among other things, that the concentration of the food of the fish is, one way or another, temperature-dependent, which in some cases makes the determination of the actual optimum temperature for a fish most complicated.

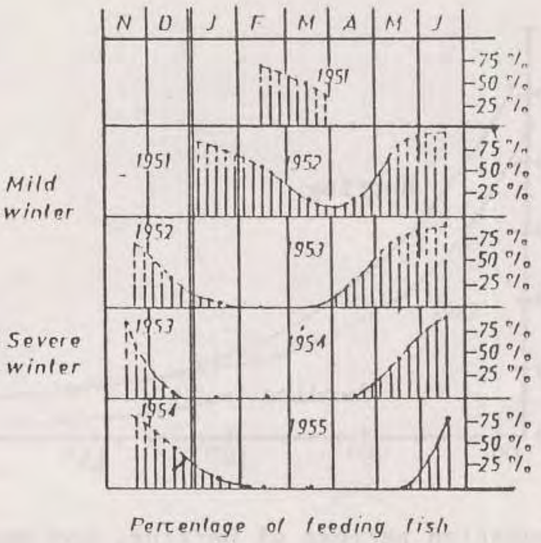


Fig. 150 The percentage of feeding Baltic herring during mild and severe winters (after Nikolajev, 1985).

The development of the eggs is undoubtedly the most critical period in the life history of fish, because this is when they are most strongly influenced, directly and indirectly, by physical conditions. Temperature directly influences the rate of development of the eggs (and, by the way, in conjunction with salinity, will also determine the water density, which affects the buoyancy of the pelagic eggs). The length of time taken for the incubation of eggs depends directly upon the temperature of the environment (Fig. 151); as shown by the following empirical equations:

herring *(Clupea harengus)*:

$$T = 4 + 44.7e^{-0.167\nu}$$

Cod *(Gadus callarias)*:

$$T = 7 + 30.3e^{-0.215\nu}$$

Japanese sardine *(Sardina melanostica)*:

$$T = 0.5 + 28.8e^{-0.159\nu}$$

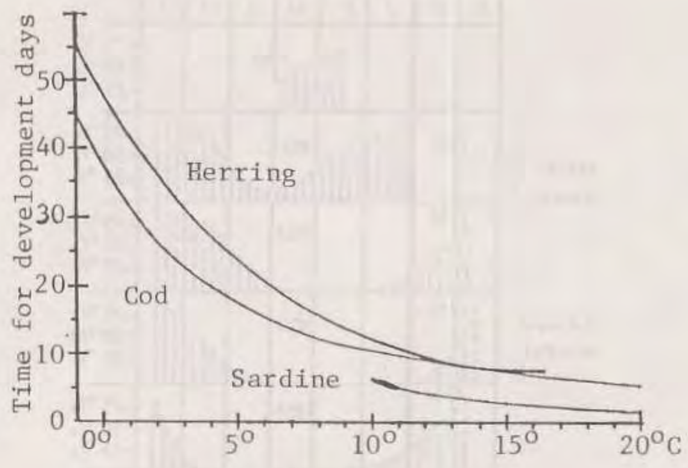


Fig. 151 Incubation periods of herring, cod and Japanese sardine eggs as functions of water temperature.

where ν stands for the temperature and T for the time in days. Obviously, the length of larval life must often be similarly related to the water temperature.

It is generally assumed that the strength of a year-class of a fish species frequently depends upon the first days of life or even of the first hours after spawning or after hatching. Actually, very little is known about the physiology and associated ecological requirements of the very young fish. Nevertheless, one may observe that the survival ratio of fish fry depends upon:

(1) the mortality due to biological causes, and

(2) the mortality due to physical causes.

In addition to these generally accepted causes, survival also depends upon

(3) the horizontal transport of fish eggs and fry, caused by advective water movements and by turbulent diffusion, which is significant for the survival of fish fry and thus for the strength of the year-class.

It is obvious that the following approaches would facilitate the prediction of the survival rate of the fry and of the later strength of a given year-class:

(a) the following-up of the changes in temperature in the spawning grounds,

(b) the following-up of the temperature in the region later occupied by the fry, with

(c) the following-up of the availability of plankton food, and

(d) a knowledge of the optimum temperature for survival of the fry of a given fish stock.

Again in this consideration the unique role of temperature is obvious. Actually, there are several ways in which the temperature can influence the survival of fish fry. The most important of these is probably its effect on the availability of food. Obviously the availability of zooplankton food suitable for fry at the appropriate time is related, not only to the abundance of phytoplankton, but also to the reproduction period of adult planktonic animals, which again is controlled by temperature.

The effect of temperature upon the rate of photosynthesis in the sea must be pronounced even when it is only indirect: the warmer the water, the faster the bacteria are able to remineralize the dead organic matter for reuse in primary production.

The yields of many of the major sea fisheries are widely variable from year to year, even from decade to decade. In a few cases these can be related directly to the strength of year-classes. In some other cases, these fluctuations are correlated to large-scale changes of the physical conditions in the sea. Among these, the secular changes in the temperature affect the distribution of various species considerably. The cod of the northern Atlantic is a good example in this respect: an increase in temperature seems to displace the spawning grounds northward.

The long-term temperature effect may be in reality only apparent. The cod catches of the Baltic Sea increased rapidly after 1983 without an analogous increase, say, in the neighbouring North Sea. Thus the phenomenon cannot be explained as a result of the warming-up of the seas; the casual relationship was much more complicated. First of all, we have to observe that in a sense the Baltic Sea is analogous to a fjord with a sill. The schematic drawing (Fig. 152) shows how the stagnant conditions frequently found in the deeper parts of a fjord may temporarily cease to exist. The observed warming of the Baltic waters was the result of an intensification of the atmospheric mean circulation, which (as indicated by Meyer and Kalle (1950) among others) resulted in 1937 in the plentiful penetration of less diluted, more saline water into the western and southern basins of the Baltic Sea. This penetrating water, being heavier than normal, displaced the lighter stagnant bottom water of the basins, with resulting reutilization by photosynthesis of the phosphates and other nutrients stored there. At the same time the newly arrived oxygen-rich waters led to a rapid increase of the benthos in the area. Both factors contributed to the heavy cod catches of the following years. Furthermore, one has to observe that the simultaneous increase in the salinity brought about a permanent increase in the stocks of Baltic cod.

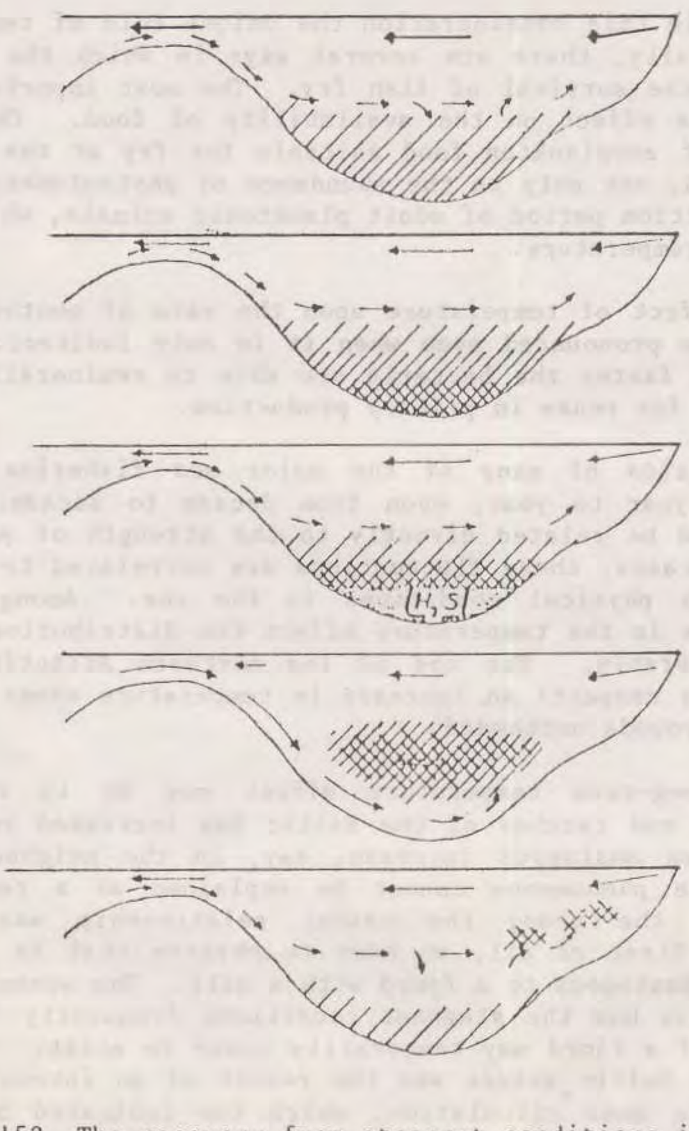


Fig. 152 The recovery from stagnant conditions in a typical landlocked basin.

Also the sharpness of the thermocline, that is, of a discontinuous layer of temperature, and the thickness of the mixed surface layer had a broad biological significance in at least two different ways:

(1) Because of the difference in density of the thermocline, sinking organic detritus has a tendency to remain at least for a while, forming a feeding layer for the zooplankton. Thus the thermocline becomes a layer where fish concentrate.

(2) In the tropical seas, for instance off the west coast of India, under certain circumstances the thermocline is very steep and the oxygen content of the water below it extremely low. In such regions fish are plentiful only above the thermocline. The changes in the depth of the thermocline cause alterations in the concentrations and catchability of fish in the surface water above the thermocline.

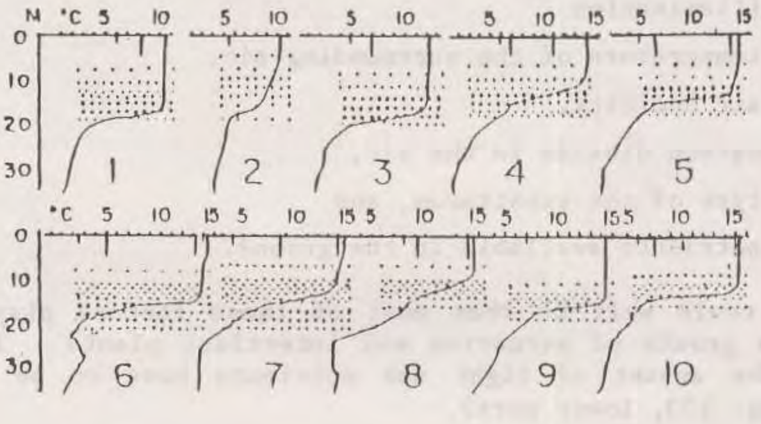


Fig. 153 The echograms and the vertical distribution of temperatures in the southern part of the Bothnian Sea in August 1956 (Sjoblom, 1961).

In this representation (Fig. 153) the sharpness of the thermocline in the Baltic Sea, as shown by Sjoblom (1961), is indicated by bathythermograph recordings, while the amount of life is shown by the simultaneous echograms indicating echoes from zooplankton and fish. The sharpness of the thermocline varies considerably, thus also affecting the fish and other concentrations at the thermocline, as can be seen from the presentation.

3.3 Salinity and osmotic pressure

The effect of salinity must be recorded also. The salinity variations in the offshore areas are relatively small but in coastal areas they are of considerable magnitude due to runoff. These variations affect the osmotic regulation of fish and determine, with the temperature, the buoyancy of pelagic eggs. Most fish are adapted to life in solutions of a relatively limited range of osmotic pressure. The well-known exceptions to this rule are the salmon and the eel.

3.4 Nutrients

On land (Fig. 153. upper part) there are quite a few factors which limit the photosynthesis and growth of plants, the dominant ones being:

- illumination
- temperature of the surrounding air,
- air humidity,
- carbon dioxide in the air,
- type of the substratum, and
- nutrients available in the ground.

It could well be that most of these factors play a certain role in the growth of estuarine and intertidal plants. In the open sea only the amount of light and nutrients have to be taken into account (Fig. 153, lower part).

Thus the availability of nutrients alone is the decisive factor in the primary production of the open sea, assuming that light is plentiful. Ordinarily, the nutrients available in the mixed surface layer are rapidly exhausted: they are used up by the growing phytoplankton and, finally, they are removed from the mixed surface layer by the death and sinking of organisms. The local run-off from the rivers may be a significant fertilizing factor but only in the estuarine and coastal waters. However, the large-scale renewal of the nutrients of the surface layer is possible only within the framework of vertical mixing or upwelling from deeper layers.

In connection with the nutrients one has to remember that some trace metals like iron, manganese, copper, zinc, cobalt and molybdenum are considered important for the growth process of marine organisms.

3.5 Primary production

Numerous efforts have been made to relate measurements of the rate of primary production to the yield of fisheries. The success has been limited because of the ambiguity of the principal method. However, the method now seems becoming ripe for standardization, as indicated by Steemann-Nielsen, the inventor of the method. On the other hand, as pointed out by Chapman, the difficulty with the thesis of primary productivity has been that very careful and long continued studies have largely failed to demonstrate any relationship between the standing crop of phytoplankton and the available standing crop of harvestable fish of any particular variety in any particular area. Also, the quantitative relation between zooplankton and pelagic fish is valid only in very general terms. In spite of these poor results, the production of organic matter by phytoplankton must be the basic condition for the existence of other forms of life in marine biotopes. Thus, there must, in general, be a relation between the basic organic

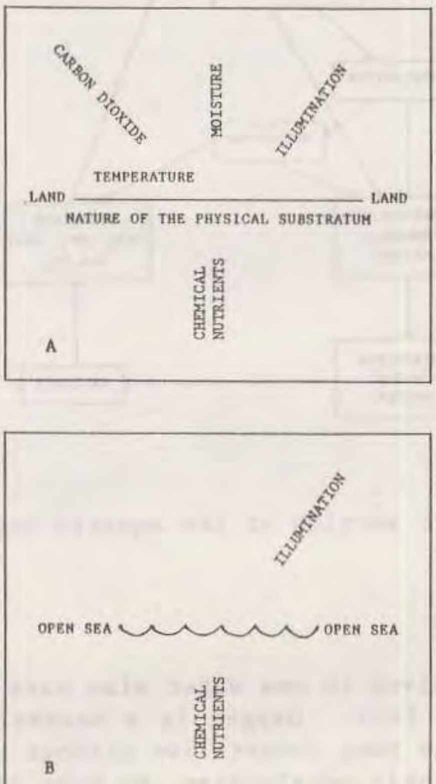


Fig. 154. The factors affecting the photosynthesis and the growth of plants on land (A. above and in the open sea (B. below).

production and the size of the population of other marine organisms that form the lower and even the higher links in the marine food chain. These relations are often indirect, over several links, and the correlations are difficult to trace because of time lags and transport by water movements.

The aquatic organic cycle is shown schematically in Fig. 155. It is necessary to emphasize that the concept of primary production, correct as such, is frequently related to the concept of such a stepped foodcycle, which is a very crude simplification of the actual condition.

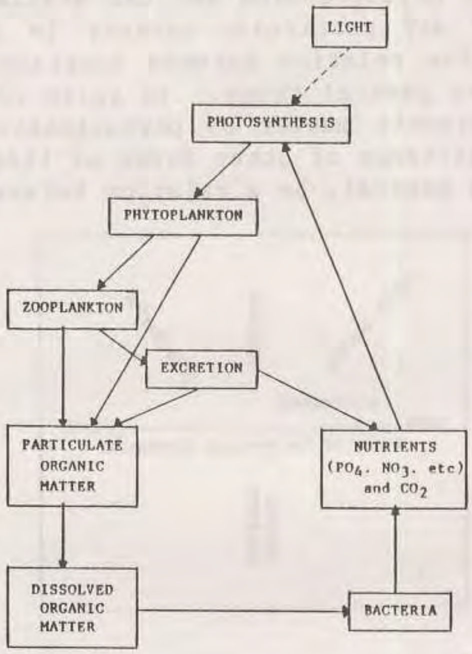


Fig. 155. Basic section of the aquatic organic cycle.

3.6 Dissolved gases

The gases dissolved in sea water also have a profound influence upon the well-being of fish. Oxygen is a necessity for fish, as for all other animals, since they cannot live without a supply of oxygen in their blood to ensure their metalbolism. We have already seen a diagram showing how the oxygen deficit occurs in many fjords, and similarly in the Baltic Sea, although not as equally pronounced. Fig. 156 presents schematically the distribution of dissolved oxygen in the bottom water of the Baltic Sea in May 1922, as shown by Schulz (1932). The large

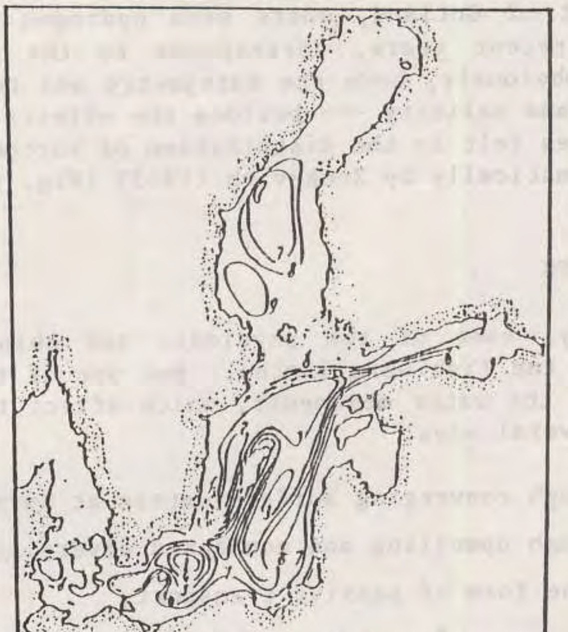


Fig. 156 Distribution of dissolved oxygen (ml/l) in the near-bottom waters of the Baltic Sea in May 1922 (Scmulz, 1932)

Fig. 157 Distribution of bottom communities in the Baltic Sea (as summarized by Zenkevich, 1963, from the presentations of various authors).

deficit area east of Gotland, where even hydrogen sulphide has been observed during recent years, corresponds to the deep part of the Baltic proper. Obviously, both the bathymetry and the distribution of dissolved oxygen and salinity ----besides the effects of biotic factors ----make themselves felt in the distribution of bottom community types, as presented schematically by Zenkevich (1963) (Fig. 157).

4. WATER MOVEMENTS

Previously, some of the physical, and abiotic environmental factors affecting the fish were listed. But one of the most important is still missing, the water movements, which affect the fish and their environment in several ways:

(1) through converging surface waters at current boundaries,

(2) through upwelling and connected diverging surface waters,

(3) in the form of passive transport,

(4) as a means for orientation, for instance, in connection with migratory movements, and

(5) through the dispersion of concentrations.

4.1 Converging currents

When the transition zone between two water masses is becoming narrower, frontogenesis is said to take place as the result of converging currents. This results in typical current boundaries at the surface, which are observed as:

- accumulation of floating foam, debris, etc.,
- current rips,
- change in the surface temperature,
- change in water colour,
- bands of calm and rough sea, modified waves and a confused sea,
- whirlpools,
- irregular steering of ships,
- sometimes roaring noises, or
- fog.

Fig. 158 shows the temperatures at a convergence zone in the equatorial Pacific, as observed by Knauss (1957)

No phenomenon of the open ocean is so eagerly sought out by pelagic fishermen as the interfaces between water masses, since the convergences cause a concentration of zooplankton, a resulting concentration of fish —— and of fishermen. At the same time, no feature of the ocean is so changeable as to location, sharpness and persistence as these interfaces. This fact, together with the great bilogical significance of these fronts, has brought fishery scientists and oceanographers into close collaboration in many fishing areas.

Experience has shown that many pelagic fish, when following the current boundaries, tend to concentrate in the pockets of these boundaries. This fact is utilized, according to Baral. (1961), by the Norwegian and Russian herring fisheries (Fig. 159) in the northern Atlantic and, according to Terada (1959), by the Japanese fishermen (Fig. 160) in the northern Pacific.

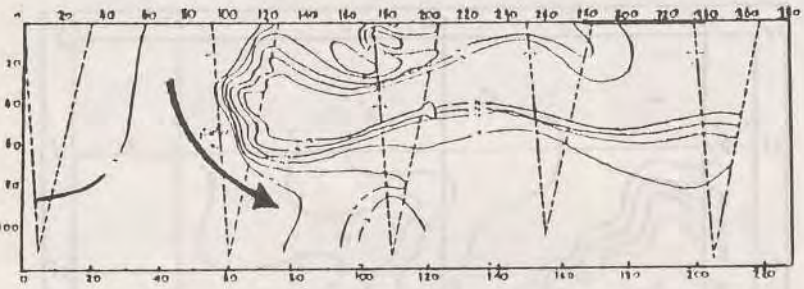


Fig. 158 An equatorial "front" plotted with no vertical exaggeration (according to Knauss, 1957). Temperatures are given in degrees Fahrenheit.

4.2 Upwelling and diverging currents

Upwelling brings nutrient-rich deeper waters into the euphotic zone and causes a stepwise invigoration of the whole food web in the area. Because of the diverging surface currents the organisms are usually not so concentrated as at the current boundaries; however, the areas of higher concentration are usually quite large.

Upwellings mostly occur:

(a) in the eastern parts of the oceans along the coast,

(b) in the boundary zones of diverging currents, and

(c) in the middle of cyclonic eddies.

This model (Fig. 161) by Hidaka (1954), taken as an example, shows how a relatively steady alongshore wind of the tropics brings about an upwelling mechanism. Moreover, a permanent ocean current along the continental shelf will bring about limited upwelling even when the horizontal flow is interrupted by outcropping islands or capes, or where the waters drift across submarine ridges or banks.

There is much variation in upwelling in every place where it has been studied so far. It is most important to expand the study of the upwelling areas to cover all oceans and seas.

It is very well known that, e.g., on the West coast of India upwelling may also have destructive effects.

(1) if upwelling goes on in an area with a sub-surface oxygen deficit layer below a sharp and shallow premanent thermocline, or

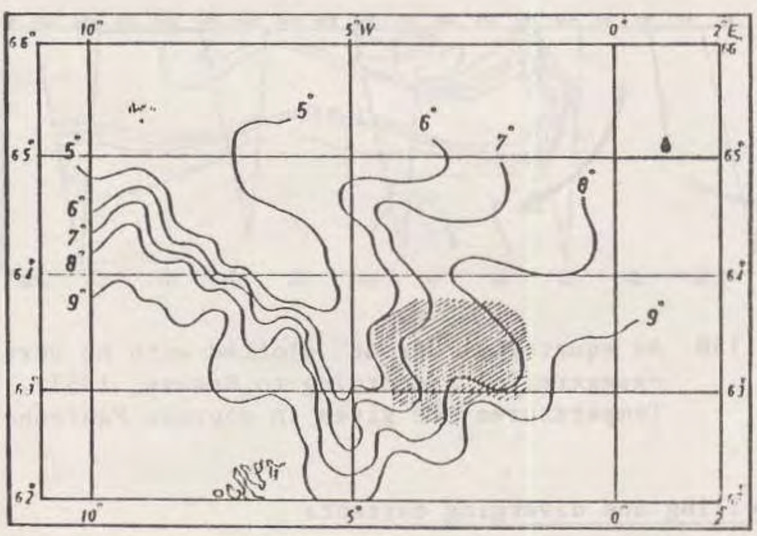


Fig. 159 Distribution of sea surface temperature and schooling of herring in the northern Atlantic in June 1959 (according to Baral, 1961).

(2) if the bottom waters, from which the dissolved oxygen has been consumed by the organic sediments, rise to the surface.

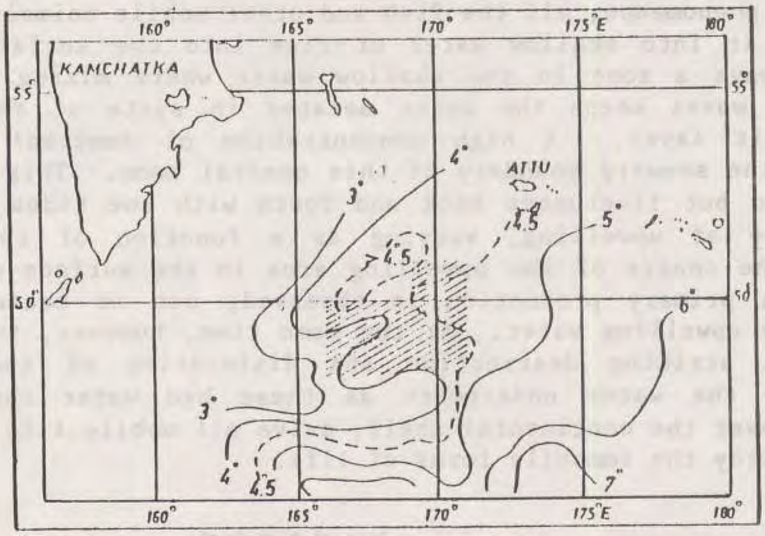


Fig. 160 Japanese high-sea fishing area in the zone of tongue like distribution of temperature in northern Pacific in July (according to Terada, 1959).

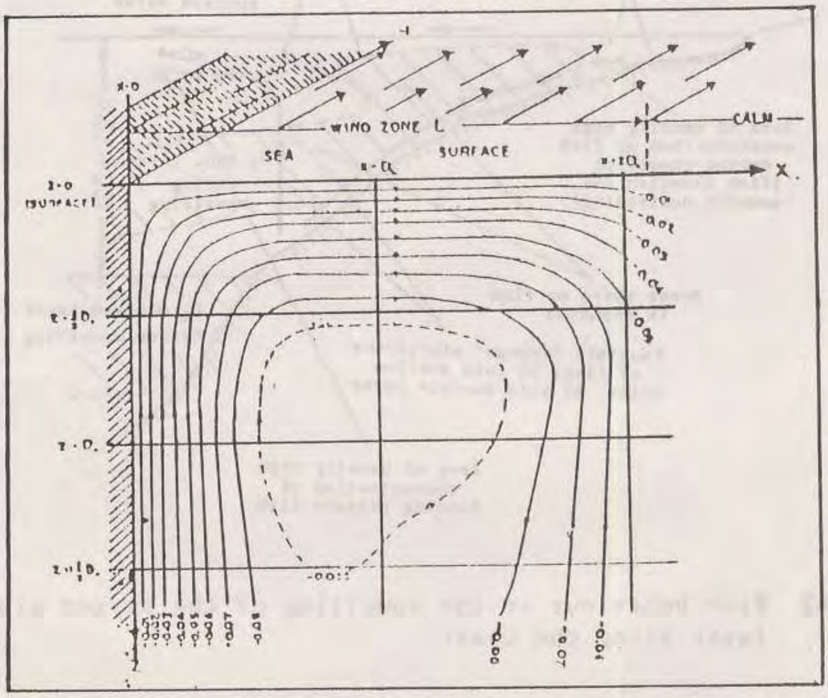


Fig. 161 Upwelling as induced by a wind blowing parallel to the coast, illustrated by the stream lines in the vertical plane perpendicular to the coast (Hidaka, 1954).

When the oxygen deficit layer (Fig. 162) starts to rise along the continental shelf (Hela and Laevastu, 1961), owing to the seasonal stage of the phenomenon, all the fish and other mobile animals migrate in front of it into shallow water or rise into the surface layer. There is always a zone in the shallow water where mixing by tidal currents and waves keeps the water aerated in spite of the rising oxygen deficit layer. A high concentration of demersal fish is gathered at the seaward boundary of this coastal zone. This boundary is not static but fluctuates back and forth with the tides and with the intensity of upwelling, varying as a function of the winds. Seaward of the centre of the upwelling area in the surface waters, a zone of high primary production is observed, set in train by the nutrient-rich upwelling water. At the same time, however, there goes on the most striking destruction and dislocation of the living organisms in the water underneath as these bad water conditions, creeping in over the continental shelf, drive all mobile life ahead of them and destroy the immobile forms of life.

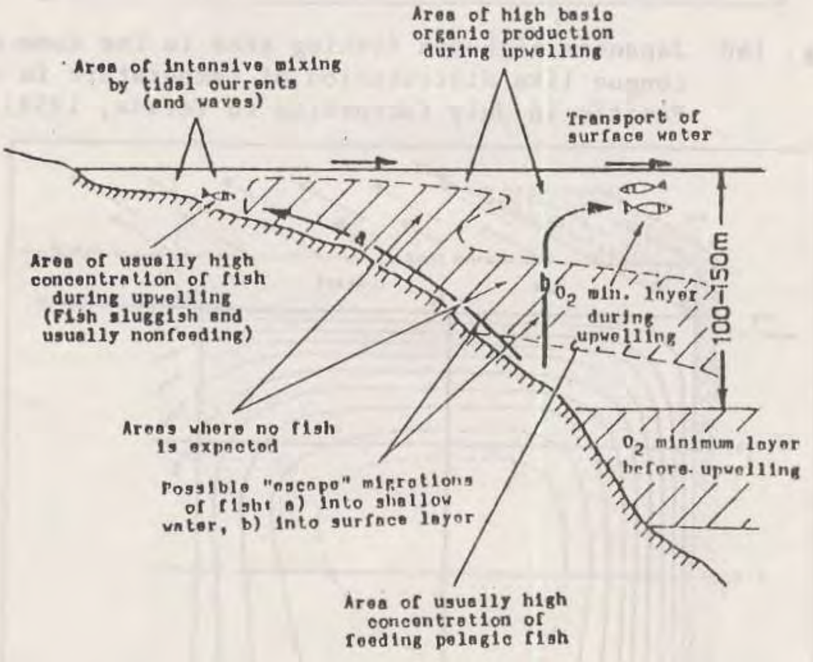


Fig. 162 Fish behaviour in the upwelling of the oxygen minimum layer along the coast.

The second type of destructive upwelling (Fig. 163) can be explained as follows (Hela and Laevastu, 1961). Under normal wind conditions the water passes over the sediments of the continental shelf rather quickly and the oxygen consumption per unit volume of water is relatively limited. However, certain cessations of the usually more or less steady upwelling and mixing may occur, if the weather is calm and the mixing by wave action therefore suppressed. Under these circumstances the water, now detained close to the bottom, is exhausted of oxygen and becomes stagnant. The fish, which usually feed around the outer edge of the normal upwelling area, migrate towards the coast during the cessation of the upwelling. When the upwelling starts again, the bottom water, now low in oxygen, is brought to the surface relatively close to the shore, with the possible result of mass mortality of fish.

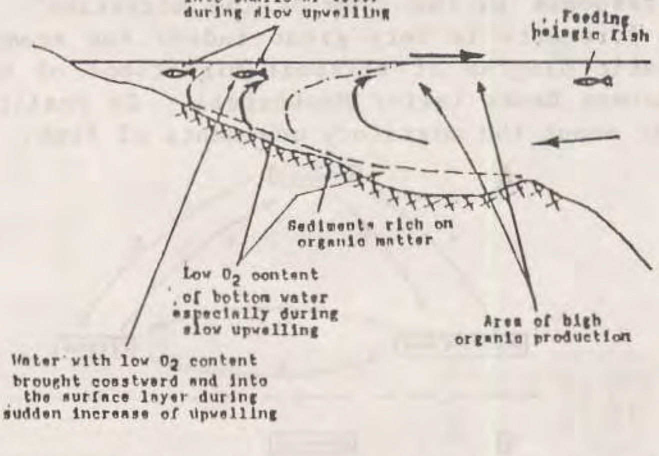


Fig. 163 Upwelling with oxygen consumption close to the bottom.

5. MIGRATIONS AND THEIR CAUSES

Schematically, the migratory movements of marine organisms may be divided into:

(a) seasonal migrations,

(b) diurnal vertical migrations, and

(c) protective migration.

The seasonal migrations (Fig. 164) consist of

(a1) feeding migrations,

(a2) spawning migrations, and

(a3) overwintering migrations.

In the interest of fisheries the study of migration problems is of great value, since practically all fish migrate in shoals, which are easier to catch than scattered fish. What do we know of fish migrations?

(a) Fish embark on seasonal migrations under certain definite conditions, firstly when the state of the fish itself (state of nourishment, fat content, state of gonads, etc.) makes the start physiologically appropriate, and secondly when the environmental changes have reached a stage necessitating migration.

According to Nicolsky (1963), "forecast of the hydrometeorological conditions makes it possible to establish the time of appearance of the particular hydrographic "signal", like a drop or rise in temperature, a particular light intensity, etc., which serves as the natural stimulus, evoking in the fish, which is prepared for migration, a response in the form of the migration". The practical value of such forecasts is very great indeed for example. Fig. 165 shows a schematic diagram of seasonal migrations of herring and its food on the Murman Banks (after Manteufel). In reality, very little is known so far about the migratory movements of fish.

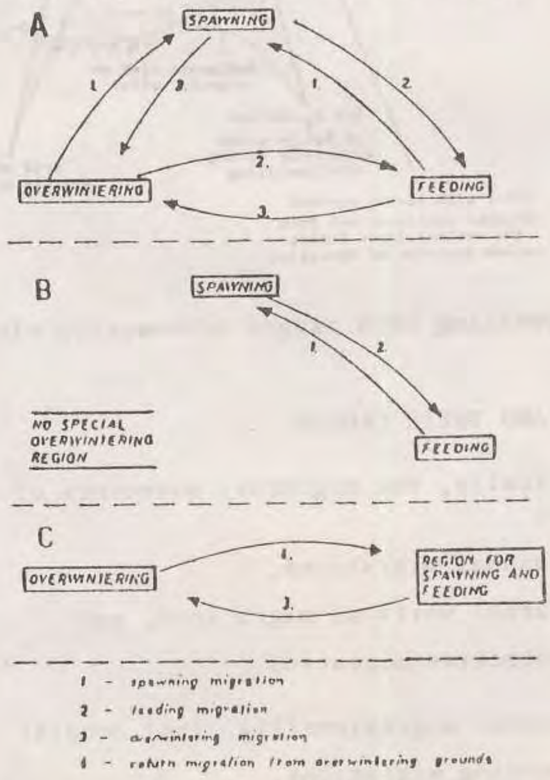


Fig. 164 Schematic presentation of the various types of seasonal migrations.

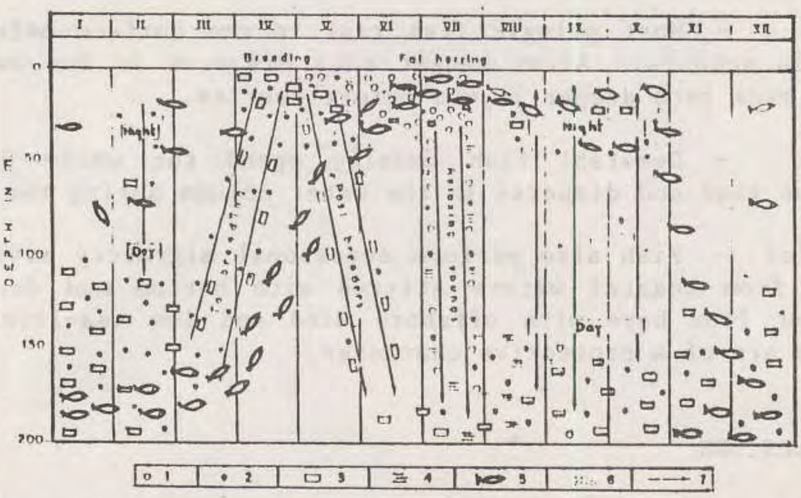


Fig. 165 Scheme of the seasonal migrations of herring and its food (Calanus and Euphausiids) on Murman Banks (after Manteufel). 1, *Calanus finmarchicus*, stages V-VII; 2, *Calanus finmarchicus*, stages I-IV: 3, adult *Thysanoessa;* 4, larval *Thysanoessa;* 5, herring; 6, high phytoplankton concentration; 7, migrations.

(b) Fig. 166 shows how the diurnal vertical migrations of marine animals and connected aggregations at certain levels are different for different fish groups. In general we may state that:

- Light undoubtedly plays a considerable role in orientation.
- The diurnal vertical migrations of fish are to a great extent feeding migrations.

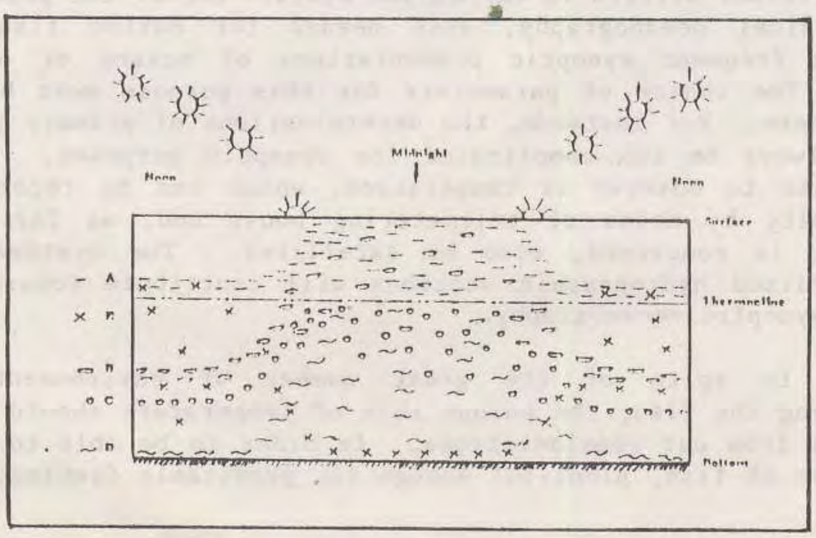


Fig. 166 Schematic presentation of different types of diurnal vertical migrations.

- Most pelagic fish rise to the surface before sunset, usually in schools. After sunset they disperse in the water column and sink back into deeper layers before sunrise.

- Demersal fish usually spend the whole day on the bottom but rise and disperse in the water column during the night.

(c) - Fish also perform occasional migratory movements, for instance from coastal waters stirred with bottom mud during stormy weather or from bays with offshore wind and low sea-levels. These movements are of a protective character.

6. CONCLUSIONS

Our considerations have certainly shown that the actual relationships between the organism: the fish and its environment are complicated. It is unlikely that in practice any full-scale multiple correlation method will provide a useful means to master the relationships quantitatively and to predict their effects. Therefore, instead of the true relationship and correct models, simplifications and simplified models, must be used. At the same time, the weakness and pitfalls of the simplifications must be remembered.

In the interests of marine fisheries, progressive steps towards understanding the dynamic behaviour of the ocean must be based upon the study of the interactions between atmosphere and ocean. Following the instinctive thinking of every fisherman, the effects of anomalous phenomena in the atmosphere are to be found in the seas and their further effects in the marine biota. One of the practical goals of physical oceanography, also needed for marine fishery, is to achieve frequent synoptic presentations of oceans or of parts of them. The choice of parameters for this purpose must be made with great care. For instance, the determinations of primary productivity will always be too complicated for synoptic purposes. The easiest parameter to observe is temperature, which can be recorded without difficulty by means of telemetering buoys and, as far as the sea surface is concerned, also by satellites. The systematic use of standardized hydrographic sections will contribute towards the same goal, synoptic oceanography.

In spite of the great number of environmental factors affecting the fish, the unique role of temperature should have become obvious from our considerations. In order to be able to predict the presence of fish, plentiful enough for profitable fishing, in a given area:

(1) the optimum temperatures of all economically significant species must be known,

(2) a sufficient number of frequent hydrographical and meteorological observations must be made to provide information on the location of critical surface isotherms, and, furthermore, on the areas of sharp temperature gradients, on the water pockets formed by meandering eddies of the currents, and on the depth and sharpness of thermoclines, and

(3) changes in the hydrographical conditions must be predicted.

When the marine biologists and the oceanographers in co-operative research have finally ascertained the relationships existing between changing environmental conditions and the behaviour of fish, the oceanographers must continue to observe the environment and especially its short and longterm changes. The results of this observational work, with the behaviour relations ascertained, will be used to make the forecasts needed by the fisheries of the world. This has long been the ultimate goal of fishery oceanography and the hope of fishermen. It is evident that science is now moving into a new era where this goal will be much closer than ever before.

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