FISHING TECHNIQUES

Compilation of Transcript of Lectures
Presented at the Training Department, SEAFDEC

By

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Somyos.

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PREFACE

As the food shortage is one of the worldwide problems, the need of securing food supply is becoming more important recently.

Recognizing the vital importance of increasing food supply and of improving the nutritional standard, especially of increasing the supply of animal protein, five Southeast Asian countries and Japan formed in 1967 the Southeast Asian Fisheries Development Center, SEAFDEC, whose purpose is to contribute to the development of fisheries in the region. SEAFDEC is consisted of three departments, namely the Training Department in Thailand, the Research Department in Singapore and the Aquaculture Department in the Philippines.

The main objective of the Training Department is to train senior fishery technologists of the member countries. More than one hundred graduates have been sent out from the Department so far.

The authors of this textbook, Dr. M. Nomura and Mr. T. Yamazaki, were engaged in the education of fishing technology at this Department for six and seven years respectively since the establishment of SEAFDEC. This textbook is mostly composed of the transcript of lectures by these two experts, thus, it may be called fruits of their past experiences.

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

Shinsaku Hogen
President,
Japan International
Cooperation Agency

FOREWORDS

Out of training curriculum of the lectures in the Training Department, so far the fields of fishing techniques are included in F2, F3, F4 and F5 as stated later on. Equivalent to these items of curriculum the authors gave a series of lectures during the period of their stay in SEAFDEC, a total of 6 years from May 1968 to March 1972 and from Sept. 1973 to Nov. 1975 of Dr. Nomura and a total 7 years from March 1969 to Dec. 1975 of Mr. Yamazaki respectively, the compilation of which has been formed into this textbook. Although it is regretable that there was no time enough to cover all items in this textbook within such a limited period, the authoris intend to prepare more texts later on. This textbook, however, has been very kindly printed through the courtesy of JICA, Japan. The author himself never thought that he could present the lectures to trainees in English over such a long period of time.

The initial stage in the establishment of SEAFDEC, a lot of unsettled matters used up much of our time preventing us from preparing documents and texts etc. Each transcript of lectures was made in accordance with the progress of discourse at convenient times within each part of the curriculum. The readers are requested to remember then that this textbook, therefore, is so to speak an accumulation of these papers, and not necessarily a separate compact volume. In our Fishing Course curriculum at SEAFDEC, F1 is equivalent to Basic Science, F2 ~ F5 to Fishing Techniques which are covered in this textbook, F6 to Navigation and Seamanship, F7 to Oceanography and Meteorology, F8 to Marine Electronics and F9 to Marine Engineering. In each part of the curriculum, the title of the lecture corresponding to it is given in the *Table of Contents.*

The trainees who came from the Philippines, Malaysia, Singapore, Thailand and Vietnam were requested to have suitable qualifications such as graduation from high school in their own countries, experience for more than 2 years in fisheries, and a sufficient command of spoken and written English. The level and contents of the lecture, therefore, should be suitable for the level of these trainees which would be higher than the level of trainees in vocational fisheries training. Off shore, or deep sea fisheries techniques were emphasized.

Finally, in the process of preparing lectures, the author was so much obliged to a large number of contributions by many scientists throughout the world. Particulary he would like to give deep appreciation to the courteous Dr. M. Tauchi, Dr. H. Miyamoto, Dr. T. Kawakami, Dr. C. Hamuro, Mr. T. Koyama, Dr. M. Ogura, Prof. Dr. v. Brandt and Dr. J. J. Shärfe of FAO, who enlightened the author by their contributions and also encouraged him by affording significant advice.

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2.1 Fisheries in general

1. Total catch amount of fish

Fisheries are classified by type of water: freshwater and sea water. Another classification is based on the object – as in tuna line fishing, salmon gill net fishing, sardine purse seine fishing and so on. Sometimes the fishing method is used as the classifying characteristic: behave with light, palarizing, traping, harpooning, luring and so on.

According to the FAO statistics, most of fish are caught in the sea, with only about one tenth coming from freshwater production. Since late 1930s, the total world catch has been increasing at a rate of some 7 percent per year and recently seems to be doubling each decade. During this time, the world total catch in tons has been as follows:

1938	23,000,000 tons
1948	21,600,000
1958	36,600,000
1968	71,000,000

The world catch in 1970 of approximately 74,000,000 tons represented an increase of 6 percent. It has also been found that the fishing industry can damage stocks, sometimes permanentely, if it takes large catches when fish stocks are low due to natural fluctuations. Prof. Dr. von Brandt points out that from 100,000,000 to 200,000,000 tons is realistic world products for the 1970s.

2. Fishing in general

Fisheries is carried on in all types of waters, in all parts of the world, except where are impeded by depth or dangerous currents, or prohibited by law. In seawaters, fishing is the oldest form of marine expolitation.

Fisheries can be done in a simple manner with small vessels, little technical equipment and little or no mechanization as in small local, traditional or artisanal fisheries. It can also be done on a large scale with powerful deep sea vessels, and sophisticated mechanical equipment similar to that of modern industrial enterprises.

Man takes both plants and animals from the sea. Two types of fish are caught: demersal, living at or near the bottom, although sometimes in midwater; and pelagic living in the open sea near the surface. Cod, snaper, flatfish, croaker etc. are common demersal fish. Sardine, herring, tuna, skipjack, mackerel are common examples of pelagic fish. Both demersal and pelagic fish can sometimes be found far from coastal regions. Other aquatic animals that may be the object of commercial fishery include crustaceans (lobster, shrimp, prawns, crabs, crayfish) and mollusks (oyster, scallops, mussels, squid, octopuses). Certain mammals (whale, porpoises, seals), reptiles (serpents, crocodiles), amphibians (frogs), many types of worms, coelenterates (coral, jellyfish), and sponges are also regarded as marine and freshwater products.

The important water plants commercially obtained in seawater and freshwater are algae. Seaweed is harvested from the water and collected on the seashore. Algae play an important role in many countries, not only as human food but also as fodder for cattle, as fertilizer, and as a raw material for certain industires. Other water plants such as laver, undaria, kelp, rush and reed are also harvested. Some of the above animals and plants are cultivated in natural waters or in artificial ponds and lakes.

3. Development of fisheries

Fishing is a form of primary production. Food gathering people first obtained fish and other aquaitic products in the shallow waters of lakes and along side seashores, in small ponds remaining in inundation areas, in areas with ebb tides, and in small streams. It is believed that in the earliest times, fish were rarely caught because of the inadequacy of fishing gear. Shellfish, however, can be gathered easily by hand and large prehistoric shell mounds indicate their importance as food. Such hills are found in many parts of the world, sometimes also on inland lakes.

In earliest times most foodstuffs were used at once and not stored, but as expanding populations increased food needs, techniques were developed for preserving fish by drying, smoking, salting and fermentation. It became desirable to catch large quantities, and specialized equipment was devised. Individual fishing was replaced by larger and more effective gear.

Fishing equipment and methods improved through the centruies. Herring and sardine were caught in huge number. Whaling with large fleets began in the 17th century, both in Atlantic and in the South Pacific.

Mechanization came to fishing in the 19th century. The steamer replaced sailing boats in sea fisheries during the final quarter of that century, and was supplanted in turn by motor vessels. Small fishing boats became motorized at the beginning of the 20th century. In the 1940s, instrumentations – such as the echo sounder (for vertical searching) and, later, sonar (for horizontal searching) – were introduced to fisheries. The total catch of fish and other living aquatic products tripled from 1948 to 1968. Today, some industrial countries lack sufficient manpower for their fisheries and are attempting to make mechanization and automation by computers.

The development of commercial fishery is largely due to the development of fishing techniques that grew in response to various demands, especially the growth of the market. Larger catches could be obtained by increasing the number or the size of the fishing gear. Simple lines fitted with one or several hooks were replaced by longlines with thousands of hooks. Single small traps were combined. Nets were greately enlarged; netmaking machines were invented and produced netting in large quantity. Mechanical netmaking brought replacement of the old local fibers as linen and hemp, with cotton. But all such natural fibers, especially those of cellulose, begin to rot in time; thus, the introduction of rotproof nets made of synthetic fibers represented a major advance. In some certain fishing gear, usual knotted netting was replaced by knotless netting.

The development of fishing gear in another direction stemmed from the desire to fish in deep water inhabited by larger fish. Fishing in deeper waters required not only gear adapted to the depth, but also suitable vessels, although today properly equipped fishermen in small boats can fish at considerable depth. Fishermen sometimes fish in such deep waters. A modern fishing gear and vessel, such as a stern trawl or purse seiner, is a specialized, sophisticated piece of equipment in which vessel, gear, and crew act as a unit. Originally, bottom trawling was done out to the edge of the continental shelf, where the depth is about 200 meters; today it is done up to 600 and even 1,000 meters. The time required for shooting and hauling gear, however, is an economic barrier to fishing in great depths.

With the extension of fisheries in noncoastal waters and the development of efficient refrigeration methods, long distance fishery developed. Trawlers from northern Europe, Japan and the Soviet Union are making would wide fishing trips.

As fishing gear increased in size and weight, more people were needed to handle it. Yet it was not until the end of the last century that mechanization of fishing techniques began with winches and pulley blocks. Power-driven winches were introduced as fishing gear at the end of the 19th century, but it was many years before specialized hauling devices, such as rope-coiling machines and power driven rollers, facilitated easier hauling of netting. In the beginning of the 1950s, mechanization took a great stride foreward in purse seining, when the power block was invented for hauling the net. Another important hauling device was a power driven drum to haul and store seine nets, gill nets, purse seines, and the large trawl net. The Japanese introduced drums in longline fishing for tuna. A trend of big stern trawler in the early 1970s was toward full automation, with the help of computers that will supply information to control speed of boat, navigation, fish searching and gear handling.

2.2.1 Outline of fishing gear and method

The trawl net, surrounding net and gill net are explained in detail in other parts of this text book.

1. Trawling or dragging gear

Dredges are generally used in shallow water by small vessels, although a deep sea dredge is operated by research vessels at depths of up to 1,000 meters. The simple dredges in sea fisheries are hand operated. Fitted with a stick up to five meters long, they resemble rakes combined with a bag for collecting the catch – usually mollusks or crustaceaus. Heavier dredge with a triangle or quadrangular iron fram may be towed along the sea floor by small vessel or pulled some distance from the shore or from an anchored vessel and then towed back with a winch. For digging out mollusks, some of dredges have iron teeth on the lower edge of the frame. They may also have a pressure plate on the upper part and chains on the lower part, depending on the catch sought. The bag of the dredge is made of wire rings that have good resistance to friction and of hard netting. Usually more than one dredge is operated by a vessel, and they are towed with the help of outriggers. The great disadvantage of dredging is that much of the catch is damaged, wasting of effort and needlessly killing of fish.

Trawling in sea fishery can be done by small vessels. More important, however, are fleets of highly mechanized trawlers whose gross registered tonnage may reach 5,000 and whose horsepower approaches 6,000. The trawl is a towed net bag with a wide opening at the mouth and closed end. The mesh size of the opening is normally 80 to 240 mm. The cod end can have meshes of 15 millimetres according to the species of fish or shrimp sought. The trawl is designed in a smooth funnel-like shape to guide the fish into the cod end. To keep the mouth of the trawl open, a large horizontal beam may be used. Up to 12 metres the beam is based on two guides that glide over the bottom. This beam trawl catches flatfish using heavy chains, called tickler chains, which are dragged along the sea floor in front of the net opening between the two gliders to frighten the fish from the bottom into the trawl. Though beam trawls were the original gear of steam trawlers, today they are used by smaller vessels only. Beam trawls are usually towed in pairs, one on each side of the vessel. Such an arrangement can considerably decrease the stability of the vessel and is dangerous except in craft specially designed for the purpose. Another method involves two vessels stretching the horizontal opening of a trawl between them. Two vessels have more power to tow a bigger trawl at greater speed. It is called bull trawling. The skippers of the two vessels must cooperate very closely. The most recent and presently the most important method for spreading a trawl opening employs two large boards or metal plates (otter boards), rectangular or oval in shape, which are attached to each side of the net and makes the net spread horizontally between the tips of two wings. This is called otter trawl.

Midwater trawling involves dragging the trawl with one or two vessels in the area between the ocean bottom and its surface to catch pelagic fish. Depth of the trawl is regulated by the length of the towing warps and speed of the towing vessel. With longer warps and lower speed, the trawl sinks; it rises with shorter warps and higher speed. The fisherman attempts to trawl at the depth where fish are observed.

Semipelagic trawl is that in this technique the otter boards remain in touch with the bottom but the trawl floats at some distance above it. Semipelagic trawls were constructed because fish often are concentrated at a short distance from the bottom outside the range of the usual bottom trawl with a low vertical opening. To overcome this difficulty, a higher opening of the trawl is needed. Though the opening of a bottom trawl can be stretched vertically by various means, such stretching decreases the horizontal width of opening. Some modern bottom trawls specially constructed with 4 or 6 seams of net designings have a high vertical and horizontal opening, and they are considered the best available gear for bottom trawling.

2. Seine nets

Mentioned above as important large-scale gear in freshwater fisheries, seine nets are similarly employed in beach seining, where fish shoals are near to beaches. Large beach-seining operations for sardine-like fishes and other species are carried on in the Indian Ocean. The importance of this method has decreased as pollution has cut the available stocks of fish in this region and as manpower costs have risen: not all fishing methods lend themselves to mechanization. More successful are boat seines or Danish seines. The gear consists of a typical seine net with a large bag and long wings connected with long towing ropes. The ropes act both to keep the net open and to herd the fish toward the net bag. One of the ropes (about 2,000 metres long) is tied to an anchored buoy. The other rope is tied to the vessel, which steams in a wide circle, returning to the buoy and capturing fish in the wings and bag of the net. Next, the vessel tows the ropes and net and hauls both ropes together until the net bag is taken on board. Special winches and coilers for the long ropes are situated in fore-and-aft position on the deck. These coilers, together with large quantities of coiled rope, are used for Danish seining. This method used in northern Europe for flatfish and cod, and in Japan, has become an important method of inshore fishery for bottom fish.

3. Surrounding nets

The most important sea-fishing gear is the surrounding net, represented by the older lampara nets and the more modern purse seines. Both are typical gear for pelagic fish schooling in large and dense shoals. When these nets are used, a shoal of fish is first surrounded with a curtain or wall of netting that is buoyed at the surface and weighted at the bottom. The lampara net has a large central bunt, or bagging portion, and short wings; the school of fish is worked into the bunt and captured. With the purse seine, once the school is surrounded, the bottom of the net is closed by drawing a line through purse rings attached to the line; the fish are then concentrated and removed by a dip net or are pumped aboard the fishing vessel.

4. Gill nets

Quite important in commercial sea fisheries, gill nets are sometimes operated in large sets thousands of metres long. These generally drift with the vessel or are set as anchored nets in long rows at or near the bottom of the sea. Gill nets are used for many pelagic fishes, such as herring, salmon, sardines and related species, mackerels, sharks and tuna. They also are used for many bottom fishes – cod, Alaska pollack, and others. For cod, Icelandic fishermen set up to 90 nets, each about 50 metres in length, in depths up to 180 metres. About 15 nets are generally set in combination anchored on each end and marked by floating buoys. Though these nets are checked daily some have been lost in storms, leading to complaints of damage to cod in the area.

5. Drift nets

These are widely used to catch pelagic sea fishes. In northern Europe, before the introduction of trawling, drift nets were the most important method of deep-sea fishery. In the old herring fishery of northwestern Europe, drifters commonly set more than 100 nets, each about 30 metres in length. Thus a fleet of drift nets might measure three or even four kilometres. The nets are set in the late afternoon to catch the herring as they ascend in the evening from ocean bottom to higher water levels. During the night the vessel drifts with the nets like a buoy. Hauling, done by hand or with mechanical aids, begins at midnight and when big catches are taken, can continue until late morning. The fish are shaken out of the meshes by hand or with shaking machines. Salmon drift net is one of the most important fishery in northern Pacific Ocean under motherboat system of fishing by Japan.

6. Entangling nets

Similarly operated are entangling nets, single or double walled, and three-walled trammel nets. These are used in sea fisheries for hake, shark, rays, salmon, sturgeons, halibut, plaice, shrimps, prawns, lobster, spiny lobster, king crabs, etc. Single-walled nets are used in the southern part of the Caspian Sea and in the Black Sea to catch sturgeons by entangling about 150 sturgeon nets in one row perpendicular to the shoreline.

The most important sea fishery for crustaceans is the king-crab fishery in the northern Pacific. For the Japanese, who use entangling nets, this is a very important distant fishery ranking with whaling and tuna and salmon fishing. Originally carried on close to shore, king-crab beginnings in the 1870s. The old land stations for processing were replaced by floating factories that accompanied the fishing vessels. The entangling nets are set on the bottom, sometimes 200 nets with a total length of ten kilometres in one row. Larger catching vessels set 1,200 to 1,300 nets a day usually in parallel rows about 500 metres apart. Nets stay in the water from five to seven days and are hauled by small open vessels with motor-driven reels, which can take from 2,500 to 3,000 nets per day out of the water. When hauling, the floats and sinkers are united and the entangled king crabs are taken from the netting. The catch and nets are then transported to the mother ship, where the catch is processed and the nets cleaned, an operation that may require 30 minutes per net. Large racks for drying and cleaning the entangling nets are used. A single fishing unit may own a permanent set of 15,000 to 30,000 nets.

7. Lift net

The net is generally put in the water to wait the fish school naturally in the center of the net or induce them by giving baits or fish gathering lamp. Sometimes fish schools are frightened into the net by special long lines with wooden pieces operated by other boats, and if the fish school is at the center of net, fishermen try to lift the net in a particular way. The shapes of nets are square, rectangular, round, etc., with either floats or leads, or both. Most nets have their own cod end or bag part to catch fish at the end.

The classification of lift net are as follows:

- Floating lift net
  - Stick held dip net
  - One-boat lift net
  - Eight angle net (two-boat lift net)
- Bottom lift net
  - Four angle dip net
  - Three-boat lift net
  - Four-boat lift net
  - Eight-boat lift net

1) Stick held dip net (Fig. 1)

The gear consists of net, stick or pole, and rope. The net is a sort of square lift net, and is made of synthetic fiber thread. The size of gear varies according to the fishing boat used. In case of small type, its upper part is held by a bamboo stick or pole and in case of the net of large type, by a float, and its lower part is weighed down by weights.

In operation of net, the net is set by a fishing boat in the fishing ground. Fish are lured into the net by lights or by dropped baits, and then they are scooped. Saury fishing is a typical stick-held dip net fishery operated with aid of luring lights at night. The fish school are first attracted by lights at one side of the fishing boat, then lured by a change-over switch operation, the fish turn in group to the other side of the boat where the net has been set, and are entrapped therein.

2) Eight angle net (or two-boat lift net) (Fig. 2)

The gear consists of net, rope-float and sinker. The main net and rope are made of synthetic twine. The length of float line is about 70–80 m and that of the sinker line 35–40 m.

The net is operatd by 40–60 fishermen. In daytime operation, sometimes they use scaring long line which has a lot of wooden pieces attached to the main line for frightening the fish school into the net ("Katsuranawa" in Japan). In night time, the gear is operated by several boats including net boats (2) and light boats (2). The netting boats are used for towing a little bit to the current when extending the net opening or else they are fixed by anchor, and the nets will be opened against the current. The light boats lure fish schools into the nets.

3) Three-boat lift net (Fig. 3)

The square net is laid out in the bottom layer or close to the sea bottom. It measures 60 m on the float line and 70 m on the right and left sides. The type of net is usually rather small in structure, compared with other types of lift nets. Fishermen in three boats set the net for the current and wait the fish to enter. The net is held by two boats on the right and left sides and the other on the lead line. When the fish are seen entering over the net, the net is raised by these boats. The fishing grounds are normally 20 m in depth, where the current is moderate.

4) Four-boat lift net (Fig. 4)

The square shaped net is the same with four angle dip nets but larger in size (50 square meters). The mesh size varies from about 1.5 to 3 cm stretched.

Four boats anchoring near the four corners of the net are moored in a square formation. The net is lowered in the center. A fifth boat of small size moving over the center of net scatters bait in the water to lure fish into the net. When plenty of fish are seen gathering in the net, it is raised.

5) Eight-boat lift net (Fig. 5)

The square net measures 200 m. in circumference. The net is laid out with eight boats in the water where fish migration is expected. Immediately after the riding of fish onto the net is informed of by a watchman on land, the net is lifted up, driving the fish forward. The fishing ground is located in the coastal waters of about 30 m in depth. Fish such as mullet is extensively caught because they migrate along almost the same course along the coast where the net is set waiting.

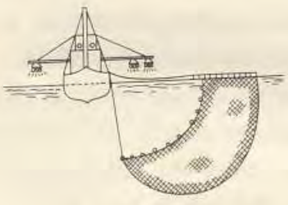
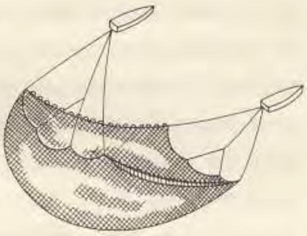


Fig. 1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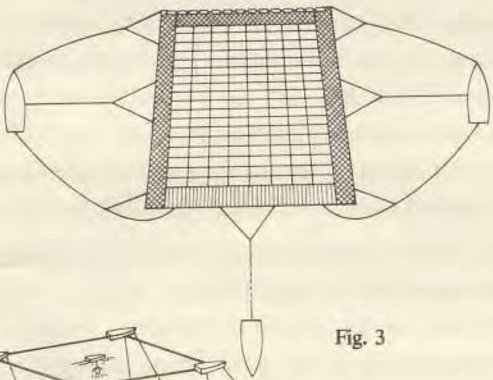
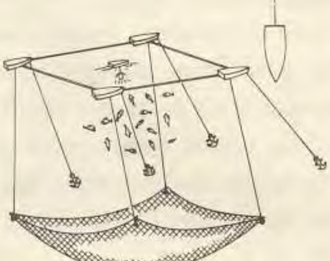


Fig. 3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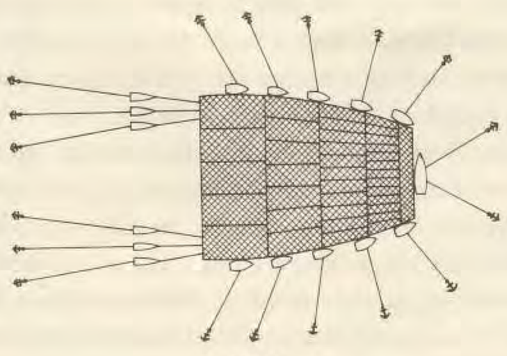


Fig. 5

8. Trap

There are only a few areas in the world where water or weather conditions prohibit the use of traps. A single small vessel can operate hundreds of traps, though lack of storage space may cause difficulties. Thus collapsible traps of netting of wire framework are preferred not only for fish but also for crustaceans. Many plastic traps are made today, especially for lobster. Some can be dismantled for easy transportation. As in fresh water, fyke nets can be set in long rows or in connected systems. Commercial sea fisheries set long rows of pots or framework traps by the longline system; i.e., single pots are tied in branch lines to a main line. Hauling is accomplished with small hand-operated or motordriven winches. More important for catching fish in commercial sea fisheries are the big wooden corrals, or weirs, and the large pound nets. The oldest type may be the Italian tonnara, used in the Mediterranean for tuna from the Bosporus to the Atlantic. Very big and elaborate trap nets are used particularly along the coast of Japan catching yellowtail and other pelagic fishes. For salmon fish off the Pacific and Atlantic coasts of North America and Japan traps are also used. The difficulties in setting large traps lies in placing them on the bottom. If the water is not deep and the bottom is not hard, the weirs can be held by sticks or piles. Where the water is deeper and the ground is hard or rocky, the weirs must be anchored.

The trap net ordinarily consists of three parts, namely bag net (or main net with bag net), barrier net (or playground net or fence net) and leader net. But there is a variety of shapes, i.e., bag net, used for both entrapping fish and as playground net with leader net. The net is set in a fixed position for certain periods of time waiting for the fish to enter the net, so nets are fixed by anchors, sand bags and floatings. The classification of fixed nets are as follows:

- Keddle net
  - Large set net of triangular shape (Fig. 10)
  - Large set net oblong or actagonal in shape (Fig. 11)
- Set net with trap net (Fig. 12)
- Pound net (Fig. 13)
- Bottom fixed set net (Fig. 14)
- Barrier net (Fig. 15)
- Fyke net (Fig. 16)
- Trap net, screen labyrinthine net (Fig. 17)

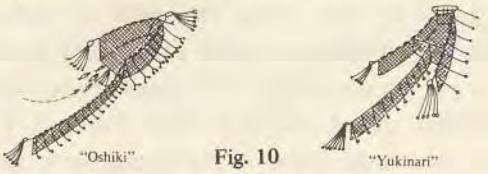
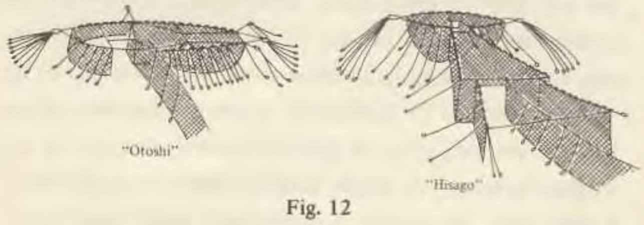


Fig. 10

Fig. 11



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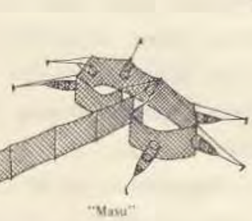

Fig. 13

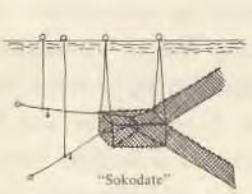

Fig. 14

Fig. 15

Fig. 16

Fig. 17

9. Pole and line

Line fishing at sea is very popular, not only in traditional fisheries with small boats employing a limited number of hooks but also in industrial operations with large vessels or fleets using thousands of hooks. For centuries, line fishing was carried on in coastal waters and far at sea in the dory fishery still famous today. A sailing mother ship carried the dories from Portugal, France, Canada and United States to the Grand Banks for cod. The one man dory operated near the carrier setting long line and sometimes fishing with handlines. In the evening the catch was carried back to the mother ship where each man prepared his catch for salting.

Some large scale modern enterprises also fish with hooks and lines, sometimes in far distant waters, as for tuna and halibut. Pole and line methods are used in Tropical Pacific and Atlantic waters to catch young bluefin and yellowfin tuna and smaller tuna species – such as albacore, skipjack, bonito and little tunny. The pole, general bamboo, ranges in length from two to ten meters with a line of roughly the same length. Hooks of various sizes are barbless to facilitate baiting and removing the captured fish. To hold on to the pole, a rod rest made of canvas, leather, or old rubber tires is generally used. Depending on the size of the vessel, the crew may number 30 or more. A large crew is needed, since fishing time may be limited and maximum possible number of rods must be worked. If larger and heavier fish are sought, two, three or even four poles may be linked to a single hook. In this case the fishermen must cooperate closely. The tuna is attracted and kept near the vessel by "chumming", throwing live bait overboard. The bait is kept alive on board in special tanks in which sea water circulates constantly. Bait can be an expensive problem for tuna fishermen; to catch one metric ton of tuna, roughly 100 kilograms of live bait fish are needed. Sometimes hooks are baited, sometimes artificial lures are used with hooks hidden in feathers. When the tuna is very eager to take the bait, a naked hook is sufficient. Pole and line fishing for tuna is done in daytime from slow moving vessels. Since considerable space is needed for the angling crew to stand side by side on the lee side of the vessel, Japanese vessels for pole and line fishing have a long extended bow. To simplify hauling in the catch these boats also have a low freeboard. American tuna vessels hang special racks outside the ship over the water; spraying water helps to attract the tuna and it also serves to camouflage the shadows of boat and crew.

10. Drifting longline

Used for tuna especially in Japan, Taiwan and Korea, and to a limited extent in South Africa, Cuba and French Oceania. Drifting longlines are particularly successful in the tropical Pacific for big fish in depths from 60 to 250 meters. More than half the fish caught in this manner are yellowfin tuna, one third are albacores, and the remainder bigeye and bluefin tuna. Sharks, marlins, swordfish and sailfish, also caught with drifting longlines, are sometimes included in the tuna statistics. Sharks can cause serious loses by damaging hooked tuna. Originally longlining for tuna was a Japanese inshore fishery. At the end of the

19th century, the Japanese 30 to 40 miles off their coasts. This fishing was extended when sailing boats were replaced by motorized craft, and by 1926 the Japanese began longlining for tuna off Taiwan, by 1929 in the Indian ocean, by 1930 in the South Pacific, by 1938 in the eastern Pacific, by 1952 off the southeastern coast of Australia, and since 1955 in the Atlantic. Longlining for tuna is one of the most valuable Japanese fishing methods. A longline crew must be willing to do a hard, though lucrative, job and remain far from home for long periods. The gear is a line composed of about 300 sections, each section with a length of 150 to 400 meters stored in a basket. The total line can have a stretched length of up to 120 kilometers. Each section is composed of subsections of different lengths. The branch lines with the hooks are composed of three sections that vary in number and length. About 3 to 5 branch lines with hooks form one section – 1,500 hooks are considered the greatest number that can be operated in one set by a vessel. With decreasing catches attempts have been made to increase the number of hooks – as many as 2,000. The shooting of the line from the stern of the vessel begins early in the morning before sunrise, when the vessel moving at the speed of about five knots or more. During shooting the lines have been tied together and the hooks are mainly baited with frozen saury or squid. Each section is tied with a float line and a buoy. Depth of the gear can be regulated by the length of the float lines and the distance of the floats. Ten to fourteen men require four hours to perform the task. Hauling from the forepart of the vessel begins in the early afternoon with the help of a line hauler. Depending on the quantity of the catch, hauling can take more then ten hours with a crew of eight to ten. With preparing and sorting the catch, the usual working day of a crew totals some 18 hours. Because of this and the fact that the vessel stay at sea more than 200 days per year, the Japanese and Taiwanese have experienced difficulty in procuring crews. This problem has led to the development of the new technology to simplified the work by mechanization and reduce the manpower. One such improvement is the reel system, especially for larger vessels. The total line is set, hauled and stored on a drum. Though the floats and branch lines must still tied by hand, research is being done on a coupling appratus to do this automatically. Another invention is a line winder system, practicable for small vessels. Such ideas can be considered as initial steps in the modernization of longlining at present. (Fig. 18)

11. Bottom longline

More popular for commercial sea fisheries in Europe are bottom long lines. These catch many species of the cod family, including cod, haddock, coral fish, hake and pollack as well as rays, and many flatfish, such as halibut. There are also longline fishery for groupers, hairtails, croakers and sea bream. Bottom lines are not as long as the more easily controlled drift lines. The hooks do not always lie on the bottom but may hang above it to protect the bait against unwanted bottom predators, such as starfish, snails or crabs. Typically, bottom lines are used for halibut in the northern Pacific. A relatively heavy main line is divided in sections of approximately 75 meters. The branch lines, each about 1.5 meters long, are tied at intervals of 4 to 5.5 meters. Modern synthetics with their greater strength and lighter weight, have replaced natural fibers for main lines. Fishing depth usually ranges between 80 meters and 270 meters, depending on the grounds and seasons. The setline is anchored at both ends, marked by a floating keg and a lighted flag buoy at night. Originally only two-man dories fished in this way, but today special mechanized boats with small crews and high yield per man do longline fishing (Fig. 19 & 20)

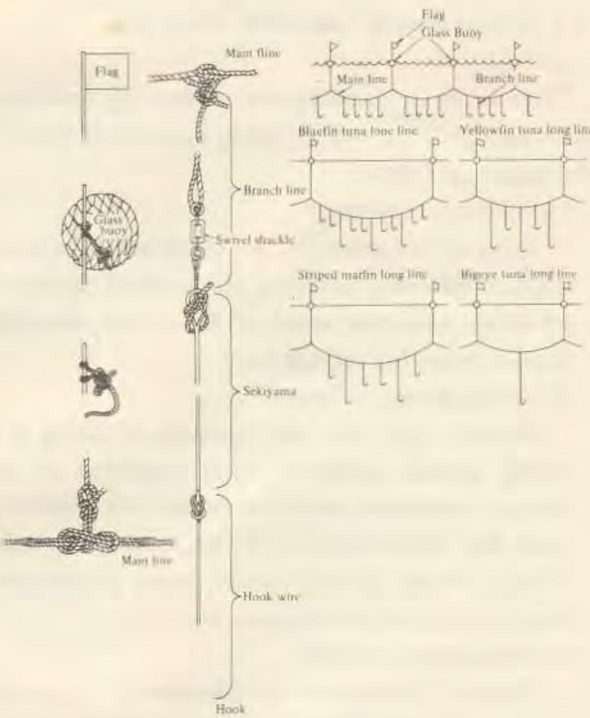

Fig. 18 Tuna Long Line

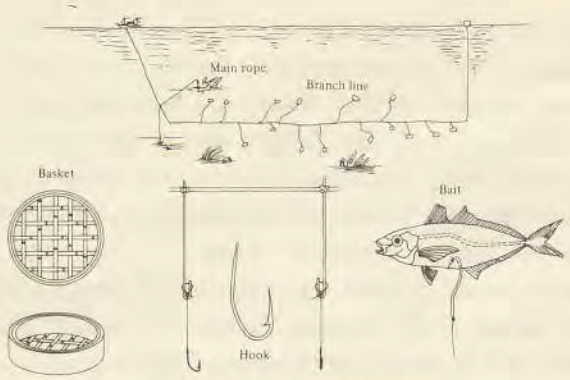

Fig. 19 Congereel Long Line

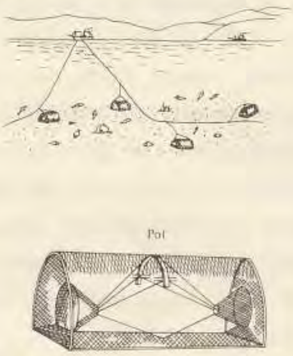

Fig. 20. Cuttlefish Pot Line

2.2.1 Factors relating to design of fishing gear

1. Introduction

There are many operating and surrounding conditions which are connected with the using of different kinds of fishing gears, as follows:

1) Fish school conditions

Kinds of fish aimed for, size of fish school, size and shape of fish body, behaviour of fish school, density of schooling, swimming speed of fish school, schooling layer of water, fish migration etc.

2) Fishing ground conditions

Distance from base port, capacity of fishing as a fishing ground, depth of water, condition of sea bottom, isometrical depth line, current, tide, plankton, small fish distribution as bait, meteorological conditions of fishing ground, salinity, water temperature, oxygen, variation of water mass, etc.

3) Back ground condition

Technical experiences of fishermen for operating gear and boat, capital available for the enterprise, consumable demand of fish, management of fishing, commercial and social activity of the region, communication means, facilities of landing port, marketing, circulation, etc.

Taking into consideration such elemental conditions for fishing, selection of fishing gear, size and design of fishing gear, size and number of boats, the number of fishermen should be the final decision to make.

2. Broad sense of fishing gear

The fishing gear means just a fishing net or hook and line for operation in a limited sense. But other articles necessary for operation of fishing can be said to be part of the fishing gear in the broad sense. That is to say when fishing, we need fishing net and rope, fishing boat, fishing machine and so on. Therefore, if we plan to make some kind of fishing, we must consider and design the fishing gear, fishing machine and fishing boat so as to fit the size of fishing itself.

According to the necessary items for operating conditions mentioned above, first of all we should select what kind of fishing gear to be applied. Next, the size of this gear should be decided. The size of boat capable for using such scale of fishing gear should be considered next. Once we have the design of net and boat, we can consider how much house power of engine installed will need. Necessary fishing machines aboard the boat will be applied for the fishing. The number of fishermen will be counted for the fishing.

3. Some examples of the process in fishing gear design

Let us take some samples for deciding fishing gear design according to the elemental operating conditions mentioned above.

Suppose there are fishing grounds with migrating sardine in certain places. First of all we should know about the fish resources in these areas.

Sardine generally form some kind of school. The schools of this fish behave differently according to the time elapsed even within a single day.

The pattern*1 formed by schools of sardine (*Sardinops melanosticta*) deduced from fish finder records in the western part of the Japan Sea in the winter season indicates a peculiar behaviour in which they are found dotted here and there at the depth below the surface during the day, rising to the surface in a group at twilight, then sinking and dispersing later at night.

Under such behaviour of sardine, the gill net fishing will be employed spreading the net at certain depths during the day. The density of sardine school is different according to the different places in which oceanographical condition are different. If the density of school is big, purse seining will be employed.

Usually sardines are easily attracted by fishing lamp at night except around full moon. In such a case, purse seining at night will be the most efficient gear for fishing. The size of net will be discussed under conditions of fish schools. Ordinarily, the length of net ranges from 250

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*1. M. Nomura: Some knowledge on behaviour of fish schools. Proc. Indo-Pacific Fish. Coun., (III), 1958 meters to 600 meters for sardine purse seine. If the swimming speed of fish school is rather fast in the day time, two-boat type purse seine is preferable. But in the night time once the fish school is attracted by fishing lamps, one-boat type purse seine is more effective, and preferable economically. The depth of net will be also be considered from the size of fish as well as the length of net. Before pursing the purse line after laying out the net it is very necessary to have plenty of play space for the fish surrounded by the net. Otherwise fish schools are likely to get away outside the net going through under the bottom line of the net when they encounter the wall of the laid out net. Therefore the depth of net should be decided after considering this point.

The mesh size of nets is of course decided according to the size of fish body. Too small a mesh size sometimes produces much water resistance as well as increasing the weight of net in the boat. It's very troublesome when operating and carrying the net on board. The size of netting cord should be selected from the stand point of physical strength. Sometimes the net is operated in a water currents in which water resistance attains intolerable levels, and huge quantity of fish will reqauire full strength of netting cord when handling the net.

The fishing boat should have enough capacity for operating the fishing net thus designed. The style of boat will be designed according to the kind of operation, e.g. one-boat type or two-boat type. The horse power of engine should be decided according to the size of boat. The purse line winch should be designed according to the forces of purse line which relate to the size of the gear. The power block is also decided in the same manner. The size of fish holds and way of processing, such as ice-store, or freezing should be arranged according to the expected amount of catch and marketing requirement. The duration of fishing voyage will be decided by fishing ground condition and size of boat. If the distance from the base to fishing ground is long, navigation to and coming back will take many days. Subordinate boats such as fish detecting boats, etc. will be arranged according to the situation for fishing. Thus the number of fishermen on board will be decided.

2.2.2 Classification of fishing gear

Netting gear

1. Gill net

Gill net (also refer to "gill net" in this textbook)

- Surface gill net: Buoy line is floated on the water surface.
  - Fixed surface gill net: E.g. Sardine gill net. One or both ends of a net are fixed by anchors so as to settle the net. Used in shallow inlets or narrow waterways where the migrating of fish is very often.
  - Drift surface gill net: E.g., Salmon gill net. Net is drifted by the current. Used in the open off-shore waters. Fish are caught either enmeshed or entangled therein. In night operation light buoy is used attached to the end of net to show its position.
- Mid-water gill net: Main nets are suspended in mid-water layers by float ropes.
  - Fixed mid-water gill net: The construction is not different from fixed surface gill net. The float ropes are adjusted in its length with the depth of fish swimming layer.
  - Drift mid-water gill net: E.g., Sardine net, mackerel net and saury net.
- Bottom gill net: Nets are set at the bottom of the sea either settled by anchors, or drifted without anchors. It can be used up to depths of 200 m. E.g., cod net, flounder net, shark net, mackerel net, sea bream net, shrimp net, crab net, and "genshiki" net.
- Encircled gill net: Surrounding net and gilling nets are used. Once the former one surrounds the fish school, then the latter one is set inside the circle. E.g., young yellowtail encircling gill net.
- Sweeping gill net: Unique gill net which gills fish so that a boat towing one end of the net in a circle encounting the fish to the net with the other end of the net fixed with an anchor.

Entangle net

- Single entangle net: E.g., tuna drift net. One sheet of net is used, the sinkers are usually omitted.
- Trammel net: A net sheet with small meshe in the center and net sheets with large meshe on the sides, thus it is constructed by three net sheets, catching the fish by entangling with the meshes.

2. Towing net (Also refer to "trawl net" in this text book)

Beach seine: A bag-shaped net with wings which are longer than those of ordinary trawl nets. It is pulled towards the beach by manpower.

Boat drag net:

- Upper layer drag net: E.g., "Battch ami". The net is a long conical bag with wings.

Danish seine: The net is set at first, with the end of one towed rope fastened to a buoy under water. The boat sails in a trianglar course, paying out the gear, towed rope, net and towed rope in their order, and finally picks up the buoy. The boat thus towed the net ahead and ropes and wings slowly close in, driving the fish into the net mouth.

Trawl net: A conical-shaped net pulled by one or two boats for a certain period of time mainly to catch fish which live right on the bottom, or which stay near the bottom.

Bottom trawl net:

Beam trawl net: Beam trawl, dredge and coral net

Otter trawl net: Side trawl, stern trawl and multi-net trawl (outrigger and boom trawls)

Two-boat trawl net: Pair trawl (or bull trawl), paranzella

Mid-water trawl net: Mid-water otter trawl, mid-water two-boat trawl, sailing drag seine.

Push net: A trianglar net forming a bag shapeed, two sides of which are fixed to scissor-like cross bamboo sticks, is used. The gear is pushed forward in shallow water either by hand or by boat in bigger scale.

3. Lift net (Also refer to "lift net" in this textbook)

Lift net: The operation is done by raising or hauling the submerged netting upward out of the water. The nets range from the small hand-operated lift nets, hoop nets, blanket nets to large mechanical lift nets.

Floating lift net:

Stick held dip net: The net is set a little deeper under the water surface and is flowed freely from the boat by the current. Saury fish, mackerel, and horse mackrel fishes are easily guided into the net by attracting with fishing lamps or bait.

One boat lift net: Small scoop net

Eight angle net: Two-boat lift net.

Bottom lift net:

Four angle dip net

Three-boat lift net

Four-boat lift net

Eight-boat lift net

4. Surrounding net

Surrounding net: The manner of operation is to surround the fish not only from the side but also from underneath allowing fish to be caught over deep waters. The net is generally rectangular in shape or with a bag in the center and wings on both sides that look like a drag net.

Surrounding net with pocket net: Japanese semi-surrounding net ("Nuikiri ami"). The bag net (better called lift net) is accompanied by a pair of wing nets. After the lighting boat attracts the fish school, netting boats, towed by small boats set the net around the fish.

Surrounding net without pocket net:

Surrounding net having purse-line: There are various purse seine according to the species of fish. The net is set around the fish school and then purse line is quickly pulled onto the boat to close the bottom of the net.

One-boat type purse seine: The netting boat, holding one end of the net, surrounds fish school at full speed and in such a way as to block the fish passage, while a skiff standing still holds the other net end. After that the netting boat receives the purse line and bridle from the skiff, and the net is then hauled up by pursing the purse line.

Two-boat type purse seine: The purse lines or wire ropes which are designed to close the bottom of the net are attached to the sinkers, almost the same manner of construction with one boat type purse seine, but operate by two boats.

Both one-boat and two-boat type purse seine are of different construction in their twine size, mesh size, length of net, width of net and the ratio of the length and breadth of the net. Sardine, mackerel, horse mackerel, skipjack, tuna are the main kind of fish to be taken by one-boat and two-boat purse seine.

Surrounding net not having purse-line: Lampara type nets. The net has neither rings nor purse lines in the lower part of the net.

5. Covering net

Covering net: The fishs are caught by covering them with the gear and then gathering them when the net is lifted, mainly operated in shallow waters.

Cast net: A conical net which is thrown by hand to fall flat upon the surface of water. The net quickly sinks by the weights to cover the meters to 600 meters for sardine purse seine. If the swimming speed of fish school is rather fast in the day time, two-boat type purse seine is preferable. But in the night time once the fish school is attracted by fishing lamps, one-boat type purse seine is more effective, and preferable economically. The depth of net will be also be considered from the size of fish as well as the length of net. Before pursing the purse line after laying out the net it is very necessary to have plenty of play space for the fish surrounded by the net. Otherwise fish schools are likely to get away outside the net going through under the bottom line of the net when they encounter the wall of the laid out net. Therefore the depth of net should be decided after considering this point.

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Cast net: A conical net which is thrown by hand to fall flat upon the surface of water. The net quickly sinks by the weights to cover the fish.

Lantern net: The net is constructed to cover the wooden frame, the shape of which looks like a lantern. The gear is used to cover the fish, and is operated by hand.

6. *Trap net* (Also refer to "trap net" in this textbook)

Trap net: The fish are trapped in collecting units from which escape is prevented by labyrinths and retarding devices such as gorges, funnels, etc.

Large scale trap net:

Keddle net

Large stationary net of triangle shape: "Oshiki ami". The gear consists of a leader net and a main net. The leader net is usually made of straw rope.

Large stationary net of oblong or actagonal shape: "Daibo ami". In the largest type of the gear, the main net measures 400 m in length and 100 in width, and the leader net attains nearly 4000 meters in length.

Stationary net with trap net: "Otoshi ami". The net consists of three parts, bag net (or main net with bag net), barrier net (or play ground net) and leader net.

Stationary net with one-sided trap net: Ordinary type of net is used in this type. The length of main net is about 200 meters. The most popular type of fish caught are yellow tail, horse mackerel, squid and other pelagic fish.

Stationary net with two traps

Medium stationary trap net:

Sardine stationary net: "Hisago ami". The bag net does not reach to the bottom. It has leader net and big playground net with upward bottom slope net.

Herring stationary net: "Kaku ami". The box type bag net is used.

Salmon stationary net: This is a surface or a bottom trap net used in fishing grounds with rather swift currents.

Small scale stationary trap net:

Pound net: "Masu ami". The gear consists of main net, leader net and conical bag nets.

Guiding barrier: Screen labyrinthine net. A guiding barrier normally consists of a fence, or fences, which guide the fish to one or more retaining chambers in which they are trapped.

Portable trap and stow-net

Covered pots and fyke net: These can be used as single units or arranged in systems with wings and leaders. Basketlike or cage-like implements made of wood, netting, wire, and plastic are used.

Stow net: It is fixed on stakes or anchored with the mouths opened by frames, and faced to the strong current in rivers.

Hook and line fishing gear

Hook and line gear

Angling gear: "Ipponzuri"

Pole and line

Hand Line

Trolling line

Long lines

Drift line: Floating long line

Bottom long line

Vertical long line

Miscellaneous fishing gears

Harpoons and spears

Curved hooks

Tongs, clips and twisters

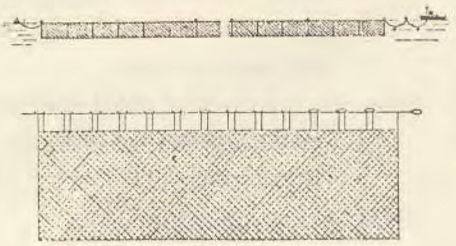
Spatulas and rakes

Shelters, pots, baskets and traps

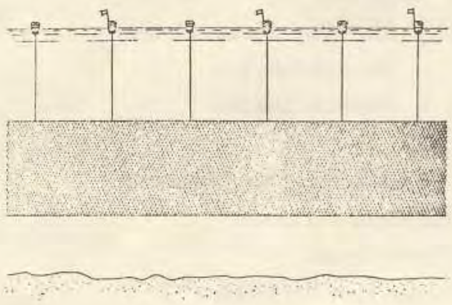
Fish fences

Fish weirs

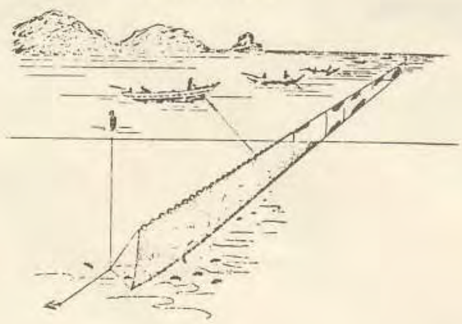
Drift surface gill net



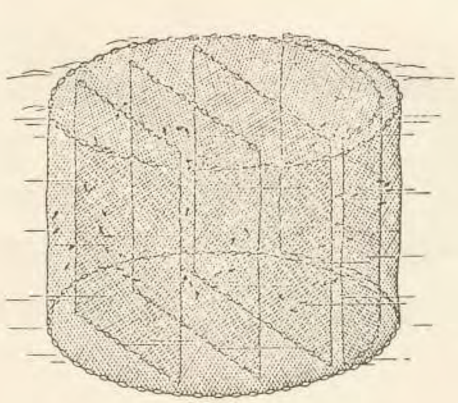
Drift mid-water gill net



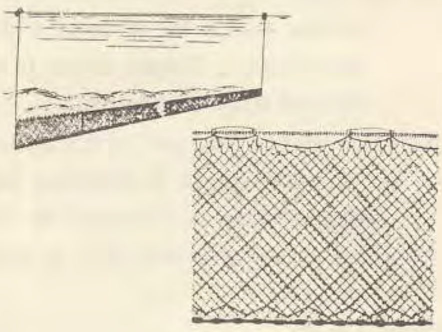
Bottom gill net



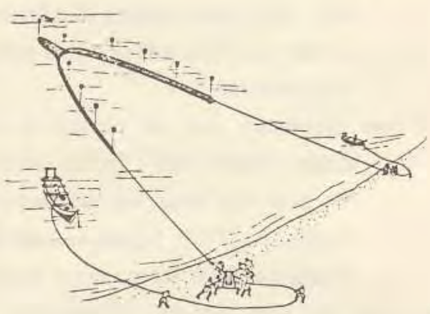
Encircled gill net



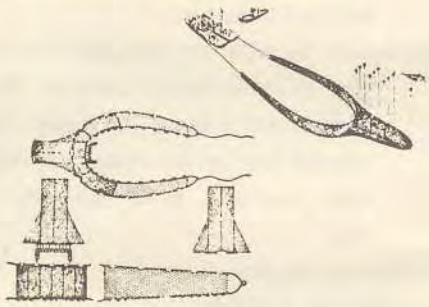
Trammel net



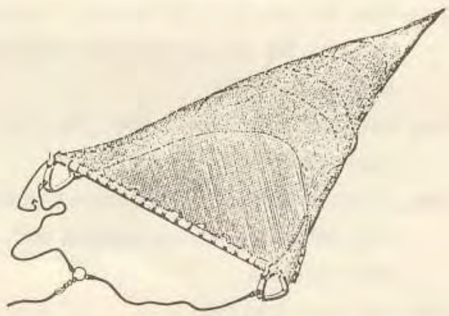
Beach seine



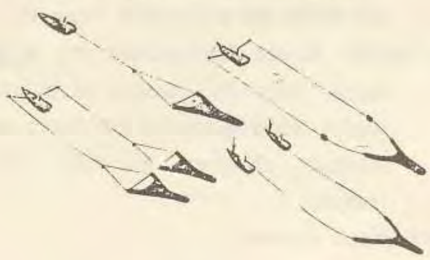
Upper layer drag net ("Battch ami")



Beam trawl

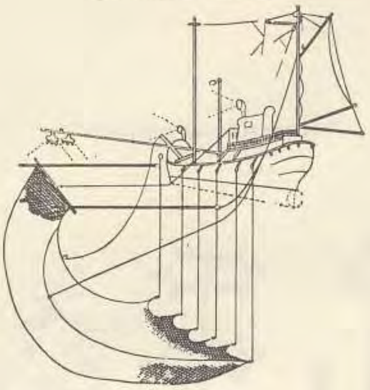


Various types of small bottom trawls

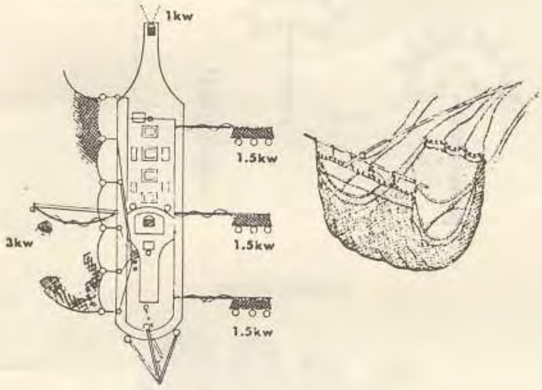


Stick held dip net

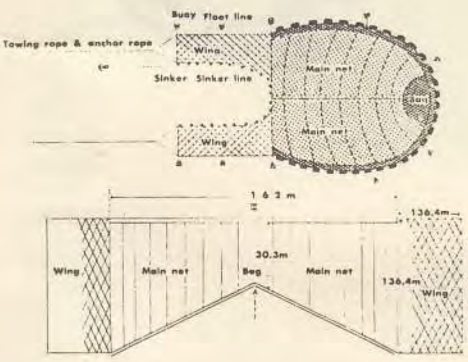
Operation of Net



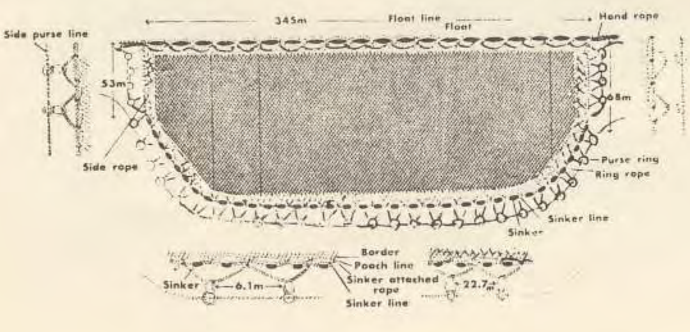
Fish-luring Light



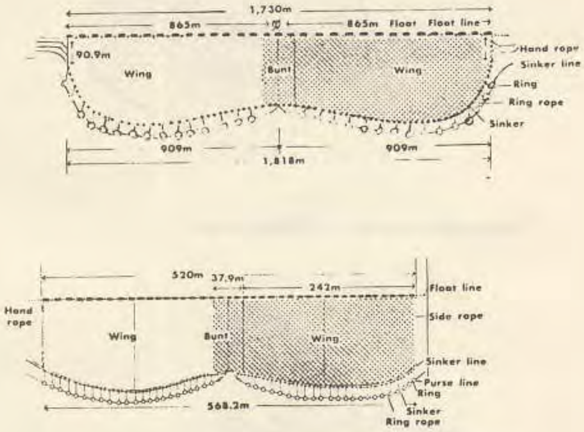
Semi-surrounding net ("Nuikiri ami")



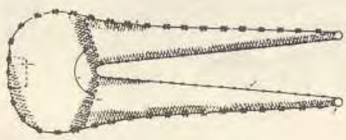
One-boat sardine purse seine



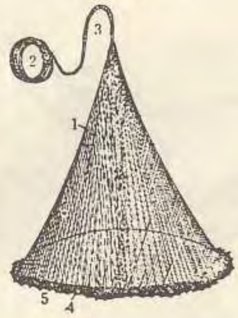
Two-boat type purse seine
(Upper: Tuna, Lower: Sardine)



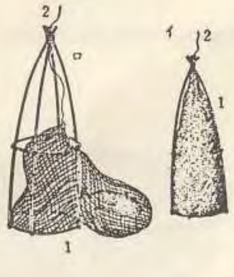
Lampara



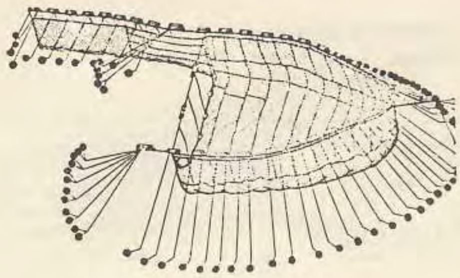
Cast net



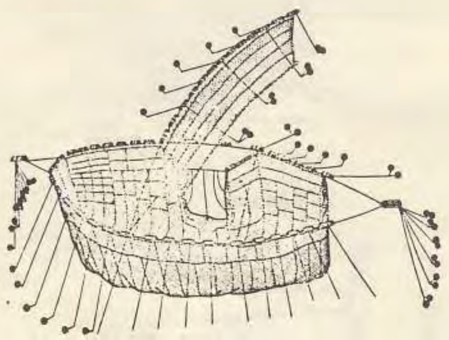
Lantern net



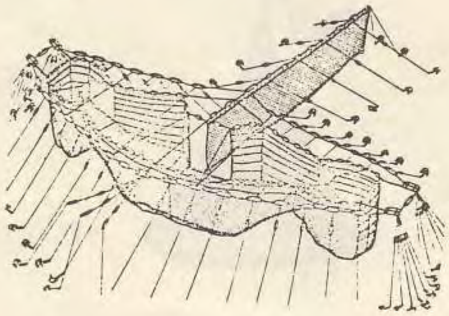
Large stationary net of trianglar shape



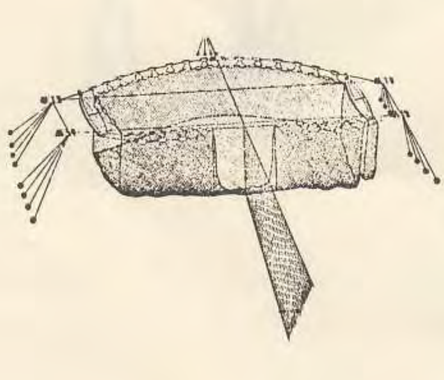
Large stationary net of oblong shape



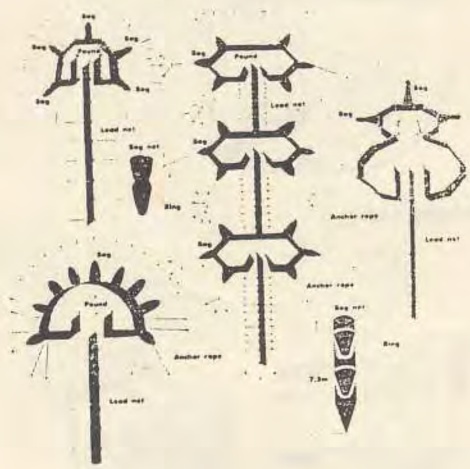
Large stationary net with two traps



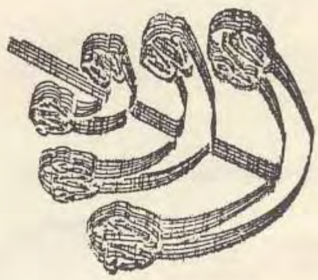
Herring stationary net ("Kaku ami")



Various types of pond nets



Guiding barrier



2.2.3 Necessary check items for surveying fishing gears

Introduction

In an attempt to improve any enterprise, the first and perhaps one of the most important phases must be to get thoroughly acquainted with its present status. Like in any other industry, this is also applicable to renovation or modification of a type of fishery particularly of its gear, including various technological features.

Once every item of information about a type of fishery has been completed in accordance with the suggestions made in this textbook we can see an overall picture of the fishery with all details needed, evaluate merits as well as demerits, realise whether any improvements or modifications are necessary and/or feasible under existing circumstances, and discuss how to materialize the idea within available means with regard to construction and operation of the proposed gear.

The manual was prepared basically by Dr. H. Miyamoto during preliminary stages in the establishing and organizing of a Fishing Gear Laboratory for the Government of India. This is based on the experiences accumulated by the Faculty of Fishing, Tokyo University of Fisheries during the periods when Dr. Miyamoto was a professor of said University. And some information checks for modernized fishing are also added by Dr. M. Nomura.

Items covered under Part I can be applied to every type of gears which is substantially constructed with net, such as stationary nets, lift nets, gill nets, all modifications of round hauls and trawlers, no matter how large or small they are. One of important gears that comes under Part II may be long line fishery. However, pole and line fishery can be investigated as well in accordance with most of the items listed there, regardless the scale of gear. Miscellaneous types of fishery may includes weirs, traps, pots, and other gear which is not classified under Part I and II.

Although the manual has been prepared in the hope that this can be of service for various types of fishery in all regions of the world, all these items enumerated here are no more than a set of examples which cover a large range of needs in field surveys. Therefore, specifications should be adjusted to the range of survey, using the manual as well as the existing situation of the fishery to be investigated. That is to say, one unit of gear could be specified in accordance with items applicable to it, while leaving out other items not feasible for the gear. This is also the same with a group, or groups of similar or different types of gears, which are employed by individual fishermen, or by one or more fishermen organizations in an particular area. Though it is desirable to secure information and data requested in the manual as it becomes available, a user need not always stick to every items of the manual for that reason.

Instead, he can, as a matter of course, eliminate a number of items altogether from his survey when they are not applicable for a fishery under survey at the present level of development. On the other hand, some items should be expanded in further detail or newly added in alike manner or to an extent needed for a particular occasion of survey.

As for manner of recording, some items are specifically requested, as the user will see, to be described or illustrated, while most of the items can be well satisfied by tabulation when not specified otherwise. However, to those who follow the manual for the first time, it is recommended to take field notes in detail and as deliberately as possible, and then tabulate the suitable information from his field notes. When he has more experience with the survey, he may take information more quickly and directly into tabulation.

Items of information such as fishing boats, localities of fishing grounds, changes in season, and ecological conditions of fish which are common to all types of fisheries, are listed only in Part I, items 4 to 14, without repeating them in other Parts. However, a user should collect these items in accordance with the corresponding items in Part I when gears in Parts II and III are to be investigated. It must be born in mind to specify unit of the amount or the measurement wherever it is involved. When lunar calendar has to be used in regard with fishing conditions or alike data, specify them to that effect. Some other requirements for recording may be self-explicite in the text of the manual.

Part I. Net and seine fishery

Type of fisheries:
Name of place observed:
Date observed:
Name of the representative of the fishery:

1. Brief history of the fishery (describe when started, how developed, etc.)
2. Present condition of the fishery
   - 2.1 Amount and value of catch in general and operation expenses per average season and/or per trip.
   - 2.2 Economic importance of the fishery in the region (describe in comparison with other types of fisheries or other industries in the local community).
   - 2.3 Number of fisheries in this district

3. Fishing gear
   - 3.1 Outline of construction of the gear with the name of each part (illustrate).
   - 3.2 Net fabric
     - a) Material and quality of netting twine (material, producing district, twist, number of thread and ply, thickness, total number of tex, weight and price)
     - b) Kind of knots
     - c) Mesh size (stretched)
     - d) Length and width of a sectional net fabric
     - e) Number of sectional net fabrics needed for a whole net
     - f) Lacing method (Material, quality, weight and price of lacing twine)
     - g) Weight of net fabric used
     - h) Total price of net fabric and lacing twine (per 1 set)
     - i) Period of past, plus possible future service
   - 3.3 Rope (describe or tabulate separately for each part)
     - a) Material and its producing district
     - b) Quality
     - c) Detail of twist
     - d) Thickness (diameter or weight per unit length, total number of tex)
     - e) Breaking tensile strength and elongation during operation
     - f) Length
     - g) Weight
     - h) Price
     - i) Period of past plus possible future service
   - 3.4 Antiseptic dyes (if different dyes are used for net and rope, separate them accordingly)
     - a) Material (producing district, quality, price per unit of quantity)
     - b) Dye-liquid making method
     - c) Net-dyeing method
     - d) Cost for dyeing
     - e) Period of re-dyeing, re-dyeing method
     - f) Serviceable period of dyed materials in comparison of non-dyed materials
   - 3.5 Floats
     - a) Material, producing district and maker's name, if not selfsupplied
     - b) Quality
     - c) Shape
     - d) Size
     - e) Weight
     - f) Buoyancy
     - g) Arrangement on float line
     - h) Total number used
     - i) Price, if not self-supplied
     - j) Period of past, plus possible future service
   - 3.6 Lead and anchor
     - a) Material, producing district
     - b) Quality
     - c) Shape
     - d) Size
     - e) Weight
     - f) Specific gravity
     - g) Arrangement on lead line
     - h) Total number used
     - i) Price
     - j) Period of past plus possible future service
   - 3.7 Accessories. For example, ring, bridle or purse line etc. in purse seine, describe or tabulate as in item 3-6
   - 3.8 Method of net framing
     - a) Order of gear framing
     - b) Hanging ratio in each part
     - c) Number of days and manpower to complete the gear (separate for items 3-2, 3-3, 3-4, 3-5, 3-6, 3-7, and sum up)
   - 3.9 Detailed sketch of items 3-2, 4, 5, 6, 7.

     (Attach samples, models or photos of them and item 3-3)
     - a) Fastening of float to line
     - b) Fastening of lead to line
     - c) Method of net fabric lacing
     - d) Fastening of float and lead lines to net fabrics
     - e) Remarks
   - 3.10 Preservation of the gear
   - 3.11 Drawing design of the gear (Draw diagrams and specifications on section papers)
     - a) Arrangement of net fabric in drawing
     - b) Hang-in
     - c) Arrangement of float and lead
     - d) Necessary amounts of materials in each section (tabulated)

4. Fishing boat
   - 4.1 Hull
     - a) Name of ship
     - b) Owner and port of registry
     - c) Name of ship-builder
     - d) Date of launching
     - e) Kind and qualification of the ship
     - f) Main measurement (length x width x depth)
     - g) Gross tons and registered tonnage
     - h) Speed, at full and average
     - i) Loaded draft at bow and stem, draft without

load

j) Number of crew

k) Fish hold, cold storage and freezing arrangement

l) How to maintain, and period of past, plus possible future service

4.2 Engine

a) Kind of engine

b) Maker's name

c) Horse power

d) Kind, quality and consumption of fuel, supercharge. Cost of fuel per unit hour

e) Number of screw blades

f) Number of revolution per minute, reduction ratio

g) Propeller pitch and diameter, variable pitch controller

h) Auxiliary engine

4.3 Equipment (number, material, size, etc.)

a) Spar

b) Sail

c) Rigging

d) Anchor and anchor chain

e) Skiff

f) Other accessories

4.4 Trawl winch, Gallos, Net hauler, Line hauler, Power block, and other instruments for gear operation and mechanization

a) Kind

b) Maker

c) Horse power

d) Mechanical drive or hydraulic pressure drive

e) Number of revolutions per minute

f) Efficiency of the instrument

g) Way of operation

4.5 Special equipments (wireless telegraphy, direction finder, echosounder, fish finder, radio buoy and navigational equipments such as Radar, Loran, Decca, etc.)

a) Kind

b) Maker

c) Capacity

d) Efficiency

e) Remarks

4.6 Characteristics of the ship and critical evaluation of efficiency for fishing

4.7 Building cost of the ship

a) Hull

b) Main engine and auxiliary engine

c) Equipment

d) Cost for launching

4.8 Plan of the construction and arrangement

5. Fishermen in general for the fishery under survey

5.1 Method for employment

a) District employed

b) Terms of contract

c) Period of employment

d) Average age and education

e) Occupation during off-season

f) Remarks

5.2 Wage system

a) Wage in each grade of fisherman

b) Bonus system by amount of catches

c) Other form of allowances such as medical leave

d) Any other form of wage system

e) Food and uniform during employment

f) Remarks

5.3 Local customs of fishermen & living standard

5.4 Labour union

6. Fishing season and fishing ground

6.1 Fishing season (if there are more than one season within the area, with or without regard to species, describe separately.)

a) Begining of the season

b) Best season

c) End of the season

d) Weather during the season and its effect

e) Changes in the fishing season over the past several years

f) Average number of operations during season

6.2 Fishing ground (if there are more than one fishing ground in the area, with or without regard to season and/or species, describe them accordingly.)

a) Locality, area and topography, value of fishing ground

b) Depth of the ground in average

c) Bottom nature and inclination

d) Current (direction, velocity its seasonal and daily variation)

e) Water temperature, color of water, ebb and flow

f) Changes in the ground over the past several years

g) Chart of the ground, time required to reach the fishing ground

h) Other possible fishing grounds in the vicinity

i) Number of boats with the same kind of fishing gear operating in the fishing ground

7. Operation of the gear (if operation varies depending on season, ground and species of fish, separate them

accordingly.)

7.1 Gear, boat and fishermen

a) Amount of gear used
b) Number of boats and duty of each boat
c) Duty and assignment of fishermen in each position

7.2 Preparation in starting for fishing ground

7.3 Casting and hauling net

a) Distribution of fishermen on board
b) Method of finding and scouting fish school
c) Method of casting net
d) Method of hauling net
e) Method of hauling fish
f) Time needed for casting and hauling net
g) Number of operations per day and operating time
h) Treatment of catch on board immediately after hauling
i) Duration of storage of the catch in the hold

7.4 Disposition and treatment after returning to port

7.5 Changes in the operations over the past several years

8. Catches

a) Quantity of catch per species per season, and per year
b) Size of fish caught
c) Seasonal change in the catches
d) Annual or monthly statistics of catches over the past several years

9. Disposition of catches

a) Disposition on the boat following item 7-3-f
b) Disposition after landing
c) Method and cost of packing
d) Selling method
e) Commission
f) District for consumption
g) Method of transportation and arrangements during transporting
h) Monthly average price of fish throughout a season and factors of seasonal variation in the price
i) Others

10. Behaviour of fish (if there are more than one major species caught with the same gear, separate them accordingly)

10.1 Change in swimming layers

a) Variation by seasons
b) Variation according to spawning
c) Variation by weather and time of the day
d) Variation due to predators and food
e) Variation by current and tide
f) Variation depending on size of fish

10.2 Making school or dispersion

Specify like item 10-1

10.3 Migration

Specify like item 10-1

10.4 Food

Specify like item 10-1

10.5 Body length, weight and body circumference

a) Seasonal difference
b) Differences according to spawning and other factors

10.6 State of swimming

a) In natural environment
b) When encountering the net
c) When entering the net

11. Organization and finance for the fishery under survey

11.1 Organization

a) Method of investment
b) Expenses
c) Profits and dividends

11.2 Type and source of financial accommodation

11.3 Government subsidy or help

12. Income and expenses for the fishery under survey

12.1 Income

a) Income from fishing
b) Income from other sources
c) Total income

12.2 Running expenses

a) Salary and wage for employees
b) Bonus for employees
c) Boarding expense for employees during the season and during the year
d) Other expenses for employees
e) Expense for correspondence and bookkeeping
f) Repairing, replacement and supplementing of gear and boat
g) Depreciation on boats and gear
h) Cost of fuel oil and other expendables
i) Tax
j) Charge for fisheries and/or other associations
k) Commissions for selling catch
l) Other expenses
m) Total

12.3 Relation between income and expense in a fishing season

13. Regulations

13.1 Laws and regulations of the Central (Federal) Government relevant to the fishery

13.2 Regulations of local governments relevant to the fishery

13.3 Regulations of fisheries associations for the fishery

13.4 Other obligations for the fishery

14. Comments and recommendations for the fishery
    - 14.1 For the gear and boat
    - 14.2 For the operation
    - 14.3 For the enterprise
    - 14.4 Other comments

Part II. Hook and line fishery

(Pole line, hand line, long line and others)

Type of fisheries;

Name of place observed;

Date observed;

Name of the representative of the fishery;

1. Brief history of the fishery (describe when started, how developed, etc.)
2. Present condition of fishery
    - 2.1 Amount and value of catch in general and operation expense per average season
    - 2.2 Economic importance of the fishery in the region (describe in comparison with other types of fisheries or other industries in the local community)
3. Fishing gear (in case of long line)
    - 3.1 Outline of the construction of the gear with the vernacular name of each part (illustrate)
    - 3.2 Main line
        - a) Material and quality (row material, producing district)
        - b) Number of thread and ply, number of twist
        - c) Thickness, total number of tex
        - d) Length
        - e) Weight
        - f) Price
        - g) Number of man-power and day for construction
        - h) Period of past, plus possible future service
    - 3.3 Branch
      Same as item 3.2 (a-h).
    - 3.4 Float line
      Same as item 3.2(a-h)
    - 3.5 Buoy rope
      Same as item 3.2 (a-h)
    - 3.6 Anchor rope
      Same as item 3.2 (a-h)
    - 3.7 Dyes for preservation
      Same as Part I, item 3.4 (a-f)
    - 3.8 Siezing line and wire
    - 3.9 Hook
        - a) Material and quality, producing district
        - b) Shape
        - c) Circuit length
        - d) Weight
        - e) Price
        - f) Number of hook per basket
    - 3.10 Float
        - a) Material and producing district
        - b) Quality
        - c) Shape
        - d) Size
        - e) Weight
        - f) Buoyancy
        - g) Arrangement on float line
        - h) Number per basket
        - i) Number of man-power, and days required for carpentry, if self-supplied
        - j) Price, if not self-supplied
        - k) Period of past, plus possible future service
    - 3.11 Buoy and buoy-lamp, sinker, anchor and other accessories such as basket, etc. Same as item 3.10 (a-e, i-k)
    - 3.12 Detailed sketch of items 3,2, -3, -4, -5, -6, -8, -9, -10, -11, (attach samples, models or photos of them)
    - 3.13 Preservation of gear in and off season
    - 3.14 Plan and specifications (draw diagrams on section papers)
4. Bait
    - a) Kind and size
    - b) Price
    - c) Supplying place
    - d) How to preserve on board boat
    - e) Amount for use per operation and/or season
    - f) Availability
    - g) How to fix the hook (illustrate)

Similar items as enumerated above can be applied to hand line and pole line.

For other details; describe according to Part I, items 4 to 14

Part III. Miscellaneous fishery

(Excluding the gears specified in Parts I and II)

Type of the fishery;

Name of place observed;

Date observed;

Name of the representative of the fishery;

1. Brief history of the fishery (describe when started, how developed, etc.)
2. Present condition of the fishery
    - 2.1 Amount and value of catch in general and operation expense per average season

3. Gear
    3.1 Outline of construction of the gear with the name of each part (illustrate)
    3.2 Main gear
        a) Material
        b) Size
        c) Weight
        d) Price
        e) Period of past, plus possible future service
    3.3 Accessories
        Same as item 3.2 (a-e)
    3.4 Detailed sketch of items 3.2 and 3.3, (attach samples, models or photos of them)
    3.5 Plan and specifications (draw diagrams on section papers)

For other details describe according to Part I, items 4 to 14

Part IV. Fishermen's organizations, fish market, and local conditions relevant to the fisheries

A. Fishermen's Organization

1. Organization
    1.1 Number and executive position of directors and officers
    1.2 Number of membership affiliated with the organization
2. Management of accounts and property
3. How to exercise fishery rights
4. Joint facilities
    4.1 Financial assistances received (types and sources)
    4.2 Other co-operating activities
        a) Joint marketing of catch (species, amount, value in average year, and destination)
        b) Joint procurement of nets, fuel oil, and other necessities (kind, amount, price in average year and suppliers)
        c) Joint deposite by members (type, annual and total amounts deposited)
        d) Warehouse for fisheries (full capacity, idle room, room required for local needed)
        e) Technical training courses for fisheries
        f) Others
5. Sharing method of profits (form and percentage to profit)

B. Fish Wholesale Market

1. Organization
    1.1 Amount and type of capital
    1.2 Sharing of profits (general description of form and percentage to profits)
2. Manners of transaction
    2.1 Auction or sealed bidding
    2.2 Settlement of account (cash or credit, term thereof)
    2.3 Commission and other expenses relevant to transaction
    2.4 Packing for manufacturers, etc. (material, capacity per unit and expenses)
    2.5 Shipment from the market (form of facility, and expenses per distance)
    2.6 Local manners or customs peculiar to the market
3. Names of processing and consuming districts or the destination of processed fish
4. Kind of fish handling and average price per season
5. Operative conditions
    5.1 Expenses for maintenance
        a) Office
        b) Market hall
        c) Landing place and wharf
        d) Ice plant, cold storage, warehouse, etc.
    5.2 Office expense
        a) Salary and wage for employees
        b) Bonus
        c) Material expenses for maintaining office
        d) Others
    5.3 Actual amount of income and profits in recent years (kinds, sources and disposition)
6. Others
    6.1 Topographical condition of the market in relation with producers and consumers
    6.2 Comment on the market from the management
    6.3 Fishermen's comment on the market
    6.4 Buyers' comment on the market
    6.5 Consumers' comment on the market

C. Local Conditions Relevant to the Fisheries

1. Population in the district under survey
2. Number of houses
3. Number of fisherman
4. Number of processing factories and workers
5. Number of fish farms and workers
6. Average wage of fishermen, industrial and farming workers
7. Number of fishing boats
8. Name, number and capacity of ship building factories and docking facilities
9. Name, number and capacity of ice-plants and cold storages
10. Name and number of various types of fisheries and gears including the one under survey

11. Fishing season and ground of fisheries in item 10
12. Kinds of fish caught and landing amounts in item 10
13. Fluctuation in fisheries in item 10
14. Available means of transportation for people related with the market
15. Available means of financial functions (number, type and name)
16. Local manners or customs of commercial business
17. Geneal public
    a) Customs and manners with regard to fish
    b) Purchasing power
    c) Quantity of fish eaten per year
    d) State in which it is taken, fresh or processed, and their qaulity
18. Processing facilities
    a) Drying, salting, smoking
    b) Freezing, cold storage, ice making
    c) Canning
    d) Price difference between fresh and processed fish
    e) Availability
    f) People's reaction to processed goods
19. Comment or recommendation to fisheries in the district obtained from the survey

Part V. Examples of check items

The examples shown in the following were requested to SEAFDEC trainees to report after the completion of observation trip to eastern Thailand (Chombri, Ansira, Bansen, Nacurua, Satahip, Paknam Passe, Rayon and Banpei) at 6th to 10th, Oct., 1971.

A. Fishing gear survey

Name of trainee:

(For Sand launce purse seine, Plato purse seine, Spanish mackerel gill net, Encircling gill net, Trolling, Crab net, Trap net, etc.)

1. Name of gear (English & local name)
2. Brief history (describe when started, how developed, economical importance, etc.)
3. Present condition of the fishery
   1) Fishing season
   2) Fishing grouunds according to the season
   3) Fishing operation
      How many days (Go and return + Operation)
      How many persons aboarding
   4) Amount of catch (by weight and value)
      per month & per trip
   5) Management
      Value of catch (per month)
      Operational expense (per month)
      Price of one new set of gear
      Profit (per month)
4. Fishing gear
   1) Outline of the construction of the gear with the name of each part (illustrate with diagrams)
      Total length of net (stretched length & length after hang-in)
      Total depth of net (stretched length & length after hang-in)
   2) Net fabric (in each pannel of net including selvedge)
      a) Material
         Kind of fiber
         Number of denier
         Number of ply
         Number of yarns
         Total number of tex
         Stretched mesh size (by calculation also)
         Length of each pannel net (streched)
         Number of mesh in pannel net
         Kinds of knot
      b). Joining
         Material
         Way of joinning, lacing (illustrate with diagram)
   3) Ropes (Float line, Sinker line, Purse line etc.)
      Material
      Size
      Length
      Way of joinig with net (illustrate with diagrams)
   4) Hang-in
      Head line
      Lead line
   5) Accessories
      a) Float
         Material
         Estimated specific gravity (ρ)
         Shape
         Size (LxBxD)
         Weight in air (W)
         Buoyancy (B)
         $B=W\ (1/\rho - 1)$
         Total number & total buoyancy
         Interval distance between floats
         Way of joining with rope and net (illustrate with diagram)
      b) Sinker
         Material
         Estimated specific gravity (ρ)

Shape
Size (LxBxD)
Weight in air (W)
Sinking power (W')

$$W' = W(1 - 1/\rho)$$

Total number & total sinking power
Interval distance between sinkers
Way of joining rope and net
(illustrate with diagram)

c) Auxiliary fishing gear such as Fishing lamp, Coconut plam leaf, Hauling machine, Winch

B. Fishing boat survey

Name of trainees:

1. Hull
   a) Name of ship
   b) Owner and port of registry
   c) Name of ship-builder
   d) Date of launching
   e) Kind and qualification of the ship
   f) Main measurement (length x width x depth)
   g) Gross tons and registerd tonnage
   h) Speed at full and average
   i) Loaded draft at bow and stern, draft without load
2. Engine
   a) Kind of engine
   b) Maker's name
   c) Horse power
   d) Kind quality and consumption of fuel, supercharge. Cost of fuel per unit hour
   e) Number of screw blades
   f) Number of revolutions per minute, reduction ratio
   g) Propeller pitch and diameter, variable pitch controller
   h) Auxiliary engine
3. Equipment (Number, material, size, etc.)
   a) Spar
   b) Sail
   c) Riggings
   d) Anchor and anchor chain
   e) Skiff
   f) Other accessories
4. Trawl winch, Gallos, Net hauler, Line hauler, Power Block, and other instruments for gear operation and mechanizagion.
   a) Kind
   b) Maker
   c) Horse power
   d) Mechanical drive or hydraulic pressure drive
   e) Number of revolutions
   f) Efficiency of the instrument
   g) Way of operation
5. Special Equipment (Wireless telegraphy, Direction finder, Echo sounder, Fish finder, Radio buoy and navigational aids as Radar, Laran, Decca, etc.)
   a) Kind
   b) Maker
   c) Capacity
   d) Efficiency
   e) Remarks
6. Characteristics of the ship and critical evaluation of efficiency for fishing
7. Building cost of the ship
   a) Hull
   b) Main engine and auxiliary engine
   c) Equipments
   d) Cost of launching
8. Plan of the construction and arrangement
   a) General arrangement
   b) Midship
   c) Piping plan
9. Price of ship-building
   Price of main engine and auxiliary engine
10. Kinds of captain's and engineers license
    a) First grade
    b) 2nd grade
    c) 3rd grade etc.
11. Inspection of the ships
    a) Occasional inspection
    b) Annual inspection
    c) Every 4 years inspection
12. Insurance for the ship
    for the hull
    for the engines
    for the various apparatus
13. Ability of steering
    a) Turning circle
    b) Crank or tender (Righting force)
    c) Height of G.M. (GM sin)
    d) Short stopping distance
    e) Sp'd length ratio
14. Seaworthiness
    a) Heeling angle, Beam end
    b) .Against the wind (have to)
    c) Following the wind (scudding)
    d) Trim
       1. By bow
       2. Even keel
       3. By the stern
15. How to fix the ship's position. By direct navigational

methods, or indirect navigational methods.

16. Taking pictures of hull, engines, and various apparatus or equipments

C. Shipbuilding survey

Name of trainee:

1. Name of ship yard
2. Place of shipyard
3. Back ground of shipyard
4. Size
5. History of shipyard
   Employee and their quality: regular number, temporary number
7. Main aim of the enterprise
   Kind of building ship: wooden or steel boats
   Average or range of tonnage built
   Annual ship building tonnage
8. Organization of the shipyard
9. Capacity
   Dry dock: Size
   Floating dock
   Slip way
10. Wages of the employees
11. Sanitary facilities
12. Launching facilities
   Side launching
   Stem
   Slip way
13. Repairing facilities
   a. Deck part (hull)
      1) Steel workers
      2) Wooden workers
   b. Engine part
      1) Overhauling of engine (main engine, auxil-engine), repairing of small damages
      2) Engineers
14. Price of boat
   Unit price per ton or per length (m)
   Time required for completion of building ship (per ton or length)
   Total number of persons required for completion of building ship (per ton or length)

15 Expense for installation of engine (according to the horse power)

16. Insulation expense for fish hold
   Construction of insullation
   Price
17. Fuel oil tank, fresh water tank
18. Piping
19. Auxilliary fishing gear such as hauling machine, winch, etc.
20. Others

D. Port facilities survey

(Make drawing of the harbour facilities)

1. Port history
2. Scale of port
   a. Area for berth
   b. Mean depth of berth
   c. Tidal range
   d. Prevailing wind throughout the year
      Direction
      Average force
3. Main facilities
   a. Landing pier
      Length
      Breadth
      Railed
      Bill, Bollard
      Water supply
      Fuel supply
      Ice supply (ice, crack ice or flake ice)
   b. Pier, jetty or wharf
      Kinds
      Fixed direction
      Length
      Breadth
      Railed or not
      Bitt, Bollard
      Supply (water, fuel oil and ice)
   c. Apron
      Rail
      Derrick post or boom (capacity)
      Ice supply
   g. Sea marks
      Mooring buoy
      Leading light
      Light house
      Light buoy
      Pilot station
      Fair way mark
      Other land marks
   d. Processing plant
      Size
      Number
      Capacity
   e. Warehouse and storage
      Area
      Capacity
   f. Harbour patrol system
      Salvage and rescue systems
      Dredging system
   h. Back ground of port
      Fishery situation

Place back ground
Transportation
Supply and demand
Population

i. Shipyard
Kinds
Size
Number

j. Recreation facilities

k. Hospital, pharmacy, water police etc.

l. River mouth
Width of river mouth
Water depth of river mouth
Water depth of river mouth to pier

m. Number of boats mooring
On the average
Total number per month

n. Users' opinions
Convinience
Improvement points

2.2.4 Searching for fish schools, and fish finder

1. Scouting for fish.

It is the first business for fishermen going out fishing to select their fishing grounds. They should know the locality of fish in the selected fishing grounds. They should investigate the original and seasonal behaviour of the species in the fishing grounds and clarify the catch results as well as the changes in sea and fishing conditions in the past. Then they should survey the present sea conditions with which the past conditions may be compared and contrasted. Based on such data, the most promosing area will be selected as their fishing ground.

The method of detecting or scouting the whereabouts of fish includes direct observation of the movement, or jump, of fish or other indications such as the flight of sea-birds, the change of water colour and the occurence of foams, ripples or phosphorescence together with the preliminary operation by means of appropriate fishing gear or scattered baits. In addition,the radar or fish finder introduced after the war is now going a long way toward the promotion of catch results of surrounding-net, drag-net, gill-net and long-line fisheries as well as toward the survey of fishing grounds. This apparatus is designed to radiate sound waves through the water, sending back images of the sea bottom and fish school. The return time is processed electrically and recorded on paper. The strength and gradations of the record show the density of fish school and the quality of sea bottom, which facilitate the speedy discovery of their whereabouts regardless of time and weather.

Brief explanations will be given here about the estimation of the size of fish school from the flight of seabirds and the colour of water. When the movement of fish school is speedy, the flight of seabirds is also active. The direction of their flight suggests the movement of the fish school. But when the movement of fish school is slow, the seabirds fly very slowly and high in the air making a circular formation. As soon as the fish school begin to come up to the surface, however, the movement of the seabirds again becomes very active. They begin to fly vertically and show an attack formation. In most cases,the movement of migratory species of fish is accompanied by such action of seabirds.

The change of water colours may also suggest the movement of fish in the area. The colour of water surface of the sea, where fish are migrating in a big shoal in the upper layer, is different from that of ordinary water surface. Such water colour, though varied according to the conditions of weather and clouds, usually assumes a reddish or purplish brown colour when the size of fish or the density of fish school is large, while it assumes light brown colour when the body size or the density of school is small.

With regard to the scouting method of fish school by means of appropriate fishing gear or scattered baits, as in case of the preparatory operation for tuna and skipjack fisheries made on the way to the fishing ground, the density of fish school or the possibility of catch is surveyed by means of long-lining or trolling gear. Sometimes the presence of fish school may be tested by scattering sardine taken out of bait tanks of the boat.

In short the scouting of fish is a very important preparatory action for fishing operation, and every possible effort should be exerted to clarify their exact whereabouts.

2. Method of finding fish schools

1) Direct or indirect finding by the sense of sight

Jumping of fish, bird flying, floating wood, shark swimming, dolphin playing etc. are signs or indications of the existence of fish.

The fishermen observe the existense of fish schools such as sardine, skipjack, swordfish, flying fish, etc. from the top of the mast or a special fish finding tower, equipped especially in the purse seiner. They search by eye, or by the aid of binoculars. Under the sea, fishermen use diving appratus or water glass for searching the fishes.

2) Observation of sea indication

Although we cannot see the school itself even if the shoals are thick migrating near the surface of water, the water looks reddish producing some peculiar wave formations. There are often birds flying above the fish schoals, so these birds will become indication of fish schools.

The size of fish school, swimming direction and speed will coincide with the birds's flying. When the birds fly up and down above the shoals, it means that the fish school chase the small fish schools and eat them at the surface of water. Some schools of fishes easily adhere or drift around big wood or big sized fish such as shark and whale. The reason why fishes get together swimming with sharks or whales is that they could more easily obtain bait and feel safe.

We can also find fish schools after learning from accumulated oceanographic and meteolorogical datas, such as water temperature, salinity, rough condition of the sea, water colour, atmospheric low pressure, etc.

3) Judgement by use of trial fishing

In gill net fishing, at the time when there were no fish finder facilities, the fishermen use a trial nets which is a very small gill net compared to normal gill nets, and examine how the place where trial net is used would be worth for fishing or not. In shrimp trawl fish, they also use trial trawl nets of small size in order to know the volume of fish existence.

Pot fishing, angling fishing also apply small scale trial fishing.

4) Observation by scientific instruments and equipment

Recently, the fish finder has become to be widely used in the world. The fishermen can realize the existence of fish, mass of fish, swimming direction and fish species from experience.

5) Aeroplane scouting

As a most modern scouting method, the aeroplane has become to be used for seaching fishing grounds and fish schools, particularly for tuna, purse seine and skipjack pole and line fishing. The aeroplane pilots try to find the different current barriers, the warm and cold current-encounters in the ocean which make a clear water line between the two. Around this barrier it will be more likely to find the fish school. They pay a lot of attention to finding this barrier and if it is found the pilot gives the position of these area by wireless telephone to the base port where the fishing boats are waiting for such reports.

3. Fish finder

It is necessary to know the velocity of the sound, concentration of sound, loss from absorption and reflection, bending of sound, etc.

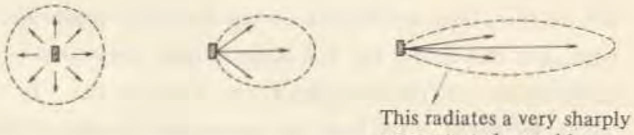
1) Velocity of sound

$$c = 1410 + 4.21\,t - 0.037\,t^2 + 11s + 0.018\,d$$

where c=velocity of sound in m/sec., t = temperature of water (°C), s = salinity in percentages by weight, d = depth of the water in meter. The effect of temperature is predominant.

2) Wave length and concentration

At high frequencies, the wave length of ultrasound in water at a frequency of 30 kc, for example, is only 5 cm, and at 15 kc, 10 cm. Thus, the dimensions of conventional transducers are larger than the wave length, so that a more or less distinctive direction effect is obtained, which is referred to as the sound beam.

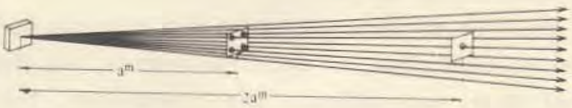


This radiates a very sharply concentrated sound beam in one direction only.

Unfortunately, if a sound beam is too sharp it is difficult to locate a target. Thus, the dimensions of the transducer plus the concentration of sound, often represents the most favourable compromise between the separate factors, where economical elements may also play an essential part.

3) Loss of sound energy

During propagation, the intensity of sound (which is the sound energy per unit area) decreases with the greater distance. The cross-section of the sound beam in which the sound energy is radiated, increases proportionally to the square of the distance. Consequently, the intensity of sound decreases proportinally to the square of the distance from the sound source.



The same unit area at double the distance from the sound source, only contains one fourth of the sound energy.

At the same time, the intensity of sound is proportionally decreased by absorption in the water. Water is not an ideal medium for the propagation of sound. It has a certain viscosity which causes friction between the separate molecules of the water. The friction of the molecules produces heat, resulting, of course, in a loss of sound energy.

Loss of absorption, however, cannot be considered as a constant factor. It increases with distance, following a logarithmic function. Loss by absorption also depends upon the frequency of the sound waves, and the condition of the water. With high ultrasonic frequencies, loss by absorption becomes an important factor, and may reduce the range of the equipment considerably. If a 20 kc sounder for example, has a range of 4,000 meters, the same equipment with exactly the same technical data, but with an operating frequency of 100 kc would have a range of only 700 meters. For good reasons, low ultrasonic frequency are, therefore preferable for long ranged horizontal and deep sea sounders.

4. Sonar

After having acquainted the fishermen with vertical fish finders, they would like to see not only below the boat, but also detect the fish horizontally. They want to know before reaching the fishing spot, the existence of fish which are ahead of the boat. By turning the transducer 90 degrees and thus directing the sound beam horizontally, we could have sonar, in principle.

Sonar has many technical problems compared with vertical fish finder. The sea and oceanographic conditions play an important role against the sonar sound beam. Eg., temperature layers and disturbing echoes etc.

At present, sonar can be utilizer. During detecting, sonar can be automatically shifted from side to side, or from side to bow, eventually indicating the schools of fish. Due to the fact that the beam has an angle, the sound pulses will meet the sea bed at a shorter or longer distance, depending on the depth of water. It was found that the reflected echoes from the bottom would be recorded and mixed with traces of fish. Therefore, sonar is more benificial for purse seine fishing and mid-water trawl fishing than for bottom fishing. It also requires very skilful operation in accordance with the operational condition of fishing.

As a rule, for purse seining, we might state that during the searching phase, use automatic program, long pulse, long range, high sensitivity and narrow beam. This is because during the searching phase, we want to be able to detect as much as possible of what is present in the sea around us. During the catching phase, we know where the school of fish is, and we switch our unit over to manual training of the tranducer:- short pulses with good discrimination, short range with detailed information and eventually a wide beam depending on the depth of the school.

In bottom trawling, it is essential that the sea bottom be smooth, and the fish be concentrated in layers piling up from the bottom. Good results will be obtained at depths of more than 100 meters. It seems that transducers with a pencil sharp beam will give better resolution and discrimination between fish and bottom, but it involves a relatively large and thus expensive transducer. The pitching and rolling of the boat will complicate the images.

For mid-water trawling, the sonar search turns the bow towards the school once it has been located. Then when the concentration of fish is below the boat and recorded on the fish finder, the height of the trawl will be adjusted according to the depth indicated. However, there is a practical limit of operation of approximately 50° angle on each bow, outside which it will be difficult to manoeuvre the trawl into catching position due to the relatively long time it takes to change the course that much.

2.2.5 Way of gathering fish

Even though we know the existense of fish, difficult situations or conditions are sometimes encountered in the fishing process. Namely:-

1) Fishing ground is too rough, reefs or shoals making it very dangeous for operating the net. (Luring by scattering bait is applicable)
2) Fish school dispersed widely not densely. (Lighting and luring by bait are applicable)
3) Fish school at considerable depth. (Light fishing is expected)
4) Fish swim too fast and scarcely stop. (Live bait fishing is possible)
5) Fish do not make for direction where trap nets are set. They escape in an other direction. (Light fishing could be considered)

However well the fishing season has been chosen, and no matter exactly the whereabouts of fish school have been discovered after being hunting for the fishing ground, it does not necessarily follow that the fish school is in a proper state suitable for being fished. In such cases, it is required to compel the school to make themselves into such a formation as to be caught readily. The measures to be taken for this purpose may include reduction in the activity field of fish school by various means, and alteration in the direction of their migration or movement. The main means for altering the movements of fish schools may be divided broadly into the following two categories: (1) inductive luring method and (2) compulsive gathering method.

1. Inductive luring method

This type of gathering method is intended to lure fish together in such state as fitted for fishing operation by choice, spontaneously or instinctively. Though this method may be called very passive or negative, if wisely devised, it will facilitate the catching effect a great deal and help get a good catch by means of comparatively small scale fishing gear. Further, a continuous use of this method will not threaten the future production in the fishing ground.

This type of method may be subdivided as follows:

(a) Luring method with baits;

(b) Luring method with lights or fires:

a. Luring method with baits: This is the most common type of fish luring method in use of various tackles or in the operation of lift-net or surrounding-net fisheries.

b. Luring method with lights or fires: This method has been developed taking advantages of the special nature of fish species that gather together, in that they are lured by lights at night. The lamp used for this purpose is called the fish luring lamp. The main species taken by means of fish huring lamps are saury, mackerel, horse mackerel, sardine and squid.

2. Compulsive gathering method

This type of gathering method is intended to compel fish to gather in such state as fitted for fishing operation by stirring up the water, making great noises or driving imitation or sham invaders. This method is required to be carried out promtly, and its repeated practice is apt to make fish so susceptible to sound and other stimli that they will be scattered and lost.

The threatening, or scare method, may be mainly divided into three types: (a) threatening method by shape or colour, (b) threatening method by sound or noise, (c) combined method of (a) and (b).

(a) Threatening method by shape or colour: The shape, colour or movement of scare articles are used to frighten fish schools away in groups.

(b) Threatening method by sound or noise: The sound or noise is made by beating the gunwales or garboards of a fishing boat. Or fish school may be confused by the water stirred up by poles or rods, and be entangled in gillnets or other nets.

2.3.1 Fishing ground

1. Characteristics of fishing ground

The necessary conditions for forming the fishing grounds are as follows:

1) The ground should have such condition that the fish easily come together in groups, and is a good place for their habitation. The density of fish distribution changes according to the seasons, specially in pelagic fishes. The proper place for fish habitation, therefore, will be naturally understood as the place of fishing. The necessary condition for the fishing ground should be satisfied with suitable environment for fish living and habitation, and also be abundant in bait and food for fishes. But the fish can select freely their dwelling places by their own will in accordance with the conditions of circumstance from time to time and from place to place. Therefore, if they stay for rather longer times in a certain place, this place will become a fishing ground of the fish.

2) The ground should be the place where it is easy to handle the fishing gear for the fishermen.

Generally speaking the coastal waters readily become a fishing ground due to the abundance of food for fish. But sometimes these waters are difficult for operating gears, especially net gears because of the existence of rocks, shoals and reefs although it is very convenient to be near the base port. Sometimes these places have very swift currents and big tidal differences. In such places the fishermen should pay attention to proper operation of fishing gear. Sometimes they use trap nets, gill nets and angling gear instead of net gears such as trawl nets and purse seine.

On the contrary, off shore fishing grounds have no such condition, but suffers from bad weather and high waves. The fishermen also should conquer these poor conditions with effective use of fishing gears.

3) The ground should be a place economically located

It is natural that the management will stand or fall on the balance between the amount of investment and of income. The articles included in the investment are mainly divided into two parts, namely fixed capital such as fishing gears and fishing boat, and running costs such as salaries and consumption of fuels and provisions. The fishery management should make profits in operation. If, the fishing ground is too far from the base port it will needs a lot of fuel. If the fishing is actually very hopeful, the efforts exerted may well justify going to more distant places. The fishermen in such case can get profits in the fishing management. If we can make device to bring up the fishing efficiency such as using more efficient fishing machines, then we could also enlarge our capacityof going to more distant places for fishing.

The fishing ground is also controlled by the market demands for fish. This demand for fish products will be influenced by the capacity of supplying from places which, for instance, is newly developed as fishing ground. So, the fishing ground always has relative value, relating with economical balance, other fishing grounds, fishing efficiency and the demands of fish in the markets.

Thus, efforts always have to be made in finding new fishing grounds by economical and effective use of modernized fishing methods.

2. Selection of fishing ground

At first we should know the existence of fishing grounds according to the species of fish and by the seasons. The selection of fishing ground will be done with the proper understanding of the efficiency, conveniency and economy of fishing. The method of selection will be done as follows:

1) Presumption of adequate environmental areas suited

for the behaviour of the fish aimed for using oceanographical and meteological research data.

2) Presumption of fishing season and ground, from the past fishing experiences accumulated on the records of past fishing operations.

3) Selection of the fishing ground economically taking into consideration the distance from the base, fish shoal's density, meteological conditions, etc.

3. Bottom character

Generally the bottom has the following character shown in the marine chart. The marine sediments consists of terrigeneous sediments, hemi-pelagic and pelagic sediments.

good fishing grounds for fishermen. The occurrence of herring schools in early spring is one of the good examples of spawning migration of fish.

Besides the species of fish as mentioned above which make big migrations, there are other species of fish which are settled in limited places in the sea. They are called sedentary fish. The radius of their movement is limited. The principal type of their movement is vertical, that is, they move between the bottom and the surface of water by day or by night. There are also some species that move between the coastal shallow waters and the deep waters offshore during the season. This type of movement is called horizontal or depth movement. Such sedentary fish also constitute good fishing groounds for fishermen.

Symbol	Element	Symbol	Element	Symbol	Element	Symbol	Character
Ck	: Chalk	Mg	: Manganese	S	: Sand	brk	: broken
Cn	: Cinders	Ml	: Marl	Sc	: Scorial	c	: coarse
Cy	: Clay	Ms	: Mussels	Sh	: Shell	cal	: calcareons
Co	: Coral	Oy	: Oysters	Sn	: Shingle	f	: fine
Di	: Diatom	Oz	: Ooze	Sp	: Sponge	h	: hard
Fr	: Foraminifera	P	: Pebbels	St	: Stone	l	: large
G	: Gravel	Pt	: Pteropod	T	: Tuff	s	: soft
Gl	: Globigerina	Pm	: Pumice	Wd	: Weed	sk	: speckled
M	: Mud	R	: Rock			sy	: sticky
Md	: Madrepora	Rd	: Radioralia			v	: volcanic

2.3.1 Fish behaviour relating to fishing ground, and kinds of fishing ground

1. Fish behaviour and the conditions of fishing ground

It cannot be said that fish live everywhere in the sea. According to their species, fish are distributed horizontally or vertically in certain limited areas. The fishing ground is also different according to the latitude and longitude as well as the depth of water where fish occur.

The main reasons why a certain species of fish gather in a certain area are thought to be as follows:

1) Fish select such life-environment as fitted for their species.
2) They hunt for abundant sourcee of food.
3) They seek for such places as suitable for their spawing and propagation.

Guided by such instinct and carried by seasonal currents, fish move in appropriate temperature waters, seek for food and spawn in such waters. This movement is called migration, and their migration course is almost fixed throughout the year. The migration for seeking for food is called feeding migration and the water area where fish seek for food is called the food-seeking ground. Again the migration for spawning is called spawning migration and the water area where they spawn is called the spawing ground. During their migrations and in their food seeking and spawning grounds, the fish gather together in dense groups. Such places crowded with fish naturally make

The various conditions of the sea bring about changes in fishing grounds. The sea is governed by the warm and cold currents. Fish select their respective home waters according to their optimum water temperature. The continental shelf which is fertile in nutritive salts flowing in from coastal land is a good fishing ground for sedentary fish. Great quantities of plankton grow in the eddies made by currents or the convergent lines of cold and warm currents. These organisms attract living things in general, especially fish that gather together on the spot as their food seeking ground. Such places are also called a good fishing ground. Further the area where the sea bottom rises and forms what is called sea-bank is also fit for fishing ground.

Most sea-banks are shallower than 400 m in depth. The origins of sea-banks are divided into two: volcanic and tectonic. Generally speaking, forms of life in the sea-bank are more abundant and various than in the continental shelf. Many migratory and demersal fishes are found in the sea-bank which makes it a good fishing ground. Such knowledge of oceanography will go far towards increasing the production of fisheries.

2. Kinds of fishing ground

The classification of fishing grounds is often made as follows according to such items as the species of fish to be taken, the types of fishing gear to be used, the water areas where fisheries are operated and the sea areas where fisheries operated:

(1) Species of fish: Tuna and skipjack fishing ground, salmon fishing ground, etc.

(2) Type of fishing gear: Trawl fishing ground, long-line fishing ground, fixed-net fishing ground, pole and line fishing ground, surrounding-net fishing ground, etc.

(3) Water areas: Deep-sea or pelagic fishing ground, inshore fishing ground, coastal fishing ground and inland-water fishing ground.

(4) Sea areas: North Pacific fishing ground, East China Sea fishing ground, South East China fishing ground, etc.

But fishing grounds are generally classified into the following two main types: coastal and off-shore fishing grounds, or pelagic (or running) fish and bottom fish fishing grounds respectively.

(1) Coastal fishing grounds

Normally, coastlines have very many good fishing grounds. The fisheries production from these grounds is steadily increasing year by year. The coastal fishing grounds include those for stationary seasweed, fish and shellfish and those for important migratory species such as herring, salmon, yellowtail, tunas and seabream that approach the shore to seek food or to spawn. These coastal fishing grounds may be subdivided into trap-net fishing ground, small trawling fishing ground, driving-in net fishing ground, beach seine fishing ground, hand purse seine fishing ground, surrounding net fishing ground, pole & line fishing ground, etc.

For the purpose of conservation of fisheries resources in the coastal waters and maintaining the value of the fishing grounds, measures should be taken along such lines as the building of barriers in the sea, artificial hatching and release of finger and fry. It is also very important for the maintenance and devlopment of the value of fishing grounds, to obtain the understanding and cooperation of fishermen for fisheries resources conservation as well as the appropriate judgement and management of the fisheries administration.

(2) Pelagic fish fishing grounds

One of the representative pelagic species of fish in the Pacific Ocean is skipjack. The fishing ground for skipjack fish are mainly located in the subtropical convergent lines formed by the confluence of the warm and cold currents. Other migratory species of fish, both warm and cold current types, such as tuna and salmon, seasonally go up north or come down south to seek for food in the eddies or current rips made by the confluence.

Further, the complicated features of topography in the coast and the waters of up to 200 meters where bottom currents come up and mix with the upper warm water-mass, produce planktons in great quantities which invite fish to migrate and stay there. The migration area of skipjack, tuna and salmon in the Pacific is vast and boundless from right on the equator to northern waters.

But it must be noted that the proper fishing ground for the pelagic species is almost limited to the current rip in these waters.

(3) Demarsal fish fishing grounds

The continental shelf which is generally 200 m in depth is most suitable for demersal fish or those living near the bottom. The waters over 400 m in depth are not fitted for fish, excepting for those of special species. Living things at the bottom of sea include those almost settled in one place, those making horizontal or deep and shallow movement, or those seasonally making a long migration. The continental shelf into which sand or other organic matters flow from the shore and settle, is generally fertilized and fitted for the growth of plankton. Owing to such merits of the shelf, the coastal or inlet waters are ideal fishing grounds for shellfish and seaweeds, especially for small fishes. As fishing means, bottom drag-nets are mostly used. Some plelagic species may be fished in these waters.

But the waters of over 800 m in depth, though there are found some species of fish, are fitted to be utilized as fishing ground not only because of the difficulties in fishing operation but also of the scarcity of fishery resources.

3. Exploitation of fishing ground and their maintenance

With the recently increased construction of fishing vessels of large sizes, the modernization of their equipment and the introduction of improved observation apparatuses for fishing use, the size of fishing grounds has been magnified.

It is of vital importance for the developmentof fishing grounds to be provided with excellent fishing boats and well-trained crews, together with overall practical techniques and knowledge of oceanography and science of fisheries resources plus the study of various factors of oceanographic observation and judgement. The current rip, water temperature, salinity and transparency in the off-shore fishing ground as well as the water temperature in the middle and lower layers are very important factors for the purpose of fishing operation. For example, the introduction of acoustic detectors for fishing has brought a revolution in the fishing operation. The development of an echo sounder has also clarified the actual status of sea bottoms which was formerly unknown to fishermen. As a result, the surrounding fishing, which was formerly operated seeing only the condition of fish shoal on the surface, has now developed to be more vertical and at the same time more effective type of fisheries.

Fisheries resources in boundless water areas appear to be inexhaustible at first sight. But if they were left to the aggressive exploitation by the latest mechanized fisheries operation without regard to the proper conservation measures to be taken for the resources, all fishing grounds would be laid waste. Furthermore, and unrestricted catch of spawning fish and finger or young fish would destroy their stocks themselves. Therefore, the preventive measures against overfishing on national and international levels are absolutely necessary for the maintenance and preservation of fishing grounds at large. 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, therefore, researches 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 hand.

2.3.6 Fishing port

1. Necessary facilities for fishing ports

The fishing port is a base of fishing operation composed of water area, land area and facilities, such as contour facilities (breakwaters, sand groins, retaining walls, sluices, locks, levees, jetties, seashore levees and parapets), mooring facilities (mooring quays, landing place, mooring buoys, bollards, piers, floating piers and slipways), water facilities (routes, anchorages and basins), transporting facilities (beltline railways, beltline tramways, roads, bridges and canals), navigation facilities (navigation aids, signal and lighting facilities of communications for entry and clearance of fishing boats), land for fishing port facilities (sites for all kinds of facilities), preservation facilities for fishing boats and gear (repairing yards for boats, gear and engines, and gear drying yards), supply facilities (water and oil supplies for fishing boats), fish catch handling, storing and processing facilities (marketing place, cranes, storages, open yards, ice-making, refrigerating and storing facilities and processing plants), communication facilities (wireless telegraph and telephone stations on land, and meteorological signal stations), crew's welfare facilities (lodgings, bath houses, medical offices and halls) and management facilities (offices and watch houses).

These basic and functional facilities as specified in the Fishing Port Law may appear too many and too expensive or too high in aim to begin with. But most of them are essential to a complete management of fishing ports. Especially in Japan where fishing boats are always battling with wind and waves and fishermen often meet with shipwrecks, it is absolutely necessary for the safe and benefitial fisheries operation to be provided with a good fishing port.

2. Selection of proper place for fishing ports

The scale of fishing ports in general is diversified according to the types of fisheries, number and size of fishing boats and quantities of catches in regard to the respective ports. There are some ports exclusively used as fishing ports while others occupy only part of commercial ports for fishing purpose. As a whole, most of the fishing ports in the country cannot be said to be located in proper places and be provided with proper equipment and facilities so as to carry out their primary purposes.

The requirements for a proper fishing port may be summarized as follows:

(1) The site should be near the fishing ground and be conveniently situated for going out fishing.

(2) The locality should be convenient for the landing, handling, storing and marketing. It must be suited for the anchorage of fishing boats, construction of quays, installation of salting, coldstoage and refrigerating facilities, building of warehouses, fish markets, manufacturing and processing plants.

(3) The locality should be a convenient place for handling the handled catches. It must be suited for the establishment of facilities for packing and transporting landed catches to consuming centers, including beltline railways, tramways and truck ways.

(4) The locality should be a place suited for the establishment of facilities for manufacturing and repairing of fishing vessels, gear and their related ship yards, wood working shops, iron works, engine and fishing gear repairing plans, net dyeing for drying yards and hangars of fishing gear and fittings.

(5) The place should be fitted and convenient for the supply and shipping of necessary materials for the operation of fisheries such as fuel oils, ice, baits, foods, water and sundries.

(6) The place should be of easy access to consuming centers. Since one of the most important roles to be played by fishing ports in a connecting link between the fishing ground and the consuming center, fishing ports must be connected easily not only with the fishing ground but also with the consuming center.

(7) Other matters. In the selection of suitable places for fishing ports, a close examination is to be made in regard to the possibility of establishment of facilities other than those mentioned above, such as health and medical facilities, lodgings, recreation centres, bath houses

for the sake of crews welfare as well as telegraph and telephone services, observatories of sea and fisheries conditions and banking organs.

3. Classification of Fishing Ports

The classification of fishing ports may be made by (a) types of construction, (b) scales or number of boats belonging thereto, (c) operation areas or catch carrying spheres of boats and (d) types of fisheries.

(a) Types of construction: Fishing ports may be divided into three types in regard to their construction: natural, artificial and river fishing ports. Most artificial fishing ports are constructed by making the best use of the geographical features of their locality.

(b) Scales of ports or number of fishing boats: Fishing ports can be classified by this category into three; namely, large, medium and small types. The small type may be called a moorage.

(c) Operation areas: By the bases of operation or catch carrying activity, they are divided in to high-sea fishing ports, off-shore or coastal fishing ports, transit fishing ports, forward base fishing ports and ports of shelter.

(d) Types of fisheries: By types of fisheries, they are classified as follows: Small trawling base, two-boat type trawling base, big trawling base, squid angling base, trap net fishing base, purse seining base, stick-held dip net fishing base, etc.

These classifications are made according to the principal features of each fishing port. But in fact there are many cases where it is difficult to make an exact classification and to give them definite terms. Further, there are a number of fishing boats that utilize several fishing ports at the same time.

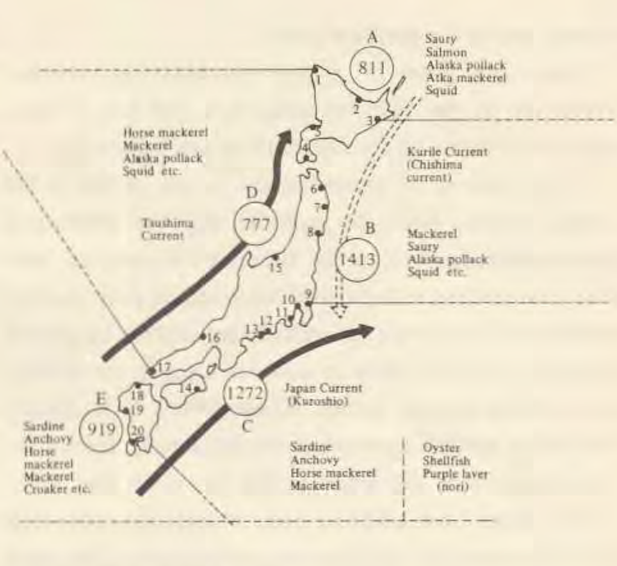
2.4 Outline of fisheries managements and its background in Japan

1. Surroundings

The seas that surround Japan contain two great warm ocean currents, the "Japan (or Kuroshio) Current" and the "Tsushima Current", and one major cold current, the "Kurile (or Chishima) Current". Many varieties of fish are distributed over these different zones, providing rich fishing grounds for the Japanese people (See Figure 1).

Being a mountainous, insular nation with a coastal line of 26,000 kilometers, Japan has, since antiquity, taken a large proportion of its food supply from the surrounding seas.

Besides, Japan is located near the North Pacific Ocean and the East China Sea, which are also among the world's richest fishing grounds. Thus, Japan today is one of the major fishing nations in the world. At the same time, it places primary importance upon the conservation of



Domestic production (Thousand metric tons)

1. Wakkanai (208) 6. Hachinoe (169) 11. Misaki (63) 16. Sakai (35)
2. Abashiri (82) 7. Miyako (33) 12. Shimizu (79) 17. Shimonoseki (166)
3. Kushiro (187) 8. Shiogama (76) 13. Yaizu (142) 18. Fukuoka (180)
4. Hakodate (15) 9. Choshi (139) 14. Muroto (10) 19. Nagasaki (208)
5. Otaru (50) 10. Tsukiji (96) 15. Niigata (43) 20. Makurazaki (22)

N.B. Total catch of Japanese fisheries in the seas around Japan (area A,B – – – E) amount to more than 5 million tons, and the production of cultures in shallow coastal seas has been maintained at level of 400 thousands tons. Half of the total catch has been produced in areas B and C, east of Japan. Alaska pollack, ataka mackerel, saury and common squid are found in the cold current areas A,B and the northern part of D, while sardines, jack mackerel, mackerel, croakers, etc., are obtained from the warm current areas, C,E and southern part of area D.

Fig. 1. Fishing ports and catch by fishing areas and by species of fish (1963)

marine resources in order to maintain a maximum level of production over a long period of time.

That the Japanese people consume considerable amounts of fish and shellfish is indicated by the level of the annual per capita consumption: 24.8 kilograms in 1964/65. Further, 17.5 per cent of the protein in the Japanese people's diet is derived from marine products. As a result of the improvement in the standards of living in recent years in Japan, the demand for food with a high protein content, that is, dairy products and marine products, has risen substantially, a trend which is expected to continue in the immediate future.

2. Harvesting the seas: Japan's fish catch

The volume of Japan's fish catch has been increasing annually. In 1952, the catch exceeded the prewar record of 4,330,000 tons, and in 1970 a record of over 7,100,000 tons was recorded. In recent years the total annual catch has been at a level between 8,000,000 and 10,000,000 tons, with the development of offshore and pelagic fishing techniques and the development of fish culture in shallow waters. Nevertheless, the annual rate of increase of the volume caught has been tapering off slightly during the past few years.

Then, the price of marine products has increased drastically in the past ten years and this rise, in turn, provided as incentive for fishermen to catch more fish.

In the interest of increasing the supply of fish in the coastal waters, both the national and the prefectural governments, as well as the fishermen themselves, have been undertaking various artificial breeding projects such as attempts to provide favorable living habitats by placing rocks and concrete slabs in suitable areas in the shallow parts of the coastal waters. These efforts have already resulted in notable increases in the fish supply. One of the characteristics of the Japanese fish harvest is that Japan catches more tuna, salmon, crab, shrimp and other high priced types of fish. At the same time, Japan's fish catch is not dominated by a limited number of species but is extremely varied. As a result Japan's fish catch, as a whole, is quite stable.

At the same time, it must be noted that in the expanding national economy, supported especially by the heavy and chemical industries, the relative position of the fishing industry has declined noticeably during the past decade. For example, the ratio of income from fishing activities to total national income fell from 2.8 per cent in 1955 to 2.3 per cent in 1960 and even further to 2.1 per cent in 1965. The ratio of the number of persons employed in the fishing industry to the total number of employed persons in Japan registered a similar decrease, from 1.8 per cent in 1955 to 1.5 per cent in 1960 and 1.3 per cent in 1965.

3. Coastal fishing

Coastal fishing is defined as fishing conducted either by boats of less than 10 tons or by fixed nets, or through artificial breeding techniques in shallow waters.

There were 214,800 independent fishery enterprises and 440,000 persons engaged in coastal fishing in Japan in 1965. The ratio of the former to the fishing industry as a whole was 96 per cent and the latter 72 per cent. Although a large number of persons are engaged in coastal fishing, its production amounted only to ¥222,300 million ($617.5 million) or 37.4 per cent of a total value of ¥593,800 million ($1,649 million). As a result, their productivity is about one-third that of enterprises consisting of medium-sized craft or pelatic fishers.

The Japanese Government, therefore, implemented in 1964 various measures designed to improve coastal fishing. It has instituted a five-year plan aimed at increasing the per capita income of coastal fishermen by an average of 6.4 per cent a year. Some of the measures call for equipping fishing boats of under 10 tons with echo sounders, wireless telephones, transceivers and hydraulic machinery. The overall purpose is to modernize fishing operations and promote cooperative fishing. At the same time, the Government is encouraging coastal fisheries to "culture" marine products such as seaweed, oysters, pearls, yellow-tail, shell-fish, and other types of fish.

Fish culture in the shallow sea waters has been developed spectacularly in recent years to raise productivity in the coastal waters and to increase the income of coastal fishermen. Improvements in this fish culture technology make it possible now to artificially control the growing process of many valuable kinds of fish, shellfish and seaweeds from the larval stage until they reach marketable size.

At present, prawn, sea bream, yellow-tail, "nori" (a kind of seaweed), oysters, pearls and other forms of marine products are being raised by this method and these are seen on the market with increasing frequency. The rapid development of this shallow sea culture program as promoted by the Government is considered the principal factor behind the steady rise in the total value of production from shallow sea fish culture, which rose by about 2.5 times during the 1960–65 period.

4. Offshore fishing

This type of fishing is conducted mainly by medium-sized enterprises with boats in the 10 to 100 ton class. The offshore fish catch in 1965 was 3,536,000 tons, which was 52.3 per cent of Japan's entire catch that year. In terms of value, however, it amounted to ¥243,600 million ($677 million) or 41.0 per cent of the total value.

Fish caught offshore are eaten fresh or in processed form, but like the herring catch in northern Europe, the catches are concentrated in certain seasons, so that during the year there are great fluctuations in market prices. These fluctuations have tended to result in lower income for the fishermen. In order to rectify this situation, the Japanesse Government has provided more funds to the offshore fishermen for the purchase of refrigerators and refrigerator trains and trucks to transport their catches to the markets and for the reconstruction of processing plants.

In addition, fishery organizations themselves have voluntarily decided to reduce the volume of their catches of those types of fish which are characterized by widely fluctuating market prices. At the present time, the Government is providing financial assistance to such organizations. Furthermore, maps of fishing grounds (charts indicating the distribution of schools of fish) are being compiled and sent by facsimile transmission to ships operating at sea. While short-wave radio broadcasts have been utilized for the past 15 years to inform the captains of fishing vessels of the location of these schools, it is expected that the facsimile transmission of these maps will greatly increase the size of the offshore catches.

In addition, the captains are kept informed of the current market prices of the different kinds of fish so that they may adjust their activities accordingly.

5. Pelagic fishing

Pelagic fishing is engaged in by large fishing vessels which operate in waters far from Japan. Their catch in 1965 totaled 986,000 tons and amounted to ¥67,700 million ($188 million) of 11 per cent of total value.

Salmon and crab fishing in North Pacific waters is carried out chiefly by large fishing fleets with mother ships which act as large floating fish-processing and canning plants.

Trawling centering on waters off the African continent is conducted by ships of the 2,000–3,000 ton class. Tuna fishing in equatorial and sub-equatorial waters around the world is mainly conducted by ships of the 200–500 ton class.

Japanese whaling fleets operate in the Antarctic, the North Pacific and waters adjacent to Japan. Japan sent several fleets with catcher boats to the Antarctic for the 1965–66 whaling season and produced 40,451 tons of whale oil and 124,502 tons of edible whale meat and blubber. Whale meat is important as a supplement to the animal protein supply in Japan. The total number of whales caught in the North Pacific Ocean and waters adjacent to Japan was 8,729 in 1965.

Ships engaged in pelagic fishing are considered the cream of the Japanese fishing fleets because of their highly modernized equipment and excellent techniques.

Fig. 2. Japan's pelagic fishing catch in 1965 (Unit: thousand metric ton)

6. Lake and river fishing

The total catch of carp, eel, trout and ayu (a trout-like fish) and other species caught and cultured in inland waters increased from 90,000 tons in 1965.

To encourage the development of inland fish resources, the Government has implemented measures to prevent the pollution of water in rivers and lakes and also drafted a five-year plan, started in 1963, aimed at further reinforcing measures to increase inland fish catches. The Government is also extending financial aid to those engaged in inland fishing to enable them to expand their stocking activities and improve facilities at fish culture sites.

7. Improved methods in recent developments

The development of Japan's fishing industry is largely due to the improvement of fishing methods. The number of powered boats in 1960 totaled 168,470 with a gross tonnage of 1,360,000. However, by 1965, the number of powered boats and increased to 221,375, with an aggregate weight of 1,910,000 tons.

The increase in the number of small boats of under 10 tons was due chiefly to the transformation of non-powered boats to powered ships. The great increase in the number of ships of over 100 tons was due mainly to the reconstruction and enlargement of ships of the 10 to 100 tons class.

As a result of the tendency toward larger size ships, practically all boats engaged in coastal fishing today are equipped with diesel engines and almost all the ships of more than 50 tons are made completely of steel.

Reflecting the acute labor shortage of recent years, more and more ships are being equipped with remote control devices, oil pressure apparatus and other equipment, a trend particularly conspicuous in the past four or five years.

Japan today is one of the leading countries in the world exporting fishing ships, engines and fishing gear.

8. Demand for marine products increasing

Ever since 1958, the Japanese economy has expanded at a real annual growth rate of over 12 per cent. As a result, personal spending also rose by a real annual rate of 8 per cent. This in turn has caused a rise in retail prices (wholesale prices remain rather stable), particularly that of fish.

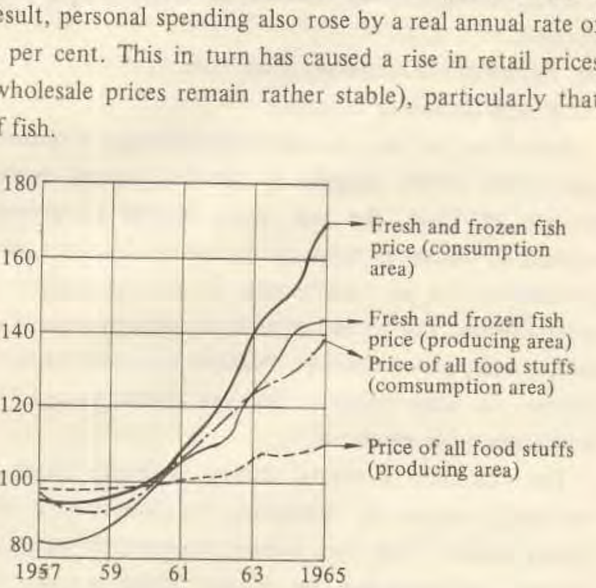


Fig. 3. Trends in fish price and general commodity prices

The rise in the price of fish has exceeded the average price rise for all foods.

Despite the fact that the volume of Japan's fish catch had increased by 11 per cent in 1965 over that in 1960, fish prices rose by an average of over 40 per cent during the same period. This indicates the strong trend of demand for marine products.

Demand for processed marine products as well as for fish to be used as fertilizer and feed had increased more than that for fresh or frozen fish.

While the domestic supply of fishery products provides the greater part of the demand for personal consumption, one-fourth of the fishery products to be used as feed and fertilizer is imported.

9. Employment trends

The development of related industries and the rise in the price of fish usually favors the fishing industry, but with the development of a large number of non-related industries resulting from the growth of the national economy, many persons employed in fishing are being relocating in other industries, resulting in shortage of labor, which in turn has boosted the wage level of fishermen but created a major problem for the fishing industry.

There is a trend toward a decrease in the number of persons employed in the fishing industry. The decrease rate in the number of fishing enterprises is also tending to rise although not as rapidly as the decrease rate of persons employed in fishing pursuits.

In order to cope with this situation, the Government as well as private fishing circles are concentrating their efforts toward introducing more labor-saving techniques into the fishing industry. Many of these have already been adopted.

10. Future of the Japanese fishing industry

(1) Rise in income of fishermen

According to the national medium-range economic plan (1964–1968) adopted by the Government in the autumn of 1964, the per capita income of persons engaged in fishing is expected to increase by 6 per cent per annum (6.4 per cent increase for persons engaged in coastal fishing and 5.9 per cent rise for persons engaged in pelagic and offshore fishing). Measures have been taken to narrow the wage disparity between fishermen and the workers in other industries.

For example, in coastal fishing, measures aimed at increasing catches by improving the structure of the fishing industry have been actively implemented and have centered on improving the coastal fishing grounds. In regard to offshore and pelagic fishing, efforts are being extended to discover new fihsing grounds but greater emphasis is being placed on coping with the acute labor shortage by introducing laborsaving techniques and raising productivity by promoting mergers and cooperative operations.

(2) Maintaining and increasing fish resources

The conservation of fish resources is extremely important because the foundation of the fishing industry would be weakened if more than a certain amount of fish were caught in a given period of time.

For many years now, Japan has implemented measures for the conservation of fish resources. A system has been adopted to limit the number of fishing ships while certain restricted areas have been designated and time limitations imposed. The artificial spawning of salmon and the release of salmon fry have also been carried out.

Five national centers for the promotion of coastal fishing and the culture of marine life have been established at various sites in the country. At these centers yellow-tail, sea bream, shrimp and crab are being cultured and their fry released.

A law for preventing the pollution of water was legislated in 1958 and in case of areas where pollution is severe, a water quality standard has been established as one part of the campaign to prevent the water from becoming more polluted.

With regard not only to coastal fishing resources but also to offshore and pelagic fishing resources, Japan is making strenuous efforts to conserve and reasonably use these fishing resources, either domestically or through international cooperation.

Japan is a signatory to numerous international treaties and conventions concerning fisheries, such as the Japan-U.S.-Canada Fisheries Treaty, the Japan-USSR Fisheries Treaty, the Japan-Republic of Korea Fisheries Treaty, Japan-China Fisheries Treaty, the International Whaling Convention, the Fur Seal Conservation Treaty, etc. In addition, although not a signatory, Japan cooperates and acts in compliance with the purposes of many other international agreements on fishery problems.

In various ways, Japan has contributed to conserving valuable fish resources in all parts of the world and to the stabilization of the fishing industry, internationally, and it intends to continue to cooperate positively with all additional efforts and fishery treaties which may be concluded in the future.

Nevertheless, with the convening of the Geneva session of the Third United Nations Conference on the Law of the Sea held in 1975, it appears that the concept of an economic zone extending up to 200 nautical miles out to sea is receiving wide support. This would a historic change in the traditional approach to the use of the seas, it is pertinent to inquire as to exactly what would happen in fisheries of Japan in future.

(3) Extensive experiments and studies

In order to realize the above goals, extensive experiments and studies are, of necessity, being carried out.

Japan is divided into eight fishing districts with a Government research institute in each. There are also 82 experimental stations throughout the country. There are also two Government-operated fishery colleges and a total of 12 universities where courses in fishing have been established. A total of 2,000 persons are engaged in studies and experiments at these institutes. There are also 45 fishery high schools in Japan.

Studies are being carried out not only on the improvement of fishing techniques and gear and processing methods, but also on the means of effectively utilizing marine resources and increasing the stock of fish.

(4) International cooperation in fishery development

There are many countries, which although blessed with abundant fishery resources, have been delayed in developing their own fisheries through the lack of proper techniques, equipment, funds, etc. It is now widely recognized that the full development of these fishery resources will not only significantly raise the nutritional levels of the people of these countries, but will also benefit the development of domestic industries within these countries. For the purpose of aiding these developments, Japan has dispatched a number of expert technicians to the developing nations and has invited numerous trainees from these countries to study in special courses in Japan, either under bilateral programs or through the Food and Agriculture Organization of the United Nations.

International cooperation is essential if these countries are to develop their domestic fishihg industries. However, effective results cannot be realized within a short period of time. Therefore, Japan is now offering various types of aid such as financial assistance and necessary services and equipment. It is expected that international cooperative efforts will be expanded in the future since current programs are proving highly successful.

Fishing Gear and Method

Fishing Gear and Method

3.1.1 Notation of twine system

1. Tex system

The tex system is expressed as the mass in grams per unit length 1,000m of yarn or twine. There are two basic ways of describing twines by the tex system; the most detailed one gives the tex value of each yarn and the number of yarns and strands e.g. 23 tex × 5 × 3. To give the weight per unit length of the twine, further information must be given as to the degree of twisting and chemical treatment. The simpler form gives only the resultant linear density of twine, called R tex, i.e., the actual weight in grams of 1,000 m of the twine.

The tex system, recommended by the Working Group on Terminology and Numbering system, formed during the first Gear Congress (1957) and endorsed by ISO (International Organization for Standarization), and has the advantage, as an international unit, that it is based on the metric system and gives a direct estimation of the twine size, as the heavier the twine is the greater the tex value becomes.

1 tex = 1 gram/1,000 meter

$$R\text{ tex} = 0.1111 \times \text{Td} = 2{,}485 \times M = \frac{594}{Ne_c} = \frac{1{,}658}{Ne_L}$$

$$= \frac{1{,}000}{\text{Nm}} = \frac{1{,}000{,}000}{\text{m/kg}} = \frac{496{,}055}{\text{yds/lb}}$$

Explanation:

a. International denier system (twines made of cotton and synthetic continuous multifilament): Td
   1 den. or Td 1 = 1 gram/9,000 meter
b. Japanese manila twine number: M (*monme*)
   M = 3.75 gram/1.5 meter or 2.48 gram/m
c. English cotton number (twine made of cotton and synthetic staple): Ne_C
   Ne_C = 840 yds/lb or 768.1 meter/453.6 gram
d. English linen number (twine made of linen, ramie, hemp, jute): Ne_L
   Ne_L = 300 yds/lb or 274.3 meter/453.6 gram.
e. Metric number (all twines): *Nm*
   Nm = 1 kilometer/kg or 1,000 meter/1,000 gram.
f. Runnage (yds/lb or m/kg) of the finished products for the hard fiber twines (manila, sisal) and sometimes also for other fibers.

Example:

210 den = 210 × 0.111 = 23 Tex.
92 tex = Td 840 den. (210 × 4)
115 tex = Td 1050 den. (210 × 5)
552 tex = Td 5040 den. (210 × 24)

Table 1. Relation between Td and Tex

Td	= Tex	Td	= Tex	Td	= Tex	Td	= Tex
70	7.6	200	22	420	46	1080	120
90	8.4	210	23	500	56	1100	122
100	11	250	28	630	70	1140	126
110	12	300	34	720	80	1280	138
125	14	360	40	840	92	1680	184
150	17	380	42	1000	112	3360	368
180	20	400	44	1050	115	5040	552
190	21						

2. Conversion

Nylon (23 tex) $\quad T_d = \frac{23}{0.11} \times (\text{No. of yarns})$

$$\therefore \text{No. of yarn} = \frac{T_d \times 0.11}{23}$$

Polyethylen (44 tex) $\quad T_d = \frac{44}{0.11} \times (\text{No. of yarns})$

$$\therefore \text{No. of yarns} = \frac{T_d \times 0.11}{44}$$

3. Diameter of twine

Manufacturers of PP and PE., sometimes, refered to as the relationship between diameter and weight of netting yarn which is represented in the Figure 1. With equal diameter, the weight of netting yarn obviously decreases or increases with the density of the fibre material of which it is made.

Diameter (mm)	Approximate corresponding R tex		
	PA c. f.	PP c. f.	PES c. f.
1.2	1000 (100%)	740 (74%)	1380 (138%)
1.5	1690 (100%)	1160 (69%)	2300 (136%)

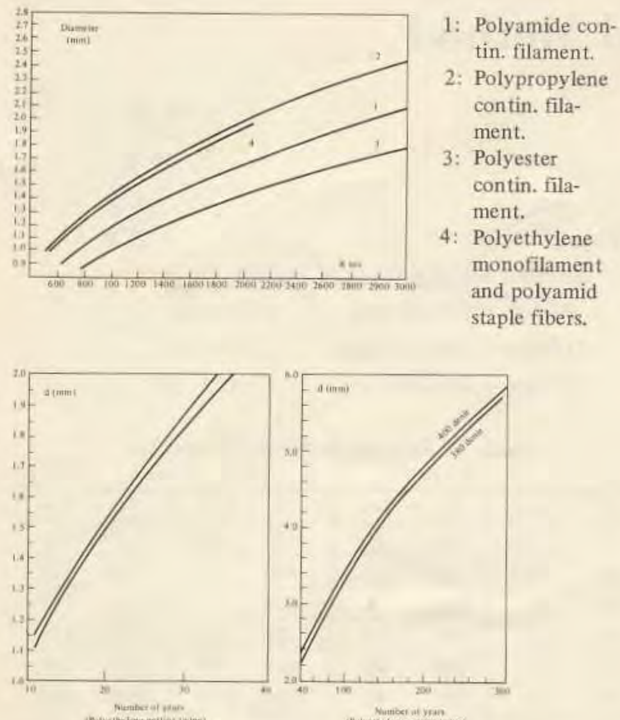
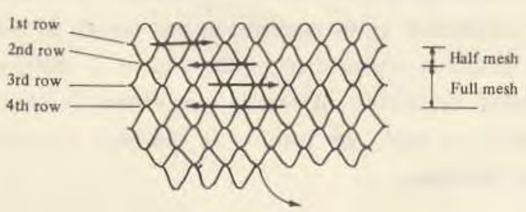


Fig. 1. Relationship between R tex and Diameter

3.2.1 Fishing net making

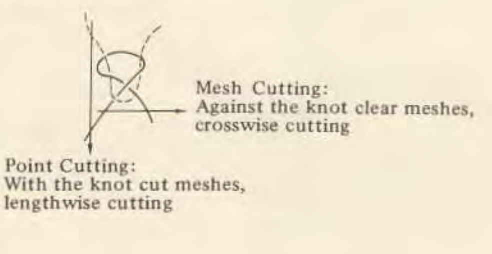
1. Introduction

The net is constructed fundamentally by the meshes. Therefore, the meaning of net making is to compose many meshes in certain number of depth and length. There are two ways of net making namely machine making and hand making. A mesh is composed of 4 knots and 4 bars. It can also be thought of as a serious of knots, each knot completing a mesh and each row of knots increasing the length of the piece of net by half a mesh.



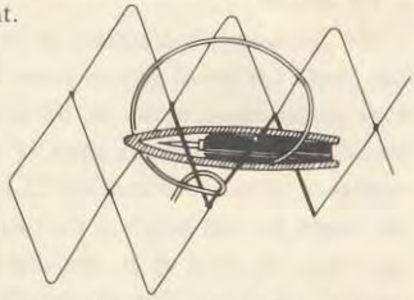
2. Clear mesh and cut mesh

If the twine is cut just below a knot and the knot untied, a loop will remain which is referred to as *against the knots clear mesh.* And, if the twine is cut just beside a knot, two loose ends will remain which is referred to as *with the knot cut meshes.*



3. Making the knot

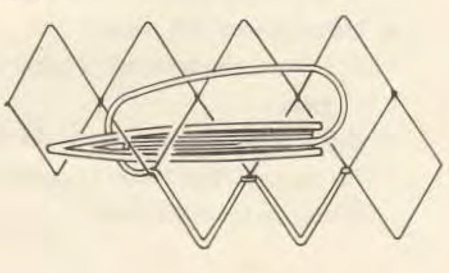
The implements used for hand braiding of netting are needle and spool. Pass the needle up through the mesh until a short tail of twine remains below the knot. Using the fingers, twist the tail of the twine around the two bars of the mesh above the twine leading to the needle. Throw the loop of twine to the left to form a sheet bend and pull tight.



Thus we make a half mesh knot. It is better to mend a nets quickly and efficiently. The rows of knots must be lined up in the right direction and the netting properly supported.

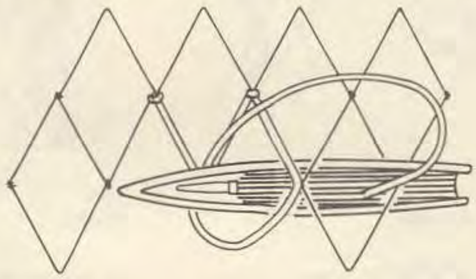
When making half mesh knots from left to right across the net the needle is brought up through the mesh. The size of the loop (half mesh) should be formed by adjusting with the finger. The thumb and index finger clamp the twine at the center point of the half mesh on which the knot is being tied. A sheet bend is formed by making a loop to the left and the needle is passed through a half mesh and over the loop. Then the knot will be formed by pulling the twine tightly with the moving of needle to the right.

When working from right to left the needle is passed down through the mesh. The palm of the hand (not the back of the hand) is towards the net making operator. On the contrary the back of the hand is towards the net making operator when it is proceeded to make net from left to right. The twine is clamped in the half mesh by the index finger and the thumb and a sheet bend is formed in the same way.



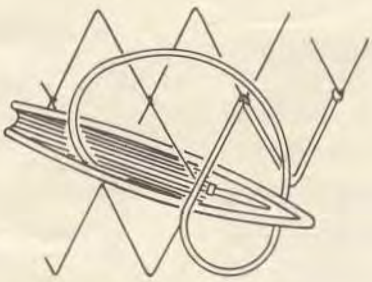
Right side knots :

Lay the twine to the right of the knot of the side mesh with the index finger behind the knot. Measure the length of the bar of the mesh being formed by lining up the two knots above the one being made. Clamp the twine with index finger and thumb just below the knot in the side mesh. Throw the loop in the twine to the left from an overhand knot around the knot in the side mesh and pull tight by moving the needle to the left.



Left side knots :

Lay the twine to the left of the knot in the side mesh with the index finger behind the knot. Measure the length of the bar in the same manner as for the right side knot and clamp the twine in the same way. Throw the loop of twine to the right from an overhand knot around the knot in the side mesh and pull tight by moving the needle to the right.



3.2.1 Basic fishing net composition

1. Net braiding

Net braiding can be done by machine or by hand. Any size of mesh can be braided by the net machine. Also several types of knot nets can be braided with various thickness of twines, as flat knot net, trawler knot net, double trawler knot net, knotless net etc.

2. Kinds of knot

Flat knot (or reef knot or square knot) and trawler knot are most popular type of knot in practice. (Fig. 1)

From the view point of fishing operative convenience the comparative characteristics of knots between the two knots are shown in the following table:

Items	Flat Knot	Trawler Knot
Friction at the knot	small	large
Slippness at the knot	large	small
Quantity of twine in a part of the knot	small	large
Weight of net	small	large
Bulk of net	small	large
Breaking strength at the knot	large in value when the net is pulled with the knot	large in value when the net is pulled against the knot

Others:

The knotless type net does not belong to a knot category but is widely used particularly for trap net and trawl net in Japan, which is constructed by special joining with strands different directions. Generally, two strands in one direction are used for construction. Three types – Running type, zigzag type and Hexagon type – are widely used as the knotless net webbing which are particularly produced by knotless net webbing machine. (Fig. 2)

Running type: The strand of one direction runs straight through. (1)

Zigzag type: Two twines from different directions are crossed and run zigzag. (2)

Hexagon type: Although the stands of one direction run cross with the other strands, the mesh gives hexagonal shape when it is spread. (3)

The merits and demerits of knotless net as a fishing materials used in fishing are introduced as follows:

Merits		Demerits
Quantity of net ········· small		Repairing·········troublesome requiring many man-hour
Bulk of net ··············· small		Required time for making net by machine ··· great
Mesh size ················· precise		
Friction of net ········· small		
Hydraulic resistance ··· small		Cost of net ··············· high

The *cross type* net of which the mesh is kept in squares by crossing the twines of different direction, are produced. This is called the minnow net. This is used especially in small mesh nets, e.g. plankton net, etc. (Fig. 3)

The *russel type net* is made by the system of lace netting fishing net machine. The demand of this type of net is not so widely used commercially being used in purse seine fishing only.

3. Disadvantages of net braiding by machine

The introduction of net making machines nearly one hundred years ago made efficient production of webbing. This accordingly accelerated the fishing industry to a larger scale. In spite of this before the presense of synthetic fiber net, the natural fiber net had to be washed, preserved with tar or tannin and dried in the sun taking many hours.

Then synthetic fibers were introduced around 1950 with remarkable advantages of physical properties, as greater strength, longer life, etc.

However, the main drawbacks of machine made nets are: they cannot be bated – decrease the net – or creased – increase the net, and machines can't braid flymeshes onto net pieces which is necessary for the construction of trawl net gears. But the above set-backs are not so seriously in practice because if it is necessary to decrease or increase the net, this can be done by cutting to the shape required and braiding the edges with twine later by hand. Also, the flymeshes can be braided by hand once the net has been made and cut to shape. In the process of making nets in such a manner, a certain amount of waste netting will be left over but this can be reduced with careful initial planning.

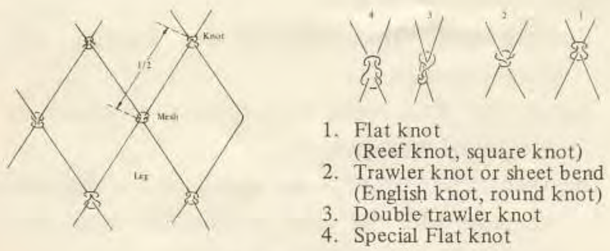


Fig. 1 Knot and leg

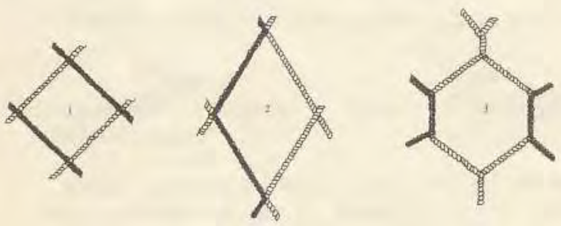


Fig. 2 Knotless net

Fig. 3 Minnow net

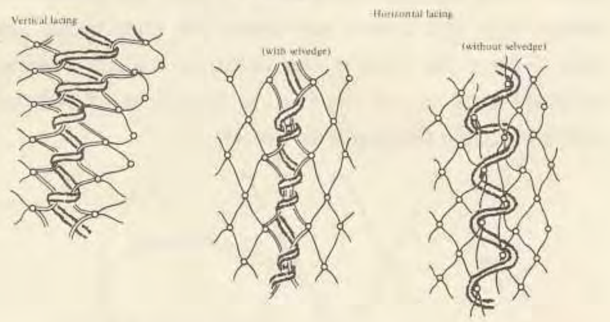
4. Joining

When two different compositions of net pieces are joined together, the cases will be considered as follows:

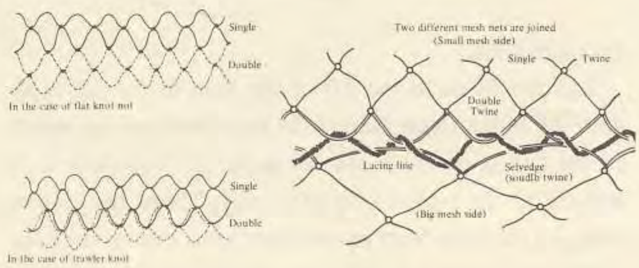
1. The two net pieces are the same length but different in mesh size
2. The two net pieces are differnt in length but same in mesh size
3. The two net pieces are different both in length and mesh size.

Case 1 is a simple joint and the take-up small mesh are inserted at suitable intervals. In cases 2 and 3, the longer net piece allows the webbing freedom to bulge out laterally, as in the case of round haul nets and some types of bagnets. The longer net piece is treated as if it were baited at a faster rate, and at the same time the joining helps to shift the stress toward the side or selvedge of the shorter one.

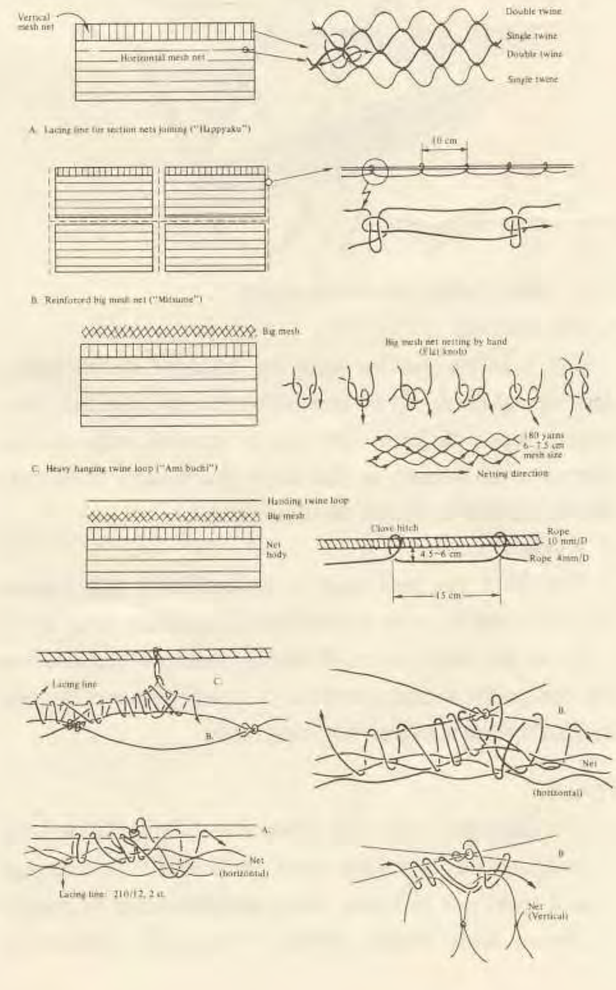
Joining



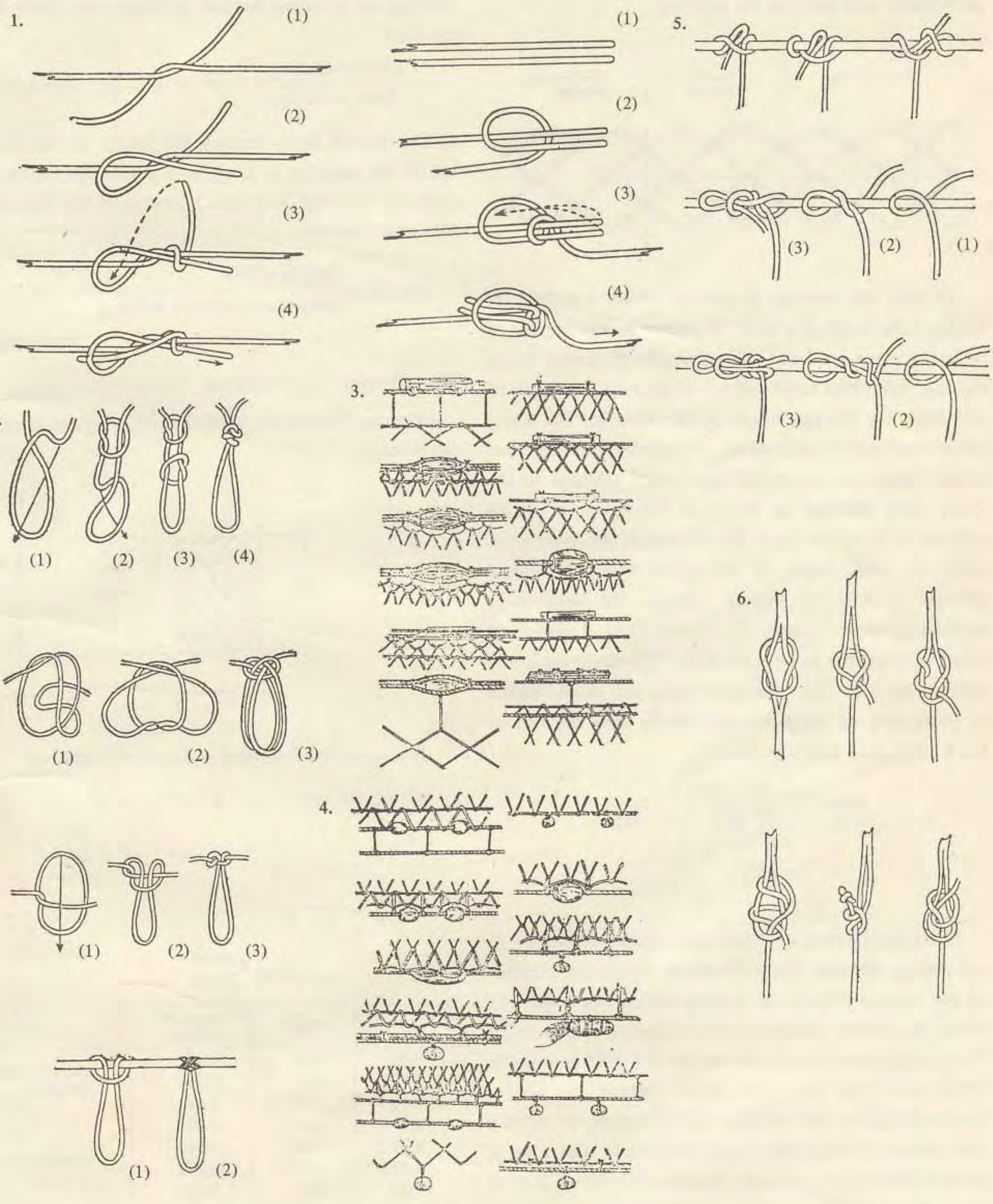
Selvedge **Joining**



Lacing line

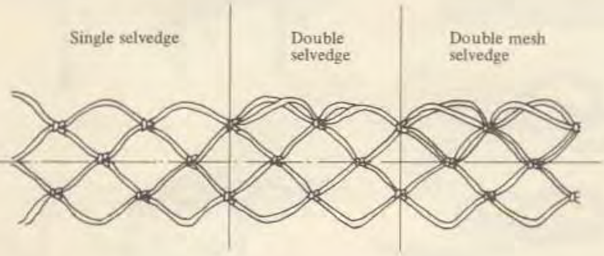


Twine bindings and float line and foot line composition

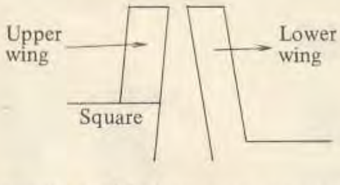


5. Lacing

The selvedge runs along each side of the net strengthing the gear. When braiding, one should know whether the net selvedge needs, or not, and single selvedge means no selvedge. The selvedge is to be made of the twine of the same size as that used for the webbing.



To *lace* the selvedge of two net pieces together, for instance the belly of a trawl net, three to five meshes of each net piece are laced with a needle of double twine making two round turns and a half hitch at a distance of one mesh for the full length of the selvedge. The lacing often needs careful adjustment. for example, in trawl net when lacing the square and upper wing selvedge to the lower wing selvedge as shown in the figure, a certain amount of slack net has to be allowed in the lower wing, since the total length of the upper wing and square selvedge is only 19 meters, whereas the lower wing selvedge is approximately 21 meters. Thus, 2 meters of extra selvedge has to be worked in. This slackness in the lower wing is to make the lower wing part more flexible or elastic and the wings are also usually laced up with far less hitches than used elsewhere.



In the preparation of fishing gear, ropes are fastened to the netting selvedge. Since the whole weight and tensility of the netting effects the netting twines which directly fasten the roping, certain counter measures must be taken for the reinforcement of the twines. For small and simple types of netting gear, the rope is fastened by border roping directly to the netting. And in case of the netting gear made of thick and large mesh sizes, the rope is fastened directly to the net. But for the netting gear of large and complicated types, narrow selvedge part made of thick twine is fastendd between the roping and netting. In contrast with selvedge netting, the part of main body of netting is called main netting.

6. Shortening

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.

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

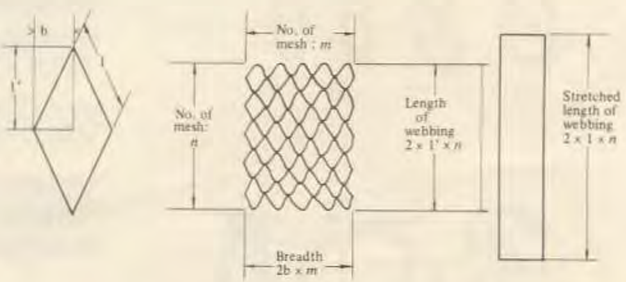
2) The second is to express the length of the line, to which the webbing is hung, in a percentage of the total stretched webbing. It is called *hanging* in US, Canada and European countries.

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

(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:

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

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

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

Height of a mesh Table

s	$\sqrt{2s-s^2}$	length of a mesh	Remarks
0.10	0.43	0.90	
0.134	0.50	0.866	used in trawl designing
0.15	0.52	0.48	
0.20	0.60	0.40	
0.25	0.66	0.34	
0.292	0.707	0.292	square shape in mesh
0.30	0.71	0.29	
0.35	0.76	0.24	
0.40	0.80	0.20	
0.45	0.83	0.17	
0.50	0.87	0.13	
0.55	0.89	0.11	
0.60	0.91	0.09	
0.65	0.94	0.06	
0.70	0.95	0.05	

In the case of the ratio of breadth to length

$\frac{b}{l} = 0.5$, then $\sqrt{2s - s^2} = 0.5$

$s^2 - 2s + 0.25 = 0 \quad \therefore s = 0.134$

In the case of a mesh shape is square,

$\frac{b}{l} = \frac{1}{\sqrt{2}} \quad \therefore \sqrt{2s - s^2} = 0.707$

$s^2 - 2s + 0.5 = 0 \quad \therefore s = 0.292$

Thus, the table shown is drawn.

7. Handling of netting

1) Introduction

Small braiding of net as scoop net or cast net can be produced in required sizes by repeated netting operation by hand with bate or crease. But in the case of large scale netting, many units of netting must be combined together. For this purpose of combination, the length and width of webbing are cut according to the measurements specified in the design, with other netting, triangular or trapezoid in shape being prepared. Putting these net section together, a large set of fishing gear such as trawl net, purse seine, etc. can be formed.

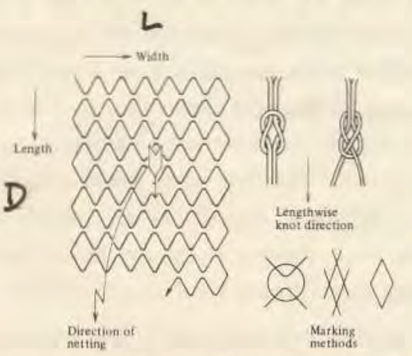
2) Combination and joining the webbing

Several pieces or units of netting are combined into a set of net. In the combination, there are two main ways of joining the webbing: the sides of net pieces are joined to increase the width, or the edges of net pieces are joined to increase the length.

Prior to the use of new netting, it must be stretched fully both lengthwise and sideways, tightening the knots at the same time. This prearrangement is needed especially in the operation of gill net. In stretching the meshes or nets, check those parts of netting where the length of leg is not even, and so are easily broken. It is necessary to repair or rearrange those parts before hand.

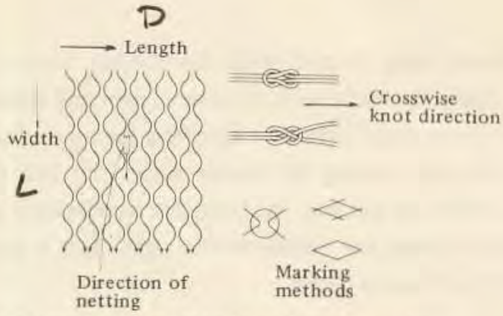
3) Direction of mesh

If the direction of netting, that is, the direction of the length of net, and the direction of knot are the same, we call this longtitudinal netting. If these two directions make a cross, it is called lateral netting, as shown in the diagram.



Longitudinal netting: webbing by hand, both in flat knot and trawler knot.

The lengthwise cutting of the net is used to reduce the width of netting, in which the netting is cut by two legs in the direction of knots. Care must be taken not to cut the legs too short otherwise they may become loose.



Lateral netting: trawler knot webbing by machine.

The crosswise cutting of the net is used to fix the length of netting, in which the netting is cut by two legs crosswise to the knot. In this case the legs may be cut very near the knot, and then the remaining twine pieces removed.

The determination whether the webbing be used as lateral knot direction or longitudinal knot direction in the arrangement of net to the float line or lead line when making fishing gear is made in consideration of the following conditions :

1) Direction of the power acting on the netting,

2) Direction of spreading the gear rapidly and in full,

3) Convenience for the composition of gear.

Of the three conditions, 1) is the most essential. Since there are many cases where fishing gear is dragged horizontally to diminish damage, the netting is usually used in longitudinal knot direction.

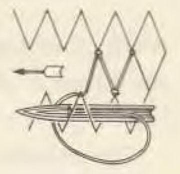
8. Net mending

1) Introduction

The damage to netting gear includes the breaking of netting, and the cutting of twines used for joining the webbings, ropes etc. If even a small damage in the net is not found in an early stage or it is not repaired, it will break the balance of combined power of gear, which may result in a greater damage. Therefore, a constant inspection and repairing should not be neglected, especially during fishing operation. In the repairing of webbings, proper measures are taken according to the degree of damages, size of mesh, kinds of knot and necessary conditions for repairs. For example, in repairs of any great damages made in part of netting gear composed of various netting, only the damaged part will be replaced by new netting as an emergency measure, and the remaining less damaged parts may be replaced afterwards. In case of small damage, that part only need be replaced or repaired with netting twines of the same kind and size.

2) Pick-up knot

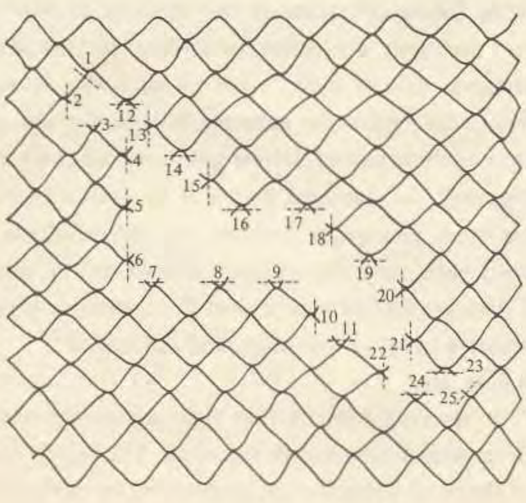
When working from left to right across the net the needle is *passed up* through the mesh. The length of the bar of the mesh being formed is measured by lining up the knot being formed with the adjacent knot on the left. Clamp the twine with the index finger and thumb. A sheet bend is then formed by 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 of figures 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 of above figure.

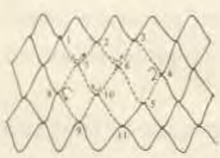
3) Cutting out

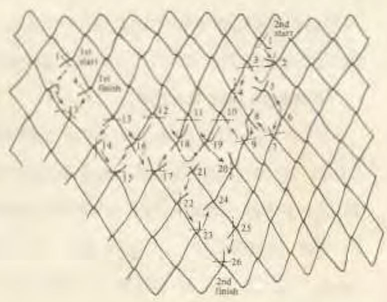
When cutting out a hole, preparatory to mending it, the knot to which the starting knot (1) is to be tied must have three bars leading to it, only one of the normal four bars being cut away. All the other knots tied in mending the hole, except the finishing knot, must be tied to a knot with only two bars leading to it, requiring two bars to be cut away. The finishing knot (25) is tied to a knot with three bars leading to it, so only one bar is cut away. The procedure is to be done as; select the starting knot at the highest point of the hole and cut away one bar, leaving three bars to the knot. 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. 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 (12 to 23) to within a few meshes of the bottom of the hole. Cut two bars away from each remaining knot alternately on the left then the right hand side of the hole (2 to 24) until a finishing knot (25) remains, where only one bar is cut away. The hole is then ready for mending. With large holes in the net it is easier to cut out on each side for the first 5 to 10 meshes from the starting point. Mend this and then cut out a further section and mend it.



4) Mending

The figure 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 to 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).

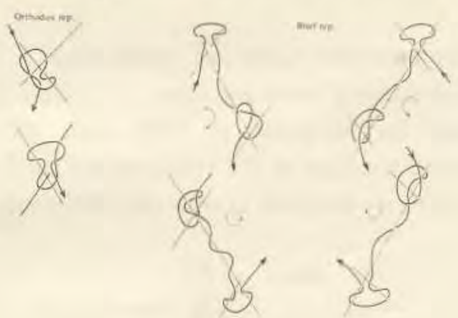




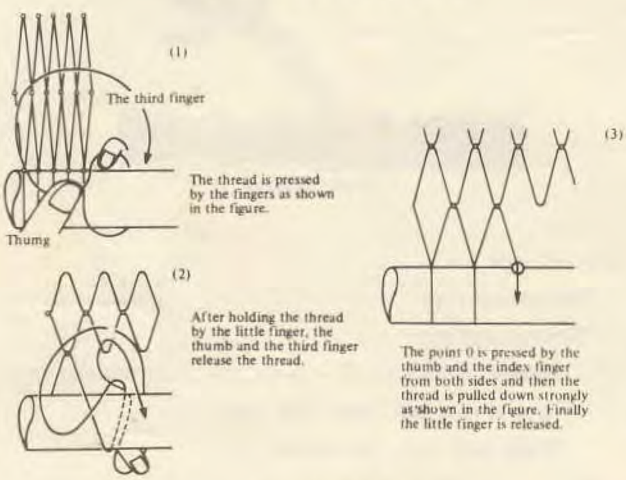
Ordinarily, all holes are not so simple and straightforward as shown in figure on the left. When a damaged net is examined, it will often be found that two or more tears run down the net, meeting at the point of most damage, and leaving a tongue or tongues of net hanging down between the tears. In the figure on the right 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).

If more than two tears lead from the top down, all but one must be repaired separately before the hole can be closed. If two or more tears run off from the bottom of a hole the netting can be turned round the other way so that the bottom becomes the top and the same procedures used. When mending to the edge of a piece of netting a selvedge mesh must be formed. Great care must be exercised when mending a hole which cuts across a section of net where tapered edges have been joined. It is essential to know the taper and direction in which it is decreasing. The easiest approach to this situation for a beginner may be to undo the tapered edges for a few meshes above and below the hole, mend each side of the taper as separate holes to a straight edge, then cut the appropriate taper on the edges and rejoin.

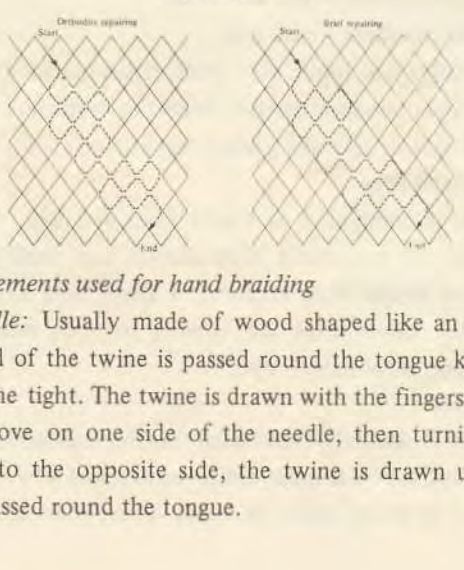
Repairing operation: How to handle the twine



Small mesh net making by hand



Repairing the net



9. Implements used for hand braiding

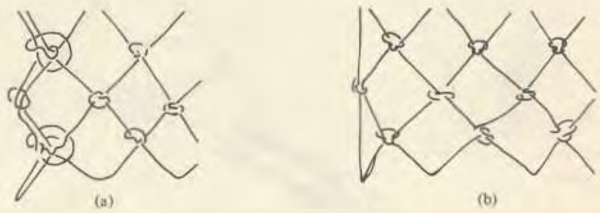
Needle: Usually made of wood shaped like an arrow. The end of the twine is passed round the tongue keeping the twine tight. The twine is drawn with the fingers round the groove on one side of the needle, then turning the needle to the opposite side, the twine is drawn up and again passed round the tongue.

Spool: Usually made of wood or metal. This is a guage to confirm a uniform size of mesh when the twine is pulled tightly round the outside of the spool. Thus, the spool should be exact in size giving allowance for the thickness of the twine and also for the amount of twine that will be taken up in forming part of the knot.

Braiding rod: This metal or wooden bar is used to keep the braiding net firm with nice arrangement while the fisherman braiding.

10. Double Selvedges

After the completion of each row by hand, braiding a triangular selvedge mesh is formed. This can be made in two ways: (a) double selvedge made by passing the twine round the selvedge mesh when making the first knot of the next row, and (b) closed selevedge which is made free.

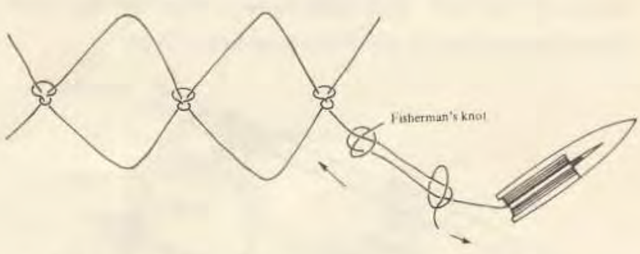


To lace the selvedges of two net pieces together, several meshes of each net piece are laced with a needle of double twine making two round turns and a half hitch in one mesh and this way of fastening is used throughout the full length of the selvedge.

11. Fisherman's Knot.

This is the type of knot which should always be used for joining on a fresh needle of twine to the remaining twine of the last needle. Make two ordinary overhand knots together with these two twines as shown in the figure and then two ends are pulled thus securing the knot.

When a fisherman is using a needle of twine, he joins it on with an ordinary reef knot.



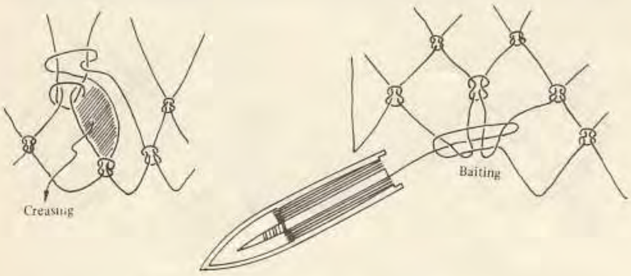
12. Bating and Creasing

When making trawl nets, the net pieces must to be done in the following ways, namely *baite, crease, cutting,* and *flymesh.*

Baiting: Baiting derived from the word abate. Two loops are taken up in one knot thus decreasing the net by one mesh. Suppose there are 20 meshes across and we want to make ten meshes in 10 rows, baiting should be performed every other row at each selvedge, i.e. 5 baiting at each side which loses a total of 10 meshes. Baitings are usually made at or near the selvedge. In deep sea trawl net it is a practice to make baitings on the 3rd or 4th meshes from the selvedge in order to avoid confusion when the net is mended, but not so far that the baiting is outside the protection of the lacing.

Creasing: Creasing derived from the word increase.

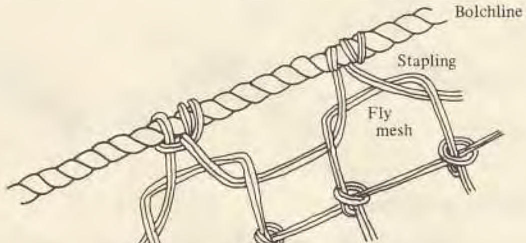
Exactly the opposite procedure to baiting. Following the completion of a mesh, a second smaller loop is made on the same knot, after which normal braiding is followed. Same as baiting, creasing also should be made at or near the selvedge.



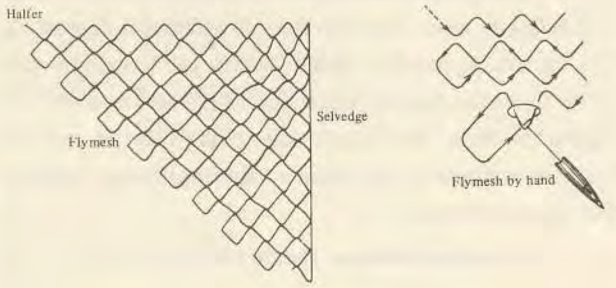
If the belly of trawl net is braided making a baiting every third round at each selvedge, the lower wing creases every third round, still maintaining the dimentions of the net. This keeps the slope of the selvedge constant and so helps to distribute strain during trawl operations.

13. Flymeshes.

Upper wing and lower wing of the trawl are braided to the inner edge forming flymeshes. They are joined to the bolchline in a hang-in fashion. The double twine passes through the flymeshes making a small bight to bolchline which is called stapling. Sometimes the wings have no flymeshes along the inner edge, instead of this, the baiting by hand braiding or by cutting meshes are made to get the shape of trawl net. And, thus the wing edges are mounted along the headline or the fishingline being fixed.



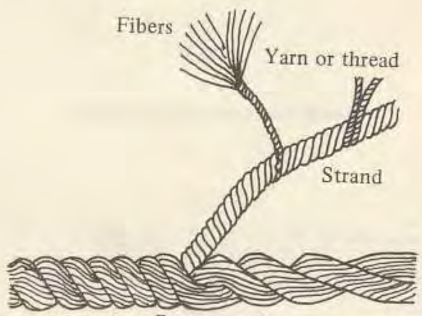
Flymesh cause the mesh decreasing and give one triangular piece, the hypotenuse of this triangular piece is called a following halfer. The figure shows how to get flymesh braiding. Flymeshes are braided along the inner edge of the full length of the wing which decreases the net one mesh for every 2 rows braided, and is equivalent to the shape of all bar cutting pattern.



3.2.2 Construction of rope and combination

1. Construction of twine and rope

Ropes are composed of fiber, yarn, and strand. Right hand laid rope or Z – twist, and left hand laid rope or S – twist are the kinds of twist used in the rope.



Twisted rope :
- Two strand rope
- Three strand rope
  - Hauser laid rope : Z – twist, the most popular type rope as it is said "plain laid rope".
  - Water laid rope : S – twist
- Four strand rope
  - Shroud laid rope : Z – twist
- Three by three strand rope
  - Cable laid rope : S – twist, three hawser laid rope, three smaller strand twine or rope are twisted together to make a larger three stand rope

Compound rope :

This is compound of textile fiber and wire. The two kinds of compound twist include one made up of a three strand rope enclosing a single wire and one in which three wires are located in each strand of a regular three strand rope.

Wire rope :

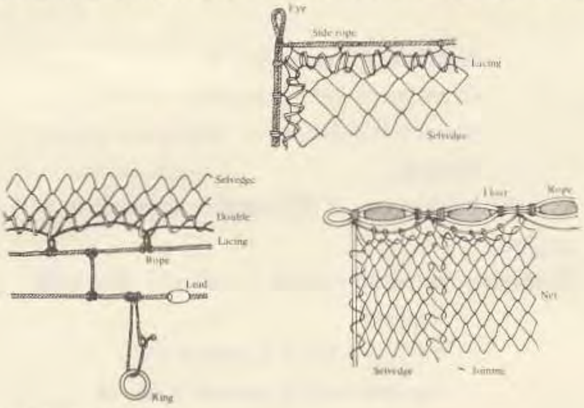
This is basically the same as the compound rope, except that it is made almost entirely of wire. The core used is either hemp or metal. When constructed with one or more hemp cores, it is called a "flexible wire rope". When constructed with one or more cores of metal, it is called "non-flexible wire rope".

Braided rope :

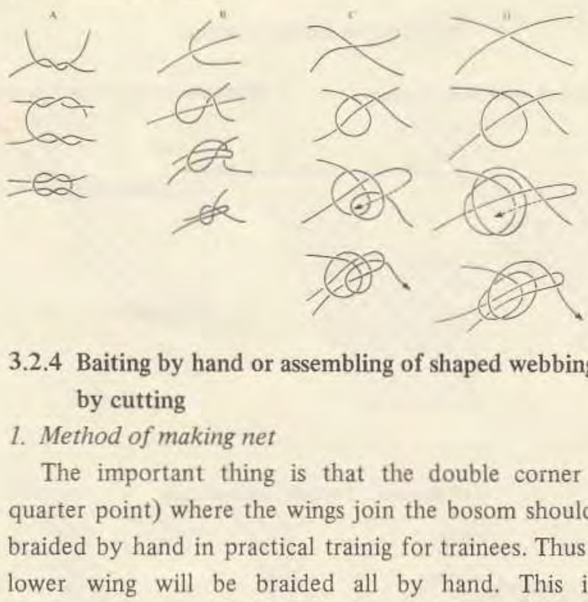
The braided twine is fabricated by plaiting several threads or strands. There are kinds: crossing laid rope, and tube-shaped braided rope. The former is produced by interweaving two strands or four strands alternatively. This is chiefly used in rope construction. The latter is made by knitting together several strands into a tube-shaped twine and is used in line or heavy twine construction.

2. Net and rope composition

Float, sinker, lines, ropes and selvedge composition (Eg. Purse scine)



Twine binding & joining



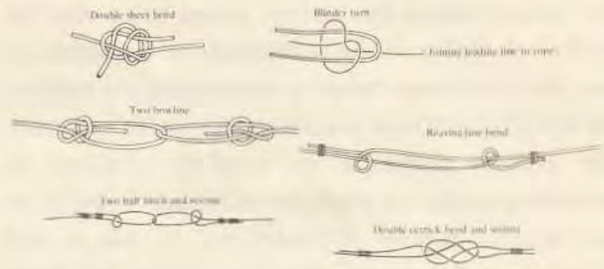
3.2.4 Baiting by hand or assembling of shaped webbing by cutting

1. Method of making net

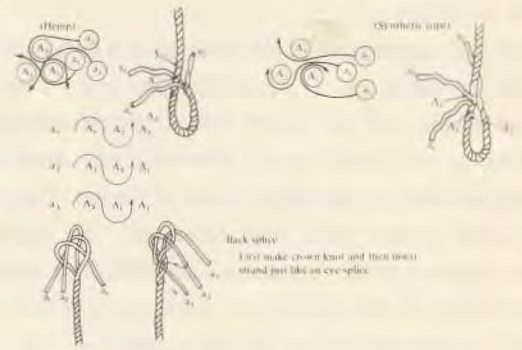
The important thing is that the double corner (or quarter point) where the wings join the bosom should be braided by hand in practical trainig for trainees. Thus the lower wing will be braided all by hand. This is a hand-made method, but the making of net also could be done by assembly of shaped webbing which can be got by cutting the machine-made strips of webbing according to the cutting patterns which can be calculated from the designing of net.

Thus the trawl net needs fashioning, either by braiding them in the roung, with baitings inserted at appropriate intervals, or by assembly of shaped webbing sections. Theoretically it is possible to cut or braid webbing to any

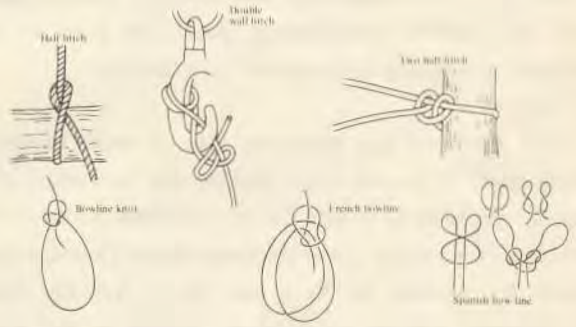
Rope and line joining



Eye splice



Hitch



shape : in practice, however, all shapes are obtained by decreasing the mesh (or increasing) at certain bating rates, as curves give rise to many difficulties both in construction and in mounting the webbing to its supporting lines. Curves, therefore, are always made by a series of straight lines, each at a different angle to the vertical or across the knots direction.

In double corner case as it was learned in our practical training, the slope can be decreased by inserting baiting under the selvedge of the wing making faster slope which, by reason of its fly mesh, has a slope of *all bar* cutting patterns (coincides with *1 mesh decrease in one mesh deep* or *1 mesh decrease every 2 rows).* And in the outer edge of selvedge the slope could be increased by inserting creasing mesh which has a slope of, for instance, 1 p 4 b cutting patterns (coinsides with *2 mesh increase in 3 mesh deep* or *1 mesh increase every 3 rows*).

The additional baiting causes a localized closing of the meshes and consequently a greater height, which allows the selvedge to stand further off.

Where desired, the meshes can be kept lower down at the normal opening by inserting creases to equalize the number of meshes. When considering the dimensions of new nets, it is always better to overestimate the width of the net which will have in action in all types of trawl nets. The desirable shapes of net could be examined by conducting model net experiments in tanks in which we can vary the number of meshes case by case in each section from the original design to get the best shape. Thus we can nearly guess the ideal figures of trawl net in actual operation.

Too high assessment of the opening of a trawl net may require the use of plenty of webbing, but still the net will be operatable and can catch fish. Underestimating the webbing at the trawl mouth, however, will cause some disconfiguration in the whole shape of the net. The wings are pulled farther open than calculated, the bosom is pulled forward while sideseams fall back; this causes a contradiction in the webbing of the throat and bad water release. It may even lead to the cod-end turning over.

The desirability to over-rather than under-estimate net webbing does not mean that it is better to chose a bigger net, but careful consideration should be given to the amount of webbing to be allowed to a headline.

2. Cutting

Net machines can braid any size of mesh required, using single or double twine, and can also be worked with various thickness of twines. But the machines can not baite (decrease the net) or crease (increase the net) nor can they braid fly meshes on to a net piece. Actually these requirement can be obtained by cutting to the shape required and braiding the edges with twine later by hand. Also, the flymeshes could be braided by hand after the net has been made and cut to shape, the only disadvantage with this process being that a certain amount of waste netting is likely to be involved, although this need not be so serious with careful planning.

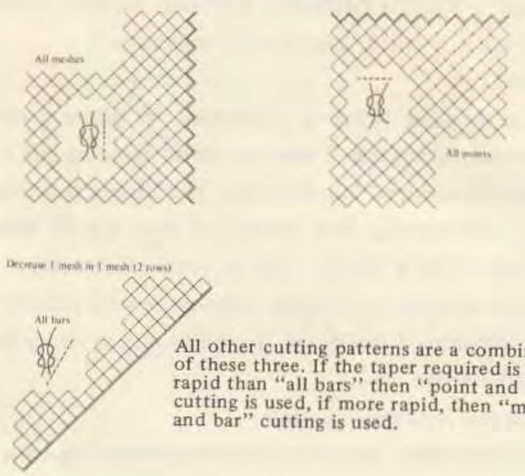
1) Point and bar cutting

As shown in the following figures, a system should be adopted 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 out, also designates the direction in which the knots lie. Where the webbing is tapered differently on its two edges, then the baiting rate for the inner and outer edge is specified on successive lines.

Half a mesh is lost every time a bar is cut and the cut webbing becomes 1 row longer, while every time a point is cut webbing becomes 2 rows longer.

Thus:- Number of meshes decrease $= b/2$

Three basic cutting patterns : -



All other cutting patterns are a combination of these three. If the taper required is less rapid than "all bars" then "point and bar" cutting is used, if more rapid, then "mesh and bar" cutting is used.

Number of rows $= 2p + b$

(Number of meshes in deep $= p + b/2$)

where b represents bar cutting and p point cutting,

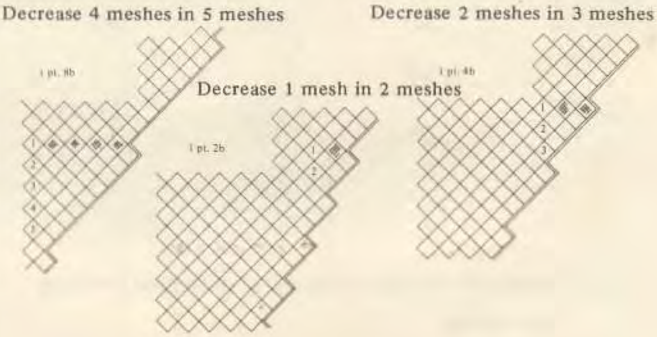
and the baiting rate is $b/2$ meshes decrease in $(P + b/2)$ meshes.

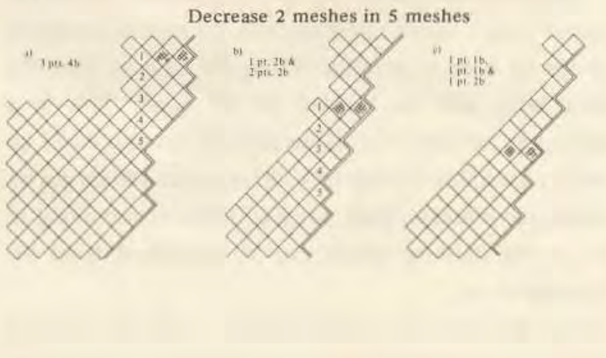
Example:- A baiting rate of 1 mesh in 2 meshes is required.

$b = 2, p + b/2 = 2$, then $p = 1$

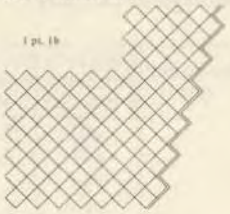
required cutting pattern is $1p. 2b$

Point and bar cutting examples

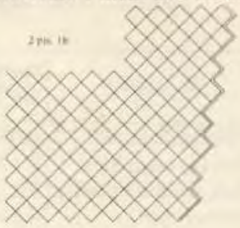




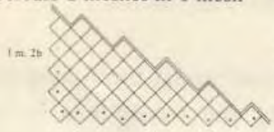
Decrease 1 mesh in 3 meshes



Decrease 1 mesh in 5 meshes

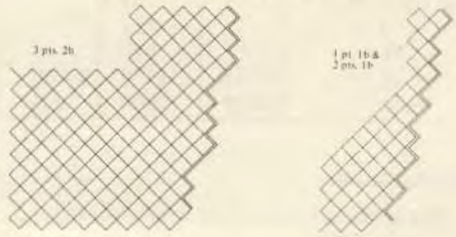


Decrease 2 meshes in 1 mesh



Decrease 3 meshes in 1 mesh

Decrease 1 mesh in 4 meshes



2) Mesh and bar cutting

Half a mesh is lost every time a bar is cut and the cut webbing becomes 1 row longer, while cutting a mesh does not increase the length of the cut webbing.

Thus:- Number of meshes decrease = $m + b/2$

Number of mesh in deep $= b/2$

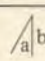
and the baiting rate is $(m + b/2)$ meshes decrease in $b/2$ mesh

Example:- A baiting rate of 2 mesh in 1 mesh is required

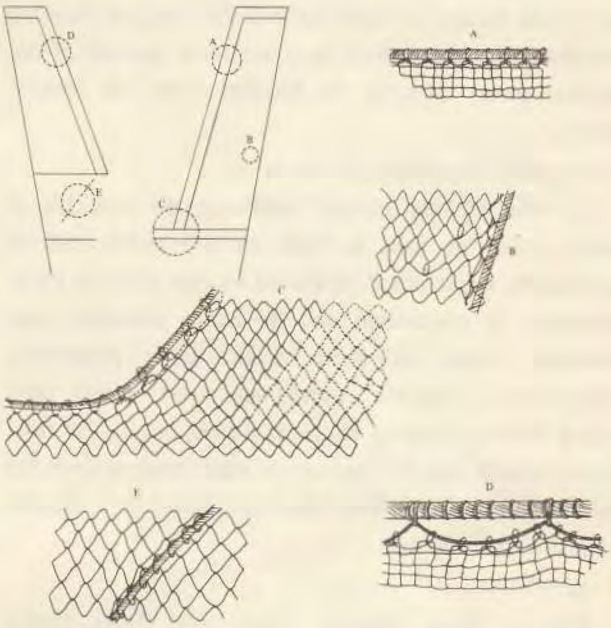
$m + b/2 = 2, b/2 = 1$, then $m = 1, b = 2$

required cutting pattern is *1m.2b*

Required figure		Bating by hand		Cutting pattern		Ratio
Number of mesh decrease	In number of mesh deep	Number of baiting	In number of row			$(\frac{a}{b})$
1	1	1	2	all	bar	1/1
1	3	1	6	1p	1b	1/3
1	2	1	4	1p	2b	1/2
2	3	1	3	1p	4b	2/3
4	5	2	5	1p	8b	4/5
1	5	1	6	2p	1b	1/5
1	7	1	14	3p	1b	1/7
1	4	1	8	3p	2b	1/4
2	5	1	5	3p	4b	2/5
1	9	1	18	4p	1b	1/9
2	7	1	7	5p	4b	2/7
1	8	1	16	7p	2b	1/8
2	9	1	9	7p	4b	2/9
1	10	1	20	9p	2b	1/10
2	11	1	11	9p	4b	2/11
2	13	1	13	11P	4p	2/13
2	15	1	15	13p	4p	2/15
2	1	1	1	1m	2b	2
3	1	($\frac{1}{2}$	($\frac{1}{1}$	1m	1b	3
4	1	2	1	3m	2b	4



3. Joining of trawl net



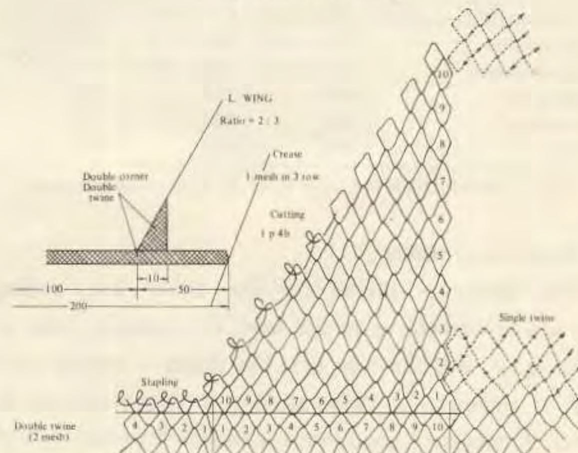
The double corner sites between the lower wing and the bosom. The double corner is the specially strengthened part to bear big strains when trawling.

Here, the number of meshes are so assumed as 200 in bosom, 30 in wing end of lower wing and 50 in start line of lower wing.

The double corner itself has 10 meshes in the base line.

Practice! – Make "Lower Wing" by the following two ways

1. By cutting Patterns
2. By Hand braiding



3.2.5 Fishing gear accessories composition

1. Function of buoy

The buoy is used for maintaining the fishing gear in ideal shape and spreading the fishing net in water. Generally, in static waters the fishing gear keeps its balance due to upward forces produced by buoyancy and downward foces produced by sinking power of lead, net, etc. Even if the external forces such as water resistance of net by the current are acted additionally, still the shape of net should be maintained by operational manner of the internal forces such as the buoyancy and the sinking power.

2. Necessary conditions for buoys

In order to keep enough buoyancy, the materials of buoy should be light in both air and water, and be sufficiently water proof. It should be also cheap in price, abundant in production and be easily processed into adequate shape of float. Cork, pine, paulowina, cryptomeria, Japanese cypress are most widely used taking various kinds of shape as fishing floats. The float which is used near the bottom of water such as floats for bottom gill net or bottom trawl net should be endurable against water pressure.

3. Buoyancy

Wooden floats, bamboo floats, glass floats, plastic floats and metal floats are the main kinds of float.

The buoyancy of float F is obtained by, $F = V - W$. Where F is the volume of the float, and W is the weight in air. If ρ denotes the specific gravity of the float, then we have, $F = W(1/\rho - 1)$.

The buoyancy and its variety are shown the following various tables.

Table 1. Weight of wooden float and its buoyancy

Materials	Specific gravity	Buoyancy in volumes 1 liter (gr)	Buoyancy in weight 1 kg. (kg.)
Cork (medium quality)	.175 (.321)	825 (679)	4.71 (2.12)
Paulownia	.294 (.785)	706 (215)	2.40 (0.27)
Cryptomeria	.432 (.964)	568 (36)	1.31 (0.04)
Silver fir	.486	514	1.06
Bamboo	.500	500	1.00
Pine	.598	402	0.67

Note: Parenthesis is the value after 30 days soaked in water

4. Function of sinker

The sinker is placed on the sinker line pulling the net downward as in the lead, for example, used in purse seine. For the trap net, the sinker – mainly sand bags or anchors – are used to keep the net stationary in water. A necessary condition for sinkers is to have a large sinking power per unit weight or a large specific gravity, be solid enough and to be easily produced.

Table 2. Glass buoys and synthetic buoys

Materials	Specific gravity	Buoyancy (gr)	Buoyancy in volume 1 liter (gr)	Buoyancy in weight 1 kg (kg)
Vinyl sponge, soft	0.099		901	9.10
Vinyl sponge, hard	0.129		871	6.75
Cork, medium quality	0.175		825	4.71
Rubber sponge	0.243		752	3.03
Artificial cork	0.294		706	2.40
Ebonite	0.375		625	1.66
Vinyl pipe	0.379		621	1.64
Glass, Dia 6 cm		62		
" " 9 "		135		
" " 12 "		630		
" " 15 "	0.348	1170	652	1.87
" " 30 "	0.244	10900	756	3.10

5. Sinking power

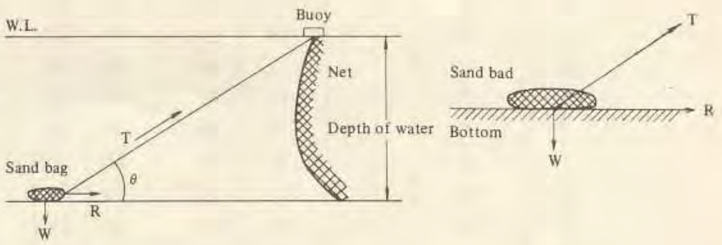
The sinking power F_s is denoted as:

$$F_s = W - V = W(1 - 1/\rho)$$

Materials	Specific gravity	Sinking power in volumes 1 liter (kg)	Sinking power in weight 1 kg (kg)
Lead	11.35	10.35	.912
Iron	7.21 – 7.83	6.21 – 6.83	.861 – .872
Brass	7.82	6.82	.872
Glass	2.70	1.70	.630
Stone	2.60 – 2.70	1.60 – 1.70	.615 – .630
Brick	1.90	0.90	.474
Sand	1.80	0.80	.444
Soil	1.50	0.50	.333
Porcelain	1.72 – 2.13	0.72 – 1.13	.420 – .530
Concrete	3.00 – 3.15	2.00 – 2.15	.666 – .682

6. Fixing power of sand bag

The sand bag weighing W in water, and which is connected to the rope of length n times the water depth, will just begin to move by pulling the rope horizontally on the surface of water by the force R which is considered the horizontal conponent of the rope tension T. Under this condition the fixing force of sand bag R equals the frictional force between the sand bag and the sea bottom. It is ccalled the fixing coefficient k of the sand bag of length rope n times water depth, and is equal R/W.



Then, $k = R/W = T\cos\theta/W$

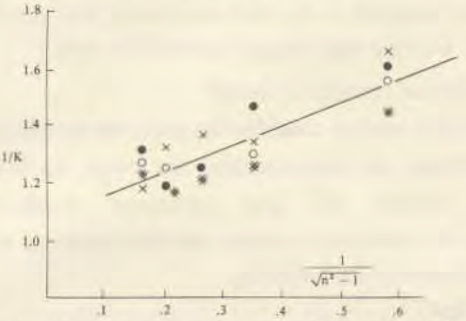
If we take the friction coefficient between sand bag and sea bottom as μ, then,

$$\mu = \frac{R}{W - T\sin\theta} = \frac{T\cos\theta}{W - T\sin\theta}$$

$$R = \mu (W - T \sin\theta), k = R/W = \mu (1 - T/W \sin\theta)$$
$$= \mu (1 - R/W \tan\theta)$$
$$= \mu (1 - k \tan\theta)$$

Taking $\sin\theta = 1/n$, then we have

$$1/\mu = 1/k - \tan\theta = 1/k - 1/\sqrt{n^2 - 1}$$



The relation between the value of 1/k and $1/\sqrt{n^2 - 1}$ by experiment under different contact conditions.

Value of μ

Condition of the bottom	μ
Sand	.84
Muddy sand	.49
Mud	.36

Value of fixing coefficient k of sand bag

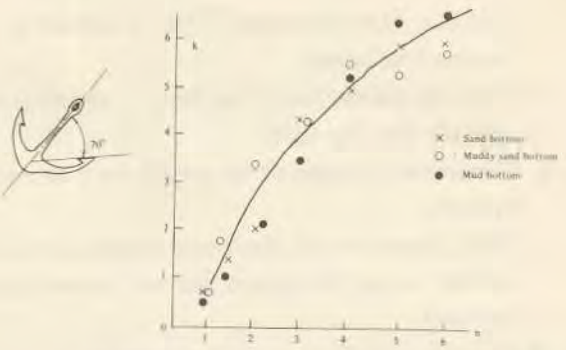
Bottom nature	Value of n to depth of water				
	1	2	3	4	5
Sand (vertically pulled)	.16	.47	.60	.71	.73
Sand (horizontaly ")	.21	.59	.65	.68	.74
Mean value	.19	.53	.63	.70	.74
Sandy mud (ver. pull.)	–	.33	.41	.49	.61
Sandy mud (hor. ")	–	.31	.31	.43	.62
Mean	.10	.32	.36	.46	.62
Mud (ver. pull.)	.05	.13	.20	.23	.30
Mud (hor. ")	.05	.33	.34	.48	.52
Mean	.05	.23	.27	.35	.41

7. Holding force of anchor

This is caused by the resistance force of sand or mud acting in the curved arm of anchor. Fixing coefficient k (= R/W)does not vary very much with different kinds of sea bottom, and becomes large as the value of n becomes large. From experiment, the k – n diagram as shown in the figure, the arm of which is inclined by an angle of 70° to the center line.

Value of fixing coefficient k of anchor

Bottom condition	Value of n to the depth of water					
	1.0	1.5	2.0	3.0	4.0	5.0
Sand	.26	1.10	1.90	4.37	–	5.83
Sandy mud	.23	1.90	3.27	4.40	5.50	5.15
Mud	.11	.60	1.99	3.29	5.11	6.46
Mean	.20	1.20	2.39	4.02	5.31	5.81
Ratio between value of k of sand bag and anchor	1.0	–	3.7	5.4	6.7	7.1



The relation between k and n at the condition of arm inclination 70° to the center line of anchor.

3.3.1 Modeling by clay works and paper model net

1. Introduction

The observation on the shape of trawl net during fishing operations can be seen in model net performances.

The experimental method by an actual model net under the law of comparison of fishing net deduced by Dr. Tauchi is explained in another paper. This experiment is conducted in a tank or in the sea.

There is however another method which is easier than the model experiment, and is an approximate observation of the shape of a trawl net. This is "the model net evaluation by clay and paper works". We could, therefore, use this method as an preliminary estimation of shape of trawl net, and we could design the trawl net from this method during an initial stage of the study. The improvement and consideration of the net design will be done scientifically by the model experiment under various water flows in a tank as stated in the above. Or, we could make fishing directly using this design of net and could discussed more and more in practical way.

Thus the design of trawl net will be achieved by degrees.

2. Method of the work for designing by modeling

1) Materials for clay works

The following materials should be prepared ;

Cardboard, White tracing paper, Artificial clay (two colours if possible), Knife, Prickly heat powder, Pin set, Scale, Paste, etc.

2) Making clay model net

The typical designs – or "standard designs" – should be prepared;

Process :

a. The cardboard is hollowed out according to the design of these standard types.
b. The hollowed out cardboard is pasted onto another plain piece of cardboard.
c. Some good artificial clay is rolled out by a cylinder rod.

d. This thin extended plane of clay is pressed to the concaved cardboard.

e. Thus, the pressed line of net design is clearly copied onto the thin clay board.

f. These lines of copied design are cut out with margin by knife.

g. Then, these cut out clay board designs are joined together using the margin and are formed into a trawl net.

3) Observation, modification and improvement

After the clay modeling, close observation of the trawl net shape is required. The model is deformed very easily so the designer needs to handle clay carefully being expanded or contracted. Thus, the modification or improvement of model net will be executed liberally on it's shape.

The deformed clay model could be cut by knife partially and these are copied by drawing on paper as the result of changing the shape of model according to his intention.

4) Paper model

This drawing on tracing paper is then cut partially by knife with margin and is formed into a paper model net by joining with paste.

Then, this paper model is more accurately fashioned than the clay model. Again we could check and modify the shapes of net and draw again on paper.

5) Giving net specifications

After getting this drawing on tracing paper, various information and experiences could give the specifications of this net such as total size (length & width), twine size, mesh size, hang-in, and then calculation will be given to the number of mesh (length & width), cutting patterns, etc. on every part of net design.

Then, other dimensions and accessories will be decided as buoyancy (number of floats), sinking power (number of leads and chains, etc.), bobbin size, lacing rope length, rope size (head rope, ground rope, lacing rope, quater rope, man rope, warps, etc.) and otter board size & shape, etc..

3.3.2 The rules of drawing of fishing gear design

The Department of Fisheries, FAO prepared the Catalogue of fishing gear designs in 1972, in which the drawings of fishing gears are drawn up in due form as in the followings.

The drawings in detail are meant neither to be to scale nor 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. Therfore, twine strength charts are also given in a separate paper.

Units adopted

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.

Conventional sections of design

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 obtained 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, e.g. 3 Z denoting 3 stranded rope with right-hand twist. Left-handed 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 on the specific drawings

To give 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 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. In the case of trawl wings they are drawn to their true length.

Construction in details

For facilitating comparison of designs, the drawings normally contain the following specifications.

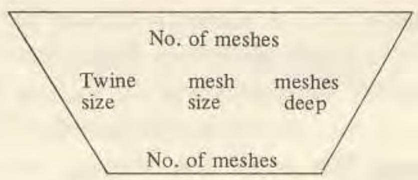
1 The number of meshes at the top and bottom of each panel

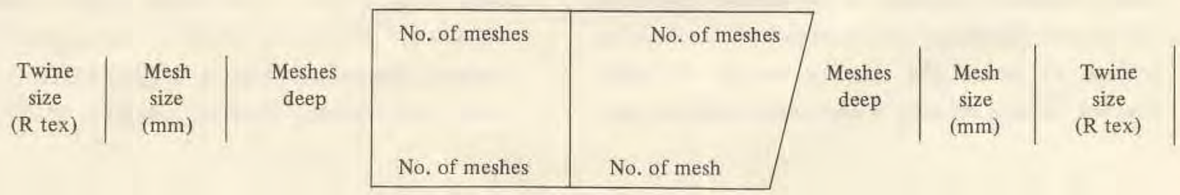
2 The depth of each panel in meshes

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 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 detail 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 detail 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 detail 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 centres 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 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 codends, 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 custs, 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 meshsize stretched multiplied by the number of meshes in a straight row.

(e.g. $E = \frac{440m}{628m} = 0.71$). 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 7kg).

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	faculative
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
∅	diameter
⊤	upper panel
⊥	lower panel
⊢ ⊣	side panels
◎	purse ring
↕	N-direction in netting
⊣ ⊢	thickness
/	optional
○	circumference
◈	double braided
~	approximately

Examples

Ropes and wire

130.50 PP 2 x ϕ18 + PVA/PE ϕ9 =
130.5 m, polypropylene, 18 mm, 2 ropes + polyamide or polyethylene, 9 mm, 1 rope

2600.00 WIRE ϕ 15-24-15=
2600 m, wire, dia (15mm – 24mm – 15mm)

3 x PA + PB 73 g/m = polyamide rope, 3 ropes lie along, plus lead 78 gr/m

40.30 3 x (PP ϕ 16 + PP ϕ 14 + PP ϕ 7) =
40.3 m, polypropylene rope, 3 ropes dia 16, 14 and 7 mm separately, lie along

70.00 WIRE ϕ 26 = Wire 70 m length, dia 26 mm

17.06 WIRE ϕ 6.8 (coc ϕ 16 cov.) = Wire 17.06 m, dia 6.8 mm. covered by coir, dia 16 m

Floats and sinker

1200 PL 660 kgf = Plastic float 1200, total buoyancy 660 kgs

600 PL 4100 gf = Plastic float 600, buoyancy 4.1 kg/float

30 PL ϕ 240 = Plastic float 30, dia 24 cm

3–5 PL ϕ 80–100 = Plastic float 3–5 individuals, dia 8–10 cm

PL $A_1 - A_3$ 10.93 kgf/m = In $A_1 - A_3$ panel, plastic float 10.93 kg/m

1350–1570 PL ϕ 60 L200 = Plastic float 1350–1570, dia 60 mm, length 200 mm

18-10/m PB 67g = Lead 18-10 individuals/meters, 67 gr/float

Rings and O.B.

40 ST ϕ 184/12 = Purse ring 40, steel, outer dia 18.4 cm, thickness 12 mm

143 ST ϕ 180/18/1230g = Purse ring 143, steel, outer dia 18 cm, thickness 18 mm, weight 1.23 kgs

Otter FE/WD + FE 80–85 kg = Otter board, iron or wood plus iron, wieght 80–85 kgs

Examples of common netting yarns

A = dry unknotted
B = wet knotted
(value for one yarn)

R tex	Length m/kg	Breaking load		R tex	Length m/kg	Breaking load	
		A kgf	B kgf			A kgf	B kgf

POLYAMIDE (PA)

Twisted, filament

R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf	R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf
155	6460	8	5	1300	770	63	35
240	4170	14	9	1500	670	67	37
320	3130	18	11	1600	625	76	43
400	2500	21	13	2000	500	99	52
480	2080	25	15	2600	385	138	73
550	1820	30	18	3180	315	157	80
650	1540	34	20	3400	294	178	85
720	1390	40	22	4000	250	210	100
800	1250	42	24	5000	200	260	125
900	1100	47	26	5700	175	330	150
1000	1000	49	27	6800	147	360	165
1100	900	50	28	8350	120	440	200
1250	800	58	32	11200	90	560	250

Braided, filament

R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf	R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf
1700	590	77	48	7000	140	346	170
1960	510	102	60	8800	114	418	205
2460	400	130	73	9600	104	460	220
2820	350	146	81	10600	94	515	245
3500	290	172	85	12200	82	590	280
4300	230	224	110	13800	72	650	310
4900	205	255	125	17500	57	800	360

POLYPROPYLENE (PP)

Twisted, filament

R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf	R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf
210	4760	13	8	1440	690	71	36
290	3470	15	9	1920	520	92	47
360	2780	19	11	2290	440	112	59
430	2330	25	14	2820	350	132	70
550	1820	28	15	3300	300	152	80
640	1560	38	19	4700	210	190	100
920	1090	44	23	5640	177	254	130
1190	840	58	30				

Twisted, split fibre

R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf	R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf
210	4760	9	6	1900	530	73	46
300	3330	13	9	2360	429	86	54
390	2560	18	12	3070	325	100	59
800	1250	32	22	4100	240	150	88
990	1010	88	24	5400	185	215	120
1390	720	57	36	6660	150	300	170

POLYETHYLENE (PE)

Twisted or braided wire

R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf	R tex	Length m/kg	Breaking load A kgf	Breaking load B kgf
370	2700	10	7	2800	360	93	67
700	1430	27	19	3400	294	116	83
1050	950	36	24	4440	225	135	97
1410	710	49	35	5300	190	170	125
1760	570	60	84	7680	130	218	160
2170	460	75	54	10100	100	290	210

POLYAMIDE (PA)

Monofilament

ϕ mm				ϕ mm			
0.10		0.5	0.2	1.10		45	25
0.15		1.5	0.6	1.20		50	28
0.20		2.3	1.2	1.30		65	35
0.25		3.8	1.9	1.40		73	40
0.30		4.9	2.7	1.50		85	47
0.35		6.3	3.2	1.60		100	52
0.40		7.6	4.3	1.70		110	58
0.45		10.5	5.5	1.80		120	63
0.50		12.7	6.5	1.90		130	72
0.55		14	7.5	2.00		145	75
0.60		17	8.5	2.50		220	112
0.70		24	12.5				
0.80		29	15				
0.90		36	19				
1.00		42	22				

Examples of synthetic fibre ropes, hawser

C = mass/length
D = breaking load

0 mm	Polyamide (PA) C kg/100m	Polyamide (PA) D kgf	Polyester (PES) C kg/100m	Polyester (PES) D kgf	Polypropylene (PP) C kg/100m	Polypropylene (PP) D kgf	Polyethylene (PE) C kg/100m	Polyethylene (PE) D kgf
4	1.1	320	1.46	295	–	–	–	–
6	2.4	750	3	565	1.7	550	1.7	400
8	4.2	1,350	5.1	1,020	3	960	3	685
10	5.6	2,080	8.1	1,590	4.5	1,425	4.7	1,010
12	9.4	3,000	11.6	2,270	6.5	2,030	6.7	1,450
14	12.8	4,100	15.7	3,180	9	2,790	9.1	1,950
16	16.6	5,300	20.5	4,060	11.5	3,500	12	2,520
18	21	6,700	26	5,080	14.8	4,450	15	3,020
20	26	8,300	32	6,350	18	5,370	18.6	3,720
22	31.5	10,000	38.4	7,620	22	6,500	22.5	4,500
24	37.5	12,000	46	9,140	26	7,600	27	5,250
26	44	14,000	53.7	10,700	30.5	8,900	31.5	6,130
28	51	15,800	63	12,200	35.5	10,100	36.5	7,080
30	58.5	17,800	71.9	13,700	40.5	11,500	42	8,050
32	66.5	20,000	82	15,700	46	12,800	47.6	9,150
36	84	24,800	104	19,300	58.5	16,100	60	11,400
40	104	30,000	128	23,900	72	19,400	74.5	14,000
44	126	35,800	155	28,400	88	23,400	–	–
48	150	42,000	185	33,500	104	27,200	–	–
52	175	48,800	215	39,100	122	31,500	–	–
56	203	56,000	251	44,700	142	36,000	–	–
60	233	63,800	288	49,800	163	41,200	–	–

3.3.3 Trawl net design

Practice 1. How to draw design of net

Already known: Main elemental length of net
Number of mesh in width
Number of mesh in depth
Others

Find : Cutting pattern
Hang-in

Drawing : Series number of designs of trawl should be noted according to the classification of trawl net.

Practice 2. How to design the net

1. Decision: Kind of trawl net according to the classification

Already known: –Species of fish, Moving and migration of fish, Schooling of fish, Speed of fish, Demersal or Pelagic, Shrimps
–Fishing ground, Bottom nature, Images of fish by fish finder
–Scale of fishing, Capitals, Tradition,

Boat (one or pairs), Engine and horse power.

Find : Kind of trawl net

2. Proportions of elemental length of net

Already known : Length of head rope (1) by calculation

Find : The values of m, b, a, c, d, e, f, on the basis of 1

e.g. ····· m/1, b/1, (m-1)/1, b/m
a/b, c/b, d/b, e/b, f/b,
(d-c)/b

3. Twine size and mesh size

Already known : Data from other design
Breaking strength of twine
Size of fish
Size of scale of net
Resistance of net
Mesh regulation

Find : Materials
Twine size of each panel
Mesh size of each panel
Cutting pattern of each panel either by hand braiding or cutting.

Elements of Trawl Net for calculation

Type of trawl :
No. of seam :
Horse power :

Length (Stretched length in meters)

l	(head rope)	:
m	(ground rope)	:
b	(total length)	:
a	(total circumference stretched)	:
c	(upper wing)	:
d	(lower wing)	:
e	(baiting or belly)	:
f	(cod-end)	:
d-c	(square)	:
p	((l + m)/2)	:

Value calculated

m/l	
b/l	
b/m	
a/b	
c/b	
d/b	
e/b	
f/b	
(d-c)/b	
p/b	
axb	
l^2	
m^2	
p^2	

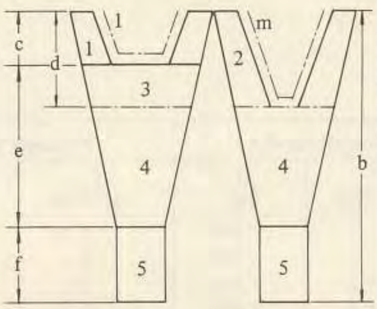
Value of d/l

Name of part	d (mm)	l (mm)	d/l

Average

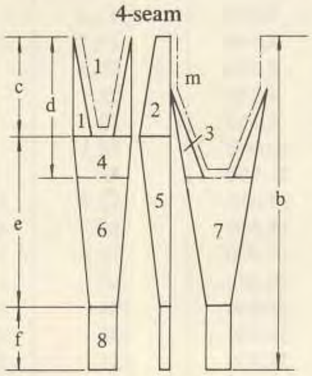
Name of part of trawl net, symbols

2-seam



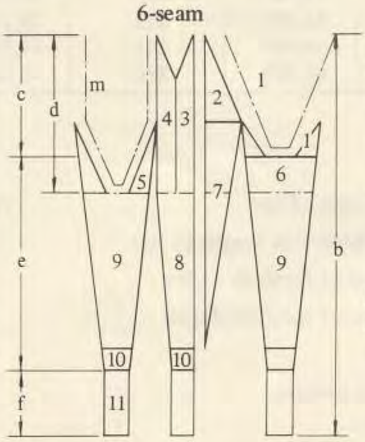
1. Upper wing
2. Lower wing
3. Square
4. Baiting or Belly
5. Cod-end

4-seam



1. Upper wing
2. Side wing
3. Lower wing
4. Square
5. Side net
6. Baiting
7. Belly
8. Cod-end

6-seam



1. Triangle square
2. Upper triangle wing
3. Upper side wing
4. Lower side wing
5. Triangle belly
6. Square
7. Upper triangle baiting
8. Side belly
9. Baiting or belly
10. Extension
11. Cod-end

Practice 3. How to make model net

1. Kinds of model net
   1-1. Model for hydraulic experiment purpose
      Law of comparison of model net
      Decision: λ'/λ'', $D'/D'' = L'/L''$, V'/V''
   1-2. Model for demonstration
      Calculation
2. Calculation
   Scale ratio, decision of mesh size (model net)
   Calculation number of meshes in corresponding panels
   Calculation on cutting pattern
   Decision of twine size (model net)
3. Making net
   Drawing design
   Cutting net or braiding by hand
   Lacing, framing, joining, etc.
   Accessories
      Number of buoys (Buoyancy)
      Number of sinkers (Sinking power)
      Construction of bobbin (Weight cal.)
4. Accessories
   Otter boards
   Warps

3.3.6 Fundamental hydraulic resistance of net

1. Introduction

Under various fishing gear operations such as towing drag net, pursing up purse line, hauling dip net, etc., hydraulic resistance to the flow of water by the fishing net will be produced.

The efficiency of fishing gear is closely connected with the net shape in water during its fishing operation. For basic knowledge of fishing net design, fundamental resistance of net with different factors such as fiber, twine size, mesh size, knot type, angle of attack, etc. should be clearly understood.

2. Basic relations to net resistance

1) Resistance and the area of net:

If specified net is kept with constant opening shape against the flow of water and with constant velocity, the hydraulic resistance of net produced by the flow of water is propotion to te area of net. That is, if the area increases n times, the resistance will increase n times.

2) Resistance and D/L.

In the same area of net between two nets the resistance of net can be compared by the value of D/L.

If net A is composed of netting cord of 0.5mm in size and mesh size of 2 cm, and net B is 1.5 mm and 3 cm respectively, the ratio of the D/L value between net B and A, is the ratio of resistance of B and A. So, the resistance of B is 2 times of that of A according to the following calculation.

$$\frac{(D/L)_B}{(D/L)_A} = \frac{1.5/30}{1.5/20} = \frac{0.05}{0.025} = \frac{2}{1}$$

That is to say if the value of D/L increases n times the resistance will increase n times.

3. Resistance and current velocity :

The resistance of net is proportion to the square of of the current velocity as shown in the following examples.

Velocity : mile/hour	1	2	3	4	. . . .
Resistance of net : kg/m^2	1	4	9	16	. . . .

For instance, if the scale of net (headline length as a size indicator) increases by 2 and towing speed increases by 2, the resistance of trawl net will increase 16 times, as shown in the following calculation.

$$R'/R'' = (\lambda'/\lambda'')^2 \times (V'/V'')^2 = 2^2 \times 2^2 = 16$$

4) Resistance coefficient in standard conditions

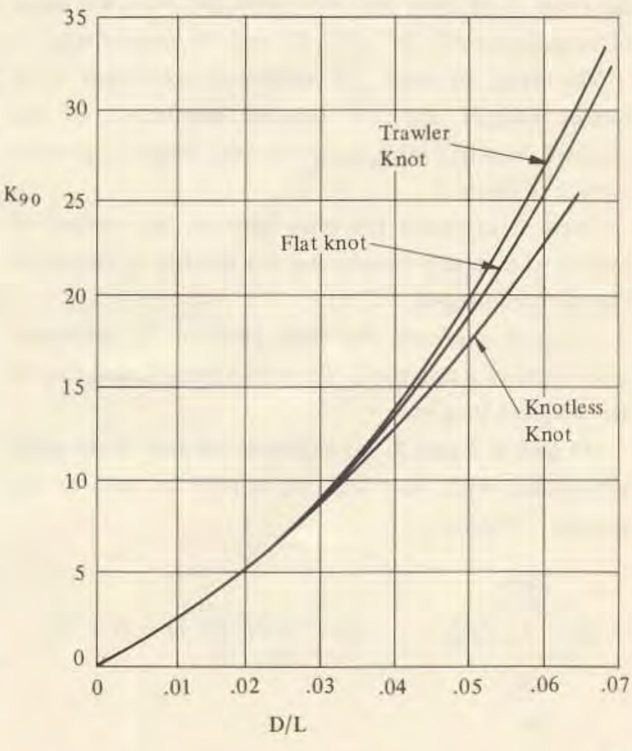
From the relations mentioned above, hydraulic resistance of net R could be expressed as,

$$R = k \cdot s \cdot v^2$$

where s is the area of the net, v the velocity of the current and k the coefficient of resistance.

(1) If the net is spread square in the mesh shape and angle between net and flow direction is 90 degree, the coefficient of resistance k_{90} in relation to the value of D/L, is expressed as in the *figure 1.* Here, the units are R kg, s m^2, and v m/sec.

Fig. 1



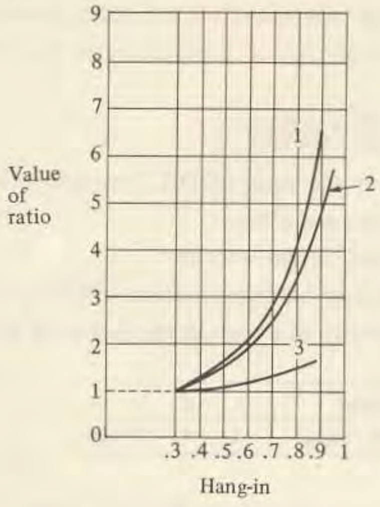


Fig. 2

(2) The difference of coeff. k against the kinds of fiber. The value of k is variable with the kind of thread material as well well as types of knot. There are some difference of value of k experimented with natural fibre and synthetic fiber.

(3) The difference of coeff. k with the angle of attack θ. If K_θ expresses the resist. coeff. of k under the angle of attack θ, K_θ. is expressed as:

$$K_\theta = K_0 + (K_\theta - K_0)\frac{\theta}{90}$$

(4) The difference of coeff. k with the angle of legs φ.

In former experiments, the net pieces are all hung with about 30 percent of all meshes in square.

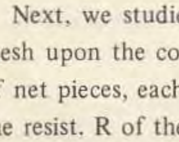
Next, we studied the effect of different shapes of the mesh upon the coeff. of flow resist. k. Taking five kinds of net pieces, each different from each other in d and 1, the resist. R of these nets were measured when the angle of mesh 2φ are 90°, 74°, 59°, 32° and 10° respectively.

The ratio between the resistance coefficient of a certain hang-in and the resistant coefficient of the standard hang-in (=0.3, square in mesh shape) is given in curve 1 of *figure 2.*

Curve 2 expresses the ratio between the number of meshes of a certain hang-in and the number of meshes of the standard hang-in.

Curve 3 expresses the ratio between the resistance coefficient of a unit mesh of a certain hang-in, and that of the standard hang-in.

As seen in figure 3, $A\varphi$ expresses the area of one mesh surrounded with four legs; A_s is half the area of the thread. Then,



$$A_\varphi = (l/2)^2 \sin 2\varphi - d(l - d)$$
$$A_s = d(l - d)$$

Fig. 3

We obtained the relation between $A\varphi/A_s$ and log $K\varphi$ as expressed in the formula;

$$K_\varphi = C \exp. (-\tau \ A_\varphi/A_s)$$

5) Experimenting with model net

Model fishing nets were so constructed as to satisfy the conditions of dynamic similitude according to the law of comparison of fishing net.

The trap-net model and trawl net model have mainly been studied.

(1) Trap-net

Many trap-net model expreiments have been performed on the purpose of how the configurationof net under various conditions of operations influences the variation in resistance under current, and the relation between weight of sand bags and the limit velocity where the sand bag first begins to slip.

And for the model experiment to avoid undesirable net deformations and to prevent the loss of net, studies on the effect of tidal current have been carried out.

Results obtained on the trap net by Dr. H. Miyamoto are as follows:-

Deformation of set-net occur with currents as weak as 1/4 knot. And as the strength of current increases, the floats attached to the upper edge of the net tends to be pulled down into the water. Under excessive strength of current, the whole net is flattened and forced to the bottom. In such situations, when larger tensions overcome whole fixing power of sand bags B, the whole net with its sand bags drifts away.

It was noticed that under a given conditions of current, the kettle net and the trap-net differ in the current limit at which the sand bags give way to the current: 1 knot for kettle net, and 2 knots for trap net.

The resistance R of the whole net to the current speed v can be expressed

$$R = v^n$$

The index n is always smaller than 2, and the more deformable the net, the less value of n. Again, n tends to approach 2 as the floats are pulled into the water and the hole net attains some stable form.

Then, we take necessary expression notations for trap nets, the resistance of net R is;

$$R = (D/2L)\ \lambda\ (\lambda_1 + 2H)\ v^2$$

and if A is $A = (D/2L)\ \lambda\ (\lambda_1 + 2H)$, the value B/A can be calculated. From the value of B/A we can estimated the critical speed of current for the first slipping of sand bags. The experimental results show the relation between B/A and v^2 under certain current directions.

If we express the total weight of the net pieces by W, when W is proportional to A, we get -

$$B/W \backsim v_1^2$$

These relations enable as to calculate the total weight of the sand bags and their necessary distribution for the safe and effective setting of a net under a given speed and direction of current at the fishing ground.

(2) Trawl-net

When a trawl net is towed, it tends to take a form of minimum resistance under towing conditions. It means the height at the front of the ceiling net decrease with increasing speed. This height lowers to a nearly constant height when the towing speed is increased over a certain velocity. The relation between the ceiling height and the towing speed was obtained by experiments. These values are converted in those of actual nets. For efficient fishing of bream, cod or sharks, it is essential to keep the front of the ceiling net as high as possible. At lower velocity, the Danish seine has largest ceiling height, but decreases remarkably when the towing speed is increased.

The hydraulic resistance can be expressed by,

$$R \backsim v^n$$

6) Inclination of threads and nets in a current

As mentioned before excessive deformations make it difficult for the fish to enter the net, and even if some fish be come trapped in the net, a deformed net is liable to let them escape again. It is desirable to have as little deformation as possible for fishing especially in set-nets.

Since synthetic fiber has been tested as fishing gear, some fibers show suitability.

For a preparatory study of the configuration of nets, tests have been performed to clarify different inclinations of various threads in a current. In addition, dying thread experiments for decreasing inclination were conducted. The order of thread inclination is Saran, Cotton, Manila twine, Nylon and Vinylon. However in coal-tar dyeing, the difference decrease nearly to 10 percent.

We can obtain the follwoing relation;

$$W \cdot \cos\theta = s \cdot C_p \cdot d \cdot v^2$$

where W = weight of thread in water,
s = specific gravity,
C_p = coefficient of resistance,
d = diameter of thread.

From this formula, in order to decrease the inclination of thread it is desirable to make value of C_p small, and W/d as large as possible. As to the value of C_p, Vinylon is the largest, but there is rather little difference between max. and min.. And regarding W/d, Saran is the largest owing to have its specific gravity being the largest among these five synthetic fibers.

If we dye with coal-tar, Vinylon is remarkable for decreasing C_p, and Nylon for increasing W/d, these two fibers are efficient for decreasing the thread inclination.

Next, as to the experiment of inclination of net, almost the same results were obtained as in the case of thread. In this case we obtained the formula:-

$$W_n \cos\theta = a \cdot (d/l) \cdot \sin\theta \cdot v^2$$

where, a is the coefficient of resistance, and the order value is shown in the following.

Straw	Cremona	Twine	Cotton	Nylon	Saran	Crehalon
28.4	23.2	22.8	22.0	21.0	20.0	19.2

As the case of net, it is desirable to make value of a small, and the value of $W/d/l$ as large as possible.

3.3.6 Law of similarity of fishing nets

The law of comparison of fishing net was deduced by Dr. M. Tauchi. That is "A relation between experiments on model and on full scale of fishing net", in Bulletin of the Japanese Society of Scientific Fisheries, 3(4), 1934.

Since this, many model experiments on trawl net, set net, purse seine, etc., have been done by scientists.

At the second International Fishing Gear Congress Dr. T. Kawakami contributed the paper, and gave a explanation on the law of similarity of fishing net.

This paper aims to explain simply this modelling theory for persons who want to know the relationship between model and full scale.

1. The construction of the net

Here, we think of net as a unit. A mesh consists of two legs and one knot. That is to say, the minimum composition of a net unit. The external forces produced by the weight of net in water and the hydraulic resistance by the current acting on the two legs and the knot should be considered. On the other hand, some tension which balances with external forces, may be called internal forces. Thus, the net keeps its balance and takes some deformation under the current with these two forces.

2. The weight of net in water.

When we think of the weight of net in water, the quantity of cord that is necessary to compose a knot may be negligible compared with the quantity of the two legs, especially if the net uses thin cord with a big mesh. Then the weight of net per mesh is obtained as follows :

$$2\pi (D/2)^2 L (\rho - 1)$$

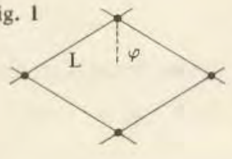
Here, D is diameter of the cord, L is the length of one leg and ρ is the specific gravity of the cord.

If the shape of mesh is similar within two comparative nets, the area of a mesh can be expressed as proportional to L^2. Therefore, the weight of net in unit area is obtained as follows :

$$W = k(\varphi)\left(\frac{D}{L}\right) D(\rho - 1) \tag{1}$$

Here, $k(\varphi)$ is a coefficient according to the angle of two legs.

Fig. 1



As the hang-in of net is dependent upon the angle φ, $k(\varphi)$ is a function of angle φ. (Fig. 1)

3. The hydraulic resistance of net

The hydraulic resistance of net is proportional to the projected area of net against the direction of the current and square of velocity of the current. So, the resistance of net of a mesh is proportional to the following value :-

2 (DL) v^2, if the angle of attack to the current is perpendicular to the plane of the net.

Although the angle of attack has some degree in corresponding parts of net in two cases, the resistance is also proportional to the above value because the degree is the same in each. Therefore, the hydraulic resistance of net per unit is obtained from the above value divided by L^2 as follows:

$$R = C(\alpha, \varphi)\left(\frac{D}{L}\right) v^2 \tag{2}$$

where, the coefficient C (α,φ) is dependent upon the situation of the net against the flow.

4. The tension of net

The tension of net to which we might call an internal force, acts to keep the balance with external forces mentioned above. In the net of Fig. 2, we take the area A of circumference S. The external forces acting on this part are weight in water AW, and hydraulic resistance AR. Along the circumference of his part, there are tensions T and ST, where the total T should be balanced with the forces of (AW + AR).

The relation of these forces is shown in Fig. 2.

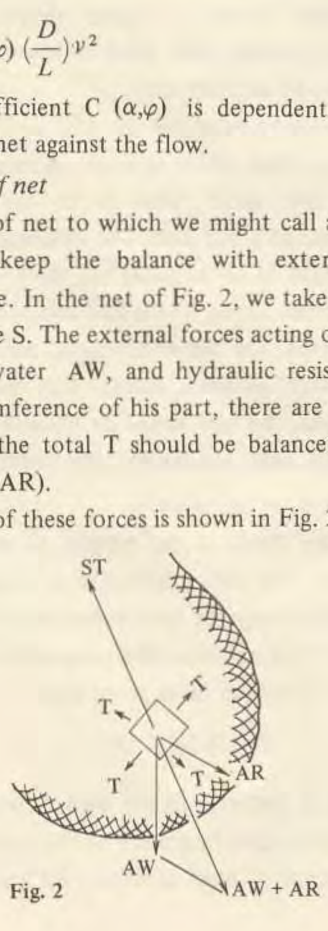


Fig. 2

5. The necessary conditions in order to maintain the similarity between the model and full scale

Now, we think of the similar shapes between two gears N_1 and N_2 under the current velocity v_1 and v_2 respectively, taking the tension on every part of net as T_1 and T_2 respectively, and considering forces F_1 and F_2 on the corresponding position of two gears. If we take the scale as λ_1 and λ_2 in two gears, the scale ratio is given by,

$$\Lambda = \frac{\lambda_2}{\lambda_1} \tag{3}$$

The next relation holds between two gears in Fig. 3.

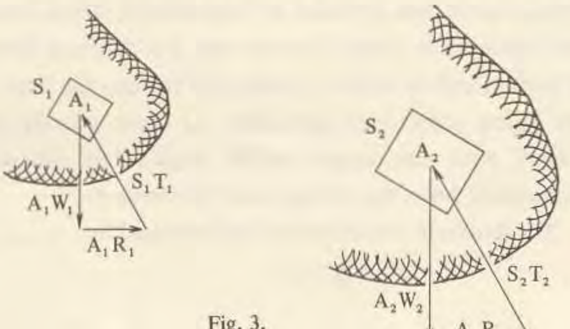


Fig. 3.

$$\frac{A_2}{A_1} = \Lambda^2 \tag{4}$$

$$\frac{S_2}{S_1} = \Lambda \tag{5}$$

The net takes its shape not by its own forces but by the force F from outside.

Therefore the balancing triangle of AW, ST and AR in Fig. 3 must be similar for the two gears when the shapes of the two shapes of the two gears are similar.

So, the ratios A_2W_2/A_1W_1, A_2R_2/A_1R_1 and S_2T_2/S_1T_1 should be the same and this is equal to the ratio of forces acting on whole net or on corresponding part of nets, F_2/F_1. So, the necessary conditon for maintaining similarity is expressed by,

$$\frac{A_2W_2}{A_1W_1} = \frac{A_2R_2}{A_1R_1} = \frac{S_2T_2}{S_1T_1} = \frac{F_2}{F_1} \tag{6}$$

Putting the formae (1) – (5) in (6), we have,

$$\frac{\lambda_2^2 k(\varphi_2)\left(\frac{D_2}{L_2}\right)D_2(\rho_2 - 1)}{\lambda_1^2 k(\varphi_1)\left(\frac{D_1}{L_1}\right)D_1(\rho_1 - 1)} = \frac{\lambda_2^2 c(\varphi_2\alpha_2)\left(\frac{D_2}{L_2}\right) v_2^2}{\lambda_1^2 c(\varphi_1\alpha_1)\left(\frac{D_1}{L_1}\right) v_1^2} = \frac{\lambda_2 T_2}{\lambda_1 T_1}$$

$$= \frac{F_2}{F_1} \tag{7}$$

The two nets should be $\varphi_1 = \varphi_2$ and $\alpha_1 = \alpha_2$ (8), (9)

And if we take the relation $D_1/D_2 = L_1/L_2$ between the two nets, (10)

the formulae (7) is simplifies to

$$\Lambda^2 \frac{D_2(\rho_2 - 1)}{D_1(\rho_1 - 1)} = \Lambda^2 \frac{\nu_2^2}{\nu_2^2} = \Lambda \frac{T_2}{T_1} = \frac{F_2}{F_1}$$

Here, if we put,

$$\frac{D_2(\rho_2 - 1)}{D_1(\rho_1 - 1)} = V^2, \tag{11}$$

then we have the next three necessary conditions for keeping similarity.

$$\frac{\nu_2}{\nu_1} = V \tag{12}$$

$$\frac{T_2}{T_1} = \Lambda V^2 \tag{13}$$

$$\frac{F_2}{F_1} = \Lambda^2 V^2 \tag{14}$$

Now we could arrange the law of comparison of fishing nets between model and full scale from the discussions mentioned above.

1. At first, the scale ratio is to be taken between model and full scale,

$$\frac{\lambda_2}{\lambda_1} = \Lambda$$

and we can take this value freely according to the situations as the length of tasting tank, experimental costs, etc.

2. The ratio of mesh size and diameter of twine should be,

$$\frac{D_2}{D_1} = \frac{L_2}{L_1} = M,$$

and it is not necessary to take the same value in Λ and M.

3. The specific gravity of the material should obey the relation,

$$\frac{D_2(\rho_2 - 1)}{D_1(\rho_1 - 1)} = V^2$$

4. The corresponding speed between model and full scale is,

$$\frac{\nu_2}{\nu_1} = V$$

5. Then, we have the tension T in the net and the force F at any definite point in the net acting on the corresponding part of net as,

$$\frac{T_2}{T_1} = \Lambda V^2, \quad \frac{F_2}{F_1} = \Lambda^2 V^2.$$

In other words, T_2 and T_1 are the tension acting on the fixed length of net such as buoyancy or sinking power of the net per unit lenght, and F_2 and F_1 are forces acting on definite point in the net such as the force of pulling warp of trawl net or holding power of mooring rope in a trap net.

6. Law of mechanical similarity for warp or rope

Let us consider two warps of different size and material, one of which is full scale and the other its model, then consider the conditions to be fulfilled in order to make the configurations in both cases similar. These conditions are that any similar points on the two ropes, the forces acting on an element must bear the same ratio to each other. The forces that act on an element of a rope in a current are threefold in origin: (1) the hydrodynamic force due to the flow, (2) the weight of the element of rope in water, and (3) the tension in the rope at the ends of the element. When it is desired to get a geometrical and mechanical similarity for both, the full scale and the model, it is necessary that the ratio between these forces is the same at each similar point on both the ropes.

The angle that the element of the warp makes with the current and with the direction of gravity are equal in both the model and the full scale when the ropes take the geometrically similar configuration. Then the hydrodynamic force R due to the current will be proportional to the diameter D, length l of the rope and square of the current velocity v, namely:-

$$R \backsim D l \nu^2$$

The apparent weight W, of the rope in water is simply given by

$$W \backsim (\rho - 1) D^2 l.$$

According to the law of fishing net, the forces that comes from the net is proportional to the square of the current velocity and the area of webbing, thus the tension T in the rope is given by

$$T \backsim \lambda^2 V^2$$

These three forces must be in the same ratio to each other for two ropes in order to maintain the mechanical similarity. Then the following relation must hold:

$$\frac{T_2}{T_1} = \frac{R_2}{R_1} = \frac{W_2}{W_1}$$

In making the model, the mean densities of the rope can be regulated by inserting short strips of cord of different material at regular intervals at a proportion of (a:1). For small models, this can easily be done by the use of modern chemical adhesives. Let ρ' and D' be the density and the diameter of the inserted cord, which may be a metal filament under certain circumstances. Then the equation given above becomes

$$\frac{\lambda_2^2 \nu_2^2}{\lambda_1^2 \nu_1^2} = \frac{[(1-a)D_2 + aD'_2]\, l_2\, \nu_2^2}{D_1 l_1 \nu_1^2}$$

$$= \frac{[(1-a)(\rho_2 - 1)D_2^2 + a(\rho'_2 - 1)D'^2_2]\, l_2}{(\rho_1 - 1)D_1^2\, l_1} \qquad (15)$$

This is the most general expression of the model law for ropes. In the case where

(1) $a = 0$, and $\frac{l_2}{l_1} \neq \frac{\lambda_2}{\lambda_1}$

this gives

$$\frac{\rho_2 - 1}{\rho_1 - 1} = \left(\frac{\nu_2}{\nu_1}\right)^2 \left(\frac{l_2}{l_1}\right) \left(\frac{\lambda_2}{\lambda_1}\right)^{-2}$$

$$\frac{D_2}{D_1} = \left(\frac{l_2}{l_1}\right)^{-1} \left(\frac{\lambda_2}{\lambda_1}\right)^2$$

When the rope is sewn entirely to the main body of the net, namely

(2) $a \neq 0$ and $\frac{l_2}{l_1} = \frac{\lambda_2}{\lambda_1}$

the following relations must be satisfied simultaneously:

$$\frac{(1-a)(\rho_2 - 1)D_2^2 + a(\rho'_2 - 1)D'^2_2}{(\rho_1 - 1)D_1^2} = \left(\frac{\nu_2}{\nu_1}\right)^2 \left(\frac{\lambda_2}{\lambda_1}\right),$$

$$\frac{(1-a)D_2 + aD'_2}{D_1} = \frac{\lambda_2}{\lambda_1}$$

Thus the wide applications of the rule would be obtained.

And if, (3) $a = 0$ and $\frac{l_2}{l_1} = \frac{\lambda_2}{\lambda_1}$

we get; $\frac{\rho_2 - 1}{\rho_1 - 1} = \left(\frac{\nu_2}{\nu_1}\right)^2 \left(\frac{\lambda_2}{\lambda_1}\right)^{-1}$

$$\frac{D_2}{D_1} = \frac{\lambda_2}{\lambda_1}$$

The ropes which are used for headline or ground rope etc. should be calculated in their diameter by the next formula.

Here we neglect the hydraulic resistance and only take into consideration the weight in water from equation (15), we have:

(4) $a = 0$ $\quad \frac{\lambda_2^2 \nu_2^2}{\lambda_1^2 \nu_1^2} = \frac{(\rho_2 - 1)D_2^2 l_2}{(\rho_1 - 1)D_1^2 l_1}$

If, $\frac{l_2}{l_1} = \frac{\lambda_2}{\lambda_1}$

then $\left(\frac{D_2}{D_1}\right)^2 = \frac{\lambda_2 \nu_2^2 (\rho_1 - 1)}{\lambda_1 \nu_1^2 (\rho_2 - 1)}$

$$\therefore \frac{D_2}{D_1} = \sqrt{\frac{\lambda_2 \nu_2^2 (\rho_1 - 1)}{\lambda_1 \nu_1^2 (\rho_2 - 1)}}$$

(5) a = 0 and if neglect weight also,

$$\frac{D_2}{D_1} = \frac{\lambda_2}{\lambda_1}$$

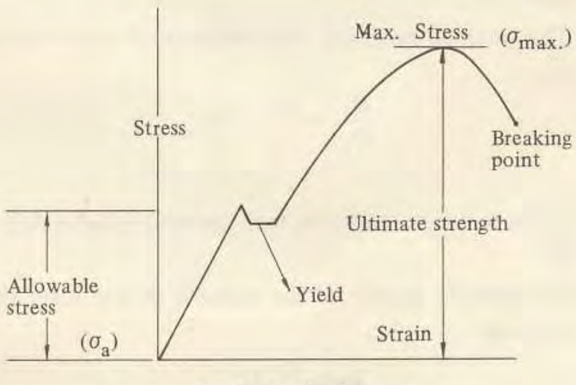
3.3.6 Tension of netting cord and distribution in fishing net

1. Introduction

When designing fishing gear, one must select the adequate size of twine for fishing net which will have enough strength against the tension of netting cord caused by external forces such as hydraulic resistance of net to the current, tension of net due to hauling and setting net operations, and some other unexpected impact external forces.

The netting cord has it's own breaking strength according to the kind of material, twine size, twist, etc., and the strength will be lessen by forming a knot of mesh, by rotting in water, by repeated operations, etc.

On the strength of the material in engine and buildings, for instance, the allowable stress is limited to the range of safety factor as shown in the figure and table.



Stress – strain diagram

Value of safety factor s $(=\frac{\sigma_{max.}}{\sigma_a})$

Material	Static load	Dynamic load
Cast iron	4	6
Wrought iron & steel	3	5
Wood	7	10
Brick, stone	20	30

As for fishing nets, it is very difficult to estimate unexpected impacts imposed on net by outer unknown factors, and so it is very difficult to estimate the actual strength of netting cord in the range of safety factor under fishing operations.

As a whole, in order to secure the safety of fishing net it is needed the value of safety factor is between 10 to 100 comparing to other materials. Bearing these difficulties in mind, however, the design and decision of twine size should be undertaken on the basis of tension acting on netting cord under operative condition. There are some reports which actually measured the tension of netting cord under operative conditions such as laying out, pursing fishing line and hauling up the purse seine net[1], gill net[2),4)] and trawl net[2].

Here in this paper, we would like to take the study relating to the distribution of tensions on the sheet of net and its extension.

It is quite natural through the observation that the tension of netting cord will transfer from one mesh to another through the bars and knots of meshes, but the function of transmission is not so clear. On the rationalization of fishing or the mechanization of fishing gear, the design of fishing net particularly the selection of twine should be carefully carried out on the following: during the net hauling operation, if net is operated by man power, nets have rather small tensions in various parts of the net, but on the contrary bigger tensions will act on particular parts of the net when the nets are hauled by machine. And also the care should be taken on factors that will be affected by dynamical and concentrated loads when the operation of net is speeded up by mechanization. In response to the fishing modernization such as the mechanization of fishing operation and conversion of the net material from natural fibers to synthetic fibers, the fundamental studies[2] on the distribution of stress on the net is introduced as part of the basic fishing gear design.

2. Process of the experiment

Relating to the distribution of stress on fishing nets, are studies by Takenouchi[3], Kamiya[5], and Fukazawa[6]. These papers were on the results of experiments on static loads and its distribution on the net when the net was stressed by hanging the weight at certain parts of the net. In practice, however, dynamical stress, impact stress and their distribution on fishing nets are more important.

The modern measurement of strain meter system adopted after the war were applied in the dynamical stress experiments and impact stress upon fishing net by Dr. Y. Kondo.

This system based on the principle in which the strain of metal caused by some stress could be drawn by the changing of electrical resistance which might be proportional to the amount of stress. The characteristic of this method are being able to measure even very small strains continuously during long periods. The diagram of the process of strain meter and the pick up of strain gauge attached to netting cord are shown in the figure.

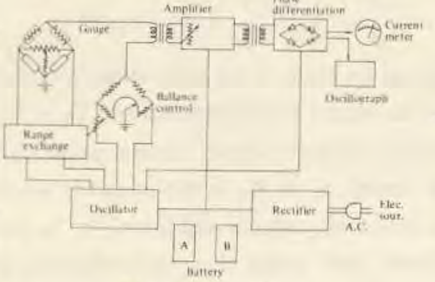
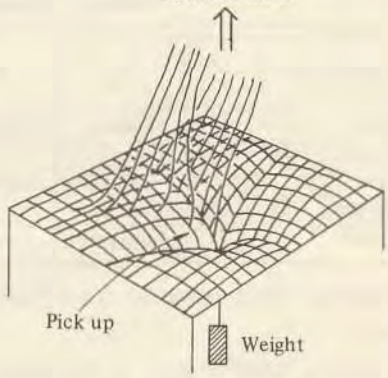


Diagram of strain meter

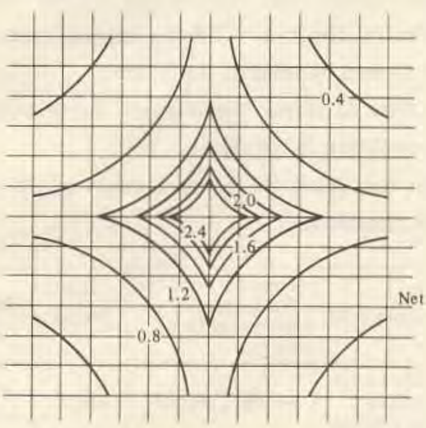
Pick up system

3. Experiment where stress is on one part of the net

The net is stretched forming square mesh along 2 meters square frames, and at the center of the net sheet the weight is hung as shown in the fiture. The leg tension (netting cord) of meshes adjacent to the central mesh are picked up and read by strain meter system. Thus, the distribution of stress on the net are indicated in the figure.



Weight : 10 kg. at the center
Net : 20'/30, 15 cm mesh size
Hang – in : 0.294



Distribution of stress

As seen in the figure, the load imposed at the center point are transmitted and emanated extensively mostly along the line of legs directly connected to the center point. The phase of declined tension along the line are expressed by the following experimental formula :

$$\frac{T}{W} = \frac{T_o}{W} + \frac{Ae^{-kn}}{W} \quad \text{or} \quad \frac{T}{W} = K_t + K_a e^{-kn}$$

Here, T is the tension on the n-th leg countering from the center point, W is the weight (load) imposed and T_o or K_t is the constant initial tension without tension caused by the stress at the center. A or K_a is the constant value depend upon the kinds of material and knot. "k" is the declination coefficient and means that the declination is sharp and distribution of stress extends in a small area if k is big in value. From the experiment, the value of K_t, K_a and k are calculated in the following table.

This table gives the characteristics of different materials and different knots. These are summarized from the standpoint of stress distribution in the following table.

Kind of material	Kind of knot	$K_t = \frac{T_o}{W}$	$K_a = \frac{A}{W}$	k
Cotton net	Flat knot	.07	.26	.52
	Trawler knot	.10	.27	.46
	Knotless	.11	.29	.45
Vinylon net	Flat knot	.09	.24	.50
	Trawler knot	.15	.24	.42
Manila net	Flat knot	.18	.20	.42
	Trawler knot	.23	.25	.36
Nylon net	Flat knot	.12	.25	.44
	Trawler knot	.17	.25	.39
Saran net	Flat knot	.09	.24	.48
	Trawler knot	.13	.26	.40
	Knotless	.17	.25	.37

Kinds of knot	K_t (T_o/W)	K_a (A/W)	Evaluation of net			
			Transmission of stress	Damage degree	Tearing degree	Superiority order
Knotless (Running type)	Largest	Smallest	Extensive area	Large	Difficult	4
Knotless (Zig zag type)	Medium	Medium	Medium	Medium	Medium	3
Trawler knot net						2
Flat knot net	Smallest	Largest	Small area	Small	Easy	1

Kind of materials	K_t	K_a	Evaluation of net			
			Transmission of stress	Damage degree	Tearing degree	Superiority order
Manila net	Largest	Smallest	Extensive area	Large	Difficult	5
Nylon net Saran net Vinylon net	Medium	Medium	Medium	Medium	Medium	2 – 4
Cotton net	Smallest	Largest	Small area	Small	Easy	1

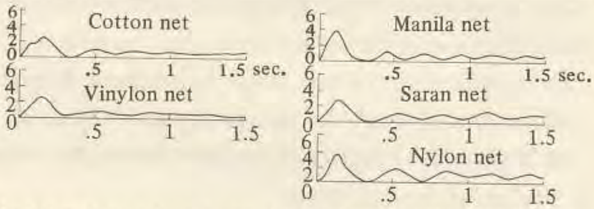
4. Experiment where impulsive stress is added to one part of net.

The impact stress is given at the center point of net sheet by dropping the weight from a certain height. The expression is the same as the case of static load in the former experiment, but the value of k is always smaller than the former one. This is due to the fact that the operation of absorption of the impact stress does not occur very well because of short time.

The state of stress variation on the first leg from the center are shown in the figure.

From the figure the characteristics of different materials are summerized.

Kinds of material	Time required for the movement of the stress declination	Period	Evaluation of net
Nets made of cut fibers such as cotton & vinylon	Nearly 1 second	Large	Almost the same tendency as the evaluation in the case of static stress
Net made of endless or long fiber as nylon, saran and manila	Nearly 2 seconds	Small	



Variation (stress-time diagram) of netting cord after the impact.

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6) F. Fukazawa: Elastic properties of net, Synthetic Study Report (Agri.) 1953

3.4.1 Outline of various types of trawl net – Europe

1. Brief history:

First step in fishing to open the net mouth horizontaly was done by boom trawl which extend the boom both to stem and aft of sailing boats.

Next step was conducted by beam trawl which was the net with the beam or iron rectangular frame at mouth of net to keep net open to the current. These were used by sailing or motored boats. Some boats had several nets for fishing at once.

The most developed fishing along with the objectives in which the net was kept opened to horizontal direction was the otter trawl. It was said that this method was invented around 1870 in Ireland. In England the country fishermen had developed British trawling at the mouth area of the Thames river. Some one said that the idea of trawling was first introduced by a person who came to Holland in 1688, but it is not certain.

Anyway, this gear already has a hundred years history since it was invented, and at present this kind of gear is the most important and essential gear in the Europe. Also this system of fishing has been introduced widely to other countries of the world.

The trawl gear developed into a large scale in order to trawl in deeper sea ground, and with this line the winch was highly mechanized through the operation in which warps were hauled up by means of power winches. This is called side trawling. Then, stern trawling developed. This more effectively enlarges the function of trawling in deep sea and gear operation. Another further development of trawling is midwater trawling. This is done both by one boat and two boats.

2. Classification in the size of trawl

ICES	Steam trawl	
	Motor trawl	
	Herring trawl	
	Pelagic trawl	
	Danish seine	
U.K.	Distant-water trawler:	more than 700 tonnage and 150 – 190 feets.
	Mid lle-water trawler:	400 tonnage, 140 feets.
	Near-water trawler:	250 tonnage, 120 feets.
	Factory trawler:	2600 tonnage, 245 feets.
West Germany	Trawler:	350 – 700 tonnage
	Lugger:	100 – 350 tonnage
	Motor Cutter:	LOA 10 – 24 meters
	Big trawler:	More than 700 tonnage

3. Brief explanation of trawl gear

Stow Net (fig. 1): This is not the net dragged at the bottom but fixed at some place to filter the fish from water current, the most primitive type of gear. Mostly done in rivers.

Beam trawl (fig. 2): Mainly for catching shrimps.

Coastal bottom trawl for plaice (fig. 3): Mainly for catching flat-fish.

Small bottom trawl for cod (fig. 4): Mainly for catching cod.

Small bottom trawl for herring (fig. 5): Mainly for catching herring

Two-boat type small bottom trawl (fig. 6): Larger size of net can be used by two-boat trawling.

Two-boat type mid-water trawl (fig. 7): Also called larsen trawl. (Denmark, Germany, etc.)

Bottom round-fish trawl (fig. 8): This net has a big ground bobbin rope specially to trawl on rough bottoms. There is a big difference between round-fish cod and herring net design and flat-fish net, particularly in the slip between upper and lower net as shown in the figure. The ponny is used in place of danleno. This net is used in West Germany.

High opening bottom trawl for herring (fig. 9): In order to keep high opening in the mouth of net, the square has enough area for opening by aid of kites as shown in the figure. This net has no bobbin in ground rope. (Germany, Polland, etc.)

Granton trawl (fig. 10): The net is dragged by the boat of around 180 feet in length. The boat will make 3 weeks including navigations and fishing. The composition of crews are, one skipper, one mate, one bosun, 8–9 deck crew, 2 engineers, some oiler, 2 firemen, one wireless operator and some cooks. At the top of the wing, danleno and butterfly are used to join the hand rope. As this net is used on rough bottoms, it has a big bobbin for constructing ground rope (England, Iceland etc.)

Wing trawl for herring (fig. 11): The round fish bottom trawl is called a wing trawl on a Vinge trawl in Scandinvian countries. The net is designed with a high opening in the mouth to catch herring, cod, mackerel, etc. It is not for use in rough bottom areas. As the footrope uses several chains for weight, the net can also catch flat-fish and lobster in Norway (England, Norway, Denmark, etc.)

Danish seine (fig. 12): The net use is a large guantity of ropes for driving the fish into the net. Therefore the net itself does not move as fast as other trawl nets. A special rope coiler is used for this fishing (England, Ireland.)

Various types of floats (fig. 13): These are special floats for opening the net mouth more effectively.

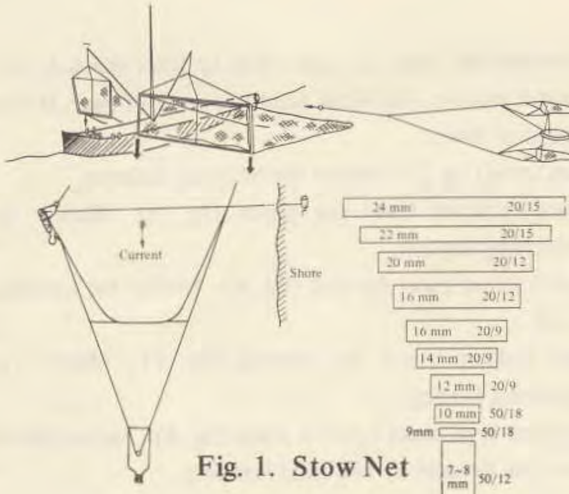


Fig. 1. Stow Net

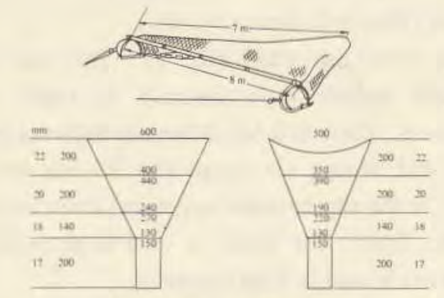


Fig. 2 Beam Trawl

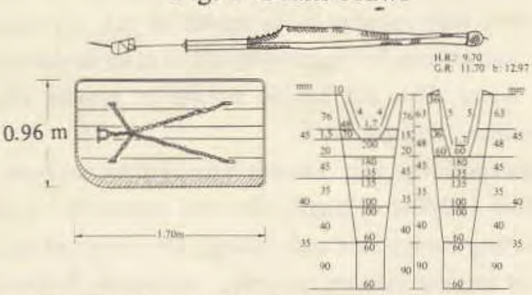


Fig. 3. Coastal Bottom Trawl for Plaice

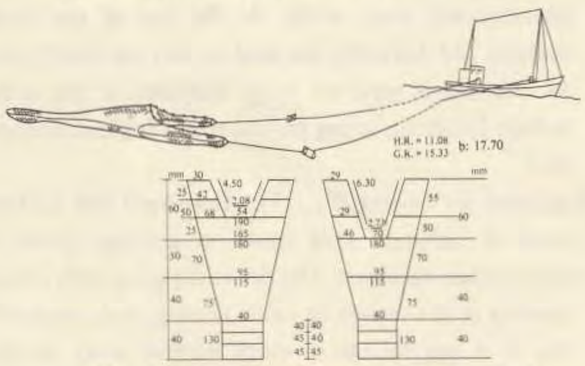


Fig. 4. Small Bottom Trawl for Cod

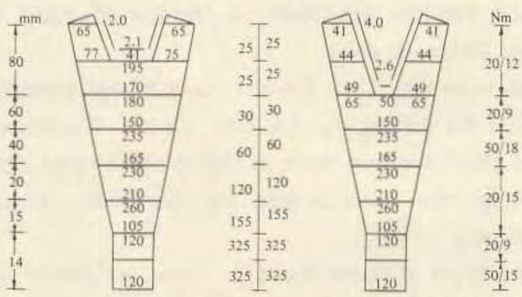


Fig. 5. Small Bottom Trawl for Herring

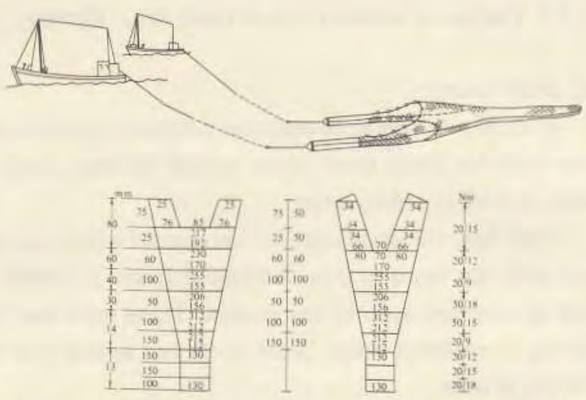


Fig. 6. Two-boat Type Small Bottom Trawl

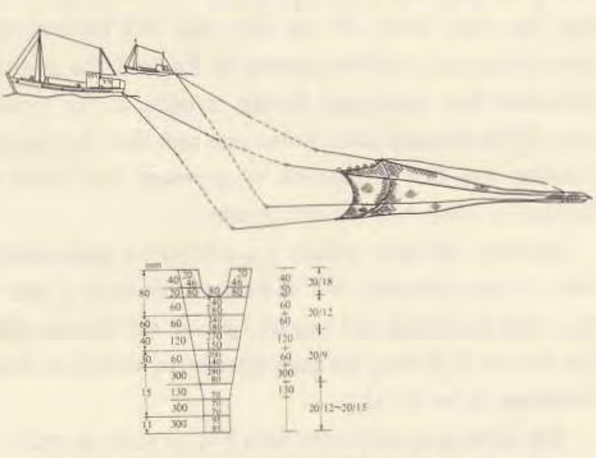


Fig. 7. Two-boat Type Mid-water Trawl

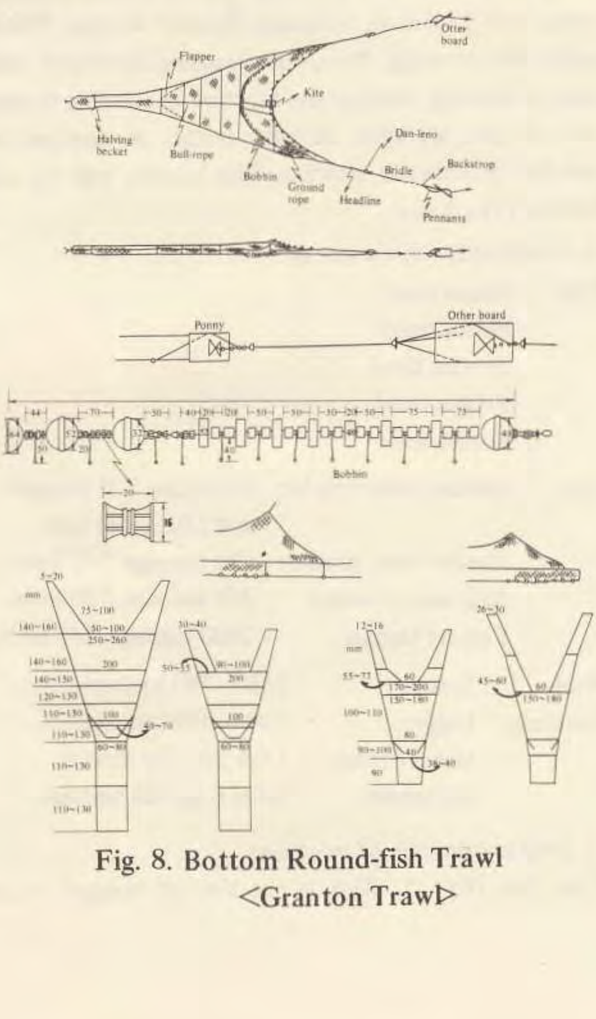


Fig. 8. Bottom Round-fish Trawl
<Granton Trawl>

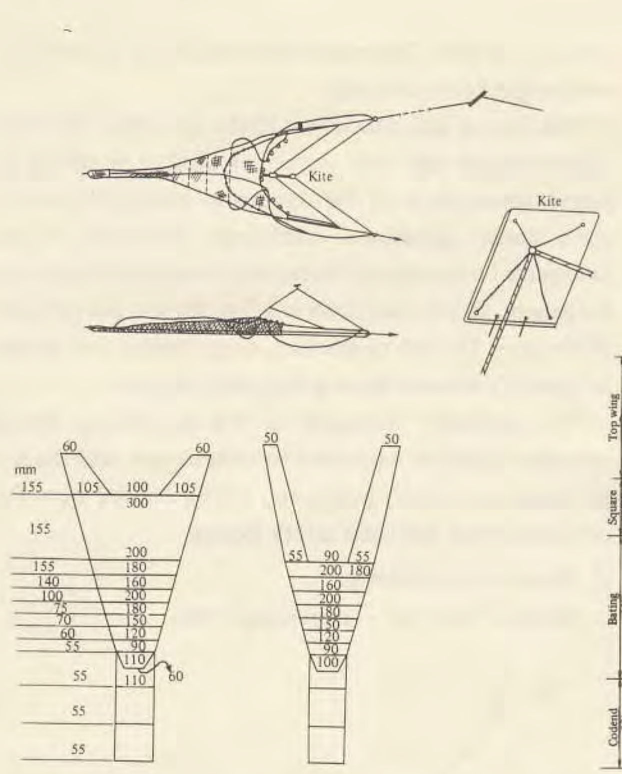


Fig. 9. High Openning Bottom Trawl for Herring

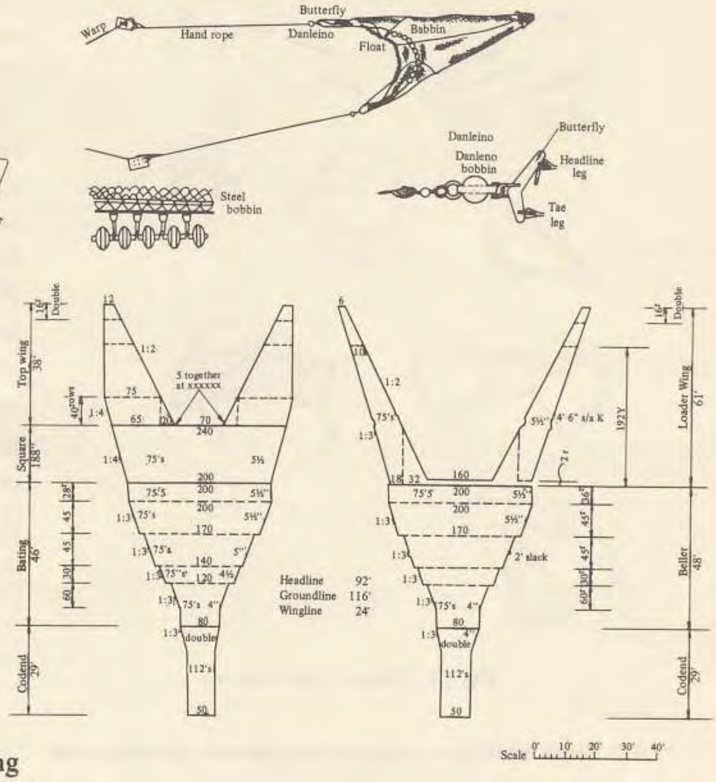


Fig. 11. Wing Trawl for Herring

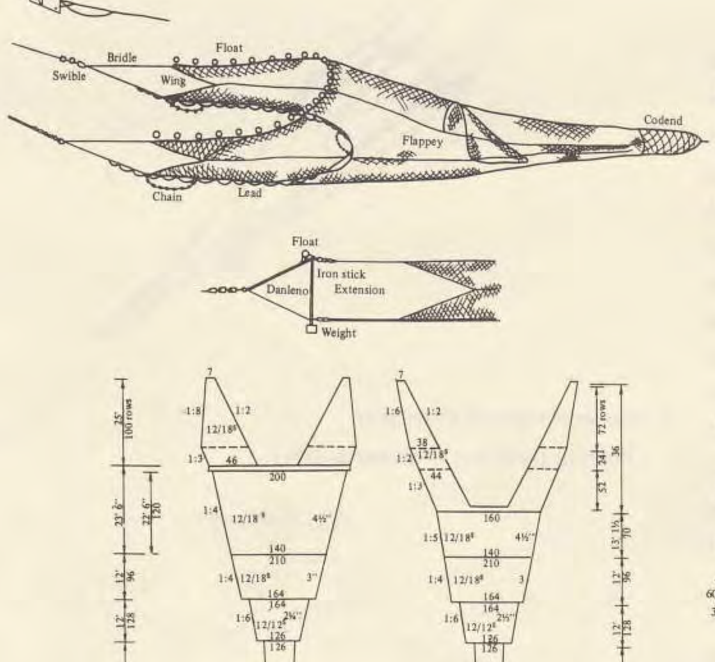


Fig. 10. Granton Trawl

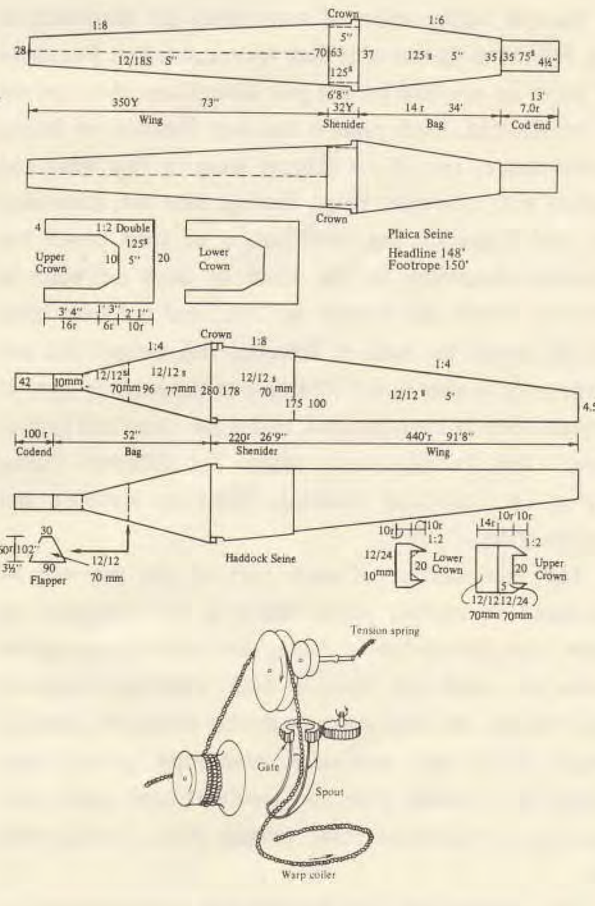


Fig. 12. Danish Sein

Fig. 13. Various types of floats

3.4.2 Stern trawl net composition, general operation and gear nomenclature

1. Introduction

General composition of trawl gears are illustrated in the following figures with their technical terms. The name of parts are essential for the gear technicians when the net is constructed. Each panel it has own function of fishing performance, i.e., Wings (Upper wing or top wing and Lower wing), Square, Belly, Baiting, Side net, Extension net and Cod-end. The combination of such panels has variation according to the kinds of trawl net such as 2-seam, 4-seam and 6-seam net, etc., and as to the kinds of fish aimed for such as demersal fish, pelagic fish and shrimps. It is also varied according to the existing layer of objects such as bottom trawl, mid-water trawl and surface trawl. The fishing system makes for different fishing styles, i.e., one-boat trawling, two-boat trawling and Danish seine.

The composition of each part of the net will be discussed in another paper, but it is very important to have basic knowledge of fishing net composition such as twine size, mesh size, kinds of knot, width and length of net, baiting, selvedge making, double twine net, hang-in, staple, bolch line, man rope, head rope, ground rope, lacing line, quarter rope, net pendant, hand rope, otter pendant, independent rope, towing chain, towing warp etc.

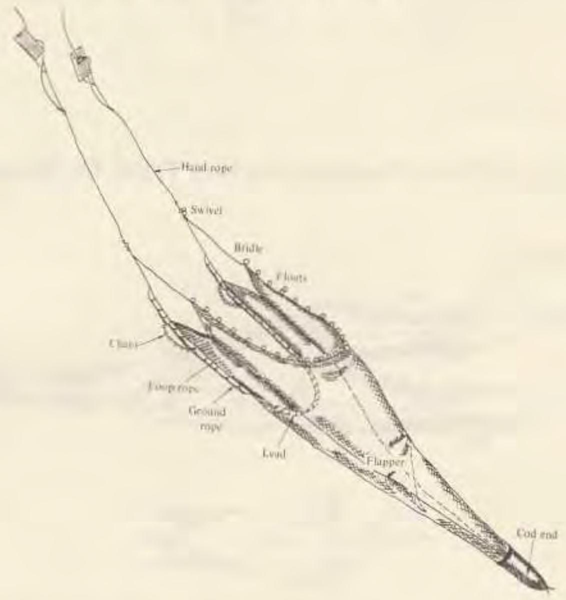
The composition, style and function of Otter Board are also important to open the net mouth horizontaly. Sometimes a depressor board to open the net mouth vertically is used. These specifications should be discussed and designed very carefully.

The joining and attachment to the net, ropes, lines and accessoires are also very important because it should be joined appropriatly to the dynamical forces imposed to them under operational conditions. Specially, at sea, unexpected extrordinary forces may be exerted on the net irregularly, so we must observe safety factors in every part of the gear. The size of shackles, rings, swibles, etc. should be carefully selected bearing this point in mind.

The hydraulic resistance of the net during fishing operation could be estimated to some extent, and the size of ropes, warps, otter board, etc. will be decided from this estimated value and some safety factors.

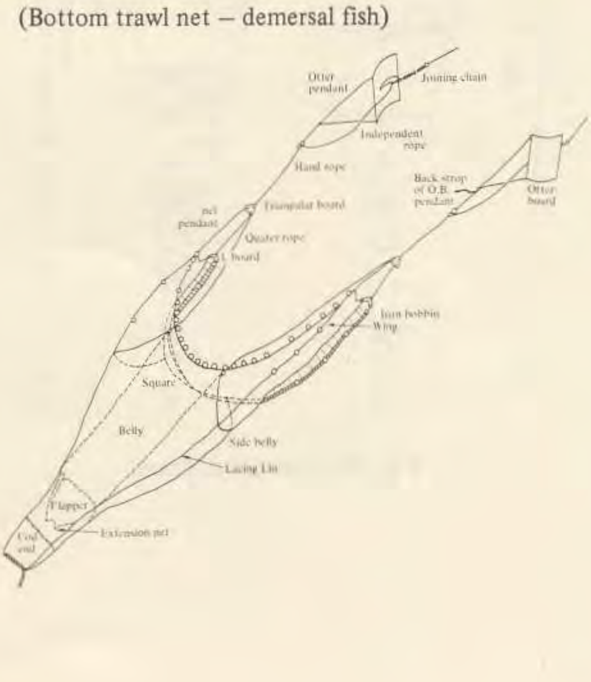
2. Trawl net composition

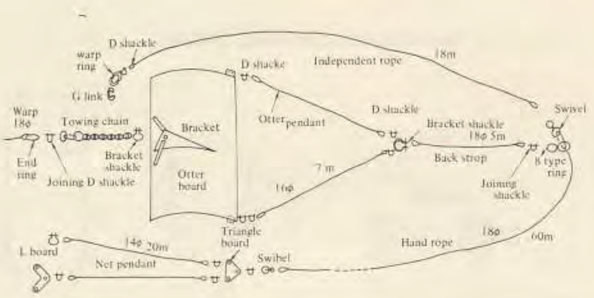
(Bottom trawl net – semi-pelagic fish)

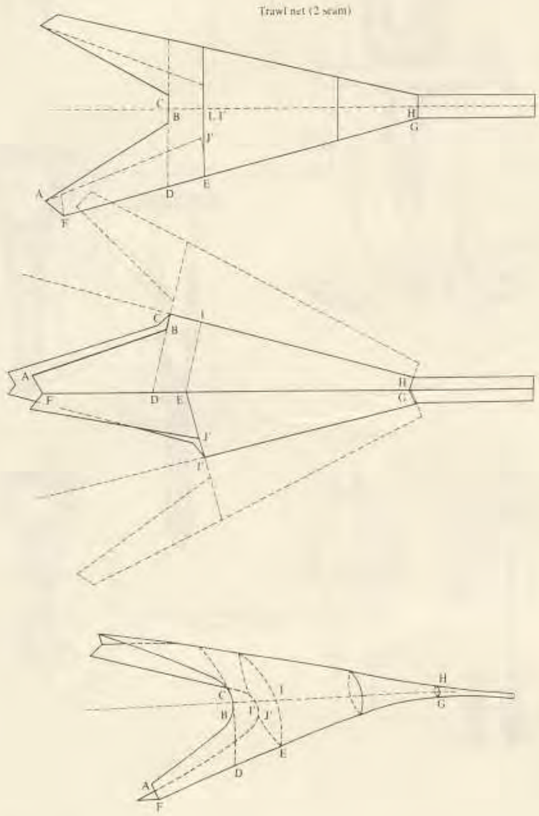


3. Nomenclature of trawl gear

(Bottom trawl net – demersal fish)







4. Rope and net construction

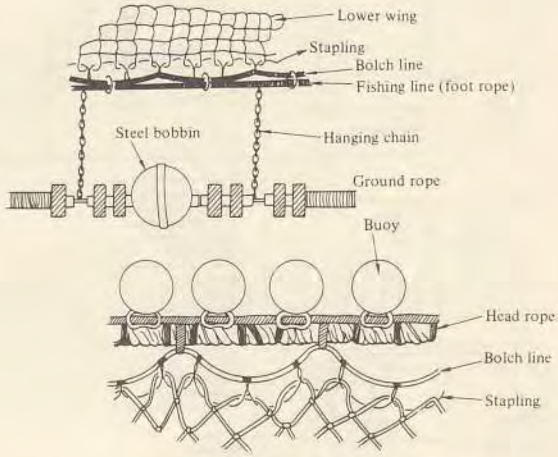
Lacing line — Usually made of compound rope and used for joining to both selvedges of belly (or baiting) and side, in order to increase the strength of netting.

Bolch line & stapling — These are used for the construction along with the selvedge of the wings which will be connected with ground rope or head rope, as shown in the figure.

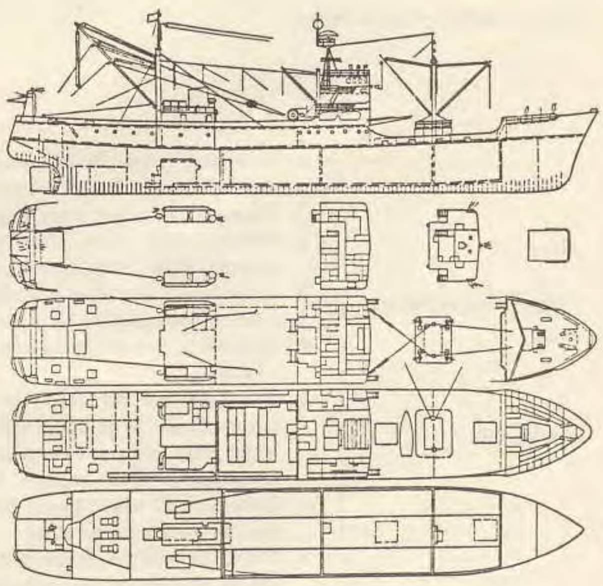
Fishing line (foot rope) — Usually made of compound rope. Flymesh of lower wing jointed with bolch line is attached to fishing rope, and this is connected with ground rope by hanging chain to lessen the tension produced by the ground rope, thus protecting the net from being broken or torn by rough bottom.

Man rope — Used to prevent the netting from breaking when extraordinary weight and tensions are exerted on the net. The loosely twisted rope is fixed along with the joining part of the upper and lower netting to the end of the cod-end.

Ground rope — Constructed with wire, and according to the conditions of the sea bottom or fish species, the ground rope is covered with tire, steel bobbin, rubber roller, wooden sinker, iron sinker etc. The end of the ground rope is connected with the ground pennant, and the quarter rope and the fixing root of the man rope are fixed to the joining point of the wing and the central part of ground rope.

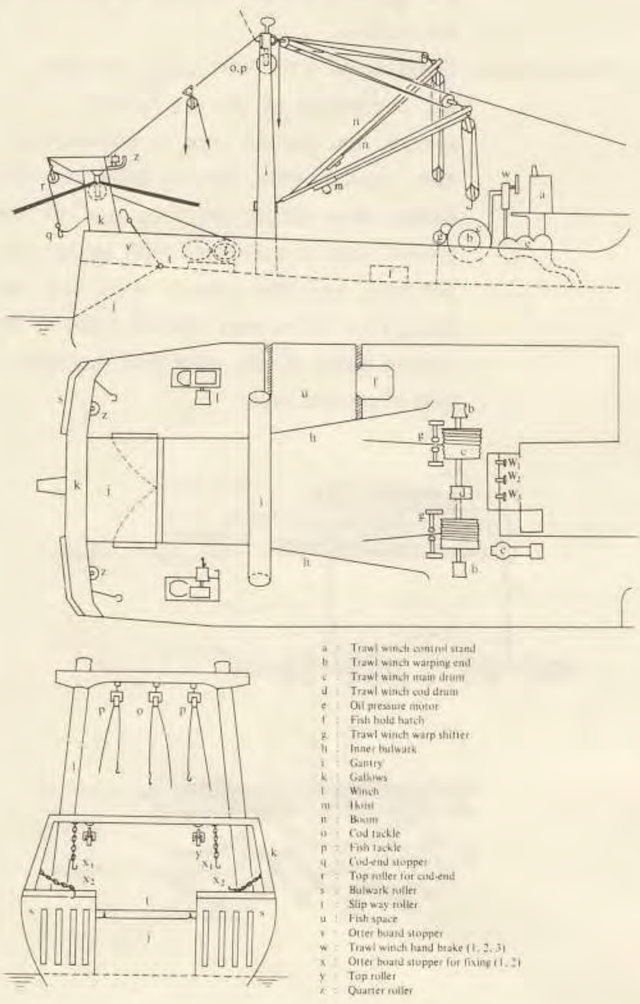


5. Trawler

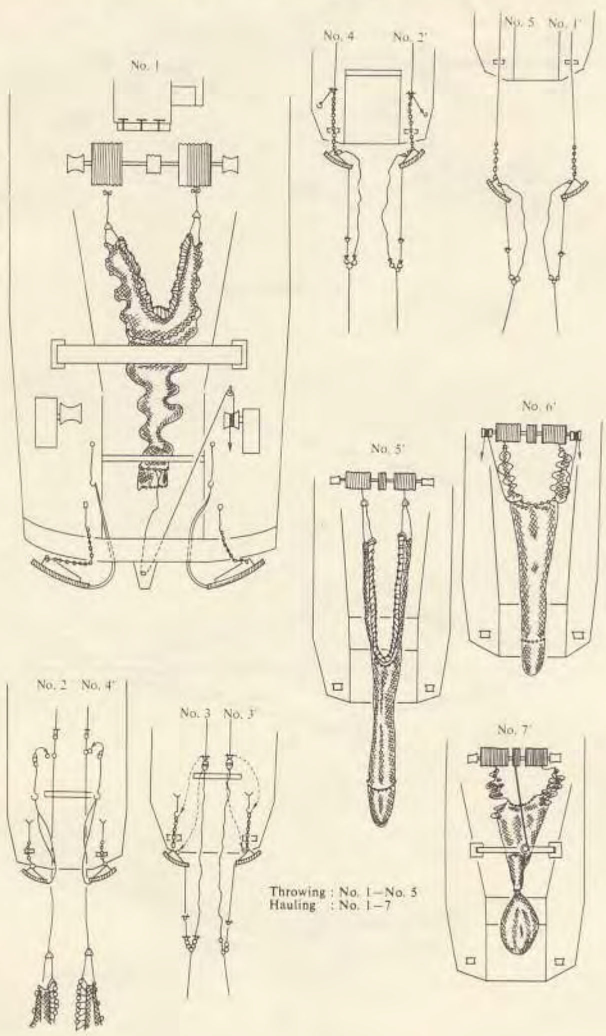


Most modern stern trawler
(1500 gross tonnage)

6. Trawling equipment on board the deck



7. Process of hauling and throwing the net



8. Trawl net operation order

		Boat speed	Engine rotation	Variable pitch
Sailing	1. Searching proper fishing ground and decision made by judging depth of water, fish school information and bottom nature.	10knot	345,	16–17'
	2. Trawling course and warp length are decided.			
Stop	3. Oceanography observation on bottom nature, water temperature at the bottom and current.	0		
Preparation payint out	4. All members take their operating position	3,	300,	7°
	5. Cod-end is suspended by cod-end stopper over the slip way.	3,	300,	7°
Paying out	6. Cod-end is thrown by loosening the stopper with the order of "Let go".	3,	300,	7°
	7. The nets are let into the water from cod-end to wing automatically by pulling force of net produced by the flow of water with both net pendants running out. The winch stops immediately after triangle iron board is in the sea. Also, inspection of winch brake, the balance of net shape pulled by boat at the surface of water.			
Hand rope paying	8. Then, the brake is slakckened until 8 type ring comes out from the winch with running of hand rope.	2,	300,	5°
	9. The shackle at the terminal point of back strop of otter pendant are joined to 8 type ring.	2,	300,	5°
	10. Again, winch brake is slackened until joining block comes out on deck.			

Preparation for otter board throwing	11. Independent rope is released from towing warp, and is joined to top of otter blacket with G link.			
	12. Then, warp ring of towing warp is joined to top of towing chain.			
	13. Right hand warp is coiled up a little to exert tension on towing warp, and then otter stopper is released.			
	14. The same operation is done on left hand otter board stopper.			
Otter board throwing	15. Both otter boards are paid out in the same manner by slacking the winch brake.	5,	300,	10°
	16. Towing warp is stopped at 30 meters length and the state of opening of otter board inspected.			
	17. Brake test 2 or 3 times.			
Towing the net	18. The warp is run out to predecided length of warp which is approximately 3 times the water depth. This is the time to commence towing the net.	3,	300,	15°
	19. Inspection of the state of towing condition, calculate warp angle, opening angle and warp tension.			
Preparation for hauling	20. After two hours elapses after commencement of the net towing, all member take their operating positions for hauling the net.	3,	300,	15°
Hauling the warp and the net	21. Operation of winding the towing warp is commenced. This is commencing time of hauling.	2,	300,	5°
	22. When otter boards come to stern bulwark, it is stopped by otter board stopper and the warp is slackened.		"	
	23. Towing warp end is released from towing chain shackle and is joined to independent rope.		"	
	24. Thus, the shackle at back strop terminal of otter pendant is released from 8 type ring.		"	
	25. Independent rope, hand ropd and net pendant are hauled up by winch until the wings appear on the slip way.		"	
	26. Wing nets are hauled up on the deck by drum.		"	
	27. Then, the body net is hauled on the deck.		"	
	28. Cod-end is taken up from the deck by cod tackle and catch inside the cod-end are released on the deck.	0		
Next preparation	29. Cod-end purse string is again braided. Preparation for the next towing operation done.	0		

Speed of boat	Rotation	Pitch
Full	200 – 350,	15°
Half	300	10°
Slow	300	7°
Dead slow	300	5°

3.4.2 Two-boat type trawl net (Pair trawl)

Introduction

Two-boat type trawls have developed from conventional small trawl in Japan. Because of high capacity of cathing comparing with otter trawl fishing, it is still commercially used. Although various gear factors–such as net construction, boat size, hull construction, speed of boat, fishing machine, navigational instruments, etc.–have been developed remarkably and have become more efficient in fishing, the fishing principle does not change. Besides Japan, this kind of trawl is popular in Taiwan, Korea, Thailand, etc. In European countries such as Denmark, Netherland and West Germany they use two-boat type midwater trawl. This net does not need any otter board and if a pair of boats have good cooperation in keeping proper interval between them, the net will open properly improving the chances of a good catch.

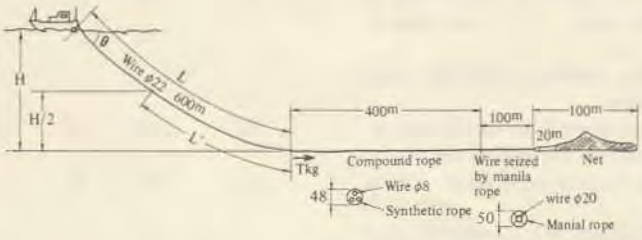
1. Type of net, boat and operations

The 4-seam and 6-seam nets are the main types of nets. The 4-seam net is mainly used for demersal fish and is not necessary any higher in net mouth, but the 6-seam net is used for fishes that sometimes leave the bottom, requiring a higher opening. The two-boat trawling fisheries are usually operated by 50–100 tonnage boats in wide areas of rather flat bottom. One operation by two-boat trawling requires 1–2 hours. The boat is aft-engine type and is equipped with hold of transverse bulk-heads before the engine room. These contain ice on the way to sea, and boxed catches on the way back. The boats are mostly powered by diesel engine. Wireless telegraph and telephone, fish finder and direction finder and various nautical instruments are installed only in the leader of the combined boats. Drums are fixed on both sides of the engine room casing, and wirereels on the upper deck behind of forecastle.

2. Length of warp (discussion)

Specially on two-boat type trawl, the length of warp is very important. About 2–3 coils of compound ropes are used for the hand rope which has some effect in driving the fish into the mouth of the net.

In the East China Sea, the depth of water is about 80 meters, the warping wire is ordinarily around 600 meters in length, and besides the wire compound rope, are used as hand ropes. The composition of these ropes is shown in the figure. In the figure, if we take the depth of water as H, and the length of wire as L, the length L' which is the length of wire in the case of H/2, is bigger than L/2.



So, L'⟩L/2, and if this inequality is divided by H/2, then we have L'/H/2⟩L/H. This means that the value of L/H will become smaller in accordance with the increasing depth of water H. From Dr. Tauchi's formula the following is expressed under the conditions where $\sin\theta \fallingdotseq \theta$ rad, and $\cos\theta \fallingdotseq 1$.

$$\frac{L}{H} \fallingdotseq \frac{2}{\theta} \fallingdotseq \frac{2 \times T}{W \times L} \qquad 1$$

On the basis of this formula, the relation between the conditions of H_1, L_1, and the conditions of H_2, L_2, is approximately expressed as follows.

$$\frac{L_1}{H_1} = \frac{2 \times T}{W \times L_1} \rightarrow \frac{L_1^2}{H_1} = \frac{2 \times T}{W}$$

$$\frac{L_2}{H_2} = \frac{2 \times T}{W \times L_2} \rightarrow \frac{L_2^2}{H_2} = \frac{2 \times T}{W}$$

$$\therefore \frac{L_1^2}{H_1} = \frac{L_2^2}{H_2} \quad \therefore \frac{L_1}{L_2} = \sqrt{\frac{H_1}{H_2}}$$

$$\text{or } L_2 = \sqrt{\frac{H_2}{H_1}} \times L_1 \qquad 2$$

In the case where depth of water changes from 80 meters to 160 meters, the length of warp 600 meters will be found from equation 2 .

$$L_2 = \sqrt{\frac{160}{80}} \times 600 = 1.4 \times 600 = 850^{m}$$

This is shorter than twice the 600 meters.

$$\text{From the equation 1 , } L = \sqrt{\frac{2 \times T \times H}{W}} \qquad 3$$

Therefore, if T, H and W are known we can find the necessary length for L.

Example:

If, head rope of trawl net = 90 m, d/1 = 0.03, v = 1 m/sec (2 miles/h), H = 80m, W (weight of wire in water) = 1.25 kg/m (wire φ22), find the length L.

$$R_{(net)} = 25.0 \times (d/1) \times \lambda^2 \times \nu^2 = 25.0 \times 0.03 \times 90^2 \times \nu^2 = 6070\,\nu^2$$

$$D'_{(\text{Compound } \phi 48 \text{ and Seized wire } \phi 50)} = C'_d/2 \times \rho \times d' \times L' \times \nu^2 = 0.04/2 \times 105 \times \nu^2 \times (0.048 \times 400 + 0.05 \times 100) = 48\,\nu^2$$

$$\therefore T = 6070/2\,\nu^2 + 48\,\nu^2 = 3083\,\nu^2 \text{ kg}$$

Thus, from the equation 3 ,

$$L = \sqrt{\frac{2 \times 3083 \times 80 \times \nu^2}{1.25}} = \sqrt{346800 \times \nu}$$

$$= 597 \times \nu$$

Suppose under such conditions, the depth of water is 80 meters, the distance between two boats 450 meters, warp length 600 meters, hand rope length 500 meters and length of net 100 meters, and if the depth of water changes from 80 to 160 meters, the length of warp will become 850 meters as has already been calculated, the distance between boats will be found easily as in the below.

$$\frac{600 + 500 + 100}{850 + 500 + 100} = \frac{450}{x}$$

$$x = \frac{1450}{1200} \times 450 = 1.2 \times 450 = 540^{m}$$

Actually, due to a small curvature in the shape of wire due to the flow of water, the distance between two boats will be 5 to 10 percentage less than this.

3. Height of mouth for pair trawl net

The models of various types of two-boat trawl nets have been experimented with in water tanks. These models are made by hand according to the law of comparison of fishing net. The results of the experiment on model No. 1 to model No. 6 are summarized below: (Jour. Fish. Boat Ass. Jap., 172, 1971)

Particulars of each net (Full scale)

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Boat size	100 ton	120	120	175	115	160
Engine	450 ps	650	450	900	650	650
Length of head rope	65 m	104	78	125	94	135
Height of mouth	4.8 m	6.8	7.1	12.2	10.0	18.0
under the condition of						
Buoyancy	400 kg	650	525	1000	650	1600
Trawling speed	2.0knot	2.0	2.0	2.0	2.0	2.0
Distance between wooden stick	30m	50	40	55	45	55

Remarks on the characteristics obtained in the experiment are as follows:

No. 1 Net: This is the most popular type of 4-seam trawl

4. Fishing boats of two-boat type trawl

A. Two-boat type trawler–Japanese style "Awa-type" – Fig. 1.

Wooden boats of Japanese type, built with transom stern and wide keel, and also with relatively large depth in proportion to breadth. Tonnage varies from 40 to 70 gross tons. Beams are protruded some 40 cm from the shell so as to make wider deck available.

Mostly powered by Diesel engine, two warp reels are equiped on the deck. The number of crews is 12 to 13. Cruise duration lasts some 20 days on an average, and cruising speed is 8 to 9 knots. They are generally inferior to their foreign style counterparts in various capacities such as propulsive efficiency, but are characterized by longer rolling speed. They are operated usually in the Yellow Sea and the East China Sea.

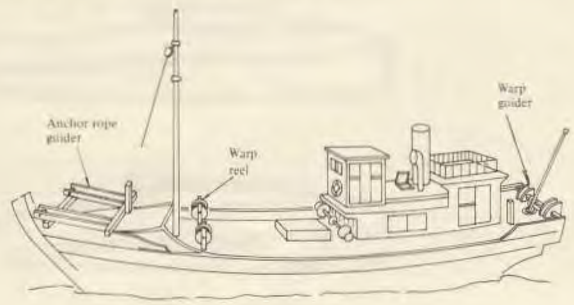


Fig. 1

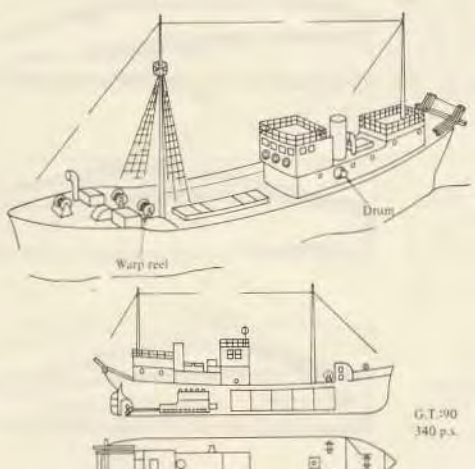


Fig. 2

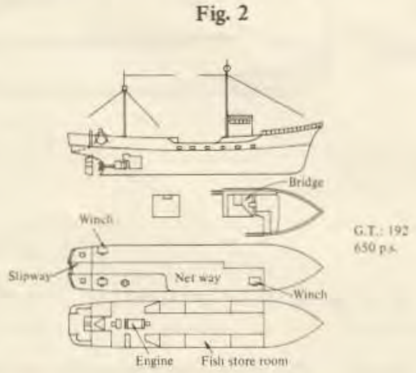


Fig. 3

B. Two-boat type trawler (larger type) – Fig. 2.

Wooden, steel, or composite boats of 50 to 130 gross tonnage. They are aft-engine type, and are provided before the engine room with holds with transverse bulkheads, which contain ice on the way out to sea, and boxed catches on the way back. Empty fish cases are piled on the top of the wheel house and galley. The boats of this type have relatively large depth in proportion to breadth, and small sheer. The deck house is located above the engine room and is a little retared toward the stern. Mostly powered by Disel engine. Wireless telegraph and telephone, fish and direction finders and various nautical instruments are usually installed. The warping end are fixed on both sides of the engine room casing as a winch, the wire reels are set on the fore deck and wireless on the upper deck behind of forecastle.

Manned by 12–13 men. Cruise duration average some 20 days, the speed being 9–12 Knots.

They are mainly operated in the Yellow Sea and the East China Sea.

C. Two-boat type stern trawler (big type) – Fig. 3

Steel boats of 120–200 gross tonnage are used since from 1965 in Japan. They are aft-engine and fore-bridge which is situated in port side of upper deck as shown in the figure. On the lower deck there is the net way for pulling and laying the net on the deck. The winch drums are situated in the aft, and sharp slope slip way is located at the end of boat.

Mostly installed with Disel engine, various electronics instruments are set in the bridge house such as wireless telephone, wireless telegraph, fish finder, net moniter, radar, loran and other nautical instruments.

Manned by 15–20 men. Cruise duration average some 40 days, the speed of the boat is 10–13 knots. They are mainly operated in the East China Sea.

5. Way at operation. (combination works of A and B)

1) 2-warp style operation

a. Boat A casts the net. Boat B approaches to A and gives the end of towing warp to ask joining with the net.

b. Extending warps by two boats.

c. Setting the whole length of warp and make operation of towing by two boats keeping proper distance between boats.

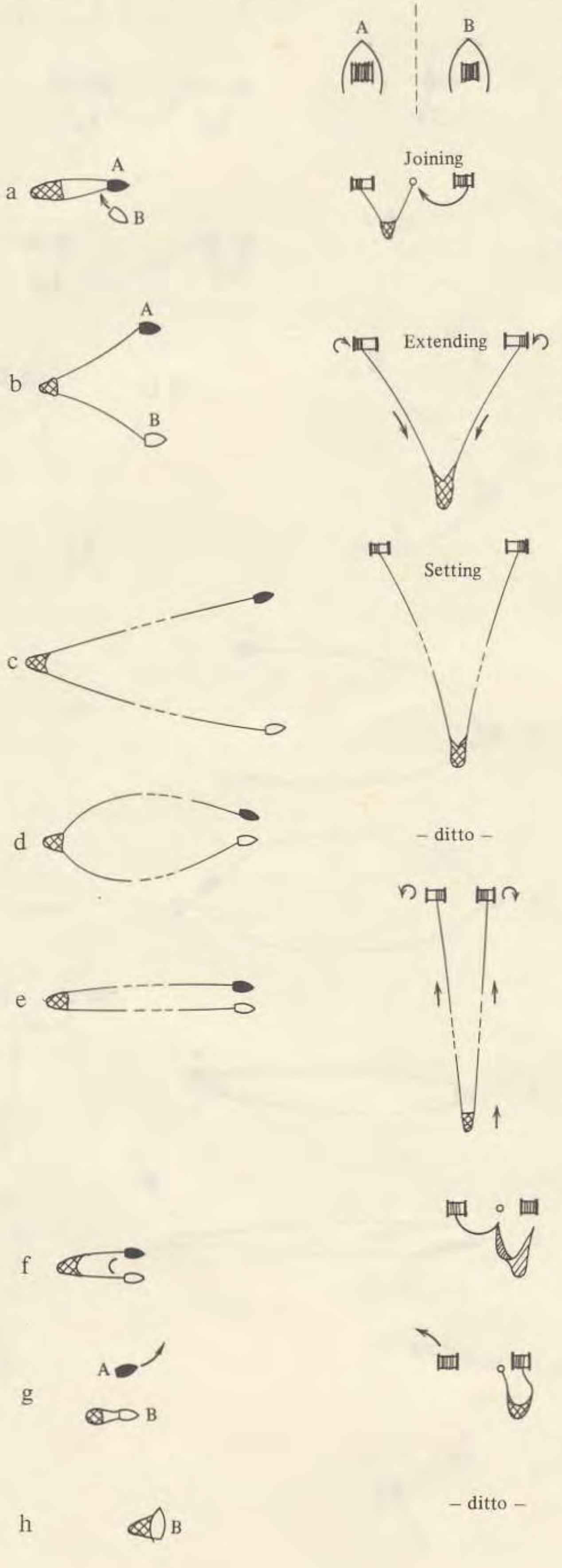
d. Approaching two boats without changing the length of warps.

e. Closing both boats and make stopper (connection ropes) between two. The boats are no more ahead and begin to wind the warp. Thus, the net makes still foreward.

f. Finish the reeling the warp. Boat A delivers the tip of wing to B.

g. Boat A breakes down stopper and parts from B. B begins the hauling net.

h. Boat B hauls the net at port side.



2) 3-warp style operation (popular type)

a. Boat A casts the net. Boat B approaches to A. Boat B gives the end of her warp to A. A joins the warp end to net.

b. Boat A gives the warp end to B.

c. Extending warps by two boat.

d. Setting the whole length of warp and make towing operation by two boats keeping proper distance between boats.

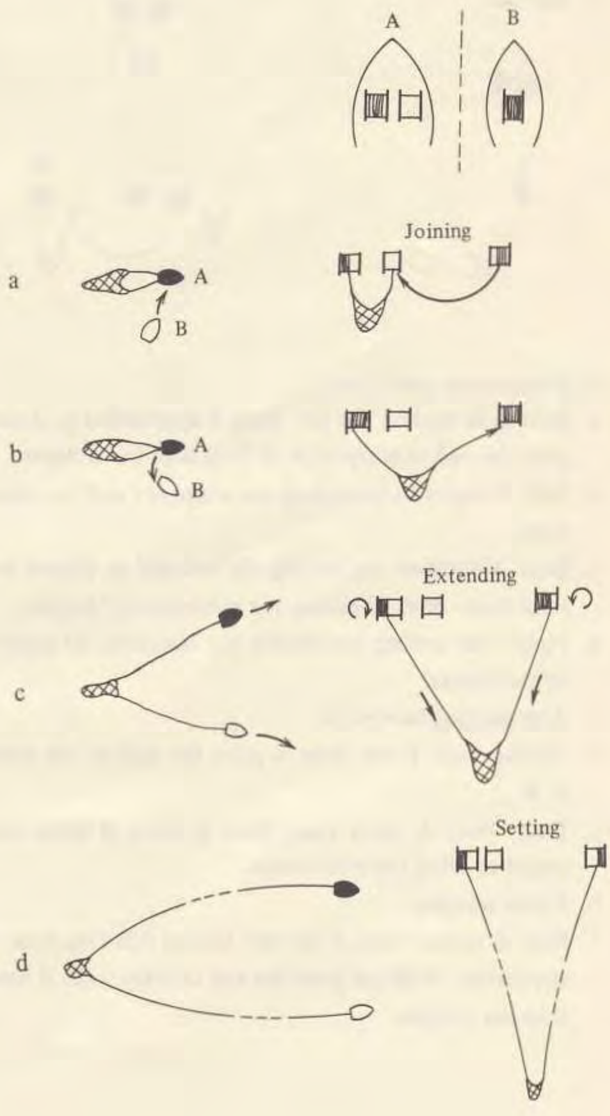
e. Approaching two boats without changing the length of warps.

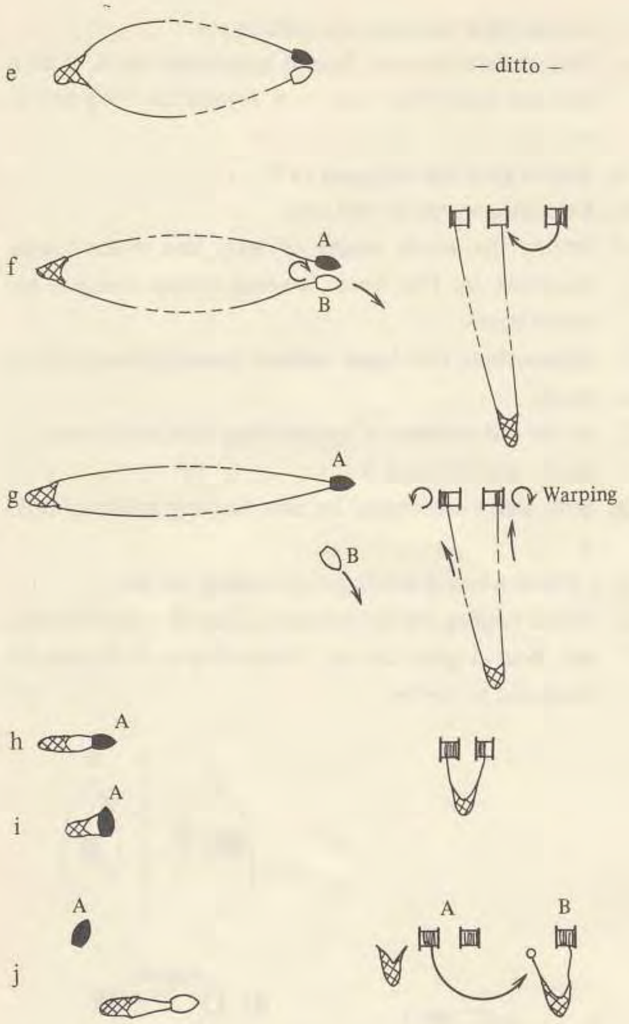
f. At the last moment of approaching boat B deliveres the end of warp to boat A.

g. Both warps are wound by two warping drums of boat A.

h, i Finish winding and begin to hauling the net

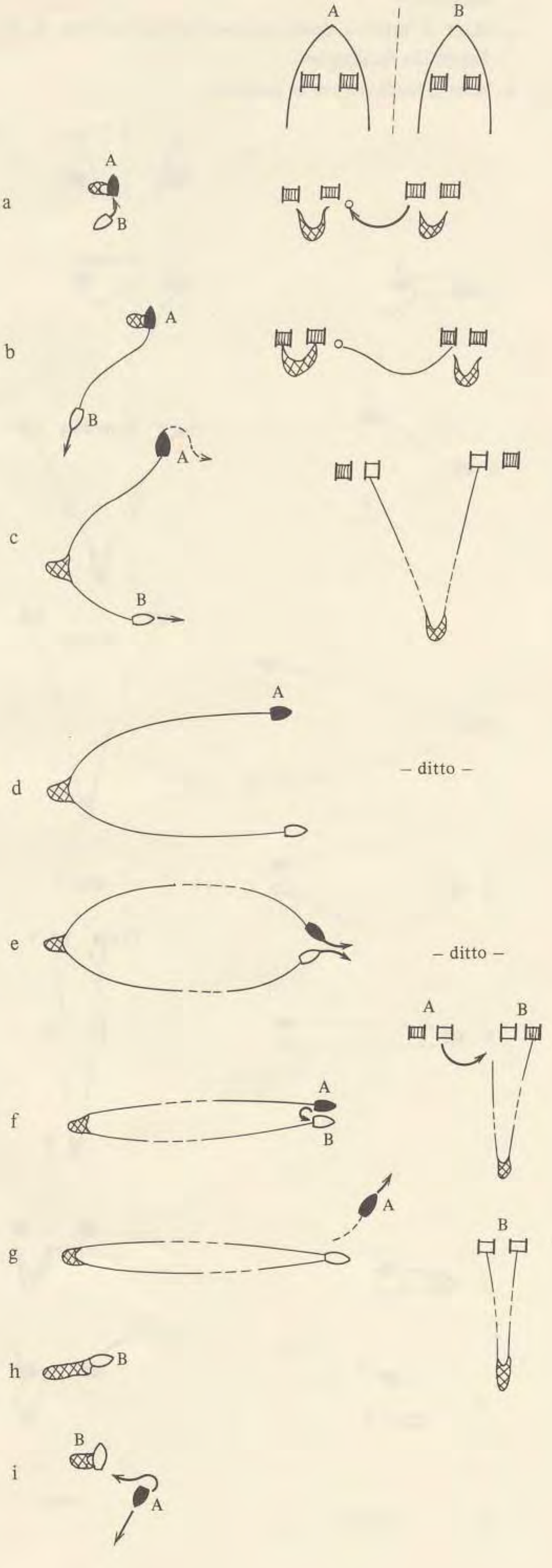
j. Finish hauling the net in boat A. Boat B casts the other net. Boat A gives the end of her warp to B. B joins the warp end to the net.





3) 4-warp style operation

a. Boat A is hauling the net. Boat B approaches to A and gives the end of warp to A. A fixes it to the stopper.
b. Boat B begins to extending one warp, net and the other warp.
c. Boat A finishes the hauling the net and at almost the same time. Boat B finishes the extension of the gear.
d. Finish the setting and makes the operation of towing by two boats.
e. Approaching two boats.
f. Closing both boats, boat A gives the end of one warp to B.
g. Then, boat A parts from boat B. Boat B stops and begins to wind the both warps.
h. Finish warping.
i. Boat B makes hauling the net. During this time boat A approaches to B and gives the end of warp to B. B fixes it to the stopper.



6. Characteristics of net design

The net of two-boat type trawl has developed in accordance with the boat which has also advanced in the construction and the size as they are seen in Fig. 1–3. At present the net are constructed with 4-seam or 6-seam in which man ropes are used for the seaming the net, sometimes it takes 30 percents hang-in in the shortening. The wing of the net is very long, occasionaly it attains nearly 200 meters in head rope particulary in the most modern stern type boat of two-boat trawl net. It is notably mentioned that since after the practical using of fish finder, the states of fish behaviour become clear little by little by reading images of this instrument, the height of net mouth is learned to be the most important factor to catch semi-pelagic fish near the bottom.

Thus, in Japan, much efforts have been paid for increasing the height of net mouth by giving big scale of net, improving net designing and increasing capacity of engine. The height of net mouth, the vertical distance between the bottom of the sea and the center point of head line was only 3 meters in the age of up to 1955, the recent big net attains over 15 meters in the height, catching many semi-palagic fishes that are swimming a little apart from the sea bed. This is the most characteristic point of the fishing by two-boat type trawl net which is much efficient in the catching semi-pelagic fish than otter trawl net.

7. Characteristics of fishing method

The towing rope are used around 300 – 600 meters in one side, which has such effects as scaring the fish and drive them to the net mouth area. Recently the compound rope are used for this rope. As for towing warp between the boat and the ropes the wire rope is used, normally 400 – 1,000 meters long in case of big boat. The junctions between wire and compound rope, and between two compound ropes each separated nearly 100 meters long, are used chains normally affording the weight in water. The total length including towing warp and rope is nearly 1000 – 1500 meters particularly in recent big trawler at the operating fishing ground of about 30 – 100 meters in the depth of water.

The distance between boats are normally 400 – 600 meters. The speed of trawling is about 2.5 Knots. The trawl fishing time of one operation is about 1.5 – 2 hours. Normally, after some hours of trawling, the two boats are coming together and continue the pulling net operation for a while, this is understood by the fishermen that fish concentrated in the space between two ropes parallel are more likely to get into the net mouth. This operation is called "the pulling with approaching", during this time two boats make prepare for winding up warps, normally sub-boat delivers his warp end to main-boat for the operation.

Then, the main-boat stop its going and begins to winding the warps. Even in this stage, the net goes ahead by the winding, so the fish might go inside the net more and more. As it is shown the two-boat type trawler in Fig. 2, the warping ends at the both side of engine room casing have been longly used as the winch which was directly driven by main engine. The warps through warp guider are wound up by warping end and the wires are reeled by two warp reels which set at fore deck, the towing ropes (compound rope), on the other hand, are coiled and laid on the aft deck of the boat. Sometimes when the sea is rough, the high waves attack to the aft of boat and big banging at the bottom of the boat in the aft causes some trouble to the rudder and other part of boat accordingly. Direct driven winch by main engine is also rather dangerous for operation sometimes it leads some accident. In around 1960 the hydraulic motors began to use for trawl. Now almost winch and wire reels are driven by this hydraulic oil motor system. In the case of stern type boat, the boat makes keep slow ahead and winds up the warp in order to avoid aforementioned trouble. Thus, the capacity of winch become big – 10 tons, 90 meters per minute in the big boat such as shown in Fig. 3. The boat has steep slop slip way or sometimes has horizontal roller at the aft of the boat easy to pull the net from the sea.

8(1). Comparison between otter board trawl and pair trawl in the catch operated in Thailand based on the catch statistics in 1973.

Table 1. Numbers of fishing units

unit: metric ton

	Number of fishing units	Total catch	Average catch per fishing unit
Otter board trawl	3,185	788,315	248
Pair trawl	351	223,074	633
Beam trawl	599	5,894	10

Table 2. Catch by the species of fish

unit: metric ton

	Total	By Otter trawl	By Pair trawl
Grand total	1,178,223	788,315	223,074
Sub-total fish	1,016,500	697,998	187,668
Trash fish	682,713	559,334	114,486
Sub-total Crustaceaus	86,681	55,547	2,248
White shrimp	4,344	2,420	42
Jumbo shrimp	181	147	5
Tiger shrimp	1,730	1,650	7
Yellow shrimp	593	430	3
Pink shrimp	9,624	7,026	93
Others shrimp	44,262	35,736	182
Lobster	1,465	1,189	232

Swimming crab	16,265	6,949	1,684
Blue crab	2,775	–	–
Sub-total Molluscs	75,042	34,770	35,158
Squid	44,691	18,531	24,049
Cuttle fish	23,920	15,172	8,524
Ark shell	553	–	–
Sea mussel	89	–	–
Octopus	4,222	1,067	585
Other shell fish	1,567	–	–

Above tables denoting statistics in Thailand are notably explained on the comparison as:

1. Average catch per fishing unit

The average catch in a year per fishing unit of pair trawl 633 tons in Table 1 surpass comparing with 248 tons of otter board trawl and 10 tons of beam trawl.

2. Weight of fisheries

From table 2, the percentages of fishing by otter trawl and pair trawl to the total are calculated as follows.

	Total (%)	By otter trawl (%)	By pair trawl (%)
Grand total	100	67	20
Sub-total fish	100	69	18
Trash fish	100	82	17
Sub-total crustaceaus	100	64	2.5
Sub-total Molluscs	100	46	47

It is clearly understood that 1) otter board trawl catch fish but nearly 70% of them are trash fish, and the percentage of catching trash fish is very high comparing with pair trawl, 2) catching crustaceans is very low in pair trawl, thus this fishing method is not good for catching shrimps, but 3) catching molluscs is very high in pair trawl, thus this fishing method is much efficiently than otter board trawl in case of catching squid and cattle fish.

Conclusively it can be said that the pair trawl having high opening in net mouth is good for catching pelagic or semi-pelagic fish, on the other hand otter board trawl is good for catching demersal fish and shrimps.

8(2). Comparison between otter board trawl and pair trawl in the catch operated in East China Sea based on the catch data in 1946 by Japanese fishing boats.

The following Table 3 is rather old data for the comparison but still it could get some comparative characteristics on fishing operation between otter board trawl and pair trawl.

It is understood that the average catch an hour of pair trawl of 80 G.T. tons of steel boat is 1.6 times that of otter trawl of 340 G.T. tons. On the other hand the operative condition is more easier in otter trawl from the data in the table that the average trawling hours a operation of otter trawl is 17.3 hours which is much hours than 10.7 hours in the case of pair trawl. Farthermore the pair trawl is more difficult in the operation than otter trawl in such conditions as fishing in narrow fishing ground with rough situation of the sea, because they should operate long warps, big scale of net and should keep well cooperation between two boats. It needs more fishermen for operation particularly dealing with long ropes. On the rough bottom it is not proper to operate by two-boat trawl because it is difficult to change trawling course so often. The unfavourable conditions of the above

Table 3. Comparative datas between other trawl and pair trawl

Items \ Kinds	Otter trawl	Pair trawl			
	Steel boat G.T. 340 tons	Steel boat G.T. 80 tons	Wooden boat G.T. 80 tons	Wooden boat G.T. 65 tons	Wooden boat G.T. 45 tons
(a) Number of boat surveyed	9 boats	4 pairs	1 pair	1 pair	1 pair
(b) Kinds of engine	Diesel 550 ps: 8	Diesel 160 ps: 3	Semi-diesel	Semi-diesel	Semi-diesel
	Steam 800 ps: 1	Diesel 210 ps: 1	200 ps: 1	115 ps: 1	115 ps: 1
(c) Total number of navigating days	950	549	173	195	83
(d) Total number of fishing days	732	388	126	142	61
(e) Total fishing operation	3,159	2,179	556	612	294
(f) Total trawling hours	12,636	4,140	1,168	1,285	617
(g) Total number of catch (kg)	47,385	15,525	4,380	4,818	2,313
(h) Average fishing operation a day (e/c)	4.31	5.61	4.41	4.31	4.82
(i) Average trawling hours a operation (f/e)	4.0	1.9	2.1	2.1	2.1
(j) Average trawling hours a day (f/c)	17.3	10.7	9.3	9.0	10.0
(k) Average catch a day (g/c)	4,275	4,230	4,132	3,851	3,378
(l) Average catch a operation (g/e)	990	753	937	892	697
(m) Average catch an hour (g/f)	247	397	446	423	333
(n) Comparing rate of (m)	100	161	180	171	135

Note: The fishing ground of otter trawl and steel pair trawl of G.T 80 tons were the same, both cases are available to compare accordingly. The net were 2-seam in otter trawl and 4-seam in pair trawl.

can be overcome in some extent by otter board trawling.

3.4.2 Shrimp trawl – Its fisheries in the world and double rigger

1. Introduction

The kinds of shrimps sought for by trawling fishing are shrimps (except lobster), deepwater shrimp, and fresh-water shrimp. These shrimps or prawns are distributed widely throught the world from 35 degrees latitude north (and south) to the equatorial regions. The ways of fishing shrimp varies from cast net, beach seine, boat seine, trawl net, double rigger trawling net etc.

In the Gulf of Thailand, for instance, gear such as otter trawl, beam trawl, otter board boom trawl and pair trawl are used to capture shrimps.

2. Amount of shrimp caught around the world

The production of shrimps, recently, has been very important in tradings. According to the statistics, the total catch of shrimp amounted to 672,000 tons in 1965 and increased to 899,000 tons in 1970. This means that the increased amount of shrimp was 227,000 tons, in these five years. The share of production by percentages in the world are 37 percent in America (North and South), 33 percent in South East Asia, 20 percent in Middle East, etc. The main producer by countries are as follows.

North America: 135,000 tons (1968), 143,900 tons (1969), 167,000 tons (1970) has been the top position among shrimp producing countries in the world. Almost all are caught in the Gulf of Mexico and adjacent areas. And 42,000 tons of shrimp were produced on the Pacific Ocean side in 1970.

Mexico had a stable production of shrimps from 54,700 tons to 58,600 tons, 21,300 to 23,100 tons were caught in the Atlantic, and 33,400 to 35,500 tons in Pacific.

Central America: Catch amount in 1970 was Guatemala 2,600 tons, El Salvador 5,600 tons, Nicaragua 6,100 tons (Atlantic 4,500 tons and Pacific 1,600 tons), Costa Rica 2,600 tons, Panama 6,900 tons, and Cuba 5,500 tons.

South America: The most productive country is Brazil. The production was 39,500 tons in 1968 and 36,700 tons in 1970. Other countries are Columbia 5,200 tons, Ecuador 6,200 tons, Chile 1,000 tons, Guiana 4,800 tons, Venezuela 8,700 tons. The most promising area in shrimp production is the vast down stream area of the Amazon river. The fishing grounds off Guiana have been developed remarkably.

Southeast Asia: Thailand has developed rapidly with 35,200 tons in 1965, and 83,600 tons in 1970. Ninety percent of shrimp production is from the Gulf of Thailand. The other countries are Japan 54,500 tons, Malaysia 48,700 tons, South Vietnam 33,300 tons, Taiwan 30,700 tons, Philippines 21,400 tons, Hong Kong 12,400 tons, Korea 10,700 tons. It is estimated that Indonesia will become the top country in this region in the production of shrimps.

Middle East: India caught 115,200 tons of shrimp, this being the second position in the world production in 1970. Bangladesh at 25,700 tons is increasing 5,000 tons every year. Iran and Saudi Arab caught 4,000 and 12,000 tons. While Kuwait produced 6,000 tons in 1970.

Africa: Nigeria has 6,400 tons, Senegal 4,400 tons, Egypt 3,600 tons, and Madagascal 2,000 tons. But development looks very promising.

Australia: Production has increased by as much as from 5,500 tons in 1965 to 13,200 tons in 1970. The west coast and also the north coasts are being developed rather than east coast.

3. Fishing gear for shrimps

1) Mid-water trawl: Particularly shrimps in high latitude area such as North Pacific or the North Sea suddenly become abundant in the early summer. The shrimp might migrate sensitive to the delicate variety of the water temperature and the salinity of the water mass. Sometimes they reproduce very rapidly. So, large scale fishing gear such as mid-water trawl is particularly good for catches. But the meal composition of these shrimp is not so tasty as shrimps caught at lower latitudes.

2) Small scale trawl fishing including Mexican trawl: The shrimp produced at low latitudes normally live in oceanographical conditions of less changes in water temperature throughout the year, and live in places not so far from fresh water river estuaries. The spawning of these shrimps may be influenced by the quantity of fresh water from the river, and many groups composed of small numbers spawn in many different places. Thus, the growth and size of shrimps have many varieties. In areas abundant with plankton and small fish and with little change throughout the year, the migration of shrimp from deep water to shallow water is not so strong. They simply move with the tide and search for food. Therefore, the sudden occurrence of shrimp stock might be isolated or cut by some big river.

It is obvious that such small groups of shrimps can be caught better by small class of trawl net. This net will dip the shrimps here and there by the trawling. Especially the Florida type double rigger is adapted for such kind of shrimps. At present about 5,000 boats of this type are engaged in the shrimp fishing in Mexican Gulf.

3) Medium size bottom trawl fishing: The shrimps produced in the middle latitude fishing regions such as the large quantities of prawns in the Gulf of Po-hai of China. The migration of prawn when feeding is remarkable, and this kind is some sort of combined character between explosive spawning of high latitude shrimps and small group spawning of low latitude shrimps. The fishing method, therefore, is modernized medium size trawl fishing.

4. Double rigger shrimp fishing

In 1920 the small trawlers of a single net about 10 to 20 tons engaged in shrimp fishing in the Gulf of Mexico. They developed to 30 to 40 tonnage in size, called single rigger. Since 1950 the double rigger system has developed in the Gulf and this system also spread as a new shrimp fishing method throughout the world. At first the double rigger was a wooden boat of 40 to 50 tonnage with 150 to 200 horse power, but since 1960 steel boats of 100 tonnage with 400 horse power have predominated. The characteristics of this system are as follows.

1) Operating boat and gear can be controlled by one man.
2) About 3 to 4 crews only are necessary for operating the boat of about 100 tonnage.
3) Trial nets are used to judge fishing conditions.

5. Productive system of shrimp in fishing process

1) American system

Mainly developed in the Gulf of Mexico using the double rigger. About 40 to 50 boats with a freezing factory, forms a production unit. They mainly catch shrimp and freeze them. Immediately after being caught, the shrimp are deheaded and washed in sea water on the deck, then frozen in the boat or stocked in ice. The boat takes them back to the shrimp processing factory, where the following process occurs.

Unloading shrimps from the boat – washing shrimps by clean water, selecting the shrimps on the conveyer (picking out trash ones, broken ones, disease ones, black coloured ones and different species) – grading the shrimps – packing shrimps into 5 pounds boxes (make separate stamps according to the size) – pouring cold water – freezing – glazing – packing master carton (make stamps of production date) – custody – dispatch.

This system has been developed in other countries also, but it needs big initial cost for installation so it is not so extended worldwide.

2) Primitive system

The middle men collect the shrimps captured by normal trawl boats. These boats are not special shrimp trawlers like the double rigger, their catches include other fish as well. The fishermen select the shrimp from the catch on deck and take them back to their own fishing ports. The middlemen collect these catches and bring them to the freezing factory so that the size selection and freshness is not as good as the American System.

6. Marketing

Vast quantities of shrimp are sold fresh, or dried and salted, but most of the world trade in shrimp is carried out in frozen and canned shrimp products. Canned shrimp is marketed and sold in almost every country in the world. However, the only two major markets for frozen shrimp in the world are the United States and Japan. Western Europe has been expanding its frozen shrimp usage but generally relies on the fresh product.

The largest buyers of shrimp are the institutional users such as restaurants, cafeterias, and schools. Shrimp processors usually pack their products in large or bulk quantities to satisfy the institutional buyers. Some retailers in the United States and Japan repack shrimp into small specialty packs which sell at very high prices directly to the consumer. Generally speaking, shrimp is a high-priced, almost a luxury seafood commodity, that is usually purchased in small quantities by consumers of medium or high personal income. Shrimp, in general, are sold according to size count, that is number of shrimp per kilo or pound. The larger the shrimp, the higher the price paid for it. Also, in the United States and Japan, most shrimp is sold on a "heads off" basis.

7. Main kinds of shrimp in Southeast Asian waters

Prawns and shrimp form a portion of the group of marine crustacea which, apart from the unicellular animals, constitute the most numerous animals in the oceans. The are widely dispersed, with respect to depth and temperature in all oceans. There are hundreds of different species of shrimp and prawns, but only about 20 are of major commercial importance in world trade.

The commodity may be considered to have two basic groups: the coastal warm-water varieties, which grow rapidly and often to a large size, and the cold, deep-water shrimp, which grow slowly and do not reach the sizes attained by the tropical species. The two groups are interchangeably referred to as prawns or shrimp.

The tropical or penaeid shrimp are the most sought after and form the bulk of the commodity "shrimp" which enters world trade in the major markets in the United States and Japan. These species have a short life history typified by rapid growth. They reach full size and, for the most part, are harvested or die from natural causes within a year.

They are large, easy to process, and have in the U.S. and Japan well-developed markets which are willing to pay high prices for the products.

Main Kinds of Shrimps in Southeast Asian Waters

Scientific Name	English Name	mm	No./kg	Countries producing or culturing
Penaeus indicus	Indian shrimp	195	7–9	Thailand, Indonesia, Singapore, Malaysia, Vietnam, Philippines Adequate salinity 29–35%
" japonicus	Tiger shrimp	210	9–11	Japan, Taiwan
" latisulcatus	King shrimp	180	12–15	Thailand
" merguiensis	White or banana	250	7–9	Thailand, Philippines, Indonesia Adequate salinity 19–30%
" monodon	Black tiger	330	2–3	Indonesia, Philippines, Thailand, Taiwan Ad. Sal. 20–30%
" semisulcatus	Green tiger	230	8–11	Thailand, Philippines Adequate salinity 30–35%
Metapenaeus brevicornis	Yellow shrimp	130	45–50	Thailand, Vietnam Adequate salinity 10–30%
" monoceros		190	13–16	Thailand, Indonesia, Taiwan, Philippines, Vietnam, Malaysia Adequate salinity 5–25%

3.4.2 Electric beam trawl for the capture of shrimp and lamprey[1)]

The electric beam trawl combines a sled mounted net, based on the typical design with an electric field.

The U-shaped sled runners are constructed of 3-inch-wide strap steel; they are 3 ft long and about 18 inches high. The runners are separated by two 5 ft length of galvanized pipe.

The towing bridle is designed to accommodate the electrode array. Three equally spaced manila lines, attached to the front of trawl sled, extend to a 5 ft wooden spreader bar. From the spreader bar the lines converge to form a single towline.

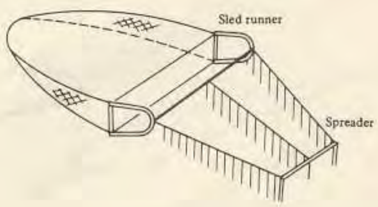
The negative electrode is attached to two outer lines of the bridle and the positive electrode is fastened to the center line.

The negative arrays extend from the spreader bar 7 ft toward the sled. The positive electrode begins 2 ft from the spreader bar and extends to the sled.

The electrodes consist of No. 10 stranded copper wire wrapped around the manila lines. Six-inch sections of brass sash chain are fastened to the copper wire at 1-inch intervals to increase electrode surface area. Electric power is supplied to the electrode array through a 2-wire, No. 12, waterproof conductor attached to the manila towline.

The trawls electrode array is energized by a square-wave generator. The imput power is provided by a 2.5 kilowatt generator which supplies 3-phase, 180 cycle, alternating current.

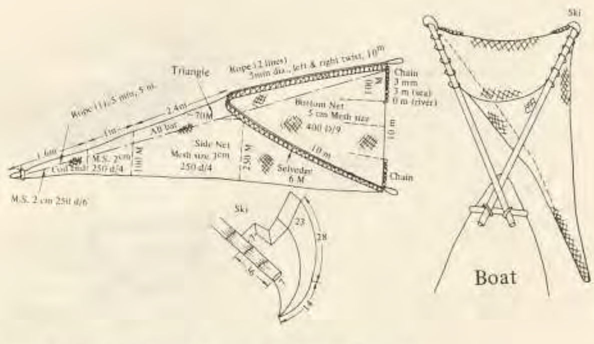
The electronic unit produces nearly perfect square-wave pulses over the complete range of duty cycles and at any desired rate up to 166 pulses per second.



1) A.L. Melain et al, American Fisheries Society, V.97-3, 1968

3.4.2 Thai push net construction and fishing comparison with beam trawl

1. Push net ("Owandun") construction



1) Construction of net (Polyethylene)

Mouth of net: 10 – 13 meters   Boat: 11 meters in length, 16 p.s. (Yammer) Bamboo with ski: 12 – 16 meters, dia 7 – 13 cm Price of net (1 set): 500 B.T. Bamboo (15 m): 15 B.T. Operation: at 1 hour intervals throughout the night Fishermen: 2 persons Depth of water of fishing ground: 5 meters average Catch ratio (quantity): fish/shrimp = 10/1 Price: fish (duck bait) is 0.5 B.T./kg, shrimps from the sea 20 B.T./kg and from river 3 B.T./kg Fishing season: throughout the year, during monsoon season, fishing is carried out in rivers, 3 sets of net are used per year. Ice cost required per night is 7 to 10 B.T. Fuel cost per night is 35 B.T.

Note: 1 U.S.$ = 20 Baht (Thai currency)

2. *Fishing gear of shrimp and notes*

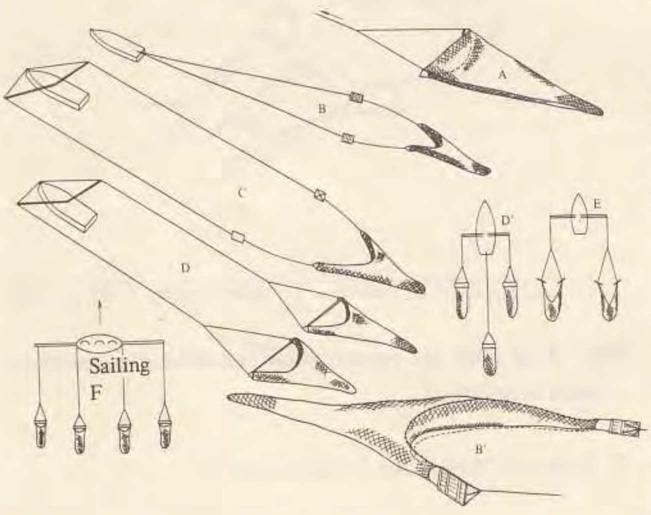
Fishing gear of shrimp in trawl

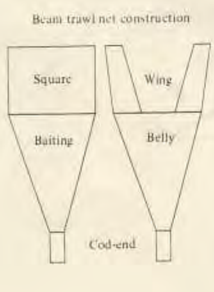
1) One-net, one-boat type
   - Beam trawl .... Fig. A
   - Otter trawl .... Fig. B & B'
   - Otter trawl with boom .... Fig. C

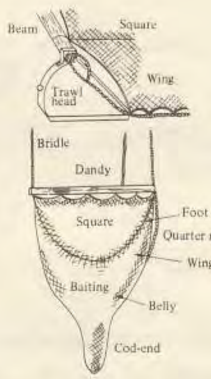
2) Two-net, one-boat type
   - Beam trawl with boom .... Fig. D & D'
   - Otter trawl with boom – Mexican type . . Fig. E

3) One-net, two-boat type

4) Multi-net, one-boat-sailing type .... Fig. F







Comparison between push net and shrimp trawl net

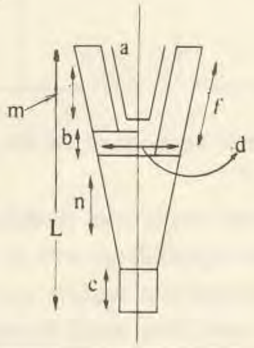
Items	Push net	Beam trawl
Scale of gear and operational expense	Small in scale	Big in scale
Number of fishermen	2	3 – 5
Boat size	L; 11m, 16 p.s.	L : 15–20m 40–50 p.s.
Boat facilities	Long bamboo (2)	Drum winch, Mast, Boom (2)
Depth of operating water	8 meters in maximum	Up to about 20 meters
Screw sound influence	Very small	Might have influence but not clear
Mouth of net	10 – 13 meters	7 meters × 2
Height of net	0.5 meters	1 meter
Trawling layer	Adjustable	Only at the bottom
Speed of boat trawling	2–3 miles/hour	Almost the same speed
Mouth area: Width × Height	13×0.5=6.5m²	15×1=15m²
Area × Trawling hours	6.5 × 1 hour	15 × 1 hour
Degree of operational difficulty	Very simple	Takes more time for handling
Catch comparison	The amount of catch per operational expense should be experimented with comparing fishing of the same time and same area.	

If we compare the beam trawl experimentally with the push net, the net design of beam trawl and its size should be decided according to the above specifications. With the results of the experiment, we should also consider the economic situation of managing the shrimp fishery carried out by the fishermen of the region.

3.4.3 Preliminary study of characteristics of trawl net construction in Thailand*

In parallel with the marine fisheries statistics, a preliminary trawl fishing gear survey was conducted. The number of samples of trawl fishing units is shown by types of net in Table 1.

Elemental length of two-seam type trawl net



* Derived from: M. Nomura; Indo-Pacific Fisheries Council Current Affairs Bulletin, Nos. 54/55, April/August 1969.

Table 1 Trawl fishing units of samples

Type of net	Total	Otter board trawler					Pair trawler					Beam trawler			Otter board boom trawler
		Total	<14m	14-18m	18-20m	20m<	Total	<13m	13-18m	18-20m	20m<	Total	<12m	12m≤	
All types	546 (100)	178 (100)	42 (100)	73 (100)	23 (100)	40 (100)	89 (100)	3 (100)	32 (100)	29 (100)	33 (100)	71 (100)	60 (100)	11 (100)	208 (100)
Two-seam type	271 (49.6)	85 (47.9)	29 (71.4)	35 (47.9)	4 (13.0)	17 (42.5)	69 (79.8)	1 (33.3)	19 (65.6)	19 (93.3)	30 (90.9)				115 (55.3)
Four-seam type	192 (35.2)	93 (52.1)	13 (28.6)	38 (52.1)	19 (87.0)	23 (57.5)	20 (20.2)	2 (66.7)	13 (34.4)	2 (6.7)	3 (9.1)	4 (5.6)	4 (6.7)		77 (37.0)
Others	83 (15.2)											67 (94.4)	56 (93.3)	11 (100)	16 (7.7)

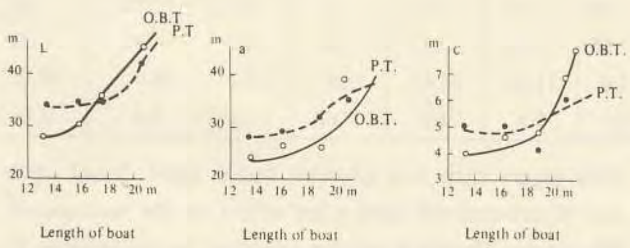
The percentages are shown in brackets.

1. Two-seam type trawl net

The average size of major parts of two-seam trawls are tabulated in Table 2.

Table 2. Construction of tw-seam trawls

Length of boat / Major part of net		Otter board trawl (OBT)				Pair trawl (PT)				Otter board boom trawl
		<14m	14-18m	18-20m	20m≤	<13m	13-18m	18-20m	20m≤	
Total length of net :	L (m)	28.3	31.1	35.3	44.5	34.5	34.3	33.5	38.9	27.5
Length of Head rope :	a (m)	22.9	25.0	24.0	37.7	26.5	27.6	30.7	32.6	23.2
Width of square :	d (m)	10.0	11.7	15.3	23.1	24.5	22.3	22.3	21.6	7.0
Length of cod-end :	c (m)	3.9	4.5	4.7	6.8	5.0	4.9	3.9	6.1	4.5
Mesh size of wing :	(cm)	6.27	6.02	6.73	10.87	11.0	11.29	11.48	12.48	5.12
Mesh size of cod-end :	(cm)	1.97	1.77	1.65	2.57	2.5	2.5	2.6	2.63	2.98



The length of other parts of the net could be found as follows:

The length of the upper wing : m

$$m = \frac{HR - 3}{2} = \frac{a - 3}{2}$$

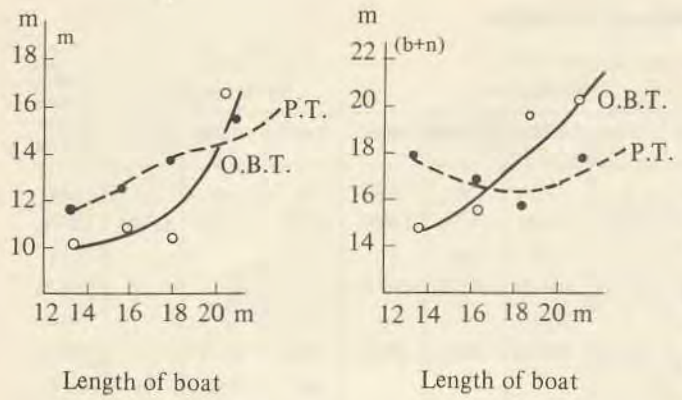
where the front line of the square attached to the head rope (HR) is taken as 3 m.

Then, the length of the baiting = b + n = L – (m + c).

Thus, one could have the following data on the major parts of the net in Table 3.

Table 3. Dimensions of major parts of the trawls

Length of boat / Major parts of net		Otter board trawl (OBT)				Pair trawl (PT)				Otter board boom trawl
		<14m	14-18m	18-20m	20m≤	<13m	13-18m	18-20m	20m≤	
Total length of net:	L (m)	28.3	31.1	35.3	44.5	34.5	34.3	33.5	38.9	27.5
Length of head rope:	a (m)	22.9	25.0	24.0	37.7	26.5	27.6	30.7	32.6	23.2
Length of wing:	m (m)	10.0	11.0	10.5	17.3	11.6	12.3	13.8	14.8	10.1
Length of baiting:	b + n (m)	14.4	15.5	20.1	20.4	17.9	17.1	15.8	18.0	12.9
Length of cod end:	c (m)	3.9	4.5	4.7	6.8	5.0	4.9	3.9	6.1	4.5



In the case of length m, it is shortened in hanging ratio by 8 per cent ordinarily, so that the original length of the upper wing can be obtained by dividing m by 0.92.

Thus, one could have each part of net denoted on the basis of the length of the head rope a. For comparison, the Japanese otter trawl net which is used in East China Sea and the German trawl used in Thai reserach boat Pramong No. 2 are also tabulated in Table 4.

the Japanese trawl has a smaller value.

4) The value of c/a is calculated as 0.18 on the average in the Thai trawls. Both the German and the Japanese trawls have bigger values than the Thai trawl.

5) From the above results if one compares the three types, it could be suggested that the German trawl has a long baiting without flapper, the Thai trawl has an intermediate length in the baiting and the Japanese trawl has a short baiting with flapper. These tendencies are due to the different kinds of fish caught, and due to the different conditions of the fishing grounds.

6) Both the German and the Japanese trawl have a bigger mesh in the wing than the Thai trawl. Among the Thai trawls, pair trawl has the biggest mesh which is 11.56 cm., otter board trawl has an intermediate value of 7.47 cm. and otter board boom trawl is the smallest with the value of 5.12 cm.

7) Almost the same tendency could be shown in the case of cod-end mesh size. Especially, otter board trawl cod-end has a very small mesh size. Pair trawl cod-end is a

Table 4. Comparison of trawl nets

Length of boat / Items	Otter board trawl				Pair trawl				Otter board boom trawl	German Trawl (Pramong No.2)	Japanese otter trawl
	<14m	14-18m	18-20m	20m≤	<13m	13-18m	18-20m	20m≤			
L/a	1.2	1.3	1.4	1.2	1.3	1.2	1.1	1.2	1.2	1.4	1.11
m/.92/a	.48	.48	.48	..49	..47	.48	.49	.49	.47	.49	.47
(b+n)/a	.63	.62	.83	.53	.68	.62	.50	.55	.55	.72	.42
c/a	.17	.18	.19	.18	.19	.18	.13	.19	.19	.31	.25
Mesh size of wing	6.27	6.02	6.73	10.9	11.0	11.29	11.48	12.5	5.12	16.0	18.0
Mesh size of cod-end	1.97	1.77	1.65	2.57	2.5	2.5	2.6	2.63	2.98	4.0	7.0

From Table 4 the characteristics of the trawl nets could be drawn on the basis of the length of the head rope a as follows:

1) The value of L/a is not very different among otter board trawl, pair trawl and otter board boom trawl. Also, it is not so different according to the size of the boat. The average value of L/a of the Thai trawl is 1.23.

In comparison with the German trawl(Pramong No.2), the value of L/a of the Thai trawl is smaller than that of the German trawl which is 1.4. On the other hand, it is bigger than that of the Japanese trawl which is 1.11.

2) The length of the upper wing to a, is on the average 0.485. This is almost the same value as the German and the Japanese trawls.

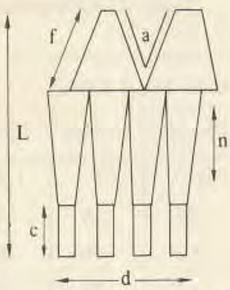
3) The value of (b+n)/a varies according to the size of boat but not very systematically. Anyhow its average value is 0.65 in otter trawl and 0.59 in pair trawl. Its value in the German trawl is notably larger. On the other hand,

little bigger than that of otter board trawl. Small mesh size of cod-end will have a bad effect on the resources of fish stocks. Therefore greater attention should be given to regulating the mesh size of the cod-end of trawls.

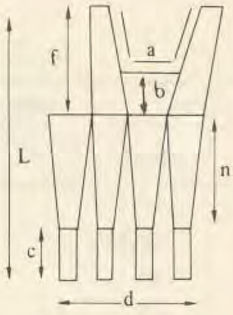
2. Four-seam type trawl net

As seen in Table I, the four-seam nets are used both in otter board trawlers and pair trawlers. The four-seam net which originated with Japan was introduced from Taiwan. On the other hand, two-seam type net was introduced by West Germany. Thus the four-seam type net fishing was operated by pair trawl boats on a small scale in the first stages. As the developement of otter board trawl fishing progressed, this net was also adopted by one boat fishing style with otter board. In addition, to increase the catch, the bigger sizes of four-seam nets are now employed by the bigger pair trawl boats. Therefore, both two-seam and four-seam type nets began to be used together by otter board trawlers and pair trawlers. Thus, any particular type of net cannot be identified with a particular type of trawler.

To examine the most effective type of net, the preliminary characteristic study on four-seam net construction should be discussed at first. The average size of major parts of four-seam net in the samples are tabulated in table 5.



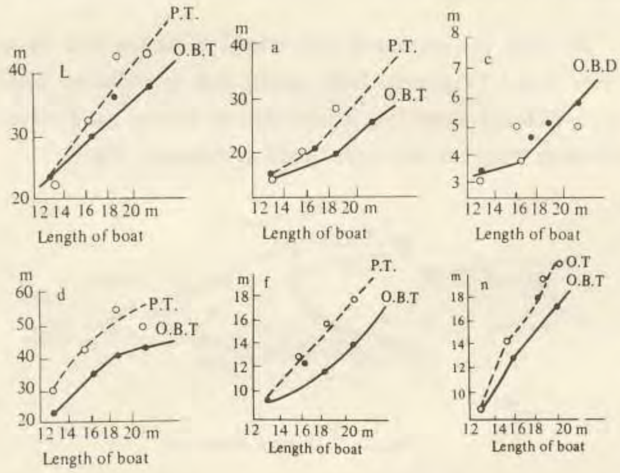
Four-seam in Thailand



Four-seam in Japan

Table 5. Construction of four-seam trawl

Major parts of net \ Length of boat	Otter board trawl				Pair trawl				Otter Board boom trawl
	<14m	14-18m	18-20m	<13m	<13m	13-18m	18-20m	20m<	
Total length of net: L (m)	23.4	31.1	36.3	38.1	22.0	33.1	43.5	44.0	25.4
Length of head rope: a (m)	18.31	24.3	23.5	28.1	17.0	24.7	30.0	34.6	21.5
Length of codend: c (m)	3.7	4.4	5.5	5.8	3.3	5.4	8.5	5.3	4.2
Circumference of bosom: d (m)	21.1	35.5	40.6	45.3	30.9	43.9	58.5	50.5	29.6
Mesh size wing: (cm)	4.3	6.8	7.7	9.1	6.8	8.2	14.0	12.8	5.7
Mesh size codend (cm)	1.5	2.3	2.3	2.6	2.0	2.1	2.1	2.9	2.0



The length of other parts of net can be found as follows:

The length of the wing (lower wing) = f

$$f = \frac{HR}{2} = \frac{a}{2}$$

The length of the belly = n

$$n = L - (f + c)$$

Thus, one can have the following data on the major parts of the net as shown in Table 6.

In the case of f it is shortened in hanging ratio by 15 per cent ordinarily, so that the original length of the lower wing can be obtained by dividing f by 0.85.

Thus, one has each part of net denoted on the basis of the length of the head rope a. For the comparison, the Japanese four-seam net used by a pair trawler is also tabulated in Table 7.

From Table 7 the characteristics of the trawl nets could be drawn on the basis of the length of the head rope a as follows:

1) The value of L/a is 1.3 on the average, and it does not differ according to the size of boat. This is a little larger than the Japanese four-seam pair trawl which has a longer head rope.

2) Other values such as n/a, c/a and d/a in the Thai trawls – otter trawl, pair trawl and otter board boom trawl are

Table 6. Data on four-seam trawl

Major part of net \ Length of boat		Otter board trawl				Pair trawl				Otter board boom trawl
		<14m	14-18m	18-20m	20m≤	<13m	13-18m	18-20m	20m≤	
Total length of net:	L (m)	23.4	31.1	36.3	38.1	22.0	33.1	43.5	44.0	25.4
Length of head rope:	a (m)	18.3	24.3	23.5	28.1	17.0	24.7	30.0	34.6	21.5
Length of wing:	f (m)	9.2	12.2	11.8	14.1	8.5	12.4	15.0	17.3	10.8
Length of belly:	n (m)	10.5	14.5	19.0	18.2	10.2	15.3	20.0	21.4	10.4
Length of cod-end:	c (m)	3.7	4.4	5.5	5.8	3.3	5.4	8.5	5.3	4.2
Circumference of bosom:	d (m)	21.1	35.5	40.6	45.3	30.9	43.9	58.5	50.5	29.6

Table 7. Comparison of trawl nets

Items \ Length of boat	Otter board trawl				Pair trawl				Otter board boom trawl	Japanese four-seam net by pair trawl
	<14m	14-18m	18-20m	20m≤	<13m	13-18m	18-20m	20m≤		
L/a	1.3	1.2	1.5	1.3	1.3	1.3	1.4	1.3	1.2	1.08
f/0.85/a	.59	.59	.59	.59	.59	.59	.59	.59	.59	.75
n/a	.57	.60	.80	.64	.60	.66	.67	.62	.48	.25
c/a	.20	.18	.24	.20	.19	.22	.24	.15	.20	.084
d/a	1.1	1.4	1.7	1.6	1.8	1.8	1.9	1.4	1.4	.57
Mesh size of wing	4.3	6.8	7.7	9.1	6.8	8.2	14.0	12.8	5.7	7.0–25.0
Mesh size of cod-end	1.5	2.3	2.3	2.6	2.0	2.1	2.1	2.9	2.0	6.0

also fairly larger than the values for the Japanese four-seam pair trawl.

3) The value of f/0.85/a in the Thai trawls which shows almost a constant value according to the size of boat is smaller than that of the Japanese four-seam pair trawl. It means that the latter has a longer wing as compared with the length of the head rope a.

4) Consequently the Japanese four-seam pair trawl has a longer wing and a long head rope which will make a wider trawling area and will maintain a high opening mouth of the net.

On the other hand, the Thai trawls both in two-seam net and four-seam net have a rather long body of webbing to prevent the fish from escaping from the net in spite of the low net towing speed.

5) For the purpose of catching shrimp or prawn, the trawl net should have a wide but flat net mouth, and it is not necessary to have a long body net. But for catching swimming fish the trawl should have a long head rope to take in the big volume of water caused by the high opening mouth of the net.

6) From the above point of view, the Thai trawl generally seems to aim at both fish and shrimp in its net construction.

7) As for the mesh size, it is so small that one must give attention to the preservation of fish stocks which was discussed earlier.

3.4.3 Discussions on essential factors of trawl net

1. Outline of otter trawl net

Historical speaking the otter trawl net started from the result of improvement on beam trawl net. As the main fish taken by trawl net are demersal fish such as flat-fish, cod, etc., the old type of trawl net was very short in its wing net with the otter board connected to the tip of the wing as shown in Fig. 1. Even at the present, this type of trawl is still used particularly for shrimp double rigger.

Fig. 1. Initial style of otter trawl and Maxican shrimp trawl

In 1925, the improved otter board called the V.D. type otter board (Vigneron Dahl trawl) was introduced. This type differed from the former due to having hand ropes between wing net and otter board as shown in Fig. 2.

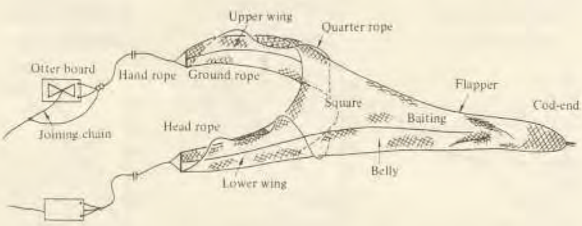


Fig. 2. V.D. type trawl net

Since then, the shape of the net has undergone further changes. In particular, the wing and cod-end have become longer, and the square part shorter.

The type of otter board has further improved into an adjustable type board. (Fig. 3)

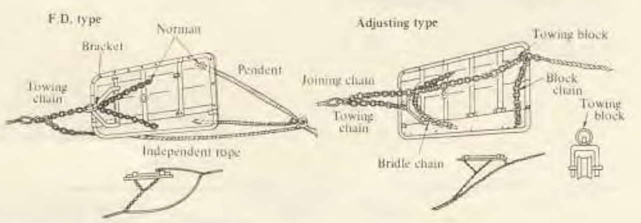


Fig. 3. Otter board

The size of boat became larger and larger to improve its fishing capacity, but the size of nets did not so much increase according to the increase of boat size. For instance, in the East China sea, the fishermen at first used 27 meters of head line trawl net, but the length became longer until it attained 42 meters.

Here is an example of the relationship between the size of net, and the size of the boat in the case of trawl net in the China Sea. Satouchi[1)] has shown this relation as in Table 1 and Fig. 4.

Table 1 Relationship between boat and the net (China Sea, depth of water 100–200m)

Gross tonnage	Head rope length	Distance between 2 otter boards	Sweeping area (4 hours)
200 ton	43 meters	72 meters	0.4 miles²
400	48	84	0.5
600	60	105	0.7*
1,000	90	150	1.0

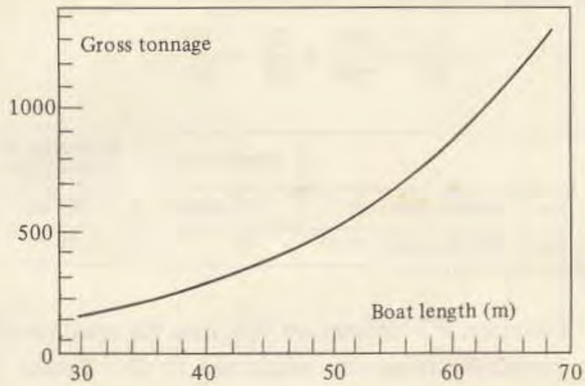


Fig. 4. Relation between boat length and gross tonnage

Length of boat	Gross tonnage
35 meters	200 – 240
40	260 – 310
45	360 – 410
50	480 – 530
55	650 – 700
60	870 – 930

Let us take one example for deciding the relation between boat size, horse power and headline length. (Note: The following values are not absolute values and have, therefore, a certain amount of variation. This is just an example.)

a) Applying the normal speed boat for trawler, that means:

$$\frac{V}{\sqrt{L}} = 1.0$$

If taking 10 knots in cruise speed of this boat, then, $L = (10/1.0)^2 = 100$ ft = 33 m

b) From the table*1, $L/B = 5.95$, $L/D = 11.15$, $B/D = 1.87$,

$\frac{\text{Gross ton}}{L \times B \times D} = 0.27$, $\frac{\Delta(\text{full load})}{L \times B \times D} = 0.500$ are taken in the trawler, then,

$B = L/5.95 = 33/5.95 = 5.54$, $D = L/11.15 = 2.95$

$L \times B \times D = 33 \times 5.4 \times 2.95 = 525.7$

So, gross tonnage = 0.27 × 525.7 = 142 ton

and Δ(full load) = 0.500 × 525.7 = 263 ton

c) From the equation*2 denoting I.H.P. as:

$$\text{I.H.P.} = \frac{\Delta^{2/3} \times v^3}{c}$$

Put $\Delta = 263$, $v = 10$, $c = 100$,

$$\text{I.H.P.} = \frac{263^{2/3} \times 10^3}{100} = \frac{41 \times 10^3}{100} = 410 \text{ ps}$$

c') In the relationship*3 between

$\frac{\text{B.H.P.}}{\Delta}$ and $\frac{V}{\sqrt{L}}$, if we take $\frac{V}{\sqrt{L}} = 1.0$

then, $\frac{\text{B.H.P.}}{\Delta}$ is found in the figure as 1.3.

So, B.H.P. = 1.3 × Δ = 1.3 × 263 = 341 ps

d) Considering the above result, B.H.P. will be 350 ps.

e) Ordinary*4 E.H.P. = B.H.P. × (0.8 ~ 0.9) × 0.95 × (0.2 ~ 0.4) = (0.15 ~ 0.30) × B.H.P.

So here, E.H.P. = 0.20 × 350 = 70 ps

f) If using the following formula, and λ is taken as m (ground rope), the value of m will be found as follows. Here, 70 = R x 1.5/75, then R = 3500.

$$m^2 = \frac{3500}{25 \times 0.03 \times 1.5^2} = 2074,$$

where d/1 = .03, v = 1.5 m/sec and m/1 = 1.25.

So, m = 45^m and 1 (head line) = 36^m

2. Floating trawl net (Surface trawl net)

Small sized fish such as sardine, anchovy etc. are comparatively easy to catch by floating trawl, because these groups of fish are often near to the surface and do not swim as fast as other kinds of larger pelagic fish. Sand launce, for instance, are particularly abundant in certain

1) S. Satouchi: Trawl net fishery and it's resources, 1943 edited in Tokyo

* $S = 4^{hrs} \times 3$ miles/h × 105^m = 0.7 miles²

Refer to

*1. 4.1.7 Speed of boat (2), p. 191

*2. 4.17. Speed of boat (1), p. 190

*3. 4.17 Speed of boat (2) ($\frac{\text{B.H.P.}}{\Delta} \sim \frac{V}{L}$ curve)

*4. 4.17 Speed of boat (1), p. 189

big lakes in Japan, and this type of trawl net was appropriate to catch this fish (Fig. 5).

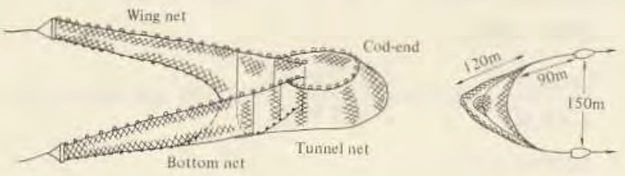


Fig. 5. Floating trawl net

The size of net is rather long being 120 meters in length, and the net is attached by 90 meter warps keeping 150 meters distance between two fishing boats. According to direct observation on the shape of net during fishing operation, the net does not open fully at very slow speeds, but at the speeds of 0.4 ~ 1.0 miles/hour, the net swells and maintains a good shape. The result of calculation by Sato[2] on the trawl speed and the tension of one warp are shown in Fig. 6.

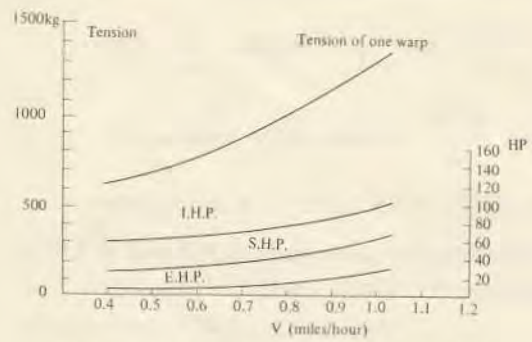


Fig. 6. Relation between the trawl speed and tension of warp

It is clear from these curves that the horse power necessary for dragging the net only, i.e. the E.H.P. is only 2 to 10 ps speeds of 0.5 to 1.0 miles per hour. These are very small values compared to I.H.P. Suppose, R=700~1400, v=.4~1.0 mile (.2~.5 m/sec), then EHP=(700~1400)x(.2~.5)/75=1.8~9.3 ps, and, from IHP (=70~110ps), EHP=(70~110)x.9x.8x.94x.23=10~17 ps.

Mr. Sato also made experimental calculations on smaller surface trawl net of similar shape, as in Fig. 7. The length of this smaller net is 45 meters and the average tension is 90 kilograms at the speed of 0.48 miles per hour. The design of the net is shown in the figure. The design will be a good example when we want to make a floating trawl, and the result of the experiment gives us important information in the comparison between two nets.

2) E. Sato: Surface trawl net experiment, Report of Central Fisheries Research Laboratory No. 1 (1934) and No. 9 (1943).

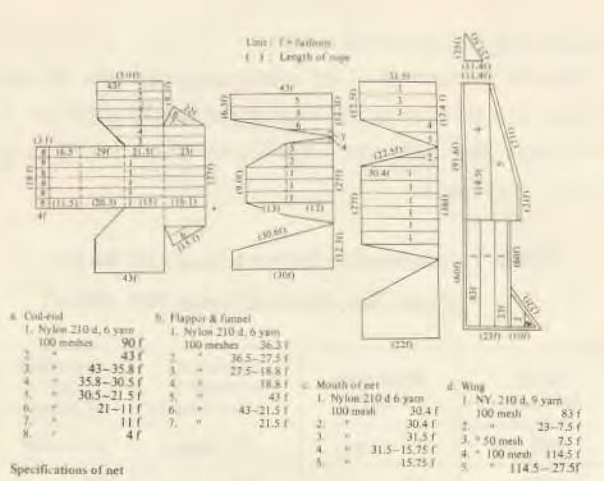


Fig. 7. Floating trawl net

Referring to the following table prepared by Mr. Sato, the relation could be confirmed as in the notes.

$$\frac{R_1}{\lambda_1^2} = \frac{700}{120^2} \doteqdot \frac{R_2}{\lambda_2^2} = \frac{90}{45^2}$$

	Length of net	Resistance at 0.48 mile/h
Net 1 Surface trawl net	120 meters	700 kg
Net 2 (Similar shape to 1)	45 "	90 "

Therefore, if λ denotes net size, then the equation will be considered as already mentioned by Dr. Tauchi, as follows:

$$R = D \times d/l \times v^2 \times \lambda^2 = 25.0 \times d/l \times v^2 \times \lambda^2$$

or, we could draw[3],

$$R = D' \times d/l \times p^2 \times b^2 \times v^2 = 32.2 \times d/l \times p^2 \times b^2 \times v^2$$

In this experiments D, D', d/l, and v are the same in value in both nets, so theoretically and this is confirmed experimentally as mentioned the following.

$$\frac{R_1}{\lambda_1^2} = \frac{R_2}{\lambda_2^2} \quad \text{or,} \quad \frac{R_1}{(p_1 \cdot b_1)^2} = \frac{R_2}{(p_2 \cdot b_2)^2}$$

3. Shape of net of two-boat type trawl during operaiton and experiments on other types

In order to increase the height of net mouth of two-boat type trawl, the six-seam trawl net with triangle net between wing net and square was designed with special depressor attached to the front of the square part. The experiment on this net was conducted by Mr. Hayashi[4] and also by Mr. Sato[5], and is shown in Fig. 8.

3) Refer to: Trawl calculation – 3

4) K. Hayashi: Trawl net experiment, Report of Central Fisheries Research Laboratory, No. 3 (1933)

5) E. Sato: Model experiment of trawl net, ditto, No. 3 (1933)

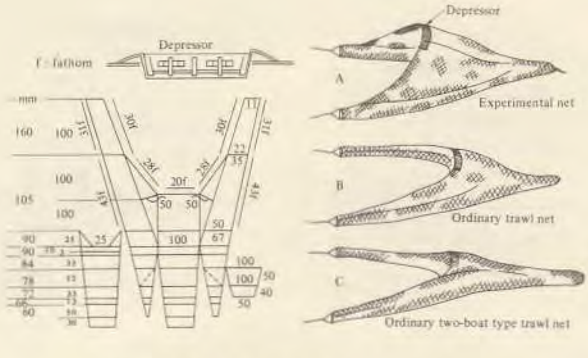


Fig. 8. Net design and the shapes of nets

From the result of the experiment, it became clear that when the speed of the boat is very slow, the depressor will not work, but if the speed increases the depressor is effective in opening the net mouth vertically as shown in Fig. 8. The resistance of net per unit area in A, B and C are calculated. The ratio of these three nets are found as:

$$R_A/S_A : R_b/S_B : R_C/S_C = 100 : 84.5 : 75.5$$

Nomura[6)] made experiments on two-boat type trawl net which also had a big triangle net as shown in Fig. 9.

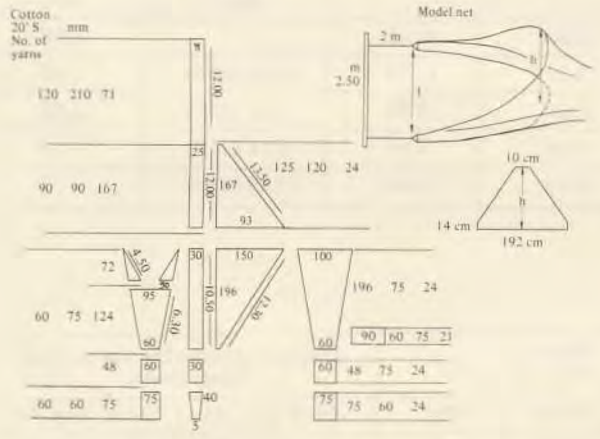


Fig. 9. Design of net (full scale)

The model net was made under the law of comparison of fishing net as follows:

$$\frac{\lambda'}{\lambda} = \Lambda = 1/10, \ \frac{D'}{D} = \frac{L'}{L} = M = 0.16$$

$$\frac{D'(\rho' - 1)}{D(\rho - 1)} = V^2 = 0.16 \times \frac{(1.32 - 1)}{(1.50 - 1)} = 0.16 \times$$

$0.64 = 0.1024$, Here, ρ(cotton) = 1.50 and ρ'(silk) = 1.32

$$\frac{\nu'}{\nu} = V = 0.32, \frac{T'}{T} = \Lambda V^2,$$

6) M. Nomura: Model experiment on two boat type trawl net, Bulletin of Japanese Society of Fisheries Science, 16 (8), 1951

$$\frac{F'}{F} = \Lambda^2 V^2 = 1/100 \times 0.32^2 = 1.03 \times 10^{-3}$$

The experiments were conducted under the following two conditions in the buoyancy and sinking power.

	Buoyancy of buoy	Sinking power of sinker	Weight of net in water	Total sinking power
Experiment A (Standard)	23.04 gr (1.5)	32.90 gr (2.2)	15.00 gr (1)	25 gr (1.6)
Experiment B	57.50 (3.8)	120.00 (8.0)	15.00 (1)	77.50 (5.1)

The heights of net according to speed are shown in Fig. 10. From this figure it can be seen that although at low speeds the height differs considerably between the two, the heights decrease and approach nearly same each other at normal trawling speeds of 3 to 4 miles (0.5 to 0.6 cm/sec, the corresponding speed of model net).

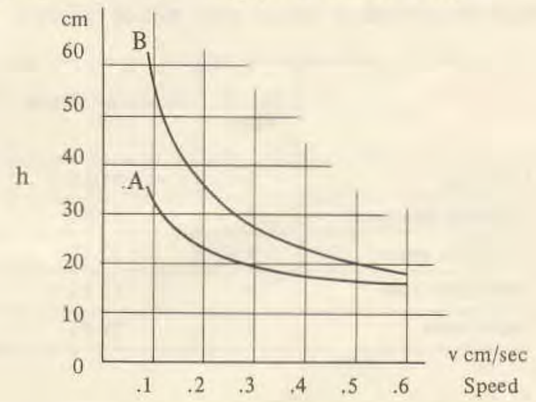


Fig. 10. Relation between h and v

Nomura and Yasui[7)] made model experiments on various types of nets, namely Trawl net, Danish seine, Two-boat type trawl net, Small boat seine and Small otter trawl net. The design of the five nets of full scale are shown in Fig. 11.

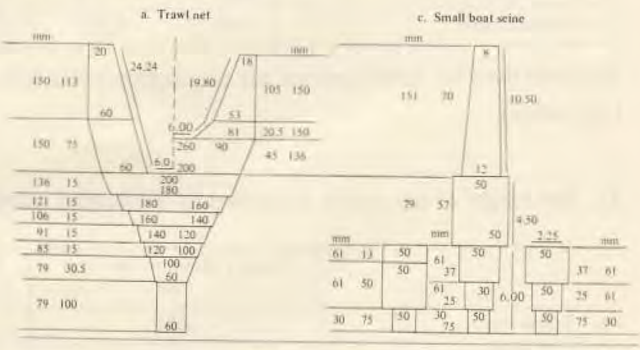


Fig. 11-1. Design of nets

7) M. Nomura and T. Yasui: Model experiment on trawl nets of various types, Bull. Jap. Soc. Fish. Science, 18(12), 1953

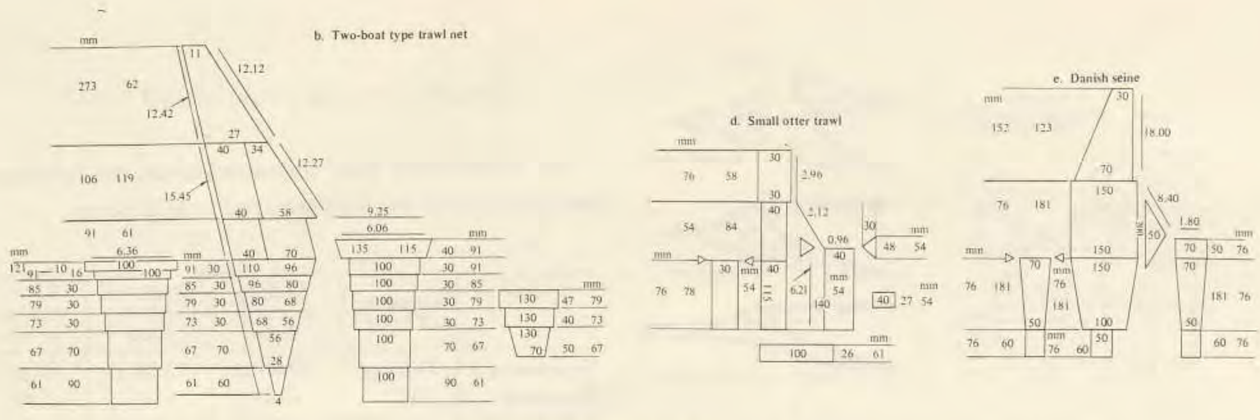


Fig. 11-2. Design of nets

In the five nets, the lengths of full scale, specifications of model nets, height of net mouth in the experiments, and the resistance of nets are shown below.

Here, each model net was so constructed as to satisfy Tauchi's law of comparison for fishing nets. The resistance of model nets were recorded on a dynamometer. To examine the deformation of the net under tow, above and side views of the nets were photographed. Each model was tested at different distance between both tips of wings as shown in the tables.

1). Main dimensions of various trawl nets of full scale

	No. of seams	Head rope length l (m)	Total length of net b (m)	Circumference a (m)	Side net's width (stretched) at square front (m)	Characteristics expressed as value l/b
a. Trawl net	2	44.16	45.80	54.40	–	0.96
b. Two-boat type trawl	4	54.84	53.27	41.23	10.01 (24%)	1.02
c. Small boat seine	4	32.25	21.09	12.20	3.95 (32%)	1.52
d. Small otter trawl	4	11.12	15.14	8.88	2.16 (24%)	0.73
e. Danish seine	6	56.50	50.75	33.44	15.20 (45%)	1.13

2). Specifications of mode nets

	λ'/λ''	D'/D''=L'/L''	$\frac{D'(\rho'-1)}{D''(\rho''-1)}$	v'/v''	Distance between the tips of both wings (meter)	
a. Trawl net	1/30	0.101	0.0576	0.24	23 m (exp. A)	36 m (exp. A')
b. Two-boat type trawl net	1/30	0.115	0.0729	0.27	27 m (exp. B)	41 m (exp. B')
c. Small boat seine	1/20	0.304	0.1936	0.44	13 m (exp. C)	19 m (exp. C')
d. Small otter trawl	1/20	0.331	0.2116	0.46	7.5 m (exp. D)	–
e. Danish seine	1/30	0.203	0.1296	0.36	24 m (exp. E)	39 m (exp. E')

Materials used for mode nets are silk net, cotton twine (for ropes), lead line (for wire ropes), cork (for buoy) and lead (for sinker).

3). The height of net mouth according to the normal trawling speed converted into full scale by the law of comparison.

	Height of net in the stop (m)	Normal trawling speed (mile/h)	Height of net at normal trawling speed (m)
a. Trawl net	4.50	3.0 – 4.0	1.00 – 1.50
b. Two-boat type trawl	6.00	2.0 – 3.0	1.70 – 2.50
c. Small boat seine	1.80	0.5 – 1.0	1.00
d. Small otter trawl	1.00	1.5 – 2.0	0.80
e. Danish seine	6.30	0.7 – 1.0	2.50

4). Height of net – effectiveness

	Height of net in stop / Side net's width (st.) × 100	Height of net in stop / Circumference × 100	Height of net at N.T.S. / Height of net in stop × 100	Height of net at N.T.S. / Circumference × 100
a. Trawl net	–	8%	27%	2.2%
b. 2-boat type trawl	60%	14	35	4.9
c. Small boat seine	45	14	55	7.7
d. Small otter trawl	46	11	80	9.0
e. Danish seine	41	18	40	7.2

N.T.S. = Normal trawing speed

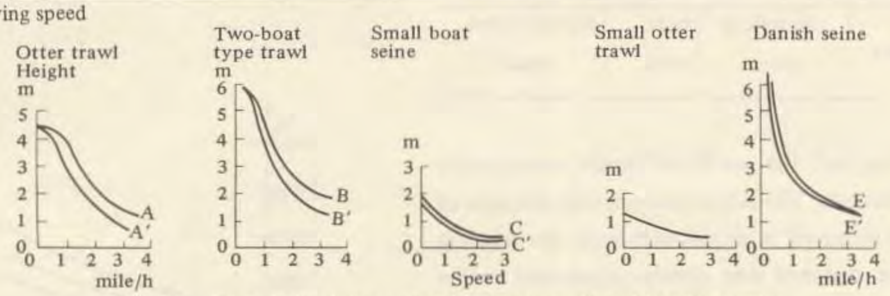


Fig. 12. The relation between height of net mouth and trawling speed

The changes of the height of net mouth according to the changes of trawling speed in the experiment, converted into full scale are shown in Fig. 12.

5) Resistance of net

According to the results of the experiment, the values of k_i have a linear relation with the height of net mouth h. Here, $k_i = r/v^2$ (r = resistance of net). The values of k_i and r of various trawl nets are shown in the following tables.

The values of k_i in parenthesis (dotted line) become constant which means the net under such speed conditions become nearly same in shape.

Hayashi[8] pointed out from his physical measurements on trawl operations that the resistance of net is different according not only to variations of speed but also to different bottom natures. And the resistance is almost proportional to the square of net size. Calculated resistances are shown in the table of next page and the differences due to bottom nature can be found.

8) K. Hayashi: Trawl net calculation, Suisan-Kenkyushi, 19(7), 1924

Distance between tips of both wings	Trawl net						Two-boat type trawl net					
	23m			36 m			27 m			41 m		
Trawling speed	r (kg)	k_i	h (m)	r (kg)	k_i	h (m)	r (kg)	k_i	h (m)	r (kg)	k_i	h (m)
0.8 mile/h	–	–	–	–	–	–	185	289	4.8	300	470	3.9
1.0	460	460	3.6	460	460	2.8	275	275	4.3	420	420	3.3
1.5	800	355	2.8	800	355	2.0	590	(262)	3.25	800	356	2.6
2.0	1220	305	2.05	1220	305	1.4	1050	(260)	2.65	1270	(318)	2.0
2.5	–	–	–	–	–	–	1600	(256)	2.25	1800	(288)	1.6
3.0	2130	(236)	1.3	2100	(233)	0.9	2250	(250)	2.0	2420	(268)	1.3
3.5	–	(–)	–	–	(–)	–	3000	(244)	1.78	3100	(253)	1.1
4.0	3200	(200)	1.2	3120	(195)	0.8	–	–	–	–	–	–

Speed (mile/h)	Small boat seine						Small otter trawl			Danish seine					
	13 m			19 m			7.6 m			24 m			39 m		
	r (kg)	k_i	h (m)	r (kg)	k_i	h (m)	r (kg)	k_i	h (m)	r (kg)	k_i	h (m)	r (kg)	k_i	h (m)
0.8	18	28	0.9	42	66	0.8	21	32.8	0.9	110	172	3.3	180	282	2.7
1.0	24	(24)	0.78	57	(57)	0.68	31	31	0.82	165	165	2.8	255	252	2.4
1.5	52	(23)	0.58	102	(45)	0.48	63	(28)	0.66	350	(155)	2.25	480	214	2.0
2.0	90	(22)	0.48	168	(42)	0.38	107	(26.8)	0.6	610	(152)	1.9	750	(187)	1.7
2.5	136	(21.6)	0.40	224	(36)	0.30	160	(25.6)	0.54	940	(150)	1.6	1100	(176)	1.45
3.0	194	(21.5)	0.38	304	(33.5)	0.30	220	(24.4)	0.5	1350	(150)	1.4	1490	(166)	1.3
3.5	–	–	–	–	–	–	–	–	–	1800	(147)	–	1900	(155)	1.2
4.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

1). Otter trawl net (120 ft. in head rope, O.B. 9ft ×4.3ft)

Time of calculation	Speed of trawling	Total	Bottom nature
Laying out net	3 – 3¼ mile/h	3931 kg	Mud and muddy sand
15 minutes before hauling	- ditto -	4249	- ditto -
Laying out net	2½ – 2¾	3955	Muddy sand
15 minutes before hauling	- ditto -	4500	- ditto -

2). Otter trawl net (130 ft in head rope, O.B. 10ft × 4.5ft)

Laying out net	3¼ mile/h	4470	Mud and sand
15 minutes before hauling	- ditto -	4844	- ditto -

Shorygin[9] applied the results of model experiments on practical trawl net. The horizontal opening distance of net mouth was observed in accordance with the trawling speed. Also this distance was closely connected to the angle between ship's foreward direction and the long axis of the otter board. These are shown in Fig. 13.

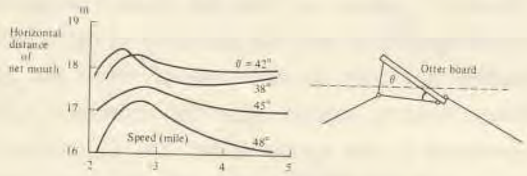


Fig. 13. Horizontal opening of net mouth (92 ft. in head rope length)

From this figure, it is clear that horizontal opening of net mouth is dependent upon the angle of otter board, and the most effective angle is from 38 to 42 degrees. The height of net mouth, on the contrary, is related to the trawl speed but not so much to the angle of otter board.

Keeping the angle of otter board at 38°, horizontal opening of net mouth was calculated under various otter board sizes. The measurements were conducted on the trawl net of 110 feet in head rope length. The results are shown in Fig. 14, and it is clear that the bigger the otter board size, the more effective is the horizontal opening, although it might have some limitation.

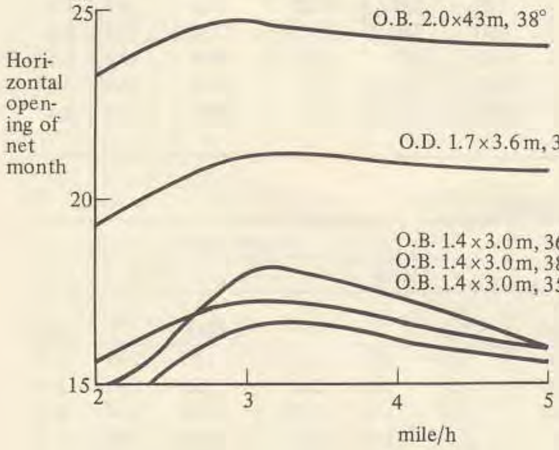


Fig. 14. Horizontal opening of net mouth

The resistance of otter board was calculated for various otter board sizes as shown in Fig. 15.

a. Otter board (2 pieces), 2.0 × 4.3 m
b. 〃 1.7 × 3.6
c. 〃 1.4 × 3.0

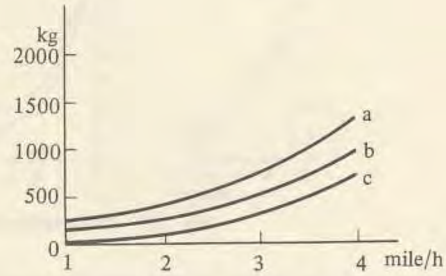
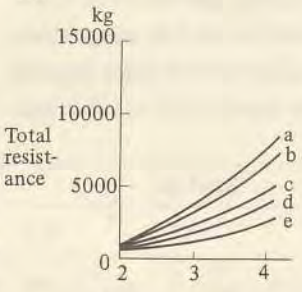
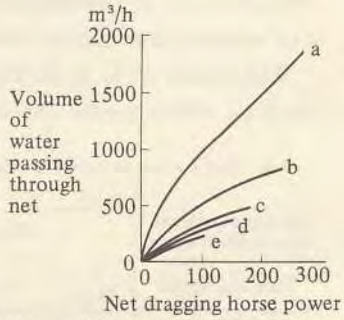


Fig. 15 Resistance of otter board

The total resistance of net including otter board, and the relation between the volume of water passing through the net, and net dragging horse power are shown in Fig. 16.





a. Shorygin type net (Mid-water trawl)
b. Schamallueff type
c. 110 ft., 2.0 × 4.3 m
d. 110 ft., 1.7 × 3.6 m
e. 110 ft., 1.4 × 3.0 m

Fig. 16-1. Relation between the total resistance and trawling speed

Fig. 16-2 Relation between the volume of water and horse power

Wood and Parrish[10] made calculations on the height of net by aid of fish finder. The results are shown in the following table.

1) Net specifications (length)

Head rope	112ft,	Top wing	43 ft,	Belly	27 ft
Foot rope	58	Square	16	Cod-end	25
Bosom	22	Baiting	25	O.B.	9′6″ × 4′3½″

Measurement:

Maximum height of net month 5 – 6 ft. & 7 ft

9) A.A., Shorygin: Transactions of the Oceanographical Institute, 3(2), 1933

10) F. Wood and B.B., Parrish: Journal du Counseil XVII, I, 1950

2) Net specifications (length)

Head rope	32ft,	Top wing	12 ft,	Baiting	10 ft
Foot rope	20	Lower Wing	25	Belly	10
Bosom	8	Square	10	Cod-end	8

Measurement:

Maximum height of Square : 4 ft
Baiting : 3½
Cod-end : 2½ – 3

Hamuro[11] measured the height of various parts of the net using the net height meter which he especially devised for this purpose. One of results is shown in the following table and Fig. 17.

		Head rope (ft)	Ground rope (ft)	Warp (m)	Hand rope (m)	Trawl speed (mile/h)	Bottom nature	Angle of warp
Specifi-	A	128	177	250	90	2.5	Mud	13°
cations	B	146		130	100	2.4	Mud	

		End of wing (m)	Center of wing (m)	Behind wing (m)	Square (m)	Cod-end (m)
Height	A	0.72	1.39	1.93	2.03	1.65
measured	B	0.86	0.86	1.29	1.72	1.29

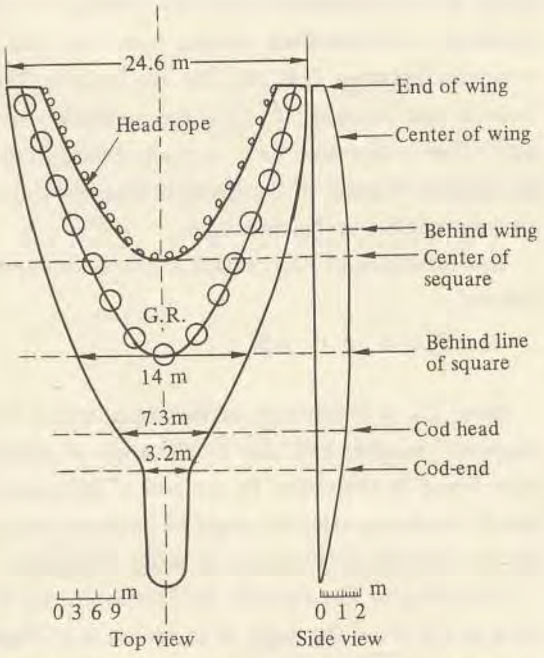


Fig. 17 Measurement of the height of various parts of trawl net by height meter.

3.4.3 Basic hydraulic resistance of trawl net

1. Equation of resistance of trawl net

According to the results of experiments on trawl-net, the hydraulic resistance of trawl net is expressed approximately by the following formula, one of the equation for trawl net resistance[1].

$$R = 25.0 \times (D/L)\ v^2 \lambda^2$$

where R is the resistance (kg), D the diameter of netting cord of main part of net (mm), L the stretched mesh size (mm), λ the size of net (m) represented by the length of headline or ground rope and v the trawling speed (m/sec). (Refer to "Discussion on essential factors of trawl net".)

Examples:

1) Main parts of certain bottom trawl net are D = 1.04mm, $L = 2.53^{cm}$, $\lambda = 30.9^{m}$ and $v = 0.8^{m/sec}$.
The force acting on one warp R′ could be calculated as:

$$R = 2R' = 25.0 \times \frac{0.104}{2.53} \times 0.8^2 \times 30.9^2 = 620 \text{ kg}$$

2) The resistance R of a certain small sardine trawl net whose main parts are $D = 1.39^{mm}$, $L = 6.0^{cm}$, $\lambda = 30.5^{m}$ and $v = 0.4^{m/sec}$, is calculated as:

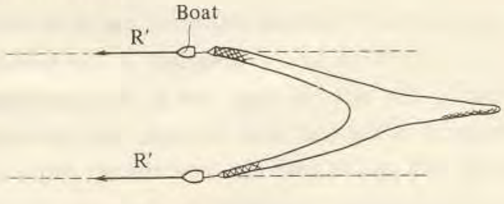
$$R = 25.0 \times \frac{0.139}{6.0} \times 0.4^2 \times 30.5^2 = 88 \text{ kg}$$

3) Two-boat type trawl net of $\lambda = 41^{m}$, $D = 2.58$ to 2.85^{mm}, $L = 8.5$ to 6.7^{cm}, the towing speed $v = 0.95$ to $1.05^{m/sec}$.
From the towing force acted on the warp which were measured directly by tension meter as 1,500 to 1,600 kg at 150 to 500 meters of interval distance between two boats, the component force in the moving direction of the net was 920 to 1380 kg.
The resistance of net 2R′ is calculated as follows:

$$R' = 1/2 \times 25.0 \times \left(\frac{.258}{8.5} \sim \frac{.285}{6.7}\right) \times (.95 \sim 1.05)^2$$
$$\times 41^2 = 580 \sim 990 \text{ kg}$$

2. Tension of towing warps (Discussion in the examples)

1) If boat towing the net immediately before the tip of wing, the tension R′ in the warp is half of the total resistance of net 2R′.



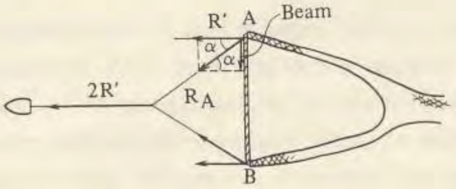
2) Beam trawl
In the case of beam trawl, if we neglect the resistance of beam, the tension RA is divided into two compo-

11) C. Hamuro and K. Ishi: Automatic net height meter on trawl net, Technical Report of Fishing Boat No. 5, 6, 9, 1955~6.

1) M. Tauchi: Fishing Physics, 116 p, 1963, Japan

nents; namely, horizontal component R' and vertical component.

Here, 2R' is the total resistance of net.



3) Two-boat trawl

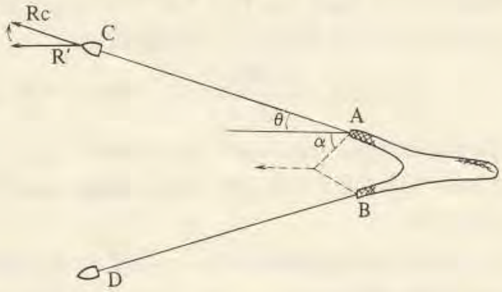
The tension of towing warp Rc at the boat has two components, R' and a vertical one.

Here, 2R' is the total resistance of net.

The relation between angle θ and α is found as:

$$R_c \times \cos\theta = R_A \cos\alpha$$

$$\therefore \frac{\cos\theta}{\cos\alpha} = \frac{R_A}{R_C}$$

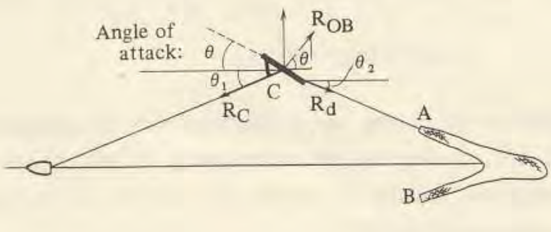


4) Otter-trawl

$R_c \cos\theta_1 = R_d \cos\theta_2 + R_{OB} \cos\theta$

Here, $R_d \cos\theta_2 = R'$ (= half of total net resist.)

$R_{OB} \cos\theta$ = Drag force of otter board.



3. Calculation of trawl net resistance and its accessories

In 3.4.3, "Preliminary designing in the case of M/V paknam", the size of trawl net is discussed using the dimensions of the boat as an example. As it is discussed in the net, 165 p.s. of EHP can trawl the net with about 8.2 tons of hydraulic resistance in the case of trawling velocity of 1.5 m/sec. If the trawling velocity of net is 2 m/sec. (about 4 knots), the resistance will be calculated in the follows.

$$R = \frac{165 \times 75}{2} = 6.6 \text{ ton}$$

If we compare the size of net having resistance 8.2 tons and 6.6 tons, the former is bigger in the length of head rope than the latter. It means that if the trawling velocity increases, it can not but decrease the size of net, except for cases where the ship uses its effective horse power fully for dragging the net only.

It is natural that this effective horse power is the value gained from the tentative result on the condition of calm sea and that these values can not be applicable in an actual case because the resistance of hull increases rapidly due to the wind pressure or waves in rough weather. Therefore, much consideration should be given to the case of rough weather. Further, consideration on the resistance including net, otter board and warps are discussed as follows. (Refer to "The resistance and horse power of big trawler")

1) Net resistance

If the length of head rope is 40m, and the d/l value is 0.03 (average) the resistance of net is calculated as follows.

$$R = 25.0 \times d/1 \times \lambda^2 \times v^2 = 25.0 \times 0.03 \times 40^2 \times v^2 = 1200\, v^2 \qquad (1)$$

2) Otter board resistance

The resistance of otter board (abbreviated to O.B. herein after) is considered from the resultant of resistance which O.B receives from running water and the friction resistance between O.B and the sea bottom. The latter force is not so clear, so only the resistance of O.B by water flow is discussed here. Actually board friction with sea bottom is small in comparison with the former and can be negligible in this discussion.

The resistance of otter board D could be expressed as follows.

$$D = C_d/2 \times \rho \times v^2 \times S \qquad (2)$$

Here, C_d is coefficient of resistance which varies by Reynolds' number and also by the angle of incidence of otter board in the water. In the case of using plate otter board, maximum effective angle of incidence which gives the best opening performance, is about 35 degrees.

According to the formula by Duchemin, C_d is calculated as 0.6 when the angle of incidence is 35 degrees. As for the otter type Süberkrüb, which is similar to the midwater trawl otter board, the maximum effective angle of incidence is about 15 degrees and C_d at this time is about 0.3 which is about half value of the plate otter board.

ρ is the density of sea water. This is 105 kg x sec^2/m^4. S is the area of otter board (m^2), and v is the towing velocity (m/sec).

As an example, the resistance of wing otter board of M/V Paknam 1.4 x 2.1^m in size is calculated. Taking the value of C_d as 0.3 as explained above, the resistance D would be as follows.

$$D = 0.3/2 \times 105 \times 2.1 \times 1.4 \times v^2 = 46 v^2 \quad (3)$$

3) Warp and hand rope resistance

Hydraulic resistance of warp and hand rope during trawl operation, D' (kg) is also expressed in the following.

$$D' = C'_d/2 \times \rho \times d' \times L' \times v^2 \quad (4)$$

Here, d' is the diameter of warp or hand rope (m), L' is the length of warp or hand rope (m) and v is the towing velocity (m/sec).

C'_d is the coefficient of resistance to the flow of water and this value will vary according to the angle of attack α. The figure 1 shows the relation between α cand C'_d

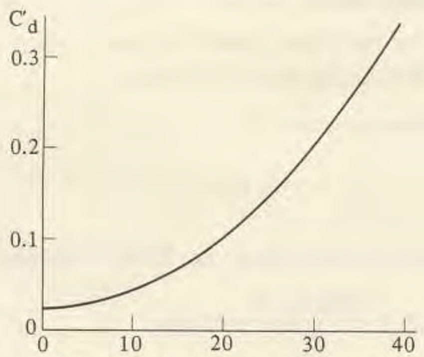


Fig. 1. Relation between α and C'd

In the case of hand rope, angle α is ordinarily considered to be about 10 degrees, so C'_d is found to be 0.04. The warp length is usually about 4–5 times the water depth of 40–50 meters, about 3 times the water depth of 100 meters and 2.3–2.4 times the water depth of 500–600 meters. And the angle will differ according to the length of warp. If the length of warp is 3 times the water depth, the angle is about 20 degrees. So, in this case the value of C'_d is about 0.1.

Here, the warps and hand rope in M/V Paknam are taken as an example, the diameter of both are 18mm. The length of warp is 250m to the water depth 80m. The length of hand rope is 80m.

Thus the total resistance of the two (left and right) hand ropes and warps, 2D' is calculated as follows.

$$2D' = (0.04/2 \times 105 \times 0.018 \times 80 + 0.1/2 \times 105 \times 0.018 \times 250) \times 2v^2 = 53 v^2 \quad (5)$$

4) Total resistance of trawl gear

The total resistance R' is calculated as follows.

Net resistance (1) + O.B. resistance (2) +

$1200 v^2$ + $46 v^2 \times 2$ +

Warp & rope rest (3) = Total resist.

$53 v^2$ = $1345 v^2$

4. Calculation of dimension of trawl net by horse power

Q: To find the size λ (m) of trawl net where $\frac{D}{L} = 0.03$. The net is pulled by trawler with 100 p.s. of B.H.P at a speed of 2 m/sec.

If E.H.P is about 13% of B.H.P, then EHP = 0.13 x100 = 13 p.s.

$$R = \frac{\text{EHP} \times 75}{v} = \frac{13 \times 75}{2} = 487 \text{ kg}$$

Then,

$$487 = 25.00 \times \left(\frac{D}{L}\right) \times v^2 \times \lambda^2$$

$$\lambda^2 = \frac{R}{25.00 \times \left(\frac{D}{L}\right) \times v^2} = \frac{487}{25.00 \times 0.03 \times 2^2}$$

$$\therefore \lambda = 13^m$$

3.4.3 Preliminary designing of trawl net in case of M/V Paknam

1. Introduction

Before the completion of building M.V. Paknam, the SEAFDEC training boat, the trawl nets fitted on this size of boat should be designed on the basis of dimensions of M.V. Paknam. The nets to be made are of 4 kinds:

4 – seam trawl net
2 – seam trawl net
Medium trawl net (for two-boat type)
Shrimp trawl net (for double rigger)

As the necessary information for designing the nets for Paknam have been given in the design of the boat, we can establish the dimensions of the nets which will be explained in this paper.

The previous information on the capacity of Paknam relating to the net design were as follows:

Main engine : Diesel 1,000 ps with variable pitch
Trawl winch : 4000 kg × 60 m/min
Trawl warp : 1200 m × 18 mmφ
Hand rope : 50 m × 24 mmφ
Distance from ramp to winch : 9 m

On the basis of these capacities the designing of trawl net should be discussed.

2. Analysis of essential factors.

1) Estimated maximum size of net (head rope length)

	D	L	D/L
Wing	0.20	9.05	0.022
Square	0.18	7.00	0.026
Belly	0.16	6.00	0.027
Baiting	0.16	6.00	0.027
Cod-end	0.20	3.00	0.066

Mean D/L = 0.030

The normal speed of trawl net dragging is 3 miles/hr. or 1.5 m/sec. The expressions below are mentioned already.

$$E.H.P. = \frac{R \times v}{75} \qquad 1$$

$$R_{net} = 25.0 \times \frac{D}{L} \times (v)^2 \times (\lambda)^2 \qquad 2$$

The sea margine is about 10 percent normally, 1,000 p.s is publicly announced for propelling engine B.H.P. of the boat, the following process could be discussed.

B.H.P. = 1,000, Taking sea margine as 0.1, then 1,000 × 0.9 = 900 p.s.

S.H.P. = (B H P × 0.9) × 0.8 = 720 p.s

E.H.P (or N.H.P) = S.H.P × 0.23 = 165 p.s.

In equation (1), if we take v as 1.5 m/sec., then

$$165 = \frac{R \times 1.5}{75} \quad \therefore R = \frac{75 \times 165}{1.5} = 8{,}250 \text{ kg}$$

If $R_{(net)}$ is approximately calculated in this case, then,

$$R_{(net)} = R - R_{(otter + warp)} \fallingdotseq R \times \frac{1.5}{2.5} = 8250 \times 0.6$$

$$= 4{,}950 \text{ kg}$$

Then, from equation (2) we get,

$$4{,}950 = 25.0 \times 0.03 \times 1.5^2 \times (\lambda)^2$$

$$\lambda^2 = 2930 \quad \therefore = 54^m$$

2) Discussion on the capacity of trawl winch relation to the net's size which is estimated from the relation between dragging gear resistance and the size of net.

Now, we take the trawling speed as 3.5 knot which is a little higher than the former case. The value of this speed also coincides with the speed calculated at the time of hauling the net by trawl winch described hereafter, then R will be:

$$R = \frac{165.6 \times 75}{1.8} = 6{,}888 \text{ kg}$$

According to the relation (by Hamuro) between gear resistance and the size of net, this resistance value gives the length of headrope as 60 meters for four-seam trawl net.

Speed of trawling when hauling the net (V') = 1.5 knot (=0.8 m/sec)

Warping speed by trawl winch (v) = 60 m/min. (= 1.0 m/sec)

Dimension of trawling warp:

for trawling 18 mmϕ, 1200 m × 2, breaking strength is 15 ton, for cod-end hauling 24 mmϕ, 50 m × 1, breaking strength is 30.5 ton

The effective horse powe of winch will be:

$$B.H.P_w = \frac{6{,}888 \times 1}{75} = 91.8 \text{ p.s}$$

If we set the margin of winch power as 40 percent, then the necessary winch horse power should be:

$$91.8 \div 0.6 = 153 \text{ p.s.}$$

3) Estimation of net's size on the basis of trawl winch capacity. Given capacity of winch driven by oil pressure is as follows.

Effective horse power of Main Drum:

4 ton × 60 m/min.

Effective horse power of auxiliary drum:

7.5 ton × 30 m/min.

As the capacity of winch is less than the resistance of gear, the dragging power and net size should be considered again on the basis of trawl winch capacity. It has already been discussed where the speed of the net is (V' + v) is 3.5 knot, so the net's size should be found when the gear resistance is 4,000 kg and v is 1.0 m/sec.

Then, from equation (1),

$$4000 \times \frac{1.5}{2.5} = 25 \times 0.03 \times 1.8^2 \times \lambda^2$$

From this, λ is 42 meters. So, E.H.P is calculated:-

$$E.H.P. = \frac{4000 \times 1.8}{75} = 96 \text{ p.s.}$$

Therefore B.H.P will be:

$$\frac{96}{0.8 \times 0.9 \times 0.23} = 579 \text{ p.s.}$$

The breaking strength of trawling warp (=15 ton) is nearly 4 times the gear resistance.

The effective horse power of winch

$$= \frac{4000 \times 1}{75} = 53.3 \text{ p.s}$$

Necessary horse power including margin

$$= 53.3 \div 0.6 = 89 \text{ p.s}$$

Photo: The maximum catch by M/V Paknam in Indian Ocean.

3.4.3 The resistance and horse power of big trawler

The big size trawlers ranging from 1,000 to 5,000 gross tonnage are intensively used by most developed fishery countries such as Japan, Russia, America, Canada, England, Germany, Polland, France, etc. in the trawl fishing grounds of the world.

1. The power necessary for pulling trawl boat and net depends upon the following elements such as size and shape of boat, size and shape of net, structure of propeller including diameter, pitch and developed blade area. The approximate way of estimation of power for trawler could be based on the various experiments by Mr. T. Koyama.

The principal dimensions of six trawlers selected for the studies from 300 to 3,500 gross tons are shown in Table 1, and the relation between power for pulling trawl gear (E'.H.P.) and maximum continuous brake horse power (B.H.P.) found by experiment, is shown in Fig. 1 (for calm sea with wind at Beaufort 1 – 3). E'.H.P. is the horse power necessary for pulling the gear including otter board on the condition that hull resistance is not calculated.

When the total resistance of gear is R' (kg) and towing velocity is v (m/s), the E'.H.P. is R'v (kg.m/sec) horse power. As 1 horse power is equivalent to 75 kg.m/sec, the E'.H.P. is calculated as R'v/75. The shaft horsepower or B.H.P. is to be called brake horsepower, which is obtained by multiplying indicated horsepower (I.H.P.) by engine efficiency. The indicated horsepower is obtained by measuring the gas pressure inside a cylinder with an indicator. Acording to Fig. 1, the relation between the E'.H.P. and the B.H.P. of each trawler is almost proportional, and accordingly it is expressed as follows:

$$E'.H.P. = k \times B.H.P. \qquad (1)$$

From the above figure it is clear the value of k will change according to the condition of horse power and diameter of propeller. As the horse power of main engine increases, the diameter of propeller increases, and relative value of k becomes greater.

Generally the horsepower of the main engine is indicated by the maximum continuous shaft horse power. And in the case of big trawlers with fixed propellers, about 60 % of

Table 1. Principal dimensions of six trawlers

	A	B	C	D	E	F
Length (Loa) (m)	39.80	73.79	88.20	88.20	88.20	99.50
Breadth	8.00	12.10	14.00	14.00	14.00	15.50
Depth	3.90	5.75	9.20	9.20	9.20	10.00
Maximum continuous B.H.P. (ps)	1200	2700	3150	3150	3500	4000
Maximum engine r.p.m.	550	225	225	225	235	240
Gross tonnage	314	1500	2800	2900	3000	3400
Propeller type	C.P.P.	Fixed	Fixed	Fixed	Fixed	Fixed
Diameter of propeller	2400mm	2950	2950	2950	3040	3150
Propeller pitch (mm)	1440	2050	2210	2220	2110	1970
Blade area developed	1.936m²	4.58	4.40	4.40	5.38	5.06
Number of blades	3	5	5	5	5	5
Trawl winch capacity	8 ton	15 ton	18.6	18.6	19.7	20
	80 m/min	70 m/min	60	60	66	80

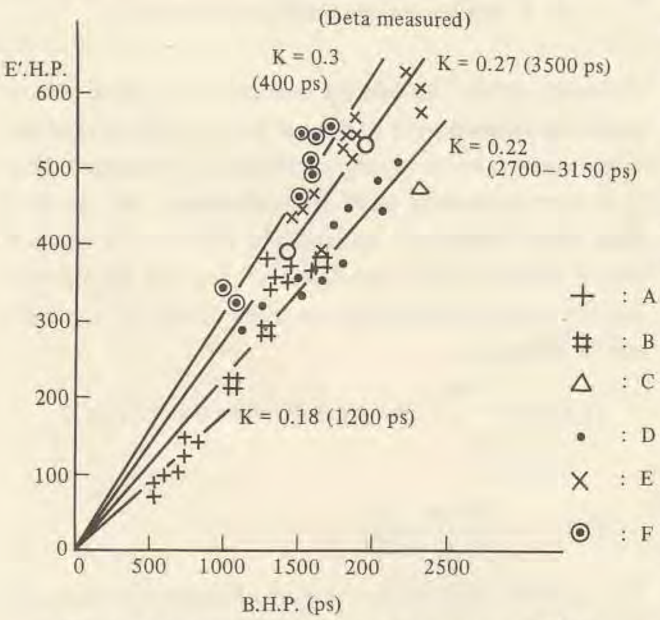


Fig. 1. Relationship between shaft horse power (B.H.P.) and power for pulling trawl (E'.H.P.).

this maximum continuous shaft horse power is used as B.H.P. during trawling. Of course, more than 60 % may be used in rough sea operation, but in computing the E'.H.P., it is recommended to take 60 % as standard. As an example, suppose the horse power of main engine is 3150 ps and other conditions such as diameter of propeller etc. are those given in Table 1, the B.H.P. used during trawling, or 60 % of 3150 ps, is 3150 x 0.6 = 1890 ps. According to Fig. 1, the value of k in the case of given conditions is 0.22, so from formula (1)

$$E'.H.P. = 180 \text{ ps} \times 0.22 = 415 \text{ p.s}$$

So, R' v = 415 ps x 75 kg.m/sec. = 31.1 tons.m/sec ∴ R' = $\frac{31.1}{2.25}$ = 13.8 tons, here, v = 4.5 mile/hour = 2.25 m/sec. The towing velocity of 4.5 knots is so determined in order to leave something in reserve for trawling in rough sea where the hull resistance increase. Fig. 2 shows E'.H.P. in rough sea. In Fig. 2, it is observed that E'.H.P. in rough waters, with a head wind of Beaufort 6, drops down to about one half of the E'.H.P. in calm sea. In practice, the towing velocity of 4.5 knots in calm sea decreases to about 3.5 knots in rough sea into a head wind. Thus, effective horse power for dragging gears will be expressed practically in the following three conditions (in case of big trawlers with fixed propeller)

1) In calm sea E'.H.P. = 0.93 × 0.27 × B.H.P. × 0.65
   (65% of maximum condition brake horse power is used for trawling)
2) In case of rough sea with head wind
   E'.H.P. = 0.55 × 0.27 × B.H.P. × 0.65
3) In case of rough sea with fair wind
   E'.H.P. = 1.31 × 0.27 × B.H.P. × 0.65

It is thought that 60 ~ 70 % of the maximum continuous brake horse power is optimum for the fixed propeller of big trawlers to drag the gear, but 85 – 90 % could be used in cases of the controllable pitch propeller of midium size trawler.

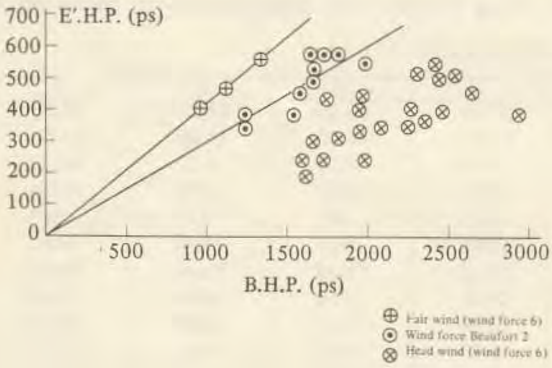


Fig. 2. Relationship between shaft horse power and power of pulling trawl

2. Trawl winch

It is no exaggeration to say that a trawl winch for trawler is as important as the main engine. When hauling operation is started in rough seas in case of big trawler, the tension imposed on trawl warps increase abruptly due to scooping action of swell, from the moment otter boards detach from the sea bed; and the transient maximum tension becomes 3 to 4 times the tension during towing operation. This should be remembered in designing a trawl winch and sufficient allowance should be given to its capacity. If it is driven by electro-motor, a low speed motor with great torque i.e. a motor with 300 % torque is needed. To meet the trend, trawling grounds have been shifting to deeper waters, the rope winding speed of which is also to be as fast as 70 to 80 m/min at the mean diameter of its drum. This is why the larger trawl winch is requested today.

Table 2 and Fig. 3 show the relation between power to pull trawl computed in accordance with the preceeding discussion, and shaft horse power of trawl winch installed on the experimented trawlers. From Fig. 3 it is clear that power to pull trawl (E'.H.P.) and shaft horse power of trawl winch (T_W) are nearly the same in the case of trawlers of 314 ~ 540 ton class (1200 ~ 1500 ps class), but with the increase in size of trawler, its winch shaft horse power becomes slightly smaller than its power for pulling trawl.

Table 2. The shaft horsepower of trawl winch (T_W)

Gross tonnage	Maximum continuous shaft horsepower of main engine P (ps)	Power to pull trawl E'.H.P.	Trawl winch	
			Capacity ton × m/min	Shaft horse-power T_W (ps)
314	1,200	130	8 × 80	142
540	1,500	163	10 × 80	176
1500	2,700	360	15 × 70	234
2800	3,150	415	18.6 × 60	248
3000	3,500	570	19.7 × 66	293
3400	4,000	720	20 × 80	350

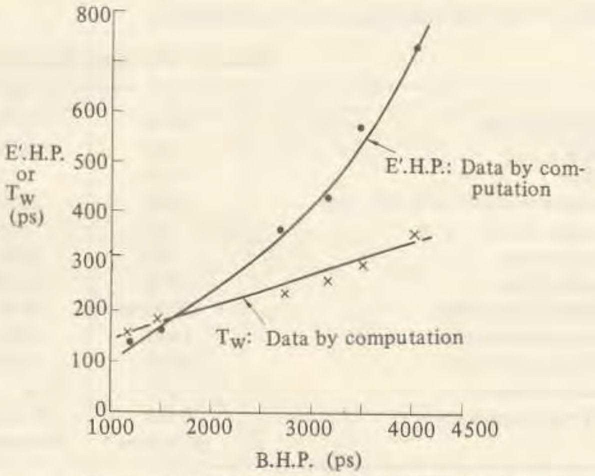


Fig. 3. Relation between B.H.P. and E.H.P. or T_W.

Normally, during the hauling operation, the speed of boat would be reduced by ½ of normal trawling speed v, and the trawl winch takes in towing warp with ½ x v of speed. That is if normal trawling speed is 4 miles/hour, the speed of boat when hauling is 2 miles/h, and the speed of winch is also 2 miles/h. Then, the speed of net will remain at 4 miles/h. Thus, the following condition during the operation can be established:

1) $E'.H.P. = \frac{Rv}{75}$ Here, R is the resistance of gear at 4 miles/h.

2) $T_w = \frac{R \times \frac{1}{2}v}{75} = \frac{Rv}{150}$

So, T_W = ½ E'.H.P. will be required. Normally, as shown in Table 2, T_W is nearly the same as E'.H.P. or more. This fact is due the winch being designed to have full safety in capacity because of the possibility of making operation in deeper waters, or sometimes unknown forces will be imposed to the warp. According to Fig. 3, the equation (2) expressed as: $T_W = 8 + 0.06P$

Warping end:

According to Fig. 4 the following equation is obvious:

$$\frac{T_2}{T_1} = e^{\mu\theta}$$

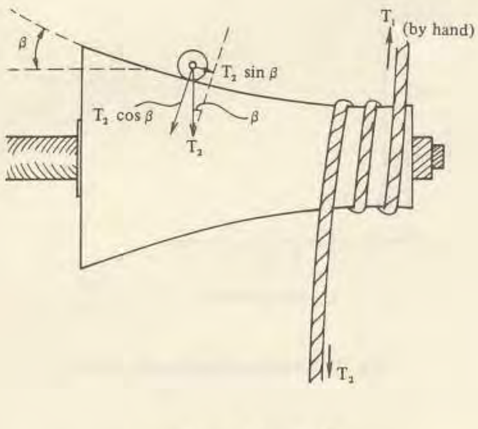


Fig. 4. Warp end

where, μ is frictional coefficient between line and drum. θ is relation of the number of coils to warping end. So to make T_1 small, θ should be big in value with a constant μ. That could be done by increasing the number of coils in warping end. The above formula will be converted to –

$$\log_{10}\frac{T_2}{T_1} = 0.00758\mu\theta$$

We take conical vertical angle as 2 β. For hauling rope, a conical type of warping end is used to prevent rope from being rolled double. The rope on warping end should not interwind with each other, and should always slip smoothly towards the conical apex when pulling the rope by hand. That is:

$$T_2 \sin\beta \geqq \mu T_2 \cos\beta \quad \text{So, } \mu \leqq \tan\beta$$

Since the value of μ is 0.3 in case of friction between wire rope and cast iron, and 0.4 in case of manila rope and cast iron, β is calculated in both cases as follows:

$\beta \geqq 16°41$ (in case of wire rope)

$\beta \geqq 21°51$ (in case of manila rope)

3. Trawl net

Even though trawl nets are equally designed and uniformly fabricated, they do not have uniform resistance if there is a different in the buoyancy of their floats or opening width of their wings. It is very difficult, therefore, to accuratly compute the resistance of a trawl net.

An empirical formula which is introduced here is an approximate expression obtained from the results of experiments carried out on trawl nets being used by seven different trawlers of 100 gross tonnage with 300 ps engine to 3500 gross tonnage with 4000 ps engine. The experiments have been conducted under common and normal conditions, i.e. the total buoyancy of floats is 200 to 650 kg., the total weight in water of ground bobbins greater than the total buoyancy of floats by 20 to 30 %, netting is made of polyethylene twine and trawler knot, towing velocity is 3.0 to 4.7 knots, and oepning width of wings is kept in the range from 15 to 35 m. Fig. 5 shows the results of the experiments.

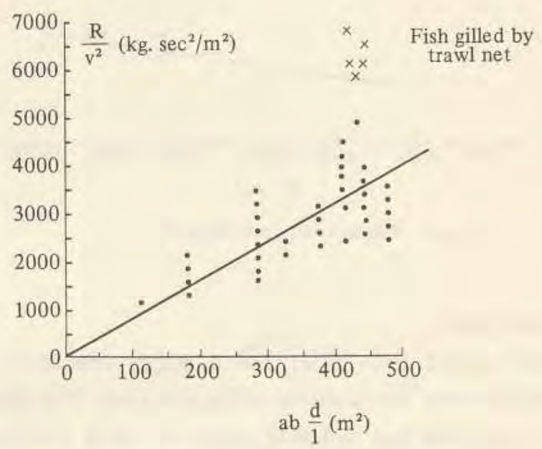


Fig. 5. Relation between ab $\frac{d}{l}$ and $\frac{R}{v^2}$

From this figure, it is clear that the relation between R/v^2 and ab x d/1 is almost linear.

Here,

R (kg)	:	Resistance of trawl net including accessories except otter boards
v (m/sec)	:	Towing velocity
a (m)	:	The maximum stretched width of body net
b (m)	:	The maximum stretched length of trawl net
d (mm)	:	Average value of diameter of net twine
l (mm)	:	Average value of length of each mesh bar
l' (mm)	:	Average value of stretched mesh size

The experimental equation of Fig. 5 is approximately expressed as follows:

$$R = 8\,ab \times \frac{d}{1} \times v^2 = 16\,ab \times \frac{d}{1'} \times v^2 \qquad (3)$$

Relation between head rope length and B.H.P.:

The relationship is expressed in Table 3 and Fig. 6 and the equation could be shown in the following:

$$H = 42 + 0.006\,P. \qquad (4)$$

Here, H is the head rope length in meters, and P is the maximum continuous shaft horse power (ps).

Table 3. H and P

Gross tonnage	Maximum continuous shaft horse power P (ps)	Length of head rope H (m)
314	1200	49.95
1500	2000	51.20
1500	2700	60.50
1500	2700	58.10
1850	3150	61.90
1850	3150	61.90
2800	3150	59.95
2800	3150	61.90
3000	3500	60.00
3000	3500	65.00

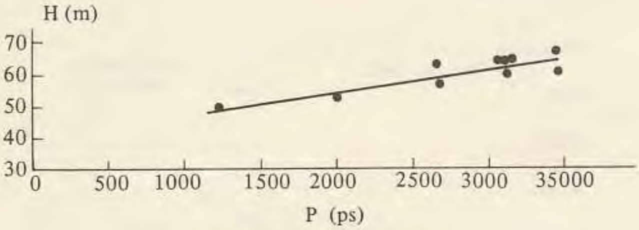


Fig. 6. Relation between H and P.

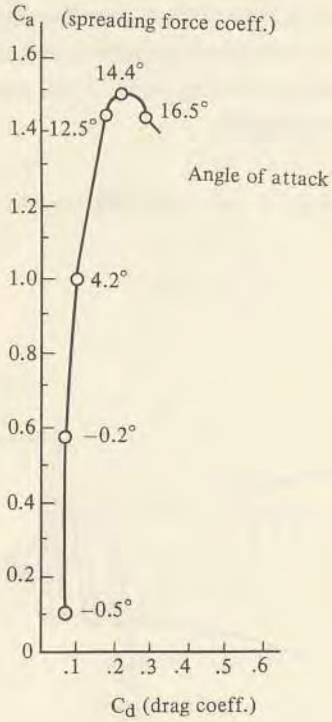


Fig. 8. Relation between C_d and C_a

4. Otter board

High aspect ratio otter board which resembles the Süberkrüb otter board shown in Fig. 7 is used. This type of otter board has less hydraulic resistance (drag force) and greater spreading force than the normal flat and low aspect ratio otter board. Fig. 8 shows the relation between spreading force coefficient and drag coefficient for different attack angles. It is clearly understood that the optimal angle of attack is 14 ~ 15 degrees where the drag coefficient is about 0.3.

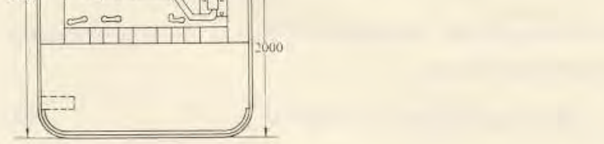


Fig. 7. Otter board used by 3150 ps trawler.

In practical operation, otter boards are used where their spreading force is kept at its maximum by means of adjusting the bracket angles. Therefore, it may be safe to say that the attack angle of otter boards during operation is equal to the optimal angle i.e., 14~15 degrees. This means that there will not be many errors if we use 0.3 as the drag coefficient for our computation. Under this condition, the resistance of otter board (R'', kg) is expressed as follows:

$$R'' = \tfrac{1}{2} C_d \rho v^2 S \qquad (5)$$

where C_d is resistance coefficient, ρ is the density of sea water = 105 (kg.sec^2/m^4), v is towing velocity in m/sec and S is the area of otter board in square-meter.

As an example, let us compute the resistance of a pair of Süberküb otter boards of 3.8 meters in height and 2.5 meters in width.

$$R'' = 1/2 \times 0.3 \times 105 \times 3.8 \times 2.5\ v^2 = 150\ v^2$$

Therefore, if the towing speed is 4.5 knots (2.25 m/sec), the resistance (R'') would be about 0.8 tons. Since this is the resistance of an otter board, the total resistance of a pair of the otter boards is about 1.6 tons.

Table 4 shows the results of a survey on the relation between horsepower of main engine (P) and the area (S m^2) and weight in air (W tons) otter board. If we plot on a logarithmic graph the figures in Table 4, they form straight lines as shown in Fig. 9.

Table 4. **Relations between the maximum continuous shaft horsepower of main engine P (ps) and an otter board.**

Maximum continuous shaft horsepower of main engine P (ps)	Otter board			Weight of otter board in air W (ton)
	height (m)	width (m)	area (m^2)	
700	3.2	1.36	4.080	0.800
850	3.2	1.60	5.120	1.040
1,200	3.2	1.92	6.144	1.635
2,000	4.0	2.00	8.000	2.100
2,700	3.8	2.50	9.500	2.600
3,150	3.8	2.50	9.500	3.100
3,500	3.9	2.65	10.335	3.200

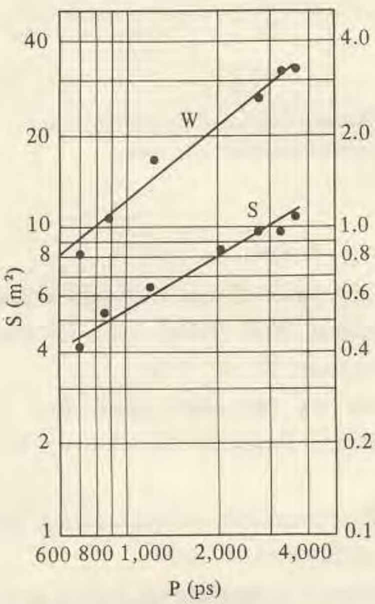


Fig. 9. Relation between the maximum continuous shaft horsepower of main engine P (ps) and otter board.
w; weight of otter board in air (ton)
s; area of otter board (m^2)

According to Fig. 9, the relation between horsepower of main engine (P) and area of otter board (S m^2) is expressed approximately as:

$$S = 0.0945\ P^{0.58} \quad (6)$$

and the relation between P and otter board weight in air (W tons) is expressed as:

$$W = 0.00478\ P^{0.8} \quad (7)$$

As the above relations have been established by the repetion of trial and error, it is fairly safe to use them for the suitable size of otter board for the horsepower of a main engine.

The function of otter board is to develop the distance between right and left wing nets, so it should have great developing force and little resistance. But in designing of otter board, its stability in water should also be taken into consideration. To make them stable in the water, the majority of upright type otter boards in use today are so designed that the height to width ratio is 1.5 to 1. To lower its center of gravity by fixing floats to the upper part and sinkers in the lower part is also helpful to improve the stability of upright type otter boards.

Table 5. **Relations between the maximum continuous shaft horsepower of main engine P (ps) and trawl warp.**

Gross tonnage	Maximum continuous shaft horsepower of main engine P (ps)	Diameter of trawl warp d (mm)	Breaking strength trawl warp (ton)
314	1,200	22	29.0
540	1,500	24	34.6
1,500	2,700	26	40.6
2,800	3,150	28	47.1
3,000	3,500	30	54.0
3,400	4,000	32	62.0

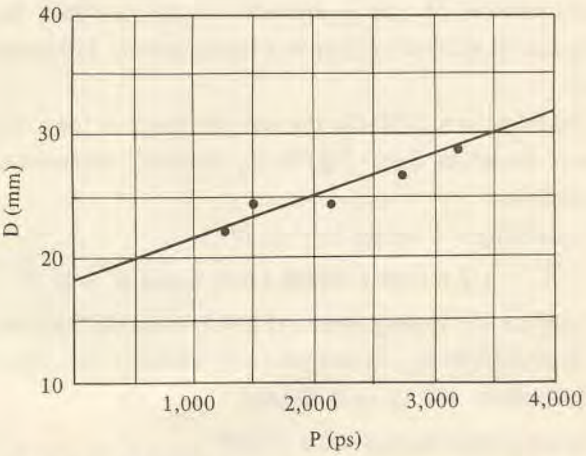


Fig. 10. Relation between the maximum continuous shaft horsepower of main engine P (ps) and the diameter D (mm) of trawler warp.

5. Trawl warp

The structure of most trawl warps used by Japanese trawlers is 6 x Filer type (No. 29) with a hemp core. Table 5 and Fig. 10 show the result of surveys on the relation between the diameter (D mm) of trawl warp and the horse power (P) of the trawler's main engine. From Fig. 10 the relation between D (mm) and P (ps) can be expressed approximately as follows:

$$D = 18 + 0.0034\,P \quad (8)$$

During trawling operations, the underwater weight of warp is much less than the tension on it. Accordingly, the warp in water can be considered linear. On this assumption, the resistance of warp (R''' kg) to the sea current is expressed as follows:

$$R''' = \tfrac{1}{2} C_d' \rho\, D\, L\ v^2 \quad (9)$$

where D is the diameter of warp in meters, L is the length of warp in meters, ρ is the density of water as 105 (kg.sec^2/m^4), v is towing speed in m/sec, and C_d' is the drag coefficient which varies with the angle a formed by the warp and the direction of sea current, and also with Reynold's Number. According to Diel, the relation between the declination angle (α) of wire rope and C_d' is as that shown in Fig. 11 provided that Reynold's Number is in the range from 2.5 x 10^4 to 7 x 10^4 (Reynold's Number in the case of trawling operation is generally within this range). Therefore, assuming the warp declination as α, we can obtain the value of the drag coefficient from Fig. 11. If the length of warp in operation is three times as long as the water depth, the declination of the warp can be obtained by:

$\sin \alpha = 1/3$

From the above, α is about 20 degrees. Then the value of C_d' for α of 20 degrees is to be found in Fig. 11.

As an example, let us compute the resistance of a pair of trawl warp of 28 mm in diameter on the condition that each warp is 400 meters long in a fishing ground 110 meters deep.

From $\sin \alpha = 110/400$, the warp declination (α) in this case is 16 degres. From Fig. 11 C_d' for α of 16 degrees is about 0.08.

Accordingly, from the formula (9),

$$R''' = 1/2 \times 0.08 \times 105 \times 0.028 \times 400 \ v^2 = 47 \ v^2$$

Suppose the towing speed (v) is 4.5 knots (2.25 m/sec), R''' is about 240 kg., so that the total resistance of a pair of warps is about 480 kg. or 0.48 tons.

6. Power to pull trawl and size of gear

Now, the suitable trawl gear to be pulled at a speed of 4.5 knots by a trawler with a 3,150 horsepower engine should be so designed that its total resistance may approximately 13.8 tons. Now let us investigate this problem about the trawl net, otter boards and warps taken up as examples already mentioned above. If the resistance of a trawl net of certain design is computed by equation (3) as 11.8 tons when it is towed at a speed of 4.5 knots, the resistance of a pair of otter boards of 3.8 m x 2.5 m each is computed as 1.6 ton as already mentioned, and the resistance of trawl warps of 28 mm in diameter is computed at 0.96 tons on the condition that they are extended to 400 meters and are pulled at a speed of 4.5 knots.

Therefore, the resistance of the whole gear will be as follows:

$$R' \text{ (resistance)} = 11.8 \text{ tons} + 1.6 \text{ tons} + 0.48 \text{ tons} = 13.88 \text{ tons.}$$

If the calculated resistance is not equivalent to an available power to pull trawl, it is necessary to adjust the size of gear to the power.

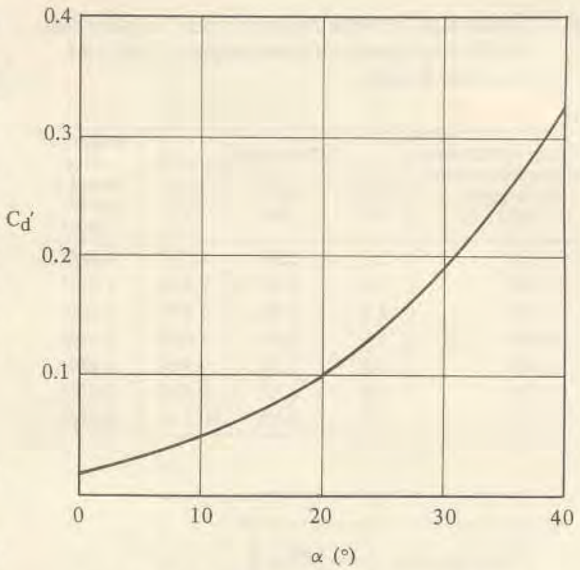


Fig. 11. Relationship between drag coefficient C_d' and declination angle α of wire.

References

1) T. Koyama: On the result of field trial with various big sixed otter trawls, Bull. Tokai Regional Fisheries Research Laboratory, No. 43, 1965

2) – ditto – : Study on the stern trawl, Bull. Tokai Regional Fisheries Research Laboratory, No. 77, 1974

3) F. Süberkrüb: Otter boards for pelagic trawling, Modern Fishing Gear of the World 1, 1959

4) J. Shärfe: Experiments to decrease the towing resistance of trawl gear, Modern Fishing Gear of the World 1, 1959

3.4.3 Resistance of shrimp trawl net

In the scientific reports concerning with shrimp trawl experiment shown in the following lists, some of this data will be analyzed and discussed in this paper.

Shrimp trawl references

1. T. Koyama et al: Studies on small stern trawl (1), Resistance on small trawl net and developing angles of the otter boards at rudder deflection; Bull. Tokai Reg. Fish. Res. Lab. No. 71, Oct. 1972
2. M. Nomura et al: Shrimp trawl fishing experiment – On the fishing comparison between Mexican net type and commercial net type. Rep. SEAFDEC & Dept. Fisheries, Thailand, June 1971
3. H. Miyamaoto: On the relation between otter trawl gear and towing power; Modern Fishing Gear of the World. April 1959

Discussion and analysis

1. The experiment on the net in the reference List 1 is analysed as follows.

The given conditions are: boat is 47 tonnage, SHP of engine 235 ps, one net system, net is 12.90 m in head rope, 18.08^m in ground rope, 18.06^m in total length.

The total resistance of gear R' including net resistance R, otter board resistance R" and Towing warp resistance R"', are actually measured and calculated by instruments such as tension meter and current meter at various speeds, length of rope and warp angle (α°) which is the angle between the direction of warp at the top roller and the direction of boat's course. (Table 1)

Table 1

Towing speed v (m/sec)	Pitch angle (propeller)	Depth of water (m)	Length of warp (m)	Tension of warp T (kg)	Angle of warp α°	Bottom nature
1.0	7°	98	300	480	19°	M.S.
1.2	8	98	300	600	19	M.S.
1.3	9	98	300	760	19	M.S.
1.2	8	430	1,000	800	25.5	M.S.

R' is obtained by the formula, $R' = T\cos\alpha$ (1)

According to the following formulas[1] R'' and R''' are calculated as shown in Table 2.

$$R = R' - (R'' + R''') \quad (2)$$

$$R'' = \tfrac{1}{2} C_d v^2 S \rho \quad (3)$$

$$R''' = \tfrac{1}{2} C'_d v^2 d' l' \rho \quad (4)$$

Table 2

Towing speed v (m/s)	Total resist. R' (kg)	Otter board (2) resistance R" (kg)	Warps(2) resist. R"' (kg)	Net resist. R (kg)	$\frac{(R''+R''')}{R} \times 100$ (%)
1.0	454	24	24	406	10
1.2	567	34	36	497	13
1.3	718	40	44	634	12
1.2	722	34	190	498	32

In this case the resistance of otter boards and towing warps, according to Table 2, will occupy about 10 to 30 % of total resistance. This percentage will differ according to the length of warp, the size of net, kinds of otter boards, size of warp, etc., so we cannot find a definit value.

As the value of d/1 is 0.035 the coefficient of resistance k is calculated using equation (5) with v = 1.0 to to 1.3 as shown in Table 3.

Table 3

d/l	v	R	a x b	k
0.035	1.0	406	21.78 x 18.06	30.0
"	1.2	497	" "	25.6
"	1.3	634	" "	27.8
"	1.2	498	" "	25.6
			Average	27.2

Note: 1) See p. 104 ~ 105

$$k = \frac{R}{ab \times d/l \times v^2} \quad (5)$$

From Table 2, the necessary horse power of engine will be conversely calculated as:

$$\text{EHP} = \frac{R' \times v}{75} = \frac{(454 \sim 722) \times (1.0 \sim 1.3)}{75}$$

$$= 6.05 \sim 12.5$$

$$\therefore \ \text{BHP} = 36 \sim 75 \text{ ps}$$

It was found from the report that in rough seas when a trawl was pulled at a rudder deflection, the warp of one side was shortened by F sin β in length while the other lengthend by F sin β, by which the tensions imposed on both warps were equilibrated and the pair of otter boards consequently developed wide enough.

2. In the experiment of net in the reference list 2, the given conditions of operation are as follows:

Boats are 16, 23 and 23 meters in length (three boats are used), BHP of engine are 180, 320 and 335 ps, one net system, nets are 14.0 m, 28.0 m and 28.0 m in headrope, and 17.2 m, 29.2 m and 34.4 m in groundrope.

The total resistance of the gear R is calculated in the following:

$$R = \frac{75 \times \text{EHP}}{v} \quad (6)$$

$$\frac{\text{EHP}}{0.23} = \text{SHP} \quad (7)$$

$$\frac{\text{SHP}}{0.8} = \text{BHP} \times 0.9 \quad (8)$$

(Taking 0.1 as a sea margin)

Here, the percentage of resistance of the otter boards and warps is taken as 40 %, the resistance of net $R_{(net)}$ is found accordingly,

$$R_{(net)} = R \times 0.60 \quad (9)$$

So, from (6) to (9), the following table is obtained:

Given conditions			from (6)	from (9)
v	BHP	EHP	R	$R_{(net)}$
1.0	180	30	2250	1350
	320	53	3975	2385
	335	55	4125	2475
1.25	180	30	1800	1080
	320	53	3180	1908
	335	55	3300	1980

According to results of trawl experiment by Sato[1],

Note: 1) E. Sato: Surface trawl net experiment, Report of Central Fisheries Research Laboratory, No. 1 (1934), No. 9 (1943)
(See "Discussion on essential factors of trawl net")

two surface trawl nets which are similar in net shape but different in scale, were compared. The length of net b_1 and b_2 are 120 meters and 45 meters respectively with the resistance of net R_1 and R_2 at 700 kgs and 90 kgs respectively under the same trawling speeds of 0.48 miles per hour. Then we found the following relations.

$$\frac{R_1}{(b_1)^2} = \frac{700}{(120)^2} = \frac{R_2}{(b_2)^2} = \frac{90}{(45)^2}$$

From this we could conclude that resistance R will be proportional to the square of scale λ. Taking m (ground rope length) as the indication of λ, we get from Dr. Tauchi's formula, the following formula

$$R_{(net)} = D \times d/l \times v^2 \times m^2 \qquad (10)$$

Taking the standard element for indication as the length of b (total length of net), then put the equation of m = pb (p is coefficient) into (1), then we have;

$$R_{(net)} = d/l \times v^2 \times D \times p^2 \times b^2$$

Using the data of Table 2 (in previous paper), the following calculating procedure will be concluded. As $p = 18.08/18.06 = 1$, so,

$$D \times p^2 = \frac{406}{0.035 \times 1.0^2 \times 18.06^2}$$

$$= \frac{497}{0.035 \times 1.2^2 \times 18.06^2}$$

$$= \frac{634}{0.035 \times 1.3^2 \times 18.06^2}$$

$$= \frac{498}{0.035 \times 1.2^2 \times 18.06^2} = 32.2 \text{ (average)}$$

Thus, the equation (1) will be expressed as:

$$R_{(net)} = 32.2 \times d/l \times v^2 \times p^2 \times b^2 \qquad (11)$$

3.4.3 Otter board

1. Introduction

The otter board is expected to open the net mouth horizontally by utilizing the hydraulic resistance against the flow of water. The function of otter board is said to be similar to a kite in the air which has two component forces, namely, the lift and drag as shown in Fig. 1.

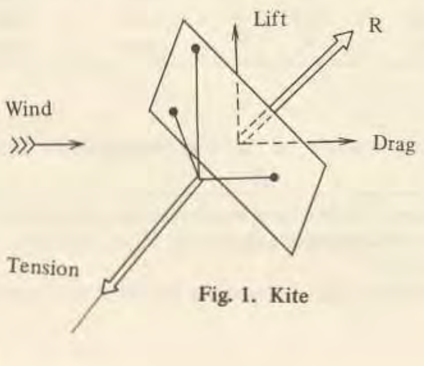


Fig. 1. Kite

Like as the kite above, the otter board produces two componets – sheer and drag. The sheer force (just like the lift in a kite) thus takes part in spreading the net mouth, on the other hand the drag force increase the total resistance of the gear.

The preferable function of otter board is, therefore, to have a big sheer force and a small drag force. Consequently, the otter board has been developed to satisfy the above by changing its shape. In view of practical use, the construction should be stout so as to endure hard frictional resistance with the bottom of the sea when running. Moreover the otter board should be easily adjustable and stable during operation.

2. Shapes of otter board

The rectangular flat type otter board has been used for a long time and so is very popular. But recently, most trawlers have changed to vertical type otter board (with a higher aspect ratio) from the rectangular type. The rectangular type is good for it's simplicity of operation and that is the reason why it has been used for so long in the world. The disadvantages of this type are that the value of C_L/C_D is smaller than other types. Nowadays, a light simply constructed board with wide keel is used, particularly for shrimp trawling, in which most trawling is carried out on clean, soft ground. The hydrodynamics of this board are similar to or slightly poorer than most typical flat otter boards.

The rectangular cambered type otter board with low aspect ratio was produced in the early 1960s. But few are in commercial use at present. It apears that polyvalent board, which is a combination of a cambered board and oval board, was the most hydrodynamic advantage.

The oval flat slotted type otter board introduced first around 1950 very popular in the U.S.S.R.

The oval cambered slotted (Polyvalent) otter board is used widely at present. It was first introduced in France. These otter boards are a combination of the oval board and the cambered board, giving increased spreading efficiency of the cambered type and the ability to traverse hard ground. This polyvalent board is very easy to handle, owing to lack of triangles and other appendages.

Vee type otter board was developed during the 1950s and has been improved since. So far, these boards are mainly used by inshore fishermen who appreciated their good performance on very hard and irregular ground. The disadvantage of this type is its inferior spreading force, even compared to the rectangular flat board. But the advantage is in the manaeuvering, that is, even with sharp changes in direction of tow, special precautions of handling up on one warp are not usually needed, so good for trawling on bad ground and large local obstructions have to be avoided.

Rectangular cambered with high aspect ratio type (Süberkrüb) otter board is at present most popular for one-boat midwater trawling. It has a high aspect ratio of approximately 2:1, that is, the height is about twice the length. The amount of camber is related to the width of the board; the curvature is the section of a circle the radius equal to the length. This efficiency, which is marked by a very low drag, makes the board a superior spreading device. When this type is used for bottom trawling, it has somewhat lower aspect ratio (nearly 1.6), a larger angle of attack, greater weight and combined construction wood and steel. The larger angle of attack which reduces the hydrodynamic efficiency is probabely meant to reduce the risk of the board falling flat due to sharp turns or excessive warp length.

3. Balance of otter board

Dynamical analysis – 1

The meaning of force and stress are that the stress is a representative force at the point where all forces are considered to act. Suppose the resistance r (force) acts at the point D, this is stress r (normal) and this is divided into two components; that is, r_1 the spread force and r_2 the drag force. (Fig. 2)

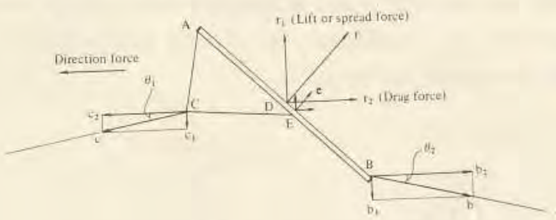


Fig. 2. Otter board force

Also, there is a ground shear force e having two components e_1, ground spread and e_2, ground drag and friction. To keep balance with r and e, two tensions acting at points C and B must exist, these are forces c and b.

Thus,

c: Tension in the towing warp

c_1: Warp in-pull

c_2: Towing force

b: Tension in hand rope

b_1: Hand rope in-pull

b_2: Net resistance (drag)

r: Total hydrodynamic forces acting on the otter board

r_1: Spreading force

r_2: Drag

e: Ground sheer

e_1: Ground spread

e_2: Ground drag and friction

These forces are balanced:

$$c_2 = b_2 + r_2 + e_2 \quad (1)$$

$$c_1 + b_1 = r_1 + e_1 \quad (2)$$

And, also the following relations are expressed.

$$c_2 = c \cos\theta_1 \qquad b_2 = b \cos\theta_2$$

$$c_1 = c \sin\theta_1 \qquad b_1 = b \sin\theta_2$$

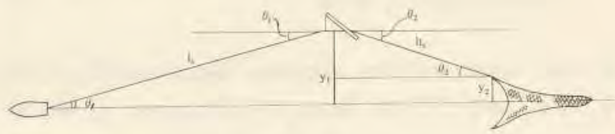


Fig. 3.

If we put l_s as the length of towing warp, h_s the length of hand rope, y_1 half of the spread of otter board and y_2 half of the spread of net mouth, then approximately we get:

$$\sin\theta_1 = y_1/l_s, \quad \sin\theta_2 = (y_1 - y_2)/h_s$$

If the tensions c and b are given, then we have:

The drag force of otter board $\quad r_2 + e_2 = c_2 - b_2 \quad (3)$

The spread force of " " $\quad r_1 + e_1 = c_1 + b_1 \quad (4)$

Calculation example:

Here, it can measure the tension of towing warp c and that of hand rope as 1,600 kg and 1,000 kg respectively by the load cell measuring, and l_s = 360 m, h_s = 46 m, y_1 = 19 m and y_2 = 6 m are also obtained.

$\sin\theta_1 = 19/360 = 0.053$

$\sin\theta_2 = (19-6)/46 = 0.28$

$\cos\theta_1 = \sqrt{1-\sin\theta_1^2} = 0.98$

$\cos\theta_2 = \sqrt{1-\sin\theta_2^2} = 0.96$

so, $c_2 = 1600 \times 0.98 = 1568$ kg

$c_1 = 1600 \times 0.053 = 85$ kg

$b_2 = 1000 \times 0.96 = 960$ kg

$b_1 = 1000 \times 0.28 = 280$ kg

Therefore, the drag and spread force of otter board are:

Drag $= c_2 - b_2 = 1568 - 960 = 608$ kg

Spread $= c_1 + b_1 = 85 + 280 = 365$ kg

Dynamical analysis – 2

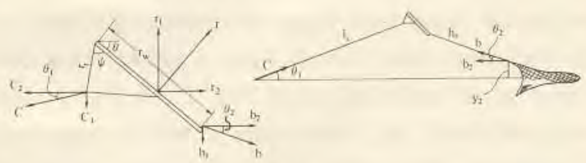


Fig. 4.

From dynamical balance of forces of Fig. 4 in which various symbols are given, the following equations could be drawn:

$$b = f_1(\theta_2) \quad (1)$$

$$y_2 = f_2(\theta_2) \quad (2)$$

$$c \sin\theta_1 + b \sin\theta_2 = r \cos\theta \quad (3)$$

$$c \cos\theta_1 - b \cos\theta_2 = r \sin\theta \quad (4)$$

$$r_t\, c \sin(\theta_1 + \psi + \theta) - r_w b \sin(\theta - \theta_2) = r\frac{r_w}{2} \quad (5)$$

$$l_s \sin\theta_1 = y_2 + h_s \sin\theta_2 \quad (6)$$

In these equations, the unknown factors are θ_2, c, b, θ_1, θ, y_2 and r. If the design of net is given, y_2 will be known and then from (1) and (2) θ_2 and b can be known. Thus the remaining unknown factors are c, θ_1, θ, r.

In (6), as l_s, y_2, h_s and θ_2 are known already, θ_1 will be found.

By (3)/(4)

$$\frac{c \sin\theta_1 + b \sin\theta_2}{c \cos\theta_1 - b \cos\theta_2} = \cot\theta \quad (7)$$

By (3)/(5)

$$\frac{c \sin\theta_1 + b \sin\theta_2}{r_t c \sin(\theta_1 + \psi + \theta) - r_w b \sin(\theta - \theta_2)} = \frac{2\cos\theta}{r_w} \quad (8)$$

In (7) and (8), all the factors except c and θ are known, the unknown c and θ will be found from these two equations.

Thus, the total resistance of net is given as:

$$2c_2 = 2c\cos\theta_1 \quad (9)$$

If attack angle of otter board is already known as stated by Dr. Kawakami [1) the solution will be much easier using equations (1) – (6).

4. C_L and C_D

The sheer and drag coefficient C_L and C_D are expressed as follows.

$$\text{Lift force (or sheer force)} \quad r_1 = \tfrac{1}{2} C_L \rho S v^2 \quad (10)$$

$$\text{Drag force} \quad r_2 = \tfrac{1}{2} C_D \rho S v^2 \quad (11)$$

where ρ is the density of water, S the surface area and v the speed of otter board. C_L and C_D are constant within same value of angle θ. If θ changes, these coefficients also change as shown in Fig. 5. This is the figure of the curves for a flat rectangular board and a rectangular board with 9 percent camber. It is seen that the cambered otter boards have a higher sheer coefficient at all angles of attack but it also has a higher drag coefficient. So, if one wants to have the same value of spreading force (lift force) at a given speed, the cambered board does not need to have such a large surface area as the flat board. This will also decrease below that of the flat board, so the cambered board is more efficient.

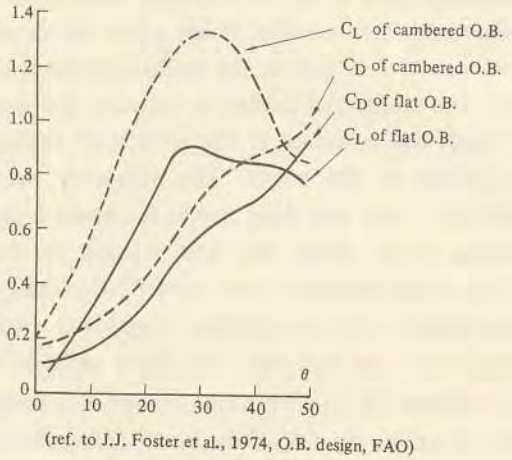


Fig. 5. C_L, C_D and θ curve

From the above equations (10) & (11), $\cot\theta = r_1/r_2 = C_L/C_D$. As the value of C_L/C_D expresses the effectiveness (spreading force to drag force), so the changes of values of C_L/C_D of various shapes of otter boards according to the angle of attack θ, will show the comparison of different types of otter boards in their effectiveness.

The various otter board efficiencies indicated by ratio of sheer to lift coefficients in relation to the angle of attack are shown in Fig. 6.

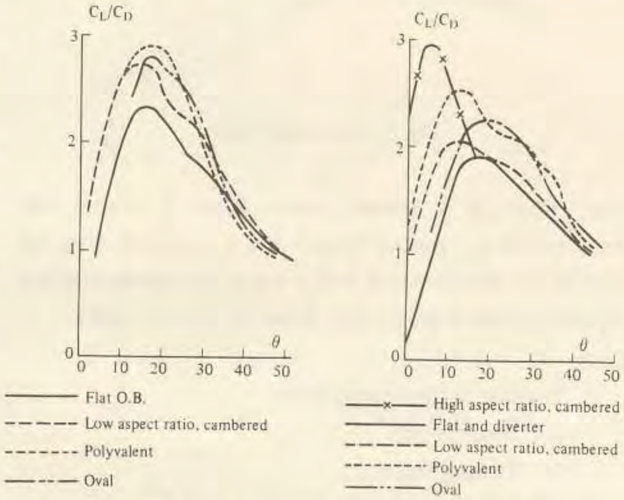


Fig. 6. The relation between C_L/C_D and θ.
(Ref. to same as Fig. 5)

Under the normal fishing conditions, a full scale otter board does not significantly change its angle of attack when only the towing speed is changed. This means that the sheer and drag coefficients will be constant with speed.

The relation between board size and horse power of boat are illustrated in Fig. 7.

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1) Tasae Kawakami: Mechanics of towed nets, Bull. Japanese Socæty of Sciengific Fisheries, Vol. 30, No. 10, 1964

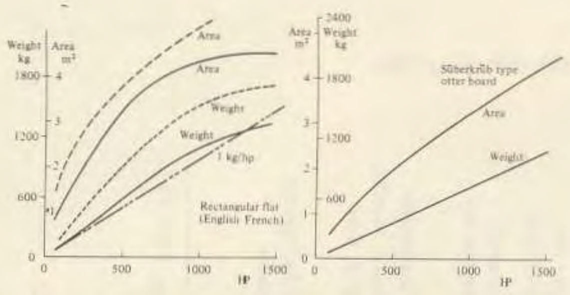

Fig. 7. The relation between board size and horse power of boat
(Ref. to same as Fig. 5)

5. Attitude of otter board

1) Heel: The forces acting on an otter board are shown viewed from its end elevation in Fig. 8.

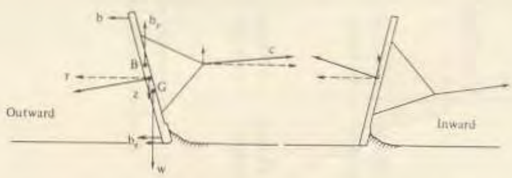

Fig. 8. Outward and inward heel

If the center of buoyancy B is located above the position of the center of gravity G, an upright moment to otter board acts. The floats, therefore, are sometimes attached along the upper edge of rectangular otter boards. The uprighting movement will depend upon the vertical distance GZ between the center of gravity and the center of buoyancy.

With the otter board heel outward, besides the resultant of weight itself there is the force of downward direction (vertical component of hydrodynamic force) which presses the otter board harder onto the ground. If it were heeled inward, an upward direction force (the vertical component of hydrodynamic force), will not press the otter board onto the ground very much. As for upward direction force, there is an upward component of warp tension as well as the buoyancy of board as shown in the figure. Normally the spreading force of otter board is reduced by the degree of heeling of both inward and outward.

2). Tilt: The tilt of otter board also influences its performance. Positive tilt shown in Fig. 9 will make light contact with the bed, while a negative tilt has a heavy contact with the bed. No tilt gives an even bottom contact along the otter board length and gives the maximum aditional sheer and drag. Usually a slight positive tilt is better. In soft mud, excessive positive tilt may reduce the angle of attack, so that the adjustment to reduce the positive tilt is needed to give appropriate sheer.

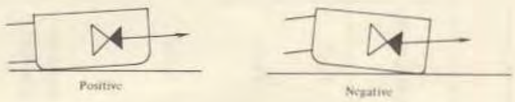

Fig. 9. Positive and negative tilt

6. *Characteristics of various types*

Characteristics of vairous types of otter boards are shown in the following table.

Otter board type	Common angle of attack	Corresponding hydrodynamic characteristics: Coefficients of sheer C_L	Coefficients of drag C_D	Lift/drag ratio C_L/C_D	Overall efficiency	Fishing suitability: Manoeuvrability	On the seabed[1]	In midwater	Construction considerations: Extent of special skills and tools needed	Costs: Purchase	Costs: Maintenance	Experience record
1. Conventional rectangular flat	40°	0.82	0.72	1.14	Average to poor	Good	A, B good C poor	Poor	Average	Average	Average	Well proven; extensively used for demersal fishing
2. Rectangular flat, wide-keeled	40°	0.82	0.72	1.14	Average to poor	Good	A good B poor C unsuitable	Poor	Less than average	Low	Low	Well proven; extensively used for small vessels and for shrimp trawling
3. Rectangular cambered	35°	1.26	0.81	1.55	Good	Average (difficult to right if fallen over)	A, B good C poor	Poor	Above average (bending facilities needed)	High	Average	Very limited commercial use to date
4. Oval flat, slotted	35°	0.86	0.63	1.36	Average	Average to good	A,B,C good	Poor to average	Above average	High	Average	Well proven; widely used, particularly by large trawlers
5. Oval cambered, slotted (polyvalent type)	35°	0.93	0.74	1.25	Average to good	Average to good	A,B,C good	Average to good	Above average (bending facilities needed)	High	Average	Recent development; use increasing
6. Rectangular Vee type	40°	0.80	0.65	1.23	Average to poor	Good	A,B,C good	Poor	Average	Average	Low	Well proven; extensive use, particularly for trawlers up to 600 hp
7. Rectangular flat special design (diverting depressor)	40°	0.82	0.72	1.14	Average to poor	Very good	A, B good C average	Average	High	Very high	Low	Recent development; limited commercial use so far
8. Rectangular combered, high aspect ratio, for midwater trawling (Süberkrüb type)	15°	1.52	0.25	6.08	Very good	Midwater good;bottom average to poor	A, B good C unsuitable	Very good	Above average (bending facilities needed)	Average to high	Low	Well proven; extensively used for midwater trawling by trawlers of all sizes
9. Rectangular cambered, high aspect ratio, for bottom trawling (Japanese type)	25°	1.30	0.50	2.60	Very good	Average (risk to fall flat)	A, B good C unsuitable	Good	Above average (bending facilities needed)	Average to high	Average	Extensive use but limited so far to Japanese trawlers

[1] For quality of seabed:
A = good ground, even, absence of boulders, etc.
B = medium ground, stones, no sudden major depth changes.
C = bad ground, large boulders, uneven, sudden and major depth variations.

(Derived from: J. J. Foster et al.; O. B. design, FAO, 1974)

3.4.4 Fishing efficiency of trawl net

As stated in the discussion on essential factors of trawl net design, the fishing efficiency has a particular connection with the height of net under operation for the purpose of catching fish. On the other hand shrimps and some flat fish, for instance, are caught more by nets particulary designed with wider net mouth opening without care of net height. Therefore the discussion of trawl net efficiency must be different for different species of fish.

1. Hayashi[1] made a special depressor device which makes the net mouth more higher – rise up square – and then compared the net with conventional two-boat type trawl net in their fishing efficiency. And he found that the former net is 10 to 20 percent higher in catch it is specially effective for sea bream, cod and sharks. The compared results of catch between the two are shown in Table 1.

Table 1. Comparison of fishing efficiency

Species of fish	Conven. Net (A)	Depressor Type (B)	B/A
Sea bream	0.4 – 0.23 box	4.2 – 6.15 box	11–27
Cod	0.38	16.20	43
Sharks	1.38	3.00	2
Plaice	3.25 – 7.12	3.25 – 14.06	1.0–2.0
Crab	258	628	2.4

Conven. Net		Depressor Type		B/A
No. of hauls	Average catch (A)	No. of hauls	Average catch (B)	
47	37 box	45	42 box	1.13
35	24	33	30	1.25
39	22	36	29	1.20
47	37	44	41	1.10

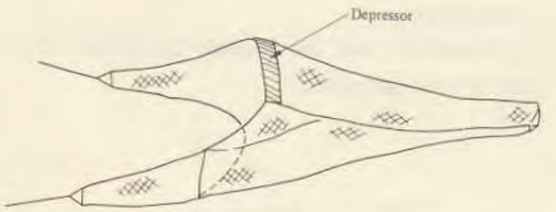

Fig. 1. Whole view of net

2. According to underwater observations, Miura expressed his opinion that such trawl nets could catch one-third of number of fish encountered by the net could be said to be a superior net in its fishing capacity.

3. Sugiura[2] made a statistical survey on floating trawl in Mikawa Bay and obtained values for sweep area of each trawl net over a year, for different kinds of gears and by different fishing areas using the following formula.

$a = \mathrm{bvt}\,N$

where, b is the horizontal distance of trawl net openings, v the speed of trawling, t average number of hours of trawling a day and N the total number of fishing boats in a year which actualy went fishing. After obtaining the a/A value, where A refers to different fishing areas in the bay, it could be suggested that even in the same area of good fishing where fishing operations were often repeated with considerable success, the fishing efficiency of floating trawl might involved this fact.

4. Some trawls use tickler chains for taking flat fish and shrimps from the mud in the bottom which is attached just in front of groundrope as shown in Fig. 2.

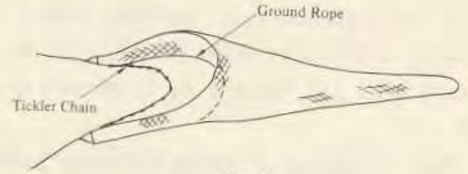

Fig. 2.

Parrish[3] made a fishing comparison between the trawl with and without tickler chain in a flat fish fishing ground using two experiment boats with different sized trawl nets. Major dimensions of these two trawl nets A&B are:

	A	B
Head line	80 ft	100 ft
Ground rope	48	46
Bosom	20	20
Top wings	32	39
Mesh size	6 inch	5.5 inch
Lower wings	66	54
Mesh size	5	5.5
Square	30	11
Mesh size	6	5.5
Belly	28	23
Mesh size	4.5–5.5	3.5–5.5
Baiting	28	23
Mesh size	4.5–5.5	3.5–5.5
Cod-end	21	22
Tickler-chain	½" chain	½" chain
purpose of net	Heavy ground rope, aiming mainly for flat fish	Light ground rope, aiming mainly for round fish

The results of the experiment were treated by the analysis of variance statistically and it is concluded that 1): the fishing efficiency of both nets are different according to the kinds of fish, 2): in the case of not using tickler-chain, the fishing efficiency of trawl net A is 13 times better in catching plaice and dab compared to that of trawl net B, 3): In the case of using tickler-chain, the fishing efficiency of both nets differ greatly as is seen in 2), 4): in the catches by trawl net A, whiting (a kind of cod) are less than trawl net B, no matter whether tickler chain is used or not, 5): in the catches by trawl net B, whiting decreases when tickler chain is used.

5. Nomura and callaboraters[4] expressed the result of trawl fishing experiments comparing three kinds of shrimp trawl nets (Mexican type net, half size of Maxican type and conventional Thai trawl net) using three fishing boats in the Gulf of Thailand. In the report, the differences of fishing efficiency are clear: 1) The proportion of fishing efficiency index of boats are expressed: $b_1:b_2:b_3=0.92:1.00:0.77$. Where, boat b_1 is 23 meters in length with 320 HP, b_2 is 23 meters with 335 HP and b_3 is 16 meters with 175 HP.

   2) The proportion of fishing efficiency index of nets in the case of catching shrimps are expressed: $d_1, d_2:d_3=1.00:0.31:0.41$. The dimensions of the three nets are shown below.

	Mexican type shrimp trawl net	Half size Mexican type shrimp trawl net	Commerical trawl net locally used
Head rope	28.2m	14.0m	28.2m
Ground rope	34.4	17.2	29.2
Safety rope	30	15	30
Bridle rope	5	5	5
Float	6 inch, 16 pcs.	6 inch, 8 pcs.	6 inch, 15 pcs.
Chain	¼", 34kg, each 5kg to the top of lower wing	¼", 24kg, each 3kg to the top end of lower wing	¼", 33.5kg, each 5kg to the top end of lower wing

6. Hickling[5] made a comparison in fishing efficiency between the trawl net with old fashion otter board directely joined with tip of the wing and the trawl net with V.D. type otter board. The value of E based on the following equation are calculated for every month and E (in percentage) show the range from minus 7% to plas 114%

   $$E=(V-S)/S$$

   Here, V is average catch volume per month using V.D type otter trawl and S is that of a month using old fashion otter board. The value of E increases in accordance with increase in familiarity with this modern fishing method at that time. The catch of cod coincides with the value of E each month, and it means that E changes with the density of cod school and is specially due to the increasing of height of net mouth when using V.D type otter board.

According to the actual experiences of trawl fishing in China sea, Goto[6] suggested the following arrangement of operation in the case of two-boat trawling in China sea.

1). Arrangement of rubbers and chains used as ground rope should be made according to the bottom nature.

2) In case of catching red sea bream-(*Pagrosomis major* TEMMINCK and SCHLEGEL), crimson sea bream-(*Evynnis japonica* TANAKA), yellow sea bream-(*Taius tumifrons* TEMMINCK and SCHLEGEL), croaker-(*Nibea mitsukurjj* J. et S.), hairtial-(*Trichiurus*), the trawling speed should be increased to about 3 to 3.5 miles per hour and the distance between two boats should be lessened to about 300 meters. Floats should be increased more than normal.

3) In case of catching gurnad-(*Chelidonichthys Kume* LESSON and GARNOT), dab-(*Limanda herzensteini* JORDAN and SNYDER), the ground rope should be heavier, the distance between two boats should be wider and trawling speed should be lowered to about 2 miles per hour.

4) Haritial, lizard fish and ray are caught only at night, while yellow sea brea, crimson sea bream gurnard and sharp toothed eel-(*Muraenesox cinereus* FOR SKAL) are mainly caught in day time. Furthermore guarnard is caught mainly at night when groundrope is light, and mainly in daytime when groundrope is heavy.

5) It can be said the brighter the colour of cod-end the better the catch.

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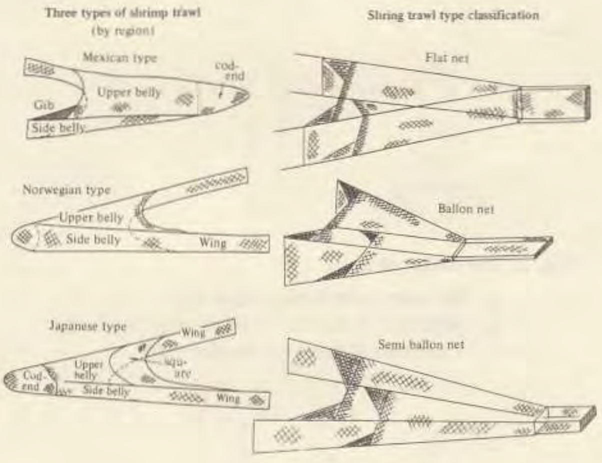
4) M. Nomura: Shrimp trawl fishing experiment, SEAFDEC, 1971.
5) C.F. Hickling: Journal du Conseil XI, 3, 1931.
6) G. Goto: Fisheries Lecture Series, Fishing (Vol. 7). 1953

3.4.4 Fishing comparison of Shrimp trawl by the experiment in Gulf of Thailand

The coastal waters of Southeast Asian countries, such as Indonesia, Thailand, Vietnam, Malaysia, etc., are rather rich in the shrimp resources. Thus, the fishing exploitation of shrimp, particulary in it's fishing technique, is very important for the region.

1. Trawl gear for shrimps

1) Types of shrimp trawl



2) Relationship between the length of elemental parts of a net

According to the study on the proportion of net design by Dr. Miyamoto[1], the essential parts length of shrimp trawl have the following relationship which are shown in the equations.

$B^{(ft)} = 0.7\,L + 6$

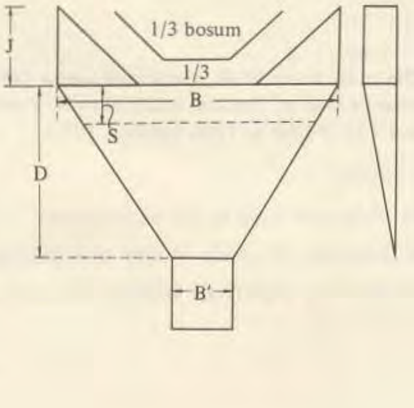
$D^{(ft)} = 0.7\,B + 2.3$

$B'^{(ft)} = 0.24\,B + 1$

$W^{(ft)} = 0.4\,B - 4$

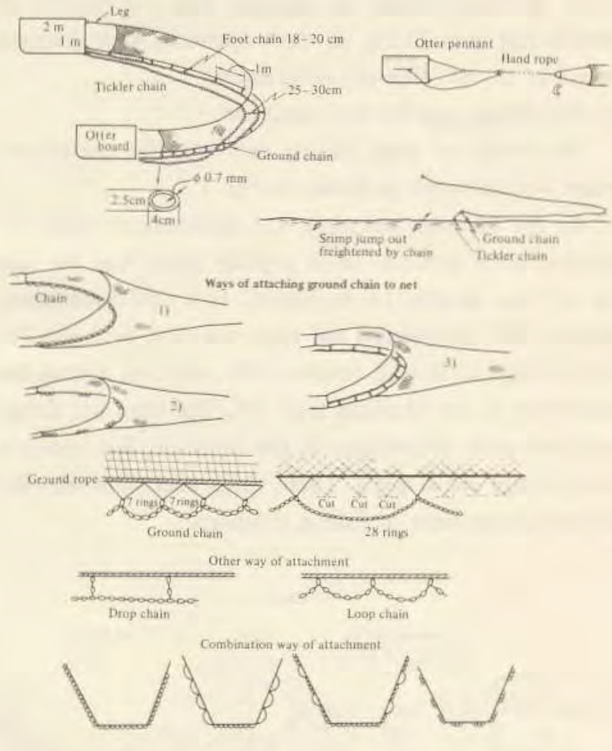
$S^{(ft)} = 0.1\,D + 1.5$

where L is the length of head rope in feet.



3) Chain

The composition of ground chain and tickler chain are given in the figures:



4) Otter board

The relation between the area of otter board and horse power is

$S = 0.105 \times p - 4$, if $p = 170$

then, $S = 0.105 \times 170 + 4 = 21\ ft^2$

The otter board $1^m \times 2^m = 40" \times 80" = 40 \times 80 \times (0.08)^2 = 20.5^{ft^2}$, the weight of O.B. (lb) = 2 x p + 17 = 2 x 170 + 17 = 357^{lb} = 160 kg. The O.B. should have shoes and space for water to pass through. The shoe (ski) is attached at the lower edge of O.B. The thickness of O.B. is more than 1 inch, width is 5 to 6 inches for operation depths of 30 meters and ¾ inch and 4 to 5 inch respectively for shallow water operation.

5) Warp

Warp length is better to be 7.5 times the length of headline length plus legs and/or sweeps.

2. Shrimp trawl experiment [2]

1) Procedure of the experiment

According to the fisheries census of the Fisheries Department of Thailand in the year of 1967 the number of shrimp beam trawl fisheries consists of about 424 units, 75 percent of which are small in boat size (less than 10 tons) and also small in size of net.

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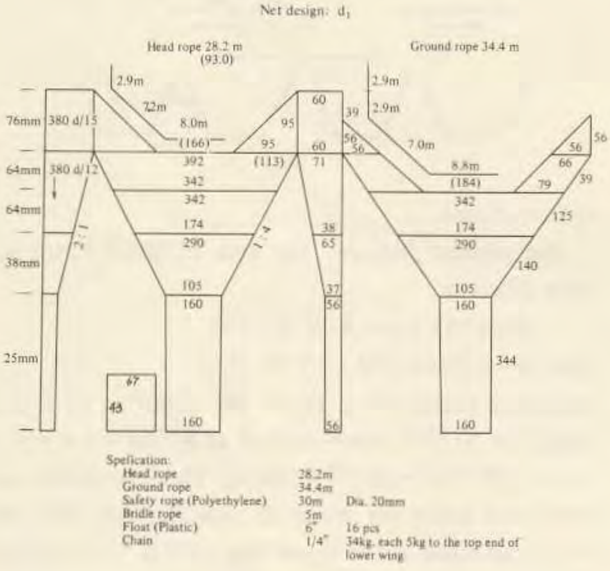
2) M. Nomura et al: Shrimp trawl fishing experiment – On the fishing comparison between Mexican net type and commercial type, Rep. SEAFDEC & Dept. Fisheries, Thailand, June, 1971

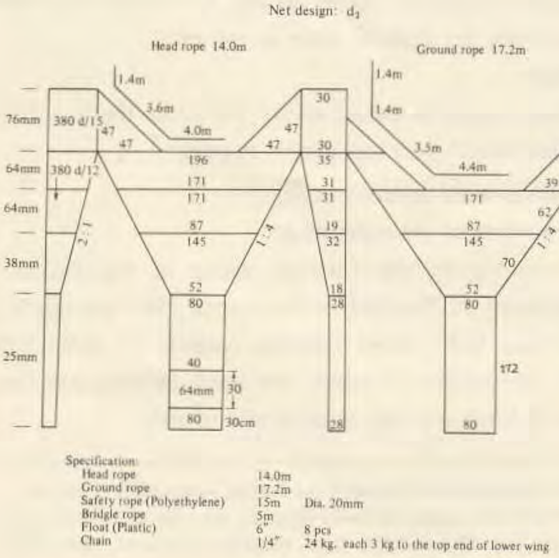
At the shrimp fishing ground, three vessels in this experiment were employed at the same time, the same place and under the same operating conditions, using three different shrimp net designs. The combination of vessels and nets during six days operation were changed as stated in the following programme.

2) Net design used for the experiment

The design of three shrimp nets used for the experiment were adopted as shown in Fig. 1.

As for Mexican net type, the semi-balloon type was applied since it is the most popular type. And the size of net was decided to correspond to a 180 horsepower engine. The commercial net type was used with just the same design as is used commercially, and was almost the same size as the Mexican type net. The third net design was the same proportion as the first one, but was just half in size in all parts. These three nets were adopted for the comparison of fishing efficiency.





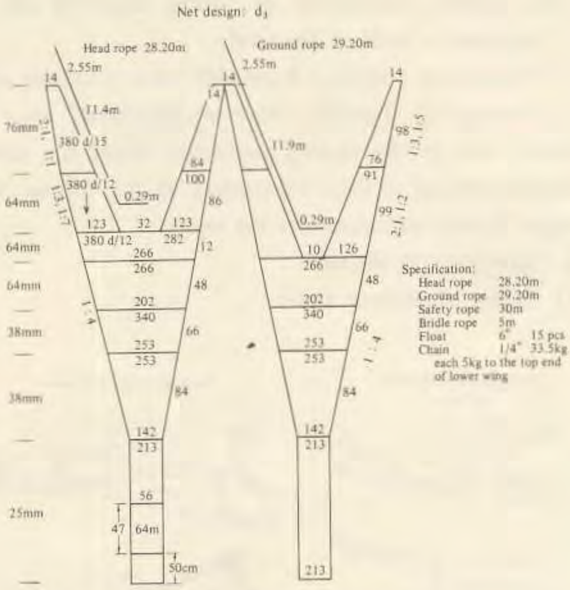


Fig. 1. The design of net

d_1 : Mexican type shrimp trawl net

d_2 : Half size of Mexican type shrimp trawl net

d_3 : Commercial trawl net localey used

Fig. 2. The cruise traces of six operational places off the east coast of Gulf of Thailand undertaken by Pramong 2,6 and 7 from 13th to 19th, January, 1971.

3) Symbols of factors used in the experiment

For the analysis of catch ability the following symbols concerning the important factors are used as shown in Table 1.

Table 1. The symbols of the factor

Factor	Symbol	Remarks
Boat	b_1	Pramong 2, L = 23m, O.B.: 2m x 1m
	b_2	Pramong 6, L = 23m, O.B.: 2m x 1m
	b_3	Pramong 7, L = 16m, O.B.: 1.8m x 0.9m
Net	d_1	Mexican type net (Semi-ballon)
	d_2	Half size of the above Mexican net (Same proportion)
	d_3	Commerical net type, almost same in size as d_1
Fishing time	n_1	17 : 00 – 18 : 00
	n_2	18 : 30 – 19 : 30
	n_3	20 : 00 – 21 : 00
	n_4	2 : 30 – 3 : 00
	n_5	4 : 00 – 5 : 00
	n_6	5 : 30 – 6 : 30
Fishing place	p_1	
	p_2	Fishing places from p_1 to p_6 are shown in Fig. 2.
	p_3	
	p_4	p_3 and p_6 are the same place.
	p_5	
	p_6	

3. Combination of factors, fishing experiment and the results of catch

The program of combination of net, boat and time during six days operation were carried out from 13th to 19th of January 1971, at the fishing ground around Chang Island (Ko Chang) as shown in Fig. 2. In six days' operational program, the former three days experiment can complete all combinations of a round, so that this could be referred to as the first round (hereinafter round I) experiment. The latter three days experiment, therefore, is referred to as the second round (hereinafter round II) experiment in this report. After round I experiment was completed, some improvement and change of gear conditions were carried out in consequent experiments of round II. The improvement and new condition of round II were as follows:

d_1: With 5 meters bridle rope between leg and otter board

d_2: With 7 meters extension wing (detachable net was placed in between upper and lower part of bridle rope and leg respectively as extension wing)

d_3: Making lower leg of both sides 1 meter longer, so that the total length of ground rope became 31.20 meters, and with 5 meters bridle rope same as d_1.

The way of attachment of the ground chain to the ground rope was changed in all nets.

The comparative fishing experiments were conducted in the following operational system where two boats b_1 and b_3 kept the same direction as the leader boat b_2 100 meters distant from each other, trawling the net just one hour and always keeping a towing speed of 2.0 miles per hour.

The schedule and experimental combination of net, boat and time are tabulated in Table 2.

The catch result by experimental combination of round I and round II are tabulated in Table 3.

4. Results of analysis on the catch

1). Appreciation by figures

On the basis of the catch statistics shown in Table 3, the catch between nets (d) and boats (b) of round I experiment and round II experiment are illustrated in Fig. 3.

According to these figures, the catches of Shrimp total, Fish (duck fish plus commercial fish) total and Grand total show a characteristic trend. It seems there are different catches according to kind of net.

Next, the catch classified by nets (d) and places (p) of rounds I and II are also illustrated in Fig. 4. The differences of catch by nets (d) and places (p) are more clearly seen in this figure than Fig. 3.

The catch classified by operational time (n) in each day on Shrimp and Fish (duck fish plus commercial fish) are shown in Fig. 5.

From the figures, it is realized that there might be no system in the Shrimp and Fish catch by operational time through 1st day to 6th day.

2) Evaluation by the analysis of variance

a. Two-factor; boat and net

In the cases of the factors of more than two populations we shall consider the very general technique known as the analysis of variance (A.V.). The object of A.V. is to provide statistics which are useful in comparing population means. The method can be used only with normal variables. The general procedure of A.V. is to determine how much of a variation in our observation is due to population differences, and how much to random variability by comparing the contribution of these two kinds of variation we can determine the importance of the population differences.

The most convenient measure of variation with a normal variable is a sum of squares. All A.V. begin, therefore, by the computation of a sum of squares to measure the overall variation of all the samples taken together; this is total sum of squares. Next, the calculation is done on how much of the variation can be ascribed to the population differences that interest us, and then, by substracting this varation from the total sum of squares, we obtain the residual sum of squares which measures the contribution of random effects on the overall variation.

Table 2. Schedule and experimental combination of net, boat and time during 6 days operation (2 rounds)

	12th Jan.	Leave Bangkok (Morning) ; Banpae, Preliminary operation (Afternoon)								
	13th	Preliminary operation (Day time), Leave Banpae to fishing ground (Ko Chang)								
	13th	Evening to night				14th	Night to morning			
		Boat	b_1	b_2	b_3		Boat	b_1	b_2	b_3
		Net	d_1	d_2	d_3		Net	d_1	d_2	d_3
		n_1	$n_1b_1d_1$	$n_1b_2d_2$	$n_1b_3d_3$		n_4	$n_4b_1d_1$	$n_4b_2d_2$	$n_4b_3d_3$
		n_2	$n_2b_1d_1$	$n_2b_2d_2$	$n_2b_3d_3$		n_5	$n_5b_1d_1$	$n_5b_2d_2$	$n_5b_3d_3$
		n_3	$n_3b_1d_1$	$n_3b_2d_2$	$n_3b_3d_3$		n_6	$n_6b_1d_1$	$n_6b_2d_2$	$n_6b_3d_3$
		Person	19	20	13		Person	19	20	13
		Place		p_1			Place		p_1	
Round I	14th	Evening to night				15th	Night to morning			
		Boat	b_1	b_2	b_3		Boat	b_1	b_2	b_3
		Net	d_2	d_3	d_1		Net	d_2	d_3	d_1
		n_1	$n_1b_1d_2$	$n_1b_2d_3$	$n_1b_3d_1$		n_4	$n_4b_1d_2$	$n_4b_2d_3$	$n_4b_3d_1$
		n_2	$n_2b_1d_2$	$n_2b_2d_3$	$n_2b_3d_1$		n_5	$n_5b_1d_2$	$n_5b_2d_3$	$n_5b_3d_1$
		n_3	$n_3b_1d_2$	$n_3b_2d_3$	$n_3b_3d_1$		n_6	$n_6b_1d_2$	$n_6b_2d_3$	$n_6b_3d_1$
		Person	19	20	13		Person	19	20	13
		Place		p_2					p_2	
	15th	Evening to night				16th	Night to morning			
		Boat	b_1	b_2	b_3		Boat	b_1	b_2	b_3
		Net	d_3	d_1	d_2		Net	d_3	d_1	d_2
		n_1	$n_1b_1d_3$	$n_1b_2d_1$	$n_1b_3d_2$		n_4	$n_4b_1d_3$	$n_4b_2d_1$	$n_4b_3d_2$
		n_2	$n_2b_1d_3$	$n_2b_2d_1$	$n_2b_3d_2$		n_5	$n_5b_1d_3$	$n_5b_2d_1$	$n_5b_3d_2$
		n_3	$n_3b_1d_3$	$n_3b_2d_1$	$n_3b_3d_2$		n_6	$n_6b_1d_3$	$n_6b_2d_1$	$n_6b_3d_2$
		Person	19	20	13		Person	19	20	13
		Place		p_3			Place		p_3	
	16–17th	Same as 13–14th, Place p_4								
Round II	17–18th	Same as 14–15th, 〃 p_5								
	18–19th	Same as 15–16th, 〃 p_6 (Same as p_3)								
	20th	Physical measurement on net (Day time) at Banpae								
	21st	ditto								
	22nd	Arrangement, Going back to Bangkok								

Table 3. An overall table showing the catch for each boat in relation to net design and operational time

Round I

1st Day (13–14)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_1							d_2							d_3						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	–	–	0.19	–	0.32	0.59,		–	0.06	–	0.08,	0.06	0.18		0.40	0.30	0.25	0.08	0.45	0.40	
	M.S.	0.34	0.06	0.27,	0.31	0.25	0.26		0.06	–	0.07,	0.05	–	0.09		0.15	0.15	0.75	0.04	0.08	0.05	
	S.S.	21.73	8.03	11.51,	11.55	14.87	12.83,		6.44	4.10	3.32	0.115	8.20	3.73		10.00	3.25	2.05	0.93	2.21,	1.20	
	T.	22.07	8.09	11.98	11.92	15.44	13.69	83.19	6.50	4.16	3.39,	0.25	8.26	4.00	26.56	10.55	3.70	3.05	1.05	2.74,	1.65	22.74,
Duck Fish		13.45	41.20	42.50	28.00	52.00	9.70	186.85	29.00	20.00	22.00	20.00	18.00	15.50	124.50	21.00	9.20	9.60	7.20	5.50	6.00	58.50
Com. Fish		19.30	16.17	20.14	20.59	17.04	24.70	117.94	8.98	7.87	11.46	10.01	9.10	13.85	61.27	6.60	2.60	4.90	2.09	2.49	6.00	24.68
Gr. Total		54.82	65.46	74.62	60.51	84.48	48.09	387.38	44.48	32.03	36.86	30.26	35.36	33.35	212.34	38.15	15.50	17.55	10.34	10.73	13.65	105.92

2nd Day (14–15)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_2							d_3							d_1						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	0.14	–	0.13,	–	–	–		–	–	0.14,	—	0.21	–		0.10	0.62	1.80	0.42	0.45	0.10	
	M.S.	0.09	0.23	0.54	0.19	0.05,	0.03		–	0.34,	1.08,	0.39	0.13	0.05		0.18	0.44	0.52	0.22	0.23	0.12	
	S.S.	1.03,	1.06,	1.66	2.35	3.56	3.90		0.01	3.85,	3.07	5.71	7.86	0.15		1.50	5.00	7.80	7.80	9.40	12.00	
	T.	1.26,	1.29,	2.33,	2.54	3.61,	3.93	14.98	0.01	4.20	4.31	6.10	8.20	0.20	23.02	1.78	6.06	10.12	8.44	10.08	11.22	48.70
Duck Fish		2.20	15.40	13.65	13.84	11.50	16.20	72.79	2.68	5.05	4.20	7.83	15.24	3.50	38.50	19.65	45.00	11.70	28.00	25.30	11.60	141.25
Com. Fish		7.72,	9.23,	9.01,	9.15	12.69,	6.69	54.51	7.60	4.56	10.18	4.20	14.62	6.50	47.66	4.15	9.80	11.02	12.05	21.42	11.14	69.58
Gr. Total		11.19	25.93	25.00	25.53	27.81	26.82	142.28	10.29	13,81	18.63	18.13	38.06	10.20	109.18	25.58	60.86	32.84	48.49	56.80	34.96	259.53

3rd Day (15–16)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_3							d_1							d_2						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	–	0.27	0.56	0.80	0.13	–		–	0.37	1.38	1.14	0.18	–		–	0.26	1.14	0.85	0.38	0.20	
	M.S.	–	0.62	0.95	0.66	0.25	0.17,		0.28	0.87	1.94	0.58	1.04	0.77		0.02	0.14	0.29	0.08	0.14	0.09	
	S.S.	0.03,	4.59	7.21	1.26,	3.33	3.91		3.82	14.64	16.88	14.28	29.58	27.73		0.40	2.90	4.10	2.01	4.02	5.50	
	T.	0.03,	5.48	8.72	2.72,	3.71	4.08,	24.75	4.10	15.90	20.20	16.00	30.80	28.50	115.50	0.42	3.30	5.53	2.94	4.54	5.79	22.52
Duck Fish		1.78	10.50	15.50	1.55	6.30	7.50	43.13	12.80	14.50	12.70	4.60	6.40	17.80	68.80	5.85	9.74	12.20	10.06	8.12	14.00	59.97
Com. Fish		8.41	42.67	7.28	10.84	11.01	9.57	89.78	9.80	67.20	21.04	24.39	22.29	17.65	162.37	20.60	32.60	7.60	3.30	8.66	13.22	85.98
Gr. Total		10.22,	58.65	31.50	15.11,	21.02	21.15,	157.66	26.70	97.60	53.94	44.99	59.49	63.95	346.67	26.87	45.64	25.33	16.30	21.32	33.01	168.47

Note: Sh.: Shrimp, B.S.: Big shrimp, M.S.: Medium size shrimp, S.S.: Small size shrimp, T.: Total

Round II

4th Day (16–17) (16–17)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_3							d_1							d_2						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	–	0.38	0.70,	0.07	0.07,	0.60		0.40	0.60	0.80	0.40	0.52	0.65		–	0.66	0.86	0.54	0.16	0.46	
	M.S.	–	0.87	0.98	0.67,	0.46	0.37		0.04	1.70	1.48	1.33	1.04	0.50		–	0.08	0.10	0.01	0.02	–	
	S.S.	0.06	0.16	0.20,	0.52	0.30,	0.13		0.10	–	0.42	1.07	0.94	–		0.02	0.02	0.04	0.02	0.06	0.72	
	T.	0.06	1.41	1.89	1.26,	0.84	1.10	6.56,	0.54	2.30	2.70	2.80	2.50	1.15	11.99	0.02	0.76	1.00	0.57	0.24	1.18	3.77
Duck Fish		25.20	0.50	1.70	10.00	11.09	1.50	49.99	37.45	16.75	5.00	8.00	8.00	3.00	78.20	32.32	12.60	0.70	8.81	7.00	4.50	65.93
Com. Fish		30.21	14.93	14.56	11.87	10.96	22.21	104.74	50.34	51.01	20.13	19.74	19.63	22.71	183.56	17.12	19.05	5.90	9.53	9.56	7.52	68.68
Gr. Total		55.47	16.84	18.15	23.13,	22.89	24.81	161.29,	88.33	70.06	27.83	30.54	30.13	26.86	273.7,	49.46	32.41	7.60	18.91	16.80	13.20	138.38

5th Day (17–18)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_2							d_3							d_1						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	0.08,	0.51	0.38	0.16,	1.02	0.07,		0.20	1.24	0.49	0.60	0.40	0.58		0.25	0.58	0.44	1.50	1.88	0.96	
	M.S.	0.14	0.32	0.17	0.35,	0.30	0.14,		–	0.76	0.58	0.13,	0.42	–		0.01	0.16	0.30	0.82	0.28	0.08	
	S.S.	0.01,	0.21	0.07	0.38	0.24	0.31		0.01	0.40	0.13	0.66,	0.18	0.55		0.01	0.42	0.02	–	0.64	1.20	
	T.	0.24	1.04	0.62	0.90	1.56	0.53	4.89	0.21	2.40	1.20	1.40	1.00	1.13	7.34	0.27	1.16	0.76	2.32	2.80	2.24	9.56
Duck Fish		3.57	0.90	6.85	4.00	4.50	2.00	21.82	3.44	8.40	11.20	20.00	11.25	5.76	60.05	27.54	19.32	27.62	21.00	14.16	20.90	130.54
Com. Fish		18.64	6.19	9.18	11.34	4.32	17.39	67.06	22.23	10.23	13.99	14.20	6.97	42.50	110.12	9.64	12.57	11.62	9.10	6.12	18.22	67.27
Gr. Total		22.45	8.13	16.65	16.24	10.38	19.92	93.77	25.88	21.03	26.39	35.60	19.22	49.39	177.51	37.45	33.05	40.00	32.42	23.08	41.36	207.36

6th Day (18–19)		Pramong 2 (b_1)							Pramong 6 (b_2)							Pramong 7 (b_3)						
		d_1							d_2							d_3						
		n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T	n_1	n_2	n_3	n_4	n_5	n_6	T
Sh.	B.S.	0.07,	0.06	1.25	0.66	0.29	0.45,		–	–	1.17	0.48	0.28	–		0.12	0.44	0.34	0.10	0.76	0.22	
	M.S.	0.19	0.88	1.57	1.06	1.07	0.42		–	0.51	0.56	0.15	0.23	0.15		0.20	0.52	0.28	–	0.22	0.12	
	S.S.	7.94,	19.20	7.13	5.60	5.32	0.72,		3.30	3.89	1.27	0.32	1.69	0.45		3.20	10.00	1.51	0.50	2.02	0.28	
	T.	8.21	20.14	9.95	7.32	6.68	1.60	53.90	3.30	4.40	3.00	0.95	2.20	0.60	14.45	3.52	10.96	2.13	0.60	3.00	0.62	20.83
Duck Fish		24.30	21.14	25.00	55.00	43.00	10.00	178.44	7.50	5.00	3.50	11.80	9.00	18.00	54.80	17.80	21.40	9.26	3.90	22.44	35.20	110.00
Com. Fish		13.67	24.38	31.75	45.10	43.10	38.73	196.73	8.88	7.51	8.96	12.97	20.80	28.33	87.45	5.40	9.94	4.14	2.70	12.76	20.95	55.89
Gr. Total		46.18	65.66	66.70	107.42	92.78	50.33	429.07	19.68	16.91	15.46	25.72	32.00	46.93	156.70	26.72	42.30	15.53	7.20	38.20	56.77	186.72

Note: Duck Fish: Trash fish Com. Fish: Commercial fish Gr. Total: Grand total

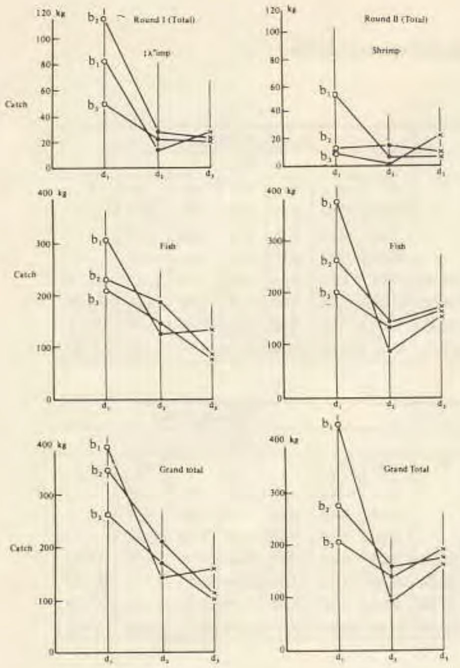


Fig. 3. Catch difference between nets (d)

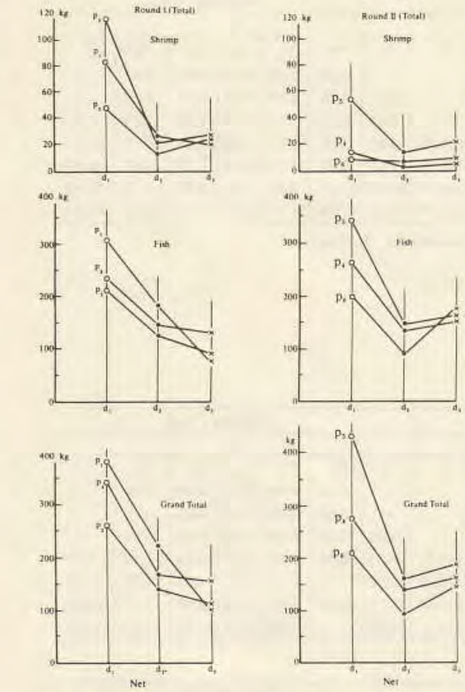


Fig. 4. Catch difference classified by net (d) and fishing place (p)

In the two-factor classification, we have the factors, boat and net, at K and N levels, giving KN observations in all as shown in Table 4.

Table 4. General formulae for the two-factor, boat and net at K and N levels for analysis of variance

Factor b / Factor d		Boat	Total	Mean
		$b_1\ b_2\ b_3\ \cdots\cdots\ b_k$		
Net	d_1	$x_{11}\ x_{21}\ x_{31}\ \cdots\cdots\ x_{k1}$	$x_{.1}$	$\bar{x}_{.1}$
	d_2	$x_{12}\ x_{22}\ x_{32}\ \cdots\cdots\ x_{k2}$	$x_{.2}$	$\bar{x}_{.2}$
	·	$\cdots\cdots\ x_{ij}\ \cdots$		
	·	$\cdots\cdots\ \cdots$		
	d_N	$x_{1N}\ x_{2N}\ x_{3N}\ \cdots\cdots\ x_{kN}$	$x_{.N}$	$\bar{x}_{.N}$
Total		$x_{1.}\ x_{2.}\ x_{3.}\ \cdots\cdots\ x_{k.}$	x	
Mean		$\bar{x}_{1.}\ \bar{x}_{2.}\ \bar{x}_{3.}\ \cdots\cdots\ \bar{x}_{k.}$		$\bar{x}$

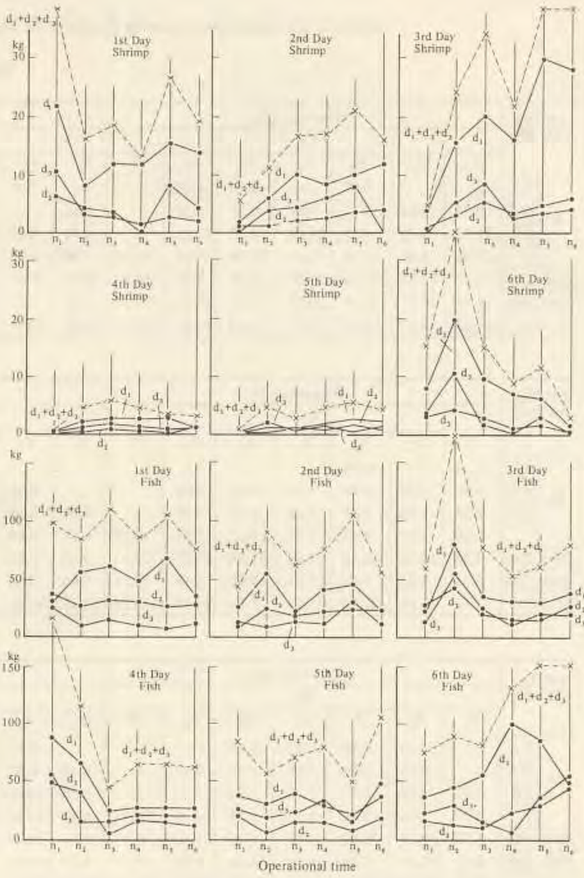


Fig. 5. Catch variation by operational time

From this table we can calculate the following variation.

1) Total sum of squares

$$S_{bd} = \sum_{i=1}^{K} \sum_{j=1}^{N} (x_{ij} - \bar{x})^2 = \sum_{i=1}^{K} \sum_{j=1}^{N} x_{ij}^2 - \frac{x^2}{KN}$$

2) Sum of squares between boats (Columns)

$$S_b = N \sum_{i=1}^{K} (\bar{x}_{i.} - \bar{x})^2 = \frac{1}{N} \sum_{i=1}^{K} x_{i.}^2 - \frac{x^2}{KN}$$

3) Sum of squares between nets (Rows)

$$S_d = K \sum_{j=1}^{N} (\bar{x}_{.j} - \bar{x})^2 = \frac{1}{K} \sum_{j=1}^{N} x_{.j}^2 - \frac{x^2}{KN}$$

The analysis of variance is shown in the table below.

Factors	Sum of squares (s.s)	Degree of freedom (d.f)	Mean square (M.s)	Variance ratio (F)
Between boats	S_b	$K-1$	$\frac{S_b}{K-1}$	Boat M.s / Res. M.s
Between nets	S_d	$N-1$	$\frac{S_d}{N-1}$	Net M.s / Res. M.s
Residual	$S_{bxd} = \sum_{i=1}^{K}\sum_{j=1}^{N}(\bar{x}_{ij}-\bar{x}_i-\bar{x}_j+\bar{x})^2$	$(M-1)\times(N-1)$	$\frac{S_{bxd}}{(N-1)(K-1)}$	
Total	$S_{bd} = \sum_{i=1}^{K}\sum_{j=1}^{N}(x_{ij}-\bar{x})^2$	$KN-1$		

Then, we can calculation whether the differences between boats and between nets are significant or not respectively at 1 percent or 5 percent level by judging the value of variance ratio compared with the values of F-table.

Following this process, the catch data of round I, shrimp on b and d factors are tabulated from the data of Table 3 as shown in Table 5.

Table 5. Catch data round I, shrimp on b and d

d \ b	b_1	b_2	b_3	T
d_1	83.19	115.50	48.70	247.39
d_2	14.98	26.57	22.52	64.07
d_3	24.75	23.02	22.75	70.52
T.	122.92	165.09	93.97	381.98

In the same arrangement for round I Fish and round I Grand total, the variance ratio of two factors, b and d, by taking logarithmic value of catch, are calculated as shown in Table 6.

Table 6. Analysis of variance, round I

Factor	Sym-bol	d.f	Variance ratio F		
			Shrimp	Fish	Grand total
Boat	b	K−1 = 2	1.12	0.79	0.85
Net	d	N−1 = 2	18.02**	12.51*	16.03*
Residual	bxd	(K−1)(N−1)=4			
Total	b d	KN−1=8	$F^2_4(0.05)=6.94$, $F^2_4(0.01)=18.00$		

From this table, in all three cases, the factor d is significant at 5 and 1 percent levels.

b. Two-factor; net and operational time

Next, the data are arranged by two factors d (net) and n (operational time). The catch data of 1st day, Shrimp from the data of Table 3 is shown in Table 7.

Table 7. Catch data of 1st day, Shrimp on d and n

n \ d	d_1	d_2	d_3	T
n_1	22.070	6.500	10.550	39.120
n_2	8.090	4.160	3.700	15.950
n_3	11.980	3.395	3.050	18.425
n_4	11.920	0.250	1.050	13.220
n_5	15.440	8.260	2.745	26.445
n_6	13.690	4.000	1.650	19.340
T	83.190	26.565	22.745	132.500

After arranging the same kind of treatment, making tables independently on Shrimp and Grand total of 1st, 2nd, 3rd, 4th, 5th, and 6th day respectively, the variance ratio on these 12 cases were tabulated in Table 8.

Table 8 (1) Analysis of variance, 1st day, 2nd day and 3rd day

Factor	Sym-bol	d.f	Variance ratio F					
			1st day		2nd day		3rd day	
			Shrimp	G.Total	Shrimp	G.Total	Shrimp	G.Total
Net	d	2	32.72**	32.19**	9.00**	16.97**	52.36**	29.50**
Operational time	n	5	5.10*	0.95	2.43	3.08	4.20*	12.40**
Residual	dxn	10						
Total	dn	17						

$F^2_{10}(0.05)=4.10$, $F^2_{10}(0.01)=7.55$, $F^5_{10}(0.05)=3.33$, $F^5_{10}(0.01)=5.64$

Table 8 (2) Analysis of variance, 4th day, 5th day and 6th day

Factor	Sym-bol	d.f	Variance ratio F					
			4th day		5th day		6th day	
			Shrimp	G.Total	Shrimp	G.Total	Shrimp	G.Total
Net	d	2	6.00*	8.57*	2.4	17.62**	10.97**	9.65**
Operational time	n	5	1.70	8.80**	2.32	4.20*	6.01**	0.73
Residual	dxn	10						
Total	dn	17						

From this table, it is seen that factor d is quite significant at 1 percent level, but factor n is only sometimes significant. The result of factor n has already been discussed with Fig. 5.

c. Three-factor; net, place and operational time

The Shrimp catches, x_{ijf}, factors d, p and n of round I, are arranged in Table 9.

Table 9. Shrimp catch data of round I, relating to d, p and n

d	d_1			d_2			d_3		
n \ p	p_1	p_2	p_3	p_1	p_1	p_2	p_3	p_1	p_3
n_1	22.07	1.78	4.10	6.50	1.265	0.42	10.55	0.01	0.035
n_2	8.09	6.06	15.90	4.16	1.295	3.30	3.70	4.20	5.48
n_3	11.98	10.12	20.20	3.395	2.335	5.53	3.05	4.31	8.72
n_4	11.92	8.44	16.00	0.25	2.54	2.94	1.05	6.10	2.725
n_5	15.44	10.08	30.80	8.26	3.615	4.54	2.745	8.20	3.71
n_6	13.69	12.22	28.50	4.00	3.93	5.79	1.65	0.20	4.085
T	83.19	48.70	115.50	26.565	14.98	22.52	22.745	23.02	24.75

$$\sum_{i=1}^{K}\sum_{j=1}^{L}\sum_{f=1}^{N} x_{ijf} = 381.97$$

Assuming that the difference of catch between nets will not be equal according to place and operational time, the interaction of d x p and d x n should be discussed as factors. Thus, after making the same calculation, we get the analysis of variance on three-factor as shown in Table 10.

Table 10. Analysis of variance, round I, Shrimp

Factor	s.s	d.f	M.s	Variance ratio
d	1202.49	2	601.25	33.60**
p	162.97	2	81.48	4.54*
n	135.74	5	27.15	1.51
d x p	220.72	4	55.18	3.08*
d x n	155.61	10	15.56	0.87
Error	537.47	30	17.91	
Total	2415.00	53		

$F^{2}_{30}(0.05)=3.32$, $F^{2}_{30}(0.01)=5.39$, $F^{4}_{30}(0.05)=2.69$, $F^{10}_{30}(0.05)=2.16$

From the table of analysis of variance we can get the following results.

1) The difference between net (d) is significant at 1 percent level indicating d_1, d_3, d_2 as the orders of catching efficiency.
2) The difference between operation place (p) is also significant at 5 percent level indicating p_3, p_1, p_2 as the orders of efficiency.
3) The difference between operational time (n) is far from significant.
4) The interaction d x p may be significant.
5) Thre is no significance in the interaction d x n.

In the same manner, analysis of variance, round II, Shrimp could be tabulated also in Table 11.

Table 11. Analysis of variance, round II, Shrimp

Factor	s.s	d.f	M.s	Variance ratio
d	83.948	2	41.974	6.99**
p	176.333	2	88.166	14.69**
n	77.575	5	15.515	2.59*
d x p	63.720	4	15.930	2.65
d x n	23.779	10	2.378	0.39
Error	179.969	30	5.999	
Total	605.324	53		

From the table of analysis of variance the difference between net (d), the difference between operating places (p) and the difference between operational time (n) are all significant, giving the orders of superiority as d_1, d_3, d_2; p_6, p_4, p_5 and n_2, n_1, n_5, n_3, n_6, n_4.

d. The orders of superiority in net design

Through the discussion on the analysis of variance in a to c, the orders of catch efficiency between net are clearly indicated in the following Table 12.

Table 12. Orders of catch efficiency between nets

Object \ Order	Superiority orders in catch		
	1	2	3
Round I Shrimp	d_1	d_3	d_2
" Fish	d_1	d_2	d_3
" G. Total	d_1	d_2	d_3
Round II Shrimp	d_1	d_3	d_2
" Fish	d_1	d_3	d_2
" G. Total	d_1	d_3	d_2

5. Discussion

1) The fishing efficiency of Mexican type net

As clearly understood in Table 12, Mexican type trawl net d_1 showed the highest fishing capability in shrimp fishing when it was compared with commercial trawl net d_3, which almost the same size as d_1. Perhaps, one of the main reasons is that d_3, constructed with two-seam net, will have smaller opening height in the net mouth than d_1, a four-seam net. The adequate design of Mexican trawl net, the type of flat, balloon and semi-balloon for instance, should be adopted for the kind of shrimp and the character of fishing ground through further experimenting. The size of net also should be decided according to the size of engine power of boat.

2) Improvement of the gear in the experiment

a. Chain attachment and ground rope

The method of joining the chain to ground rope differed in round I experiment and round II.

We could not yet see the effectiveness of changing the method of joining the chain because we could not compare the catch itself on this point in round I and round II experiment, but this problem is rather important for designing the net. It will be related to the condition of fishing ground.

As for the tickler chain, it is rigged between the otter boards or from the groundrope extensions. It scares the shrimp up off the bottom and drives them into the net which is a little ahead of the ground rope. Sometimes the ground rope can take interspace a little from the bottom because of this tickler chain, if the bottom is not very smooth or is rubbishy. Ordinarily, the distance between ground chain and tickler chain is 25 to 30 centimeters at the center of net, and this distance will have some connection with the speed of pulling, and bottom nature.

For catching not only shrimp, but also fish rather high speed of 3 to 3.5 miles per hour will be necessary for this particular purpose. And the weight of ground rope and chain might be increased.

b. Bridle rope and extension wing (detachable wing)

On the discussion of shrimp trawl experiment at Cochin, India, Dr. Miyamoto pointed out the catch is related to the horizontal spreading of the mouth of net rather than the opening height of the net. The experiments were made on the comparison of catch between having a sweep line (bridle rope) and not, and also the comparison of catch between having a detachable wing and not.

The design of Mexican type shrimp has usually a short wing. On the other hand, both Japanese type and Norwegian type net has a long with in construction. Therefore it is very much worth while to study the effectiveness of the length of wing for the catch of shrimp.

The shrimp catch ratio of d_1 to d_2 in round I and round II are shown in Table 13.

Table 13. Shrimp catch ratio of d_1 to d_2

	Round I		Round II
1st day	$\frac{83.19}{26.56} = 3.2$	4th day	$\frac{11.99}{3.77} = 3.2$
2nd day	$\frac{48.70}{14.98} = 3.3$	5th day	$\frac{9.55}{4.89} = 2$
3rd day	$\frac{115.50}{22.52} = 5.1$	6th day	$\frac{53.90}{14.45} = 3.7$

Comparing round I and round II from this table, the catch ratio of round I is a little bigger than that of round II. This difference may be caused by the effect of improvement of the gear in round II, but it is not so clearly seen with the effect of detachable wing. Therefore the problem of increasing the horizontal spread of the mouth of net is also an important subject to study for shrimp trawl net operations in these areas, and it must be in close connection with the behaviour of shrimp particularly when they come out off the bottom scared by chain.

c. Arrangement of the length of ground rope

On commercial net d_3 at round II experiment, the length of the ground rope was made 2 meters longer than round I experiment. This operation must bring the otter board into heel down. Thus, this improvement on the gear may result with some effect in the catch of round II as seen in Table 12.

d. Comparison of catch between full size d_1 and half size net d_2

Actually, in this experiment, the catch of shrimp itself was insufficeint. So, it may be difficult to make absolute conclusions on the catch ratio of d_1 to d_2. Bearing this in mind, however, when we contemplate Table 13, some consideration might be paid on the comparison between 2-net system trawling and 1-net system trawling as follows. From the table the catch of half size net d_2 is nearly one-third of the catch of full size net d_1. Therefore, the ratio of the catch of 1-net system trawl net of a certain length, to the catch of 2-net system trawl net of half length of the former will be nearly 3 to 2. Accordingly, the size of 2-net system trawl net should be decided as nearly three-fourths the length of 1-net system net for taking the same catching ability.

Then the ratio of hydraulic resistance of net between these two systems will be:

$$1^2 : 2 \times (3/4)^2 = 1 : 1.1$$

So, the hydraulic resistance to the boat will be the same in value if we obey this calculation.

3) Discussion the comparative efficiency by simple mathematical analysis[3)]

In discussing the comparative efficiency of different designs of shrimp trawl nets, the following symbols are used.

b is the Index of fishing efficiency of the boat relating to the type of boat, engine, fishing facilities and skill or cooperative attitude of crews engaged in the fishing operation.

d is the Index of fishing efficiency of the net relating to the design of net.

p is the Index of the object fish and shrimp existent in the fishing ground.

n is the Index of fishing effect by the time of fishing operation, and,

c is the catch quantity (by weight) per operation.

Assuming that the Indices **b, d, p** and **n** are independent, **c** is expressed as $c \propto b, d, p, n$.

a. From table 3 in which the data of round I and round II are treated together, the catching order from 1 to 6 of the Shrimp total according to the time n_1 to n_6 are shown in Table 14.

Table 14. Catching order according to n (Put together from p_1 to p_6)

		n_1	n_2	n_3	n_4	n_5	n_6
Catching order	1	2	4	2	1	5	4
	2	3	4	5	3	2	1
	3	1	2	5	3	4	3
	4	0	4	4	4	4	2
	5	0	3	2	4	3	6
	6	12	1	0	3	0	2

3) This discussion was based upon the letter from Dr. M. Tauchi, Honorary Professor of Tokyo University of Fisheries, to Dr. M. Nomura, SEAFDEC.

Observing this table, n does not seem to be related to c. Even in the same fishing place of 3 day and 6 day operation, Table 15 following the same arrangement as Table 14 indicates also that n does not seem to be related to c.

Table 15. Catching order according to n (on p_3 and p_6)

		n_1	n_2	n_3	n_4	n_5	n_6
Catching order	1	0	(3)	1	0	1	1
	2	(2)	1	1,(1)	0	0	1
	3	(1)	0	1,(1)	0	1,(1)	1
	4	0	1	(1)	1,(1)	1,(1)	0
	5	0	1	0	2,(1)	(1)	(1)
	6	3	0	0	(1)	0	(2)

The numerals with parenthesis are the p_6 case

b. From the result of a, $n_1=n_2=n_3=n_4=n_5=n_6=1$ will be permissable. Then c is expressed as $c \propto$ b.d.p. The following expressions, therefore, can be made from the catch data of Shrimp total in Table 3.

$$\frac{p_1b_1d_1}{83.19}=\frac{p_1b_2d_2}{26.565}=\frac{p_1b_3d_3}{22.745} \qquad (1)$$

$$\frac{p_2b_1d_2}{14.98}=\frac{p_2b_2d_3}{23.02}=\frac{p_2b_3d_1}{48.70} \qquad (2)$$

$$\frac{p_3b_1d_3}{24.75}=\frac{p_3b_2d_1}{115.50}=\frac{p_3b_3d_2}{22.52} \qquad (3)$$

$$\frac{p_4b_1d_3}{6.565}=\frac{p_4b_2d_1}{11.99}=\frac{p_4b_3d_2}{3.77} \qquad (4)$$

$$\frac{p_5b_1d_2}{4.98}=\frac{p_5b_2d_3}{7.34}=\frac{p_5b_3d_1}{9.55} \qquad (5)$$

$$\frac{p_6b_1d_1}{53.90}=\frac{p_6b_2d_2}{14.45}=\frac{p_6b_3d_3}{20.83} \qquad (6)$$

From the equations (1) and (6), the relation of

$$\frac{(b_1d_1)^2}{83.19\times53.90}=\frac{(b_2d_2)^2}{26.565\times14.45}=\frac{(b_3d_3)^2}{22.745\times20.83}$$

is found, thus giving equation (7)

$$\frac{b_1d_1}{66.5}=\frac{b_2d_2}{19.65}=\frac{b_3d_3}{21.75} \qquad (7)$$

In the same way, the following equations may be obtained.

From (2) and (5);

$$\frac{b_1d_2}{8.64}=\frac{b_2d_3}{13.0}=\frac{b_3d_1}{21.56} \qquad (8)$$

and,

from (3) and (4);

$$\frac{b_1d_3}{12.75}=\frac{b_2d_1}{37.2}=\frac{b_3d_2}{9.21} \qquad (9)$$

Multiplying equations as (7) X (8) X (9), the relation of

$$\frac{b_1^3}{66.5\times8.64\times12.75}=\frac{b_2^3}{19.65\times13.0\times37.2}=\frac{b_3^3}{21.75\times21.56\times9.21}$$

is obtained, thus the equation (10) will be realized.

$$\frac{b_1}{19.5}=\frac{b_2}{21.2}=\frac{b_3}{16.3} \qquad (10)$$

so, the proprtion among the Index of fishing efficiency of the boat may be expressed as follows;

$b_1:b_2:b_3 = 0.92 : 1.00 : 0.77$

c. The following equations may be calculated as,

from (7) ÷ (10);

$$\frac{d_1}{3.35}=\frac{d_2}{0.925}=\frac{d_3}{1.33} \qquad (11)$$

from (8) ÷ (10);

$$\frac{d_2}{0.443}=\frac{d_3}{0.615}=\frac{d_1}{1.32} \qquad (12)$$

and, from (9) ÷ (10);

$$\frac{d_3}{0.652}=\frac{d_1}{1.75}=\frac{d_2}{0.565} \qquad (13).$$

Thus, the following expressions may be realized by multiplying equations as (11) x (12) x (13):

$$\frac{d_1^3}{3.35\times1.32\times1.75\times}=\frac{d_2^3}{0.925\times0.443\times0.565}=\frac{d_3^3}{1.33\times0.615\times0.652}$$

So, the ratio of the Indices of fishing efficiency of the net may be expressed as follows:

$d_1:d_2:d_3 = 1.00 : 0.31 : 0.41$

d. From the asusmption $c \propto$ b.d.p, c can be expressed as $\frac{\text{b.d.p.}}{\text{c}} = \frac{1}{\text{K}}$ Where, K is a proportional coefficient.

So, from equation (1),

$$\frac{p_1{}^3b_1b_2b_3d_1d_2d_3}{83.19\times26.565\times22.745}=\frac{1}{K^3}$$ is obtained. In the same way, from equations (2), (3), (4), (5) and (6) the following expression will be obtained.

$$\frac{1}{K^3}=\frac{p_2{}^3b_1b_2b_3d_1d_2d_3}{14.98\times23.02\times48.70}=\frac{p_3{}^3b_1b_2b_3d_1d_2d_3}{24.75\times115.50\times22.52}=\dots\dots\dots$$

Taking the cube root of the above equation, the proportional expression of Index p is found to be:

$$\frac{p_1}{36.9}=\frac{p_2}{25.6}=\frac{p_3}{40.0}=\frac{p_4}{6.67}=\frac{p_5}{7.05}=\frac{p_6}{25.3}$$

From this result of proportional value, it is found that in this fishing area the value of Index **p** is big fishing grounds of less than 20 meters in depth but small in fishing grounds of more than 20 meters in depth.

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1) H. Miyamoto: Report to the Government of India on establishment of a fishing gear research laboratory, 1968; FAO No. TA 2599
2) Y. Kondo: Study of tension distribution in nets and fishing gear; Journal of the Tokyo University of Fisheries, Special edition, Vol 5. No. 2, March, 1962
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4) J. Robas: Shrimp trawling gear as used in the Gulf of Mexico; Modern Fishing Gear of the World, April, 1959
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3.5.1 Purse seine in Thailand

"Pla Too" (Rastrellinger neglectus) and "Pla O" (Bonito, THUNNIDAE) purse seine is one of three major purse seines in Thailand: i.e. "Uan-daum" (Thai purse seine, one-boat type purse seine), "Uan-thang-ke" (Chinese purse seine, two-boat type purse seine) and "Uan-lom-chub-pla-katak" (Anchovy purse seine, one-boat type purse seine). According to marine fisheries statistics of 1972, Thailand, the following catches are shown in Table 1.

Table 1. Catches by purse seines (1972)

Type of purse seine		Total catch (ton)
Thai purse seine	$L \leq 14$ m	3,327
- ditto -	$L \geq 14$ m	28,855
Chinese purse seine		19,004
Anchovy purse seine		14,396

The "Pla Too" and "Pla O" purse seine belong to one-boat type originated in Thailand, the netting boat were driven by rowing and sailing at first. Nowdays, the boats are driven by mechanical propeller and this type of fishing are still increasing.

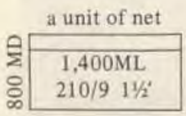
The "Uan-thang-ke" purse seine belongs to two-boat type purse seine which is said to have originated from China, Fukken province. The two-boat type purse seine consists of a net boat and two small rowing boats. Once the fish school is detected by the fishermen, the master-fisherman order the laying out the net which is taken from the net boat near by.

Results of the survey on purse seine fishing gears

1. "Uan-daum" purse seine (Surveyed on 21st. Sept., 1970)

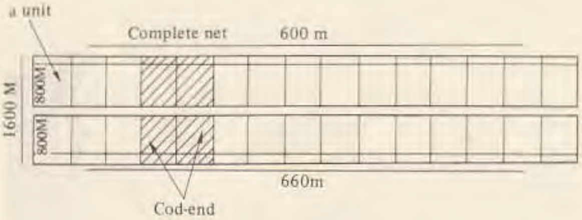
1) In order to be familiar with actual fishing gears for the Training Department trainees, SEAFDEC, observation trips on purse seines were conducted. This purse seine was surveyed in Pranburi. The gear was surveyed and practical knowledge of this gear operation was gained by the trainees through boarding practical fishing boat. Mr. Nakorn, the owner of purse seine boats kindly arranged the daytime operation for demostration of operation. Unfortunately, there was no chance to operate the hauling machine of V-roller. Neverthless, we could discuss this matter with the fishermen, and further possibilities of mechanization was convincing.

(1) Net



Selvedge 210 d/18, 6M (mesh), 40m
C.L.) 1¾ (4.0 cm)
Body net 210 d/9, Lh 1,400M (mesh)
Wh 800M, 1½' (3.8 cm)
Cod-end 210 d/12

Hang-in: $1{,}400^M = 3.81 \times 1{,}400 = 53.3$ m (Net length),
Length hung at Float line = 40 m & Sinker line = 44 m
W (weight) = 24.8 kg, $\rho = 1.14$, $W' = 2.87$ kg.



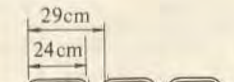
	Number of Units	
Upper	15	Total W'
Lower	15	= 2.87 × 15 × 2
	30	= 86 kg

	Hang-in	Width	Length hung
Upper	.25	20m	600m
Lower	.18	17m	660m

(2) Rope

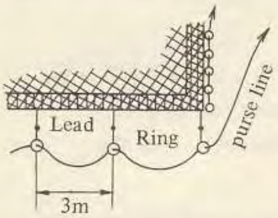
Float line, 6 m/m (D), 2 lines, 600m
Sinker line, 6 m/m, 2 lines, 660m
Purse line, Cross rope 24m/m, 300m × 2, @150 B.T.
B.S. Polyethylen 4 ton, Nylon 7 ton
W' = Neglegible

(3) Float



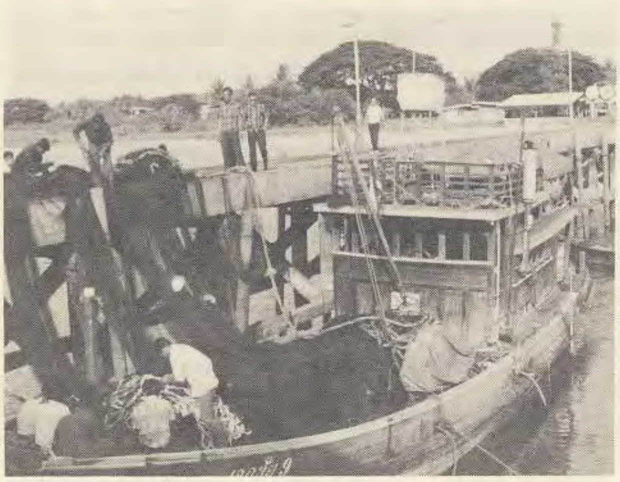
Synthetic float "Naigai" No. 8
2,000, W = 70 gr. $\rho = 0.25$
B = 210 gr. Total B = 420 kg

(4) Lead & Ring



Lead: W = 500 gr. No. = 660/3 = 220
ρ = 11.35, W' = 455 gr.
Total W' = 100 kg.
Ring: W = 500 gr. 10 cm (Dia), No. = 220, Metal, ρ = 7.8,
W' = 435 gr. Total W' = 95.7 kg

Photo. Bonito Purse Seine



(5) Gear structual elements

Boat: L = 19 m, G.T. = 40 ton, 60 p.s.

Net:

Buoyancy		Sinking Power			
	float	lead	Ring	Net	Rope
Total	420kg	100kg	95.7kg	86kg	Neg.
Value/m	.7kg	.17kg	.16kg	.14kg	

Extra buyancy: 420 – (100 + 95.7 + 86) = 138.3 kg

(6) Operation time (At demonstration, only 2/5 of net was operated)

Throwing = 2 min x 5/2 = 5 min

Hauling = 30 min x 5/2 = 75 min (from one side)

75/2 = 37 min (from two sides)

Hauling speed = 600 m/35 = 17 m/min

2) Management of purse seining

(1) Price of gear

1 complete set: 90,000 B.T. (Baht)

(net price: 1,600 x 1,400 M = 2,200

2,200 x 30 = 66,000

Ring: 10 B.T. x 220 = 2,200

Buoy: 3.25 x 2,000 = 6.500

Lead: 7 B.T./kg, 3.5 B.T. x 220 = 770

Others: 15,000)

(2) Earning

Landing 30,000 – 100,000 B.T./Month,

Estimation of quantity 10,000 – 35,000 kg/month (1 kg = 3 B.T.)

No. of operation days 20 – 22 days/month.

No. of operations per day 3 – 4 operations on the average.

Estimation of catch by one operation

(10,000 – 35,000)/21x3.5 = 136 – 470 kg

Owner: 50 – 60%, including fuels, food & repairing.

Crews: 40 – 50%

(3) Operational season and composition of fish

Month	Activity	Fishing Ground
1	None	
2	Normal	Around Rayong
3	Normal	Around Rayong
4	Small	Around Rayong
5	None	
6	None	
7	Normal	Around Pranburi
8	Most	Around Pranburi
9	Most	Around Pranburi
10	(wind)	Around Pranburi

Composition of fish: Bonito 30 percent (1 baht/kg)
Plato 70 percent (3 baht/kg)

(4) Crews 18 – 21 (total)

Staff	No.	Getting
Captain	1	1
Assistan Capt.	1	1.5
Master Fish	1	5
Engineer	1	1.5
Q.M & Netman	3	1.5
Crews	13	1

3) Mechanization

(1) Speed & Capacity

V-20: Hauling speed proper, capacity insufficient

V-30: Hauling speed a little slow

(2) Removing fish from net

Space and time for removing fish from net are indispensible to the boat.

(3) Hauling time from one side (position of cod-end should be at terminal)

Two sides by man power: 600 m long, 35 minutes, two sides, hauling speed by man power 600 m/35 = 17 m/min (from each side 17/2 = 8.5 m/min.)

Required time by machine from one side = 20 m/min.

4) Appendix:

(1) Principal items of V-roller

	V-20	V-30	V-50
Outfit electric power	2kW	3kW	5kW
Capacity (75%)	220kg, 40m/min.	377kg, 15-35m/min.	625kg, 15-35m/m.
Reduction	1/20	1/39	1/39
Air pressure (Average)	0.5kg/cm^2	0.8	0.8
Air pressure (Max.)	2.0	3.0	3.0
L x B x D	5 x 3.5 x 5,	9 x 4.7 x 6.8	9.8 x 5 x 6
Weight	50kg	120 kg	200 kg

(2) Capacity of V-roller (Example of calculation)

V-20

a. 1 HP = 75 kg·m/sec

40 m/min. = 40 x 100/60 cm/sec = .67 m/sec

Capacity = 220 x .67/75 = 1.95 HP

or

b. 1 HP = 4500 kg·m/min.

Capacity = 220 x 40/4500 = 1.95 HP

or

c. 1 KW = 102 kg·m/sec, 1 HP = 0.73 KW

Capacity = 220 x .67/120 = 1.44 KW = 1.44/0.73

1.95 HP

V-30 (max.)

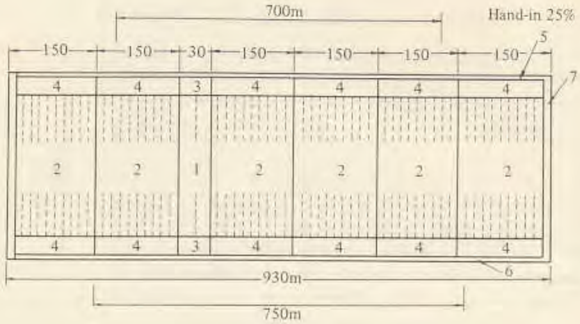
35 m/min. = 35 x 100/60 cm/sec = .58 m/sec.

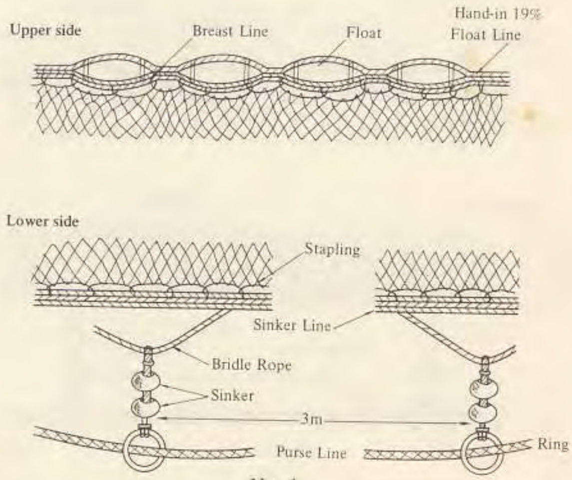
Capacity = 377 x .58/75 = 2.9 HP

V-50 (max.)

Capacity = 625 x .58/75 = 4.8 HP

5) Design of "pla 0" net (No. 1 & No. 2)

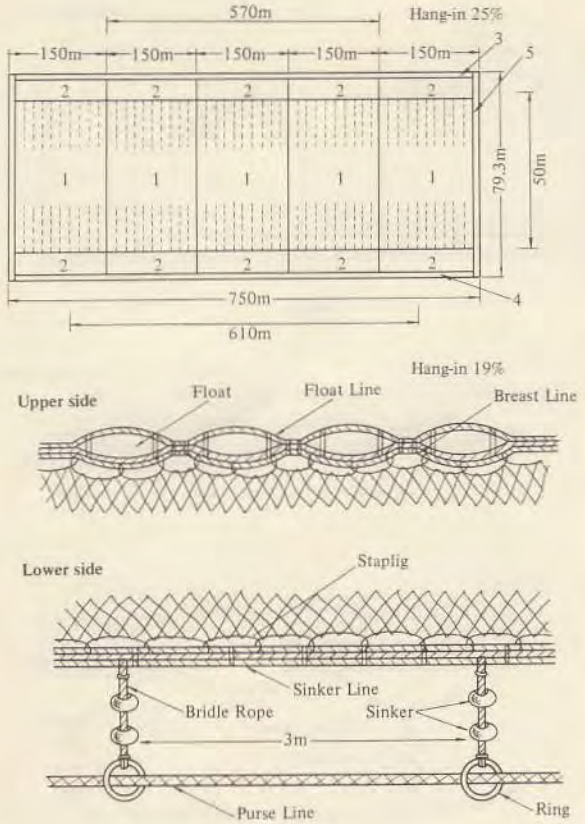




No. 1

No. 1

No.	Name	No. of twine	Size of mesh (cm)	No. of meshes	Length (meter)	Piece	Weight (kg)
1	Cod-end	210/15	3.8	400	75	2	60
2	Main net	210/12	3.8	400	75	10x6	1418
3	Sub brim	210/15	3.8	50	30	1x2	3
4	Sub brim	210/15	3.8	50	150	1x12	89
5	Upper brim	210/24	4.4	6	924	1	
6	Lower brim	210/24	4.4	6	924	1	19
7	Side brim	210/24	4.4	6	79.3	1x2	
						Total	1589 kg
8	Float line	Spun Pylen 12m/m dia. S & Z				700	
9	Sinker line	" " " "				750	
10	Purse line	Nylon Cross Rope 20m/m dia.				500x2	
11	Breast line	Spun Pylen 6m/m dia. Z				1550	
12	Bridle rope	Spun Pylen 12m/m dia. Z 1.65x250 0.2x250					
13	Stapling	Vinylon Twine 20's/90					
14	Float	Naigai 8-S Buoyancy 320/P'ce				2750 P'cs	
15	Sinker	Lead 500g/P'ce 350g/P'ce each				250 P'cs	
16	Ring	Brass (outside 125m/m, inside 100m/m dia.)				250 P'cs	



No. 2

No. 2

No.	Name	No. of twine	Size of mesh (cm)	No. of meshes	Length (meter)	Piece	Weight (kg)
1	Main net	210/12	3.8	400	75	10×5	1170
2	Sub brim	210/15	3.8	50	150	1×10	74
3	Upper brim	210/24	4.4	6	750	1	
4	Lower brim	210/24	4.4	6	750	1	16
5	Side brim	210/24	4.4	6	79.3	1×2	
							Total 1260 kg
6	Float line	Spun Pylen 12m/m dia. S & Z 570m					
7	Sinker line	" " " " 610					
8	Purse line	Nylon Cross Rope 20m/m dia. 500×2					
9	Breast line	Spun Pylen 6m/m dia. Z twist 1280					
10	Bridle rope	Spun Pylen 12m/m dia. Z twist 0.5m×203 P'cs					
11	Stapling	Vinylon Twine 20's/90					
12	Float	Naigai 8-S Buoyancy 320g/P'ce 2250 P'cs					
13	Sinker	Lead 500g/P'ce 350g/P'ce Each 203 P'cs					
14	Ring	Brass (outside 125m/m, inside 100m/m dia.) 203 P'cs					
15	Twine	Nylon 210/12, 15, 24, 45. Vinylon 20's/30.					

2. "Uan-charamet" purse seine

"Uancharamet" means purse seine net (Uan) for phomflet (Charamet).

Length of net: 400 meters

Depth of net: 60 meters

Main net: Nylon 210 d/6, 1 inch (2.5 cm) mesh size, 300 M × 60 meters × 80 p.s.

Cod-end net: 210 d/9,

Hang-in (at sinker line): 33 cm is hung in 10 M

Selvedge: Nylon 210 d/12, 3.9 cm mesh size, 6 M (same hang-in)

Sinker line: 6 mm in dia, 2 lines of left and right twist

Purse line: Cross rope 22 mm, 300 m × 2

Purse ring: Brass dia. 10.6 cm (outside), 7.6 cm (inside), 200 p.s.

Buoy: Synthetic float, 25 cm length, 1300 p.s.

Sinker: Lead, 500 grams, dia. 45 mm, 13 mm hole in dia., 300 p.s.

Heavy weight: 70 kgs, 2 p.s.

Fish gathering lamp: Kerosine lamp, 3 – 5 ps, the frames are set at the center of the boat at about 2 meters above the deck.

Coconut palm leaf: The leaves are kept in water 3 to 4 days continuously in 4 to 5 places at the fishing grounds.

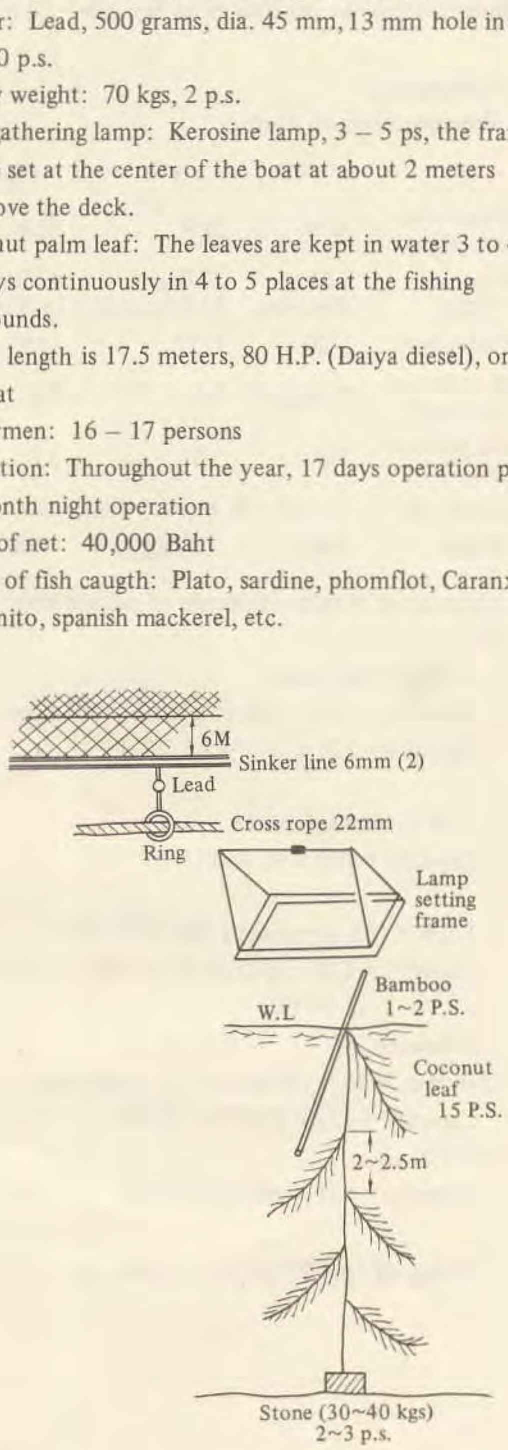
Boat: length is 17.5 meters, 80 H.P. (Daiya diesel), on boat

Fishermen: 16 – 17 persons

Operation: Throughout the year, 17 days operation per month night operation

Price of net: 40,000 Baht

Kinds of fish caugth: Plato, sardine, phomflot, Caranx sp., bonito, spanish mackerel, etc.



3. "Uan-prakata" purse seine

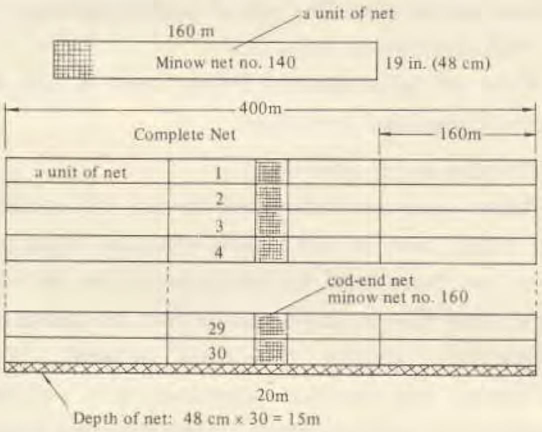
"Owanprakata" means purse seine net (Owan) for the fish (pra) of sand lance (Katak). The two main fishes caught by this purse seine are:

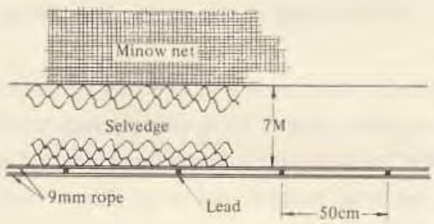
1). Acetes spp., "Kuier", the material of shrimp paste ("Kapi")

2). Sand lance, "Katak", Stolephorus spp., the material of Nampra (best quality of fish sourse)

Thus, there are two industries, shrimp paste and Nampra, using the catches caught by this purse seine as the materials.

All nets are constructed of Minow Net





A unit of net:

Length of net of 1 set: 400 meters

Depth of net of 1 set: 15 meters

Main net: Nylon minow net No. 140

length 160 m x 3 = 480 m

total units 30 unit x 3 = 90

Cod end net: Nylon minow net No. 160

length 20 m

Selvedge: Nylon 210 d/30, 3 cm mesh size, 7 M

Bouy line: 6 mm rope (2)

Sinker line: 9 mm rope (2)

Buoy: Synthetic float, 25 x 12 x 3 cm, 900 p.s.

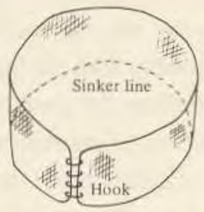
Sinker: Lead, 300 grams, 800 p.s.

Purse line: None

Hook: 20 – 30 hooks

Operation: After laying out the net in a circle, the drivers sink into water and join both sinker line by hooks one by one according to the process of hauling the net.

Boat: Length is 16 meters, 40 p.s. (Yammer Diesel), one-boat



Fishermen: 14 – 17 persons

Price of net: 50, – 80,000 Baht

Catch: 18 tons per 1 operation in max.

Fishing season: From Nov. to May, 6 months operation, daytime operation

Fishing ground: From Chonburi to Chantaburi coast line. Trad is especially abundant in sand lance.

Time required for making complete set: 10 person x 60 days, joining and framing requires much work.

Kinds of fish caught: Kuier, Katak, Plato, sardine, slip mouth

Number of purse seine boats in Rayong paknam: about 45

Processing:

Shrimp paste ("Kapi") 1 kg needs the quantity of 2.5 kg of Kuier and 0.5 kg of salt. The price of Kapi is 18 Baht/kg and fresh Kuier is 3 Baht/kg. The Kapi is produced within 5 days after processed. The best quality of Nampra is made from sand lance.

3.5.2 Comparison of purse seine between one-boat and two-boat type on the basis of purse seine fisheries in Japan.*

1. Introduction

From the fisheries statistics of 1962, purse seine accounts for 15.1 percent of the total catch showing the importance of this gear among different kinds of Japanese gears. The others in order of importance are medium type of trawl net 9.7 percent, North Pacific fisheries including salmon gill net, king crab bottom gill net and trawling 9.4 percent, squid angling 8.3 percent, stick held dip net 7.4 percent and tuna long line 6.0 percent. Thus purse seine is a very important fishing gear for both coastal and off shore fisheries.

2. Classfication and statistics

In Japan purse seine net is widely used for capturing schools of sardine, horse mackerel , mackerel, tuna and

* Derived from: M. Nomura; Purse seine fisheries development in Japan, Proc. Indo-Pacific Fish. Coun., 11 (II), 239~249, 1964

bonito both on the coast and in off-shore fishing grounds.

It is classified into one-boat and two-boat systems from the view point of fishing method. In the two-boat fishing method, two boats with half the net each, come together and simultaneously lay out the net in the sea. They can lay the net more speedily than the former system but still require calm sea conditions for operation.

Form the standpoint of construction of the gear, the purse seine can be classified into two categories, with bag net and without bag net. We can say the former one is so called "Lampara net" and the later one "Ring net". Generally the purse seine without bag net is bigger in size than the one with bag net. Purse seine with bag net are, for instance, sea bream, dolphin, flying fish and sardine semi-surrounding net, something like lampara net.

Purse seine without bag net operated by one-boat system and two-boat system land almost all of purse seine catches. They are:

One-boat type, horse mackerel and mackerel,
Two-boat type, horse mackeral and mackeral,
One-boat type, anchovy and sardine,
Two-boat type, anchovy and sardine,
One-boat type, tuna and bonito,
Two-boat type, tuna and bonito.

The main species of fish caught by one-boat type are horse mackerel and mackerel, mostly being caught in the west of Japan Sea, China Sea and south Pacific Ocean. On the other hand, main species of fish being caught by two-boat type purse seine are anchovy and tuna mostly along the Pacific coast.

The purse seine is also classified into three types from basic shapes of net shown in Fig. 1.

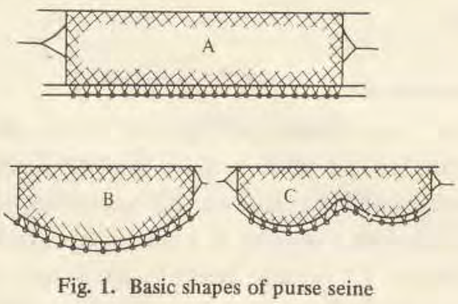


Fig. 1. Basic shapes of purse seine

In this figure, A is the purse seine of one-boat American type, B is the purse seine of one-boat Japanese type and C is the purse seine of two-boat Japanese type.

The last five years' catch data of the purse seine which is shown in Table 1 indicates that notwithstanding the slight decrease in total number of gears in five years, the catch itself has remarkably increased year by year. The catch of 1962 by this kind of gear amounts 970,000 tons which is a gain of 41 percent in five years and makes it the first of all fishing gears in Japan.

It is clear that recently one-boat type has become the main gear and though less in number of gears, catches more fish than two-boat type as seen from the same Table. There is an increase of 36 percent in the number of nets during five years and the catch amount also increased about 1.9 times of the catch of 1958. The boats have been mechanized and each boat has increased in tonnage. On the other hand two-boat type have not progressed so much in these five years either in number of boats nor the amount of the catch.

So as to know more details of one-boat type purse seine Table 2 shows the fluctuation of catch and catching effort during five years operating along west coast of Honshu and Kyushu. The rate of catch by species of fish in 1962 is shown in Table 3.

From the table both the average catch by unit effort and by voyage have been shown.

3. Materials and construction

Before using synthetic fibers for the net, cotton net was mainly used. In 1955, purse seine first began to use nylon net. Since then, use of synthetic fiber net for the purse seines have increased year by year. At present nylon (polyamide), vinylon (poly-vinyl alcohol), tetoron (polyester), and kyokurin (combination of poly-amide filament yarn and vinylidene chloride filament yarn) are employed for purse seine. Table 4 shows the quantity of synthetic fiber net used in the purse seine during the last five years.

In one-boat purse seine No. 21 to 24 twine (this means number of yarns) and 5 to 6 cm streched mesh size are used at the bunt to catch horse mackerel and mackerel. But for catching sardine and small horse mackerel by one-boat type, No. 18 to 24 twine and 3.3 cm mesh size are used for the bunt.

In two-boat type purse seine, the bunt uses No. 18 to 21 twine and 5 to 6 cm mesh size in horse mackerel and mackerel fishing, while sardine net ordinarily uses No.6 twine and 1.7 cm mesh size. Sometimes No. 4 to 6 twine and 1.1 cm mesh size are specified for the gear operated in bays and inlets.

Bonito and tuna purse seine, No. 60 to 80 twine and 9 cm mesh size are popular in the bunt.

Generally the purse seine has plenty of floats which means about 2 to 4 times buoyancy against total sinking power of the gear to prevent the float line sinking downward when purse line is rolled up during the operation. One necessary operative factor is to prevent the escape of fish school fròm lower part of the mouth of the net by sending the net downward as fast as possible after laying out the net in the sea. The net from this point of view must have quick sinking speed in water. That is to say the net should have comparatively large specific gravity and also be as thin as possible in its netting cord. On the other hand, the materials should have the property of resisting physical forces such as tension, impact and friction which are derived from the operations such as laying out, pursing and holding up the net in the operation. Thus, the synthetic fiber to be used should satisfy the above requirements and the materials of the purse seine net are made of different materials according to the environmental conditions such as the kinds of fish, the size of gear and the conditions of operation. Horse mackerel and mackerel purse seine, for instance, which operates in night time after gathering the fish school by use of fishing lamp, sometimes has its lead line at sea bottom of about 200 m depth. This does not require such a high net sinking speed, but needs suitable materials so that the shape of net will not deform easily in the current. Furthermore it should have high resistance to the friction. To meet these demands, vinylon and tetoron are used as materials of this type of gear. On the other hand, sardine purse seine which is mainly used in day time, should sink as fast as possible to capture fish school and should be comparatively small in net volume for operation. Thus the desirable materials for this type of gear should be nylon and kyokurin. As to tuna purse seine, net requires to be high in laying out speed and sinking, and be stiff enough to resist the force of impact of tuna rushing at the net which is longer along the float line compared with other kinds of purse seine. For this, mainly nylon and sometimes vinylon are used.

The length of net depends on the behaviour of fish aimed at. Large size of net is used in the capture of large schools of high swimming speed, and small size nets for capturing small schools with less movement. The depth of net is also related to the depth of fish school and speed of swimming. Thus the length and depth of net the dimension of the gear, are almost defined according to the kinds of purse seine.

Horse mackerel and mackerel one-boat purse seine in which the length of buoyline is 495 to 975 m has the ratio of 2 to 1 between the depth of bunt and that of wing net, and the depth of bunt has the ratio of 0.08 to 0.15 to the length of buoyline. In the horse mackerel and mackerel two-boat purse seine, the length of buoyline is 580 to 1,000 m and the depth of bunt is about 0.18 to 0.25 of the length of buoyline.

Sardine one-boat purse seine has buoyline of the length of 340 to 500 m almost same length in the depth of bunt and the wing, and ratio of 0.1 to 0.2 in the length of bunt to buoyline. Sardine two-boat purse seine is 270 to 780 m in length with the ratio 0.2 to 0.3 between the depth of bunt and the length of buoyline.

Tuna two-boat purse seine uses the length of 1,000 to 1,400 m buoyline and the ratio of 0.10 to 0.15 between the depth of bunt and the length of buoyline.

There are two conflicting aspects when the question of shortening of the net is considered: one is that it should be small which comes from the desire to ensure less deformation of net by the current, less entangling of net itself and less chances of getting the rings caught with net when pursing; the other that it should be large for maintaining in the volume of net capable enough to surround fish school. Generally speaking, 25 to 35 percent of shortening is used in buoyline and 15 to 25 percent in leadline. But American type purse seine net is less by around 10 percent both in buoyline and leadline.

In Table 5 the specifications of construction on some kinds of purse seine are briefly illustrated.

4. Comparison between one-boat type and two-boat type

Relative merits between one-boat and two-boat type purse seine could not always be difined. In night operation, it is possible to catch fish schools attracted with fishing lamp by one-boat, but two-boat type is likely to be used for capturing comparatively mobile fish schools with speedy movement in day time.

From theoretical point of view, necessary time for encircling the fish school is one half by two-boat type compared with one-boat type. But in the same size of net, the size of boat is bigger in one-boat type which has bigger horse power with more speedy encircling the fish school. That is to say one-boat type is more economical and efficient if the boat is mechanized. That is the reason why tuna purse seine has been recently changing from two-boat type to one-boat type system. In other words, the decision on which type one must adopt is to be examined from the economic factors of boat and the number of persons.

In the data collected by the Statistics Research Division of Ministry of Agriculture and Forestry, sampling studies of purse seine includes 22 units of one-boat type and 32 units of two-boat type. Average value of fishery size and the statement of income and expenditure by the kinds of purse seine and size of boat are illustrated in Table 6.

For one-boat type purse seine several relationships taking from original datas of Table 6 are shown in Fig. 2: the symbol "a" is the relation between the catch amount and the tonnage of fishing boat, the symbol "b" is the relation between the catch and total tonnage of basic groups of fishing boats and the symbol "c" is the relation between the catch and the number of fishermen.

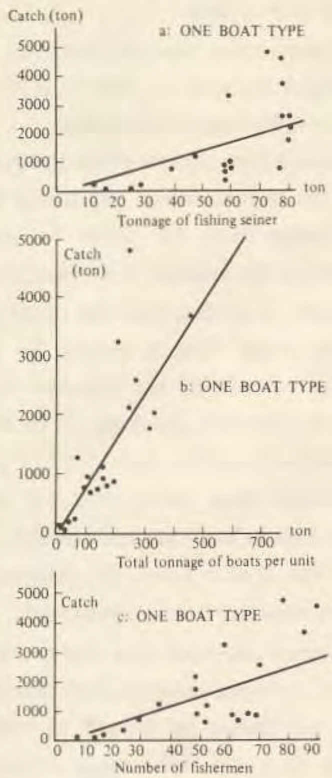


Fig. 2. The relating figures in one boat type purse seine

In the same manner, in the case of two-boat type, the symbol "a" "b" and "c" are respectively plotted as shown in Fig. 3.

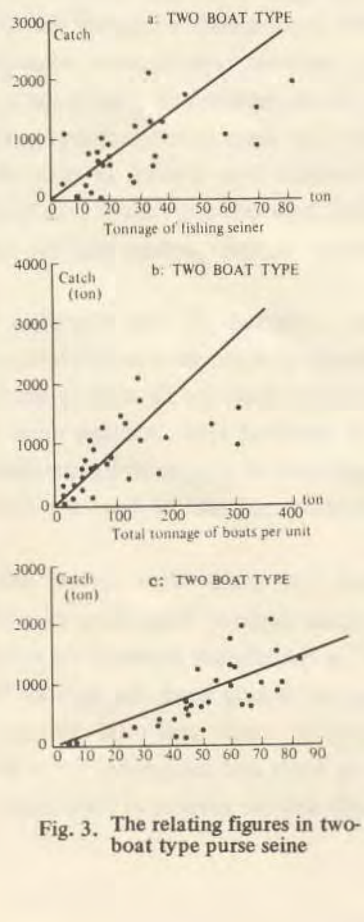


Fig. 3. The relating figures in two-boat type purse seine

Nearly linear relationship between the catch and each essential factor can be taken. Experimental equation by method of arithmetic mean are illustrated as shown in Table 7.

The one-boat type and two-boat type can be compared from these figures and Tables. Comparing the case of "a" of Fig. 2 with that of Fig. 3, the one-boat type is seen to be more efficient than two-boat type from the fact that the coefficient of a simple equation of the former is bigger than half of the coefficient of the latter. As to the case of "b", two-boat types is slightly higher in efficiency than one-boat type from the fact that the coefficient of equation of two-boat is slightly larger than that of one-boat. In same way of comparison the case of "c" indicates that one-boat is more efficient to some extent than two-boat type.

As the employment force and the cost of fishing materials, nets and boats, mainly contribute to the expense of management of purse seine fishing these two items of expenditure should be taken for discussing the efficiency of purse seine. Fig. 4 indicates the relation between the total earnings by way of the landings and the wages of labor both in one-boat and two-boat type. It is clear that one-boat type gets higher net earning than two-boat at the same levels.

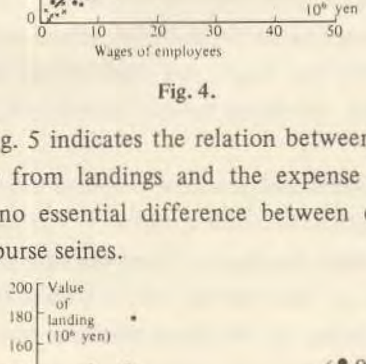


Fig. 4.

Also Fig. 5 indicates the relation between the amount of money from landings and the expense of materials. There is no essential difference between one-boat and two-boat purse seines.

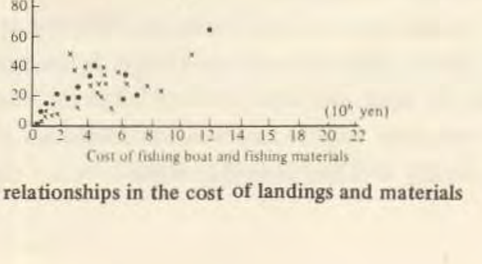


Fig. 5. The relationships in the cost of landings and materials

One-boat type fishing is decidedly superior to two-boat type as long as the analysis of statistics of the above relationships concerns with management of fisheries.

Recently one-boat type purse seine industry has increased it's mechanization as well as the number of the boats. The boat increases the number of fishing days even under hard conditions and this fact comes from the number and frequency of fishing trips. Table 8 shows that one-boat type has more days of fishing than two-boat purse seine.

Besides the above comparisons, some factors such as the condition of operation, behaviour of fish and conditions of the sea might also affect the choice of way of fishing method between these two types, so one cannot always conclude absolutely about the superiority of one-boat type purse seine.

Table 1. Statistics of Japanese purse seine during five years, 1958–1962

Unit: 1,000 ton

	1958		1959		1960		1961		1962	
	Num.	Catch	Num.	Catch	Num.	Catch	Num.	Catch	Num.	Catch
One-boat type	388	286	327	370	471	512	476	498	527	545
Two-boat type	1003	400	968	420	934	401	847	458	819	425

Table 2. Statistics of catch of one-boat type by size of boat

Tonnage	Year	Number of fishing units	Number of voyages	Number of fishing days	Amount of catch	Mean number voyages per boat	Mean catch per boat	Mean catch per voyage	Mean fishing days per voyage
	1958	32	3,793	3,793	22,047	118	698	5.8	1.0
20	1959	14	2,085	2,085	11,831	149	845	5.7	1.0
	1960	7	1,053	1,066	7,654	150	1,093	7.3	1.0
50	1961	7	623	632	5,114	89	731	8.2	1.0
	1962	3	384	384	2,434	130	811	6.3	1.0
	1958	190	25,329	28,012	204,424	133	1,076	8.1	1.1
50	1959	181	19,774	30,587	302,807	109	1,673	15.3	1.6
	1960	171	15,910	33,569	417,694	93	2,443	26.3	2.1
100	1961	172	13,614	31,552	386,718	79	2,248	28.4	2.3
	1962	167	10,424	30,450	405,494	62	2,428	30.9	2.9
	1958	2	28	320	2,111	14	1,056	75.4	11.4
	1959	1	22	316	2,469	22	2,496	112.2	14.4
over 100	1960	3	60	753	7,598	20	2,533	126.6	12.6
	1961	3	69	847	6,918	23	2,306	100.3	12.3
	1962	2	18	385	4,285	9	2,143	238.4	21.4

Table 3. Rate of catch by species of fish by one-boat type purse seine in 1962

	Amount of catch (tons)	Percent
Sardine	1,459	0
Round herring	3,160	1
Anchovy	4,321	1
Horse mackerel	322,071	79
Mackerel	73,575	18
Bream	574	0
Squid	712	0
Bonito	744	0
Others	5,595	1

Table 4. Quantity of synthetif fiber for purse seine

Unit: 1,000 lb.

	1958	1959	1960	1961	1962
Polyamid	486	651	1,264	806	1,485
Polyvinyl alcohol	224	416	1,904	4,015	4,088
Vinyliden chloride				478	253

Table 7. A simple equation of relation between catch and other factors by kinds of purse seine

	"a"	"b"	"c"
	Relation between catch and tonnage of main boat	Relation between catch and tonnage of boats of a group	Relation between catch and number of fishermen
One-boat type purse seine	C = 27.5 × t	C = 7.75 × T	C = 30 × n
Two-boat type purse	C = 35.7 × t	C = 9 × T	C = 18 × n

Table 8. Distribution of number of fishing days by kinds of purse seine

	Ton	Number of fishing group	Number of fishing days						
			Under 50	51 100	100 150	151 200	201 250	251 300	Over 301
One-	10~30	6	3	1	–	1	–	1	–
boat	30~50	1	–	–	–	1	–	–	–
type	50~100	15	–	–	–	7	2	6	–
Two-	10~30	17	2	6	7	2	–	–	1
boat	30~50	8	–	1	5	1	1	–	–
type	50~100	4	–	2	–	2	–	–	–

Table 5. Specification of construction of net by the kinds of purse seine

Kinds of purse seine	Net: Name of parts	Net: Kinds of materials	Net: Number of yarns	Net: Mesh size	Buoy line: Length of net	Buoy line: Finished length	Buoy line: Shortening	Lead line: Length of net	Lead line: Finished length	Lead line: Shortening	Note
Two-boat type traditional purse seine	Bunt Wing	Kyokurin "	6~9 4	1.9 1.9	390m	312m	20%	390m	312m	20%	
One-boat horse mackerel	Bunt Wing	Vinylon "	18~24 12	5.4 6	1212	735	39	1363	818	40	Depth of net: 59 m Weight: 5,733 kg
– Ditto –	Bunt Wing	" "	18~24 12~18	3.0 3.0	1027	690	33				Depth of net: 272 m Weight: 8,850 kg
One-boat large sardine	Bunt Wing	" "	16 8	2.6 3.3	570	342	40	570	400	30	Center part: 8 yarns, 3.3 cm, 82 pieces
One-boat medium sardine	Bunt Wing	" "	16 6	2.0 2.2	480	288	40	480	336	30	Center: 6 yar. 2.2 cm, 100 Mesh, 82 pieces
One-boat small sardine	Bunt Wing	" "	12 4, 6	1.7 1.4	420	252	39	420	294	30	6, 1.6, 100, 30p 4, 1.5, " 20p 6, 2.0, " 24p
Two-boat horse mackerel	Bunt Wing	" "	30 24	4.3 6.0	1090	586	46				Depth of net: 106 m Weight: 4,500 kg
– Ditto –	Bunt Wing	Kyokurin Nylon	18~21 9~12	3~3.8 6.0	1162	833	28	1182	994	16	Depth of net: 83 m Weight: 8,818 kg
Two-boat sardine	Bunt Wing	" "	6 4	1.3 1.3	727	520	28	727	568	22	Depth of net: 112 m Weight: 2,430 kg
Two-boat anchovy	Bunt Wing	" "	6 6	1.6 1.6	517	273	47				Depth of net: 111 m Weight: 2,370 kg
Two-boat tuna and bonito	Bunt Wing	" Vinylon	75 24~36	9.0 15~18	2503	1730	31	2503	1818	27	Depth: 272 m Weight – Nylon; 3,094 kg, Vinylon; 5,840 kg

Table 6. Average value of fishery size and the statement of income and expenditure by kinds of purse seine

in 1962, Unit = 1,000 Yen

	One-boat purse seine			Two-boat purse seine			
Size of main fishing boat	10~30 (ton)	30~50 (ton)	50~100 (ton)	~10 (ton)	10~30 (ton)	30~50 (ton)	50~100 (ton)
Number of sample	5	1	16	3	17	8	4
1. Tonnage of main fishing boat	21.10	48.49	67.84	6.49	18.08	37.57	70.15
2. Number of boat per group	2.0	4.0	6.5	4.3	4.9	5.0	4.5
3. Total tonnage per group	32.35	73.95	255.81	18.29	56.70	149.67	285.54
4. Total horse power per group	77.4	252.00	905.12	65.33	242.71	558.88	791.75
5. Number of fishing days	59	199	134	79	105	129	63
6. Number of days to fishing grounds	61	199	224	79	105	134	125
7. Number of members engaged	16	37	64	31	45	61	67
8. Amount of catch	130.9	1262.5	1989.1	173.3	552.9	1575.4	1374.0
9. Amount of money of landing	2164	20654	73679	4336	18271	45087	80201
10. Wages of employees	962	6866	18641	1689	9357	17038	29112
11. Expense for fishing boat	167	1476	7263	174	1001	2543	3246
12. Expense for facilities	–	–	4	–	28	84	188
13. Expense for net and rope	94	215	2703	270	1615	5415	3779
14. Expense for fuel	196	3086	6588	92	806	2228	4651
15. Expense for bait	–	–	–	–	–	–	–
16. Expense for ice	36	1135	2139	44	395	773	1100
17. Expense for fishing box	1165	1165	4918	10	426	378	18
18. Expense for other materials	60	583	1331	25	149	264	1847
19. Renting	173	1051	6492	202	343	165	217
20. Selling commission	63	743	2948	177	534	1701	3896
21. Office expense	13	–	3698	7	676	1078	2270
22. Expenditure of miscellaneous	41	1157	5059	96	323	474	1382
23. Total	1811	17481	61767	2792	15658	32147	51711
24. Depreciation fund	956	3850	10679	670	3834	10281	14093
25. Total expenditure	2767	21322	72447	3462	19492	42429	65805
26. Earning	–603	–667	1231	874	–1221	2657	14396

Note: Taking 100 the synthetic consumer's price index (CPI) in 1965, 1963 shows 90, 1970 shows 130 and 1974 shows 208.

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3.5.3 Size of netting cord of a major part of purse seine and the capacity of Power Block*

The first item for consideration in the design of purse seine is the kind of fish aimed for. The behaviour, size and moving speed of fish school will differ from a kind to kind. The scale of net, the length and width of the net, should be decided by such elements of fish school as well as other environmental conditions concerning operating.

At the second step, the size of mesh will be choosen according to the size of fish even of the same kind of fish. Ordinarily, twice the stretched length of mesh size "1" should be decided, since it should be a little smaller than the length of the frequency distribution of maximum circumference of fish body of migrating fish school.

Thus the main dimensions of purse seine, i.e. the length of net, depth of net and mesh size will be decided.

As the result of our experiments on small scale purse seine, the main dimensions of which were 60 meters in net length, 28 meters in stretched length of net depth, 4 centimeters in mesh size and 12 yarns of netting cord of 210 denier on a major part of net, the tension T_N of the netting cord when net was hauled by Power Block was measured at 15 grams on the average.

* M. Nomura; Study of purse seine (unprinted), 1970

During hauling time, use of Power Block, extraordinary tension in the netting cord caused by unexpected operative conditions may be produced. In the experiment, these abnormal tensions or maximum tension T_{max}. on a netting cord were observed about sixtytimes as large as average tension T_N. To eliminate this danger T_{max} could be guranteed as,

$$T_{max.} = 100 \times T_N.$$

In various scales of purse seine, the value of T_N(gram) is approximately estimated by the following empirical formula,

$$T_N = l \times n \times (2y + 26.8) \times 10^{-4}$$

where 1 is the stretched length (cm) of mesh of major part of net, n is the number of meshes along the deepest depth of major part of net, and y is the number of yarns of netting cord of major part of net.

On the one hand, as the breaking strength at knotting of major part of net in wet condition, T_B, could be physically obtained, we could research the adaptability of the size of netting cord used as a design by comparing the value of T_B and $T_{max.}$. Generally the value of ratio $T_B/T_{max.}$ will be within the following range,

$$1.5 \leq T_B / T_{max.} \leq 3$$

According to the same experiment, the tension of net P (kg) when it is hauled by Power Block could be approximately estimated by the following empirical formula;

$$P = l \times n^2 \times (4y + 53.6) \times 10^{-7}$$

The circumference of net C (inch) on the sheave of Power Block is also estimated;

$$C = 17.7 \times (0.0015y + 0.02) \times \sqrt{n}$$

Thus, advisable size and capacity of Power Block will be reckoned by applying the estimated values of P and C mentioned above.

On the basis of the estimation, some samples of purse seine which differ from operative region, main species of fish aimed for and scale of net are examined as shown in the following evaluation.

1. Herring Purse Seine:

As for large scale of herring purse seine used in British Columbia Canada, the dimensions of net construction are listed with mesh size 1 = 3.5 centimeters, the number of yarns of netting cord y = 15, the length of net L is 440 meters and the number of meshes of deepest part of net n is 2650. The necessary values of estimation based upon the process of calculation mentioned above are $T_{max.} = 5$ kilograms, and $T_B = 15$ kilograms. As the value of T_B is 3 times that of $T_{Max.}$ the size of a netting cord is regarded as a little too large. And, depending upon the same process of calculation, the tension of net P and circumference C are found as 265 kilograms and 38 inches respectively. When the possibility of increasing tension by boat is to be taken, the Power Block such as 35 inches of sheave size and 700 kilograms of pulling capacity under 105 kg/cm^2 oil pressure is thought to be suited as a practical dimension.

Also, for large scale herring purse seine used in Icelandic Waters in which 1 is 3.1 centimeters, y is 9, L is 400 meters and n is 3600, the necessary values are estimated in the same way, i.e. $T_{max.}$ is 5 kilograms, T_B is 8 kilograms, P is 360 kilograms and C is 36 inches. As the value of T_B is about 1.6 times that of $T_{max.}$, the size of netting cord is regarded reasonably. As for the dimension of Power Block fitted for this net, it will be advisable that the sheave size is 35 inches and pulling capacity is 700 kilograms by taking into consideration values of estimation listed above.

For intermediate scale of herring purse seine also used in Icelandic Waters where 1 is 3.1 centimeters, y is 9, L is 445 meters and n is 2,000, the estimations are obtained as $T_{max.}$ is 2.6 kilograms, T_B is 8 kilograms, P is 92 kilograms and C is 18 inches. As the value of T_B is about 3 times that of $T_{max.}$, the size of netting cord is regarded as quite sufficient. The acceptable size and capacity of Power Block will be estimated with sheave size of 18 inches and pulling capacity of 500 kilograms.

The Norweigian herring purse seine operated along the coast of Norway where 1 is 3.6 centimeters, y is 9, L is 380 meters and n is 2,660, the estimations are listed as $T_{max.}$ is 4.4 kilograms, T_B is 8 kilograms, P is 235 kilograms and C is 31 inches. As the value of T_B is 1.8 times that of $T_{max.}$, the size of netting cord is regarded as resonable. The acceptable Power Block will be estimated with sheave size of 28 inches and pulling capacity of 590 kilograms.

The smaller scale herring purse seine also operated along the coast of Norway where 1 is 1.5 centimeters, y is 4, L is 325 meters and n is 4,000, the estimations are $T_{max.}$ is 2.1 kilogram, T_B is 4 kilograms, P is 184 kilograms and C is 29 inches. As the value of T_B is 1.9 times that of $T_{max.}$, the size of netting cord is regarded as reasonable. The acceptable Power Block will be estimated with the sheave size at 19 inches and pulling capacity 490 kilograms.

Small scale herring purse seine of U.K. in the Irish Sea in which 1 is 4.8 contimeters, y is 9, L is 190 meters and n is 1,000, the estimations are $T_{max.}$ is 2.2 kilograms, T_B is 8 kilograms, P is 44 kilograms and C is 19 inches. As the value of T_B is 3.6 times that of $T_{max.}$, the size of netting cord is regarded as a little too large. The acceptable Power Block will be estimated with the sheave size at 18 inches and pulling capacity 185 kilograms.

2. Tuna Purse Seine:

Yellowfin tuna purse seine operated in Californian waters: 1 is 10.5 centimeters, y is 120, L is 780 meters and n is 750, the estimations are $T_{max.}$ is 18 kilograms, T_B is 170 kilograms, P is 310 kilograms and C is 97 inches. As the value of T_B is about 9 times that of $T_{max.}$, the size of netting cord is regarded as too large. The acceptable Power Block will be estimated with the sheave size at 35 inches and pulling capacity 700 kilograms.

Japanese bluefin tuna purse seine operated in the Pacific Ocean: 1 is 18 centimeters, y is 36, L is 1250 meters and n is 1,500, the estimations are $T_{max.}$ is 26 kilograms, T_B is 32 kilograms, P is 780 kilograms and C is 51 inches. As the value of T_B is about 1.1 times that of $T_{max.}$, the size of netting cord is regarded as a little too small. The acceptable Power Block will be estimated with the sheave size at 35 inches and pulling capacity 1,780 kilograms.

Norwegian bluefin tuna purse seine operated along the Bergen coast in which 1 is 19.4 centimeters, y is 36, L is 670 meters and n is is 520, the estimations are $T_{max.}$ is 10 kilograms, T_B is 32 kilograms, P is 104 kilograms and C is 30 inches. As the value of T_B is about 3 times that of $T_{max.}$, the size of netting cord is regarded as quite sufficient. The acceptable Power Block will be estimated with the sheave size at 28 inches and pulling capacity 590 kilograms.

3. Other purse seine:

Japanese horse mackerel and mackerel purse seine operated in the East China Sea in which 1 is 3.75 centimeters, y is 12, L is 900 meters and n is 7,500, the estimations are $T_{max.}$ is 15 kilograms, T_B is 16 kilograms, P is 2,250 kilograms and C is 58 inches. As the value of T_B is about 1.1 times that of $T_{max.}$, the size of netting cord is regarded as a little too small. The acceptable Power Block will be estimated with the sheave size at 42 inches and pulling capacity 5,100 kilograms.

Japanese large scale sardine purse seine operated along the Pacific coast in which 1 is 4 centimeters, y is 12, L is 600 meters and n is 3,500, the estimations are $T_{max.}$ is 10 kilograms, T_B is 12 kilograms, P is 1,000 kilograms and C is 40 inches. As the value of T_B is about 1.2 times that of $T_{max.}$, the size of netting cord is regarded as a little too small. The acceptable Power Block will be estimated with the sheave size at 35 inches and pulling capacity 1,780 kilograms.

U.S. menhaden purse seine operated along the Atlantic coast in which 1 is 3.75 centimeters, y is 9, L is 600 meters and n is 3,000, the estimations are $T_{max.}$ is 5 kilograms, T_B is 8 kilograms and C is 29 inches. As the value of T_B is 1.6 times that of $T_{max.}$, the size of netting cord is regarded as reasonable. The acceptable Power Block will be estimated with the sheave size at 28 inches and pulling capacity 690 kilograms.

Canadian salmon purse seine operated along the Pacific coast in which 1 is 9 centimeters, y is 45, L is 400 meters and n is 350, the estimations are $T_{max.}$ is 3.7 kilograms, T_B is 35 kilograms, P is 26 kilograms and C is 30 inches.

Estimated Values of Tension and Advisable Size of Power Block

No.	Main species of fish	Country	Fishing area	Major part of net		Length of net (m) L	Depth of net		Estimated tension of a netting cord (g) T_N	Estimated abnormal tension of a netting cord (kg) T_{max}	Knot breaking strength in wet (kg) T_B	Estimated tension of net to power block (kg) P	Estimated circumference of net on sheave of P.B. (in.) C	Advisable size and capacity of power block from the view point of net tension P and circumference of net C	
				Stretched mesh size (cm) 1	Number of yarns (210 d) y		Number of mesh in depth n	Depth (m)						Sheave size (inch)	Net pull capacity at 105 kg/cm² (kg)
1	Herring	Canada	British Columbia	3.5	15	440	2650	93	50	5	15	265	38	35	700
2	Herring	Iceland	Ic. Waters	3.1	9	400	3600	110	50	5	8	360	36	35	700
3	Herring	Iceland	Ic. Waters	3.1	9	445	2000	60	26	2.6	8	92	18	18	500
4	Herring & Mackerel	Norway	Bergen Coast	3.6	9	380	2660	96	44	4.4	8	235	31	28	590
5	Herring	Norway	Bergen Ct.	1.5	4	325	4000	60	21	2.1	4	184	29	19	490
6	Herring	U.K.	Irish Sea	4.8	9##	190	1000	48	22	2.2	8	44	19	18	185
7	Yellowfin Tuna	U.S.A.	California Waters	10.5	120##	780	750	80	180	18	170	310	97	35	700
8	Bluefin Tuna	Japan	Pacific Ocean	18.0	36#	1250	1500	270	260	26	32	780	51	35	1780
9	Bluefin Tuna	Norway	Bergen Ct.	19.4	36	670	520	100	100	10	32	104	30	28	590
10	Horse mackerel & mackerel	Japan	East China Sea	3.75	12#	900	7500	280	150	15	16	2250	58	42	5100
11	Sardine	Japan	Pacific Ct.	4.0	12#	600	3500	140	100	10	12	1000	40	35	1780
12	Menhaden	U.S.A.	Atlantic Coast	3.75	9	600	3800	83	50	5	8	300	29	28	690
13	Salmon	Canada	Pacific Coast	9.0	45##	400	350	30	37	3.7	35	26	30	19	260
14	Cod	Norway	Bergen Ct.	7.0	21##	380	860	60	40	4	18	70	26	18	185

Note: # ··· $1.5 \times T_{max.} > T_B$ ## ··· $3 \times T_{max.} < T_B$

As the value of T_B is about 9.4 times that of $T_{max.}$, the size of netting cord is regarded as too large. The acceptable Power Block will be estimated with the sheave size at 19 inches and pulling capacity 260 kilograms.

Norwegian small scale cod purse seine operated along the Bergen coast in which l is 7 centimeters, y is 21, L is 380 meters and n is 860, the estimations are $T_{max.}$ is 4 kilograms, T_B is 18 kilograms, P is 70 kilograms and C is 26 inches. As the value of T_B is about 4.5 times that of $T_{max.}$, the size of netting cord is regarded as quite sufficient. The acceptable Power Block will be estimated with the sheave size at 18 inches and pulling capacity 185 kilograms.

3.6.1 Tuna long line fishing

Tuna long line fishing is operated in waters of Northern and Southern Pacific, and the Indian and the Atlantic Oceans by ships, equipped with deep freezers and advanced navigational instruments. The construction of the gears are as follows.

The gear of tuna long line consists of the main line, branch line, hooks and the accessories including the float lines, buoys, pole and flag, and floating lights. The overall buoyancy of the buoys is much larger than the total gravity of the long line gear. One unit of long line gear is indicated by "baskets", since shallow baskets are used to keep a section of lines coiled up. The operation lines are connected together and unloaded in to the water for operation.

1. Kinds of tuna longline

The tuna long line varies in its structure and dimensions depending upon the kinds of fish.

1) Ordinary tuna longline

This type is used to catch large sized tuna of about 30 to 100 kgs in weight such as the bluefin, yellowfin and bigeye tuna.

2) Longline for Albacore

The main subject of this longline is the albacore weighing from 10 to 20 kgs.

3) Small sized tuna longline

The gear is for small sized tuna weighing from 3 to 10 kgs. This has, sometimes, more branch lines per unit basket than ordinary tuna longline.

2. Construction of ordinary tuna longline

1) Main line

Material to be used for the main line should be selected in accordance with the size and character of the subject fish, the size of fishing vessel, the condition of fishing ground, the number of longline baskets used, and estimated cost of materials.

The tensil strength of the main line must be strong enough to endure the strong shocks produced by the vertical movements of the vessel, plus the resistance of the longline gear itself which is composed of 100 to 450 baskets, and the tension of hooked fish. In addition, the materials are required not only to resist decay and wear, but also guarantee hard operative conditions.

As the qualified materials fulfilling the various requirements as stated above, synthetic fibers such as "Cremona" have become popular. Major materials being in use at present are cotton and cremona treated with coaltar or synthetic resins. As a standard, cotton lines consisting of 33 ~ 41 grs per 1.5 meter, 2 ~ 3 ply thread of hard twist (54 ~ 66 strand x 3 x 3) and Vinylon line consisting of 45 ~ 55 strand x 3 x 3 are employed in the main line. The length of main line per unit basket varies from 200 meters to 300 meters. Normally, the length of the main line is divided evenly by total number of branch lines.

The practical arrangements of the line is necessary in order to avoid any possible entanglement of the line.

2) Branch line

Materials to be used for branch lines must be strong enough to endure direct shock from the hooked fish. Normally, lines used are the same kind and size (or a little thinner than) as the main line. Factors to be taken into calculation for determing the length are; the swimming depth of fish in a specific fishing ground and season, the force of the current, and the drifted angle of the branch line against that current, so that the baited hooks will reach the proper depth to meet the schools of fish. For convinient handling, the length of individual branch lines is sometimes limited to less than one-half of the distance between two neighboring branch lines. However, the length of branch lines is often determined in view of higher catch rather than operational convenience.

The number of the branch lines to be fitted on the main line of a unit basket may be properly determined by considering the length of the main line, the length of each individual branch line, the habit of the fish, and the nature of the operation. It is remarked that the length of branch lines in one basket are sometimes equal and sometimes unequal.

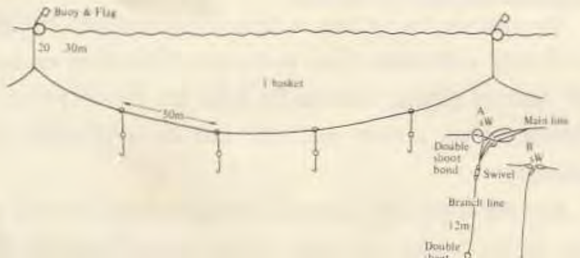
A branch line consists of four portions, the actual branch line, a Sekiyama, a wire leader and a hook. One end of the branch line is tied to a joint of the line in a double fishermen's knot (or its modifications) and other end is fitted with a universal shackle. Then, the lower end of the universal shackle is tied to the loop of the Sekiyama in a double fishermen's knot. Length of the branch line varies from 5 to 15 meters when a basket of main line has an average of four branch lines. Sekiyama is made of #3 ~ #5 cremona threads of 20 count wound around a core of 9 ply #26 ~ #29 wire. The completed size of a Sekiyama should wiegh about 10 gram per meter and the length may vary 4 ~ 8 meters. Both ends of the Sekiyama are made into a loop, the upper end is tied to the branch line and the other end is tied to the wire leader.

A wire leader is approximately 2 meters in length, and is made of 9-ply wire of #28 or 12-ply wire of #27. One end of the wire leader is made into a loop to be tied to the loop of the Sekiyama and the top end is fitted tightly to a hook. This portion of the branch line is fitted so as to be readily replaced because the wire leader may break due to abration against the gangway in hauling up the catch.

Hooks are made of galvanized steel, the eye of the hook is fitted to the end of the wire leader. Round shape hooks are widely employed. These types of hook have well designed angle of curvature so that it can hold fish on it alive for a long while, without letting them escape off the hook.

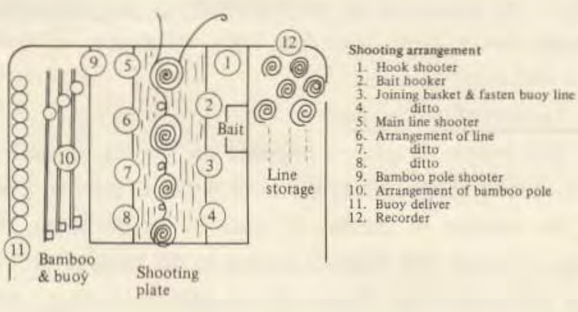
3. *The brief report on the results of tuna fishing by M/V Paknam during Cruise 5, from March to April, 1971 off Sumatra Island.*

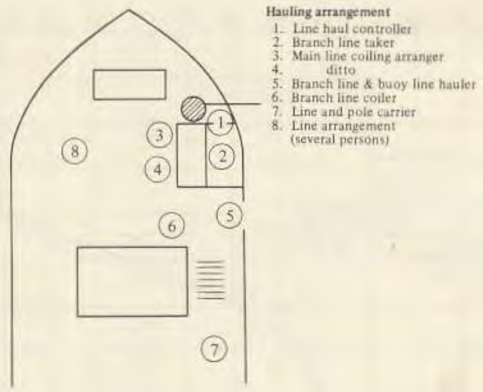
1) The structructure of tuna long line used in this fishing.



Number of baskets : 100~120
Length of a basket : 250 meters
Number of hooks in a basket : 4 hooks

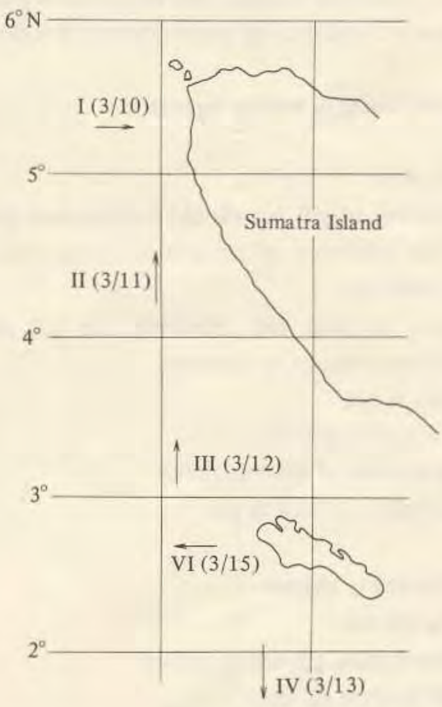
2) Distribution of persons when fitting baits, throwing the hooks and hauling the lines during working operation for training.



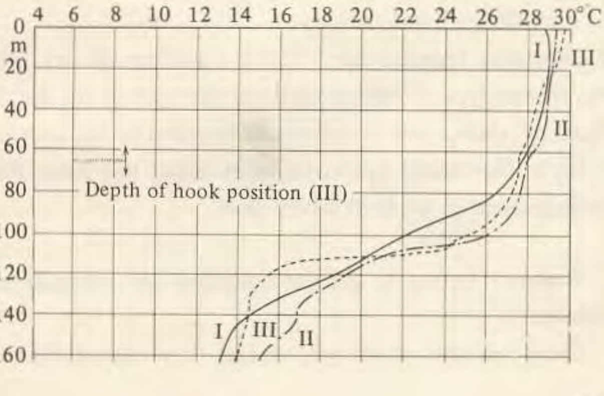


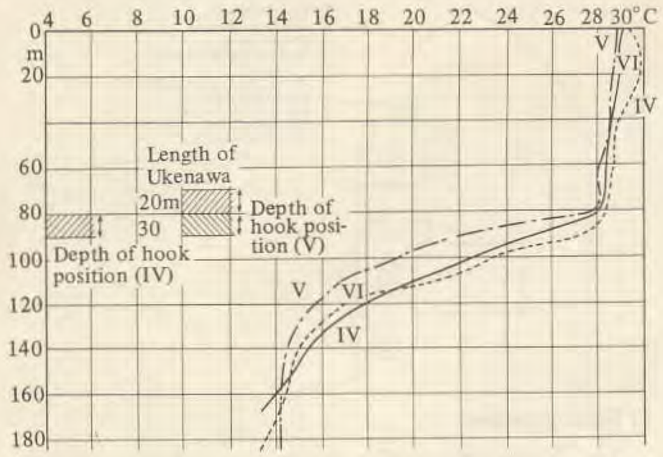
3) Fishing ground

The fishing ground of tuna long line fishing from I to VI operation were 30 to 60 miles off westside of Sumatra Island as shown in figure. It also shows approximate fishing position. The depth of these areas were 700 to 2,000 meters deep seas were very calm throughout six operations.



4) Water temperature distribution against depth of water and the depth of hook positions measured by the depth meter during operations from I to IV.





It may be suggested from these figures that the hook positions are properly situated at depths where the water temperature suddenly changes. The temperature graduatly decreases from the surface of water down to this depth.

3.7 Gill net fishing in various aspects

I. Introduction

The function of gill net should be discussed starting first from the efficiency of the gear compared with other kinds of fishing gear.

In order to raise the efficiency of gill net, the following items need to be discussed.

1. Materials of net
2. Construction of gill net
3. Fishing method of gill net fishing
4. Mechanization of boat & gear

II. Classification of gill net

1. Floating gill net
   1) Fixed floating gill net by anchor
   2) Drift floating gill net
   3) Mid-water drift net
2. Bottom gill net
   1) Ordinary bottom gill net
   2) Trammel net
3. Encircling gill net
4. Sweeping trammel net: This is a bottom gill net, but for special type of fishing method. One end of the net is fixed by anchor and the other end is pulled by the boat in a circle. One circle operation takes about one hour, the pulling speed of the boat is very slow.

Factors relating to gill net operation are itemized as follows:

1. Characteristics of gill net relating to various kinds of fish such as upper layer migrating fish, bottom fish and mid-water migrating fish.
2. Relation among the size of mesh and the size of fish, swimming force of fish, shape of fish, etc.
3. Relation between sea current and the catch.
4. The mesh selection of gill net
5. Economical view point of gill net fishery as amount of catch, species of fish, price of fish, size of gear, size of boat, number of fishermen, operating expense, fishing ground, etc.
6. Catch per effort, relating to length & width of net.

III. Discussion on the factors relating with gill net efficiency

1. Material of net

It took a long time in the history of net materials to change from natural fiber to synthetic fiber. In each period of time, the fishermen always tried to apply the best quality material for gill net in order to catch more. At present the most popular material for the gill net are synthetic fibers, especially Nylon with monofilaments also being adopted.

2. Flexibility of netting cord.

The material of netting cord is very important for gill net fishing efficiency. Even in the past, fishermen applied soft fiber of natural material for a gill net. Hemp, rummy, Chinese hemp, cotton and silk had been adopted accordingly.

Also the fishermen adopted netting cords as thin and as long as the breaking strength allow to give flexibility to the cord in the fishing operation. Sometimes they adopted only one side twisting of netting cord without dying because of the same reason.

For instance, in salmon gill net used in North Pacific Ocean the fishermen adopted rummy as the material and this changed to Nylon after the war. Nylon fiber proved to be more effective than rummy in all respects such as flexibility, breaking strength, elongation, colour, durability, etc. At present, almost all gill nets for salmon use the nylon net composed of multi-filament or monofilament, mainly due to large flexibility, high efficiency of catch and anti-decay in water.

3. Tension of netting cord

The degree of tension imposed on the leg of mesh is also closely connected to the catchability of gill net. Even if the number of meshes of main net is the same, the shape of mesh will differ according to the hang-in ratio of the gear and this effects the tension of netting cord. Moreover the tension of the legs of the meshes, differes in accordance with the quantity of the buoyancy of floats and the sinking power of the sinkers used in the net. If the net is constructed with too much tension in legs of meshes by attaching many floats and sinkers, the net will not catch many fish. Especially if the net is expected to catch the fish by trammeling, tension shuld be small as possible.

4. Breaking strength of netting cord

The breaking strength of the gill nets should be as big as possible so as to prevent breakdown while fishing. When the fish are gilled or entangled in the net, the fish have some momentum in attacking the net, and after they are caught they have some influence on the net, so they may escape from the net or break the net if the breaking strength is not enough.

The gill nets requires flexibility and low visibility and therefore, the thinner the netting cord, the better the effectiveness, although thin netting cord ordinarily has less breaking strength. Therefore, when we select the netting cord from many kinds of synthetic fibers, it is desirable to select netting cord which has high breaking strength but low in thickness, even though it sounds like a contradiction.

5. Elongation of netting cord

The proper elongation of netting cord is necessary for gill net so as to catch the fish. Ordinary, the proper elongattion ratio, the elongation at the breaking point divided by original length is about 25 to 30 percentages. The ratios of various synthetic fibers used in fishing are listed as follows:

Kind of twine	Ratio of elongation
Nylon 210 denier	26 – 30
Polyvinyl alcohol (Kuralon) 20's	25 – 30
Vinyliden chloride (Saran) 360d	20 – 25
Vinyliden chloride (Kurehalon) 360d	22 – 28
Vinyl chloride (Tevilon) 300d	18 – 23
Polypropylene (Prolon) 180d 24's	15 – 20
Polyester (Tetoron) 210d	14 – 18
Combination Nylon with Saran (2:1)	27 – 33
Combination Nylon with Tevilon (2:1)	26 – 32
Cotton twine 20's	25 – 30

6. Colour of the net

To catch fish by gill net, it is preferable that the net has less visibility in the water. Generally speaking we can say that the colour of net should be similar to the colour of the fishing ground water, that is to say the colour of surroundings. According to practical experience in which salmon gill net, sardine gill net and flying fish gill net are used in respective fishing ground, we can confirm the following facts concerning the said factor.

In the case of sardine drift net which is operated at the depth of 50 to 60 meters in day time, the result shows that the best colour of drift net is found to be a dull gray colour net. In the case of salmon gill net operated in North Pacific Ocean in which the transparency of water is very low, the fishing is conducted at twilight time, the preferable colour of this net is confirmed as greenish black. In the catch of flying fish, as the waters in which this fish migrate is highly transparent so a blue net colour is good for catching.

Recently, monofilament nets have been used for the material of gill net, specially in salmon fishing. Though this net has a very hard twine, extreme transparency of twine brings very good result in its catch.

7. Mesh of net

The proper size of mesh to the body length of fish is strictly related to the efficiency of the gear. Mesh selection is particularly important for gill nets. So many researches about mesh selection of gill net have been discussed in the world. The way of deciding optimal mesh size should be discussed in connection with elastisity of fish body, stress-strain of netting twine, elongation ratio of netting twine, momentum of fish and the shape of fish body.

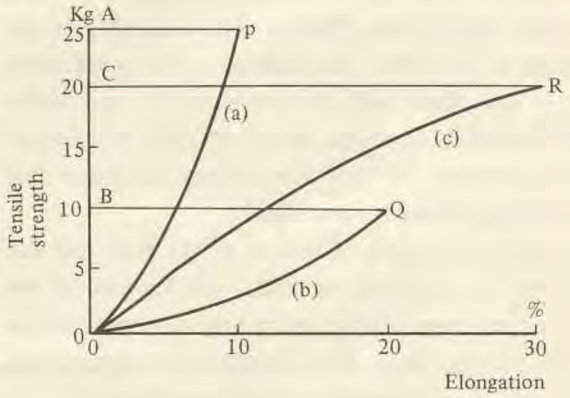
8. Hang-in ratio of the net

The shape of a mesh is decided by the value of hang-in ratio. Generally the hang-in ratio of drift net is about 25–35 percent. On the contrary bottom gill net has a higher hang-in ratio than drift net, specially for the net which take fish by trammeling. It is about 30 to 50 percent. The relation between value of hang-in ratio and the catch should be studied in actual operation.

9. Stress-strain relation on netting cord

The work load of netting cord until it is broken is calculated by the diagram of stress/strain curve of netting twine.

This is relation between the elongation of netting cord and the tensile strength which are shown in the following figures.



There are three types of curves as (a), (b) and (c) shown in the figure, for instance, which have different netting twine properties. From this figure, we can have the following property of netting cord as:

1) Breaking strength:

Orders of breaking strength are (a), (c) and (b)

2) Elongation

Elongation value when it breaks are in the orders of (a), (b) and (c).

But elongation when it is loaded with 10 kilograms, the order is (a), (c) and (b)

These values are tabulated in the following table as:

	Breaking strength	Elongation	
		when it breaks	10 kg load
(a)	25 kg	10 %	5 %
(b)	10 kg	20 %	20 %
(c)	20 kg	30 %	10 %

The catch ability of gill net depends upon elongation, young's coefficient, and rate of recovery of elastisty.

If the necessary breaking strength of netting cord in this case is more than 10 kilograms, the case (b) is unproper twine. So, we must choose proper twine among (a) and (c).

The work load is calculated by the area of A O P (a) and C O R (b). General speaking, when the amount of work load is big, it has large ability of making a constant load of work. That means the durability of twine is large.

Which twine between (a) and (c) should be chosen depends upon the necessary elongation and breaking strength under operation. If salmon gill net, in this case, the breaking strength should be more than 20 kilograms, the case (a) should be applied.

The amount of work load, average tuffness, is formulated as, W=½ x tensile strength x elongation. According to this calculation, the average tuffness is 125 in the case of (a), 100 in the case of (b) and 300 in the case of (c) is the best on the view point of average tuffness.

10. Movement of gill net udner operative condition.

A mesh of drift net of which float line is kept on surface of water takes different shape according to the condition of the wave. The float line takes some movement in accordance with the movement of wave under various condition of height, length and cycle of the wave. And this motion of float line reaches the sinker line through oblique netting twine line.

Therefore, the cycle of motion of the float line and sinker line do not always coincide, and the mesh of net may produce irregular shape according to wave condition and also net dimension. Thus, complicated expansion and contraction of mesh movement could be observed.

As the waves on the surface decrease in movement with the depth of water, the position of fish staying at a constant depth of water becomes relative to the net. Therefore the existence of net is likely to be recognized by the fish. If the above movement is high, the net will become more visible to the fish. This phenomenon will affect the catches, and the vertical movement of water and fish are affected by the following factors such as width of the net, variation in mesh size and wave's conditions.

11. The relation between behaviour of fish school in connection with brightness of surroundings and the operation of gill net.

The fish school moves up and down in connection with the brightness of surroundings in the water. That is to say the movement of school is surely influenced by brightness of the light.

Generally in day time fish school swim in deeper water in large groups, but in twilight they come up to the surface with active action. During night time they desperse with slow activity and keep their position in some constant depth of water.

Therefore the operative depth of gill net will differ according to the time of day.

Recently the existence of fish school can be found by fish finder, the proper depth of operation by mid-layer drift net could be adopted by the results of inspection of fish finder.

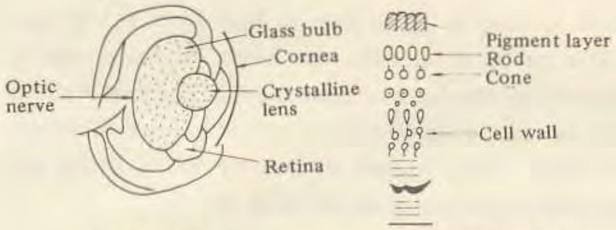
The fish has a tendency to go downward when they face the net during day time. And it is therefore necessary that the net should be set a bit deeper than the layer at which fish are swimming by adjusting the length of barrel string.

Now we must take into consideration the following operative factors before setting the mid-layer drift net.

Through the inspection of fish finder we could estimate the direction and speed of fish before laying out the net. And the net must be put in the sea a little ahead of the school of fish by considering the sinking speed of net and time necessary for attaining the expected depth. This is we can call the operative tactics of mid-layer drift net using fish finder aids. We must establish most reliable way of such operative research by experiment. The sinking speed of net is closely connected with the specific gravity of the netting cord and it is necessary for the net to reach the fishing depth as quickly as possible. Therefore, the specific gravity of gear material used for the net should be big.

12. Seeing Sensibility of fish

This is the problem of how much a fish can see in water, and does it recognize the colour of the object. The construction of eye of fish is not so different from animals. Crystalline lenz is stiff, almost completely round in shape, and scarcely deformed by the water pressure. In the case of vertebrates, Crystalline lens can change in thickness to focus objects from far distances to near. But



Section of Retina　　Section of eye ball

fish can't adjust. Each eye is independent in visual activity. Therefore, fish can not estimate the distance of object correctly. The retina can control eyesight sensibility by transmitting the sense to optic nerve. As seen in the figure of retina section, it consists of cones which can distinguish the colour and rods which can judge the intensity of brightness.

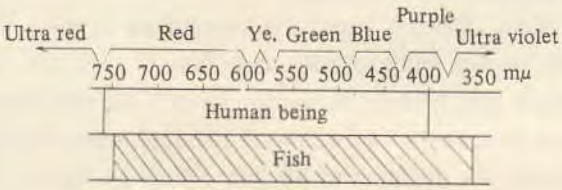
So, we can imagine that fish can distinguish both the colour and brightness of object.

But the visibility of fish is very much influenced by the transparency of water as well as the brightness of surroundings.

Human being can see objects in water up to almost half the value of transparency of water. And so we imagine that fish will have almost the same visibility as human being.

Beside sight sense, the fish has audible sense, smelling sense, taste sense, touch sense and sense of lateral line.

Among these senses the sight sense is the most important sense for fish. They can make schools by keeping each other in sight, and take food. In night time they may act in response to sound or vibration in water.



According to tank experiments on fish, they can feel such range of wave length of light which are very similar to human beings. They prefer green or blue colours to red, orange, yellow, violet, purple and white.

As for colour of net in water, it changes its colour according to the depth of water.

Comparative longer waves of colour are likely to be absorbed by water and loose its original colour. That means red will change to black in a deeper depth of water. On the contrary short wave such as green or blue, it will remain as original colour in a rather deeper depth.

So, at about 50 meters in depth, red colour of net is seen as black, but green or blue colour of net retains its colour, having rather high brightness as seen in fig. 1.

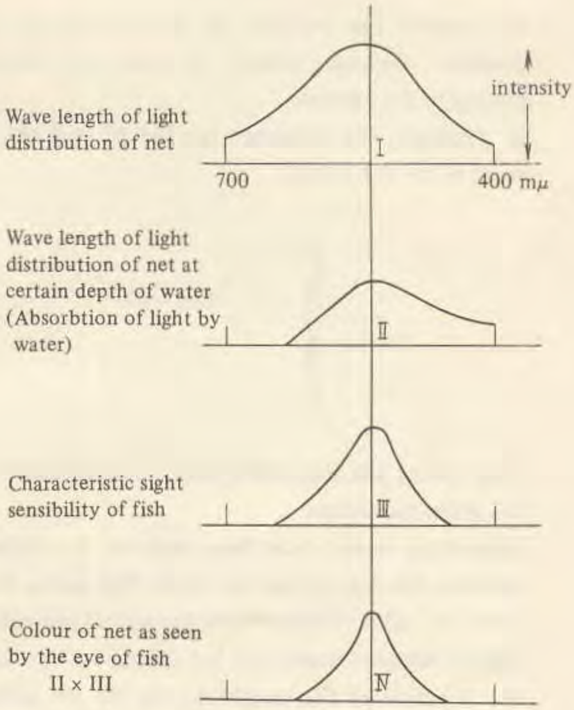
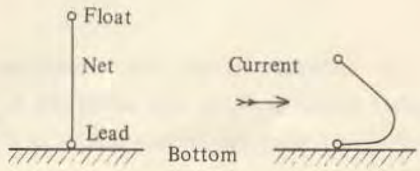


Fig. 1.

13. Relation between water current and the catch.

The current has the following influence on the shapes of gill net as well as the catch itself.

1) If there is some current of sea water in the fishing ground, the fixed gill net by anchor changes in shape as shown in vertical section.



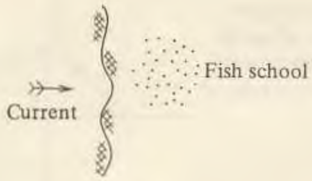
Buyos and sinkers are for fixing the net under currents. Nevertheless, if the current is too strong, the net will change. It takes a curve-like (curvature) shape along the vertical section as shown in the figure. If the deformation is too much, it is unsuitable to catch fish. We can estimate the shapes of net under a constant strong current through dynamical analysis.

Dr. Kawakami conducted this study mathematically. If there is some current, the mesh of net is changed, and the tensility of netting cord becomes big. This phenomena will influence the catch. And it also has connection to the buoyancy, sinking power and hang-in ratio.

2) The fish migrating in the sea cannot recognize the direction of the current. If the depth of water is very shallow, they can notice the bottom. So, they

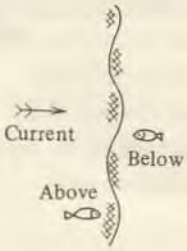
may detect the intensity of the current and its direction through relative position of bottom ground to the current.

In principle, the fishermen lay the gill net out in front of the fish school.



That means the fish will transfer in accordance to the water movement.

Interesting surveys have been made on the relation between the current and the catch. The survey were done on halfbeak (*Hemirhampbus sajori*) and needle fish (*Athlemnes hians*) gill net fishing for checking the direction of fish caught by the the net against the direction of the current.



As for halfbeak fishing, the percentage of the number below is 70 % and above 30 %. And for needle fish fishing the former is 67 % and the latter is 33 %.

That means for both kinds of fish, about 70 % of fish are caught from below the current. And so we can judge that these fish will mainly swim against the current.

IV. Gear design of various kinds of gill net.

1. Sardine drift net

Most of the material in this fishing gear is 4 yarns of cotton fiber 20 hanks. Besides this, synthetic fibers such as kuralon (polyvinyl alcohol) and kyokurin (mixing twist of nylon and saran) have recently been used for net materials. The mesh size is ordinarily about 4.3 centimeters, and stretch length per unit of net of about 50 to 75 meters is shorten to about 30 to 48 meters (about 35 to 40 percent in hang-in). The length of sinker line is a meter longer than that of float line.

It is used in fishing grounds where water depth is about 60 to 100 meters. It is drifted by the current and net body is hung by barrel lines to keep them at a proper mid-water layer. Usually, the length of barrel line is adjusted for the depth of migrating fish. The boat is about 20 gross tons using 40 units of net with 7 to 8 fishermen on board. They operate the net by aid of lifting net apparatus when raising the net. (Fig. 2)

2. Spanish mackerel drift net.

Spanish mackerel are mainly caught in drift net by entangling. Therefore, the hang-in ratio of net construction is comparatively big. The material of net used in this fishing gear is nylon 9 yarns or Tevinai (combinating twist of nylon 6 yarns and Tevilon 3 yarns) 9 yarns, and 7.5 centimeters of mesh size, 130 number mesh width, and 600 as meshes unit of length. The selvedge is Saran 12 yarns with 7.5 centimeters of mesh size and 10 number mesh width along buoy line and bottom line.

Only buoys are used along buoy line, sinkers are not used. Because it is necessary to be able to catch the fish by entangling taking less tensility to the legs of the mesh. Buoy line is made of Manila rope 26 meters in length, 2 lines. The sinker line is the same, made of 25 meters in length, 2 lines. There are 23 buoys per unit length, the buoyancy of each is 260 grams.

The hang-in ratio is 44.5 percent in buoy line, and 44.6 percent in sinker line. (Fig. 3).

3. Mackerel drift net

This drift net is as almost the same as the sardine drift net. Material is nylon 210 d/4 yarns, 7 to 8.5centimeters mesh size, 200 to 500 number mesh depth, 75 meters per unit length and 30 to 40 percentage of hang-in. (Fig. 4)

4. Mackerel bottom gill net.

Nylon 210 d/4 yarns, 7.6 centimeters in mesh size, 100 number width shorter than that of drift net. The hang-in ratio is about 30 percent. Usually, the operation is done from leeward to windward side, but when there is a current, the direction of the boat should be towards the direction of the current. The net should be set when the boat is running at low speed. First the signal flag with float should be thrown, and then the first anchor, and then the net and the hauling rope. When the net is set, the second anchor should be thrown and then the manila rope. When hauling the net, it should be started from the second anchor, and hauling line should be hauled up by using the net roller which is fixed at the bow of the boat. When the net reaches the boat, we should manually haul the net from the boat side. Suitable fishing grounds are in waters of 90 to 150 meters with some reef where fish schools readily assemble. (Fig. 5)

5. Flying fish drift net.

Flying fish come near the shore in season for spawning and after that they go back to the offshore regions.

Usually the fixed gill nets are used inshore waters and drift nets in off shore waters for catching this kind of fish.

The construction of drift net differs from that for sardine or mackerel drift net. The net consists of three parts, namely end net, 1st leader net and 2nd leader net.

The end net (cod-end net) is laid out by half surrounding curve. The fish school which are migrating along the leader net face this end net and are gilled in the mesh. In day time the fishermen drive the fish by swimming under water in the direction of the end net. So it is a "driven net". The colour of this net should be sky blue.

The constructions of all parts of this net are illustrated in the figure. (Fig. 6)

6. Shrimp bottom gill net.

Usually, shrimps or lobsters dwell in rocky crevices at the bottom. The depth of water is about 5 meters. During day time, they stay within the crevices and during night time they move out to search for food. They are more active in stormy sea condition. Formerly the fishermen used cotton 30 hanks, 6 yarns material, but since they started to use nylon net the catch amount increased 1–5 times. The mesh size is 6 to 10 centimeters with 10 to 17 number mesh width and 50 to 69 percent hang-in ratio.

For the float, lacquer is used because it does not easily absorb water. For sinkers, unpolished earthern ware and small lead are suitable. With regard to float line, very light palm fiber is fused. (Fig. 7)

7. Shark bottom gill net.

The body length of sharks are different for males and females. So mainly females are caught by bottom gill net.

Size of netting cord is about Nylon 210 denir of 15 to 24 yarns. The mesh size is about 17 to 25 centimeters.

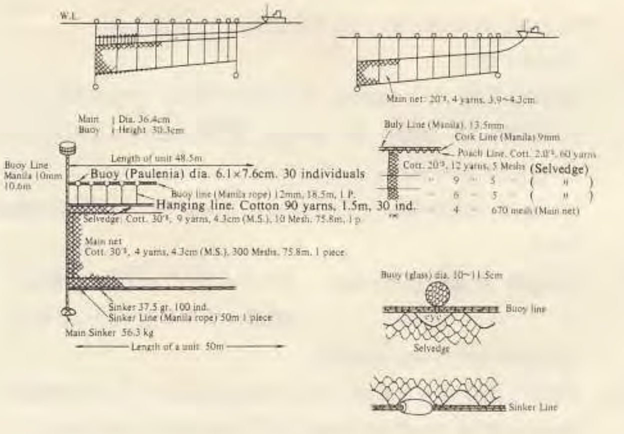


Fig. 2. Sardine drift net

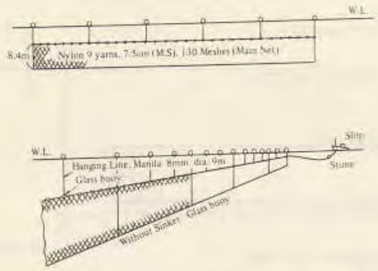


Fig. 3. Spanish mackerel drift net

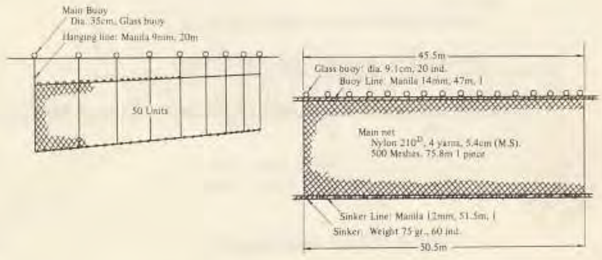


Fig. 4. Mackerel drift net

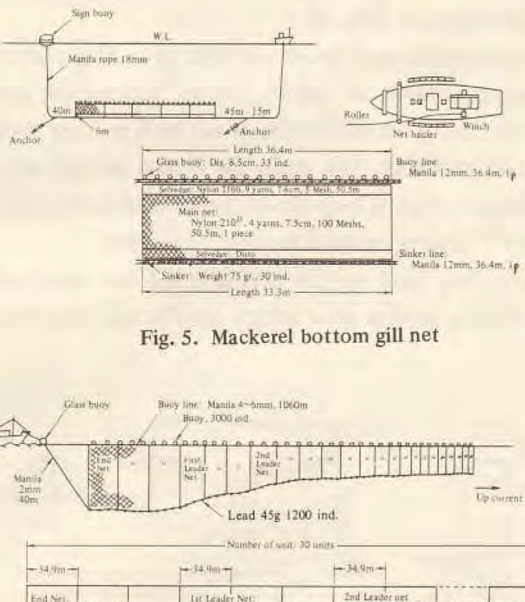


Fig. 5. Mackerel bottom gill net

Fig. 6. Flying fish drift net

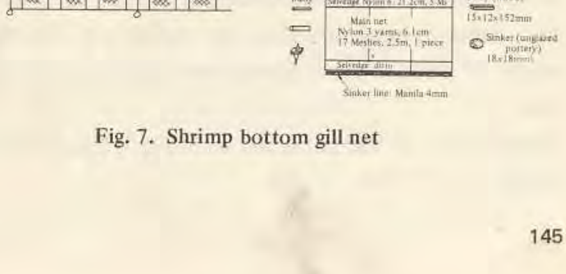


Fig. 7. Shrimp bottom gill net

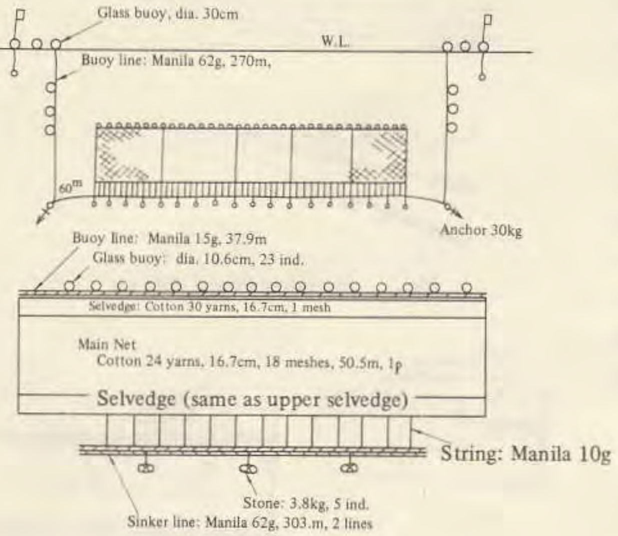


Fig. 8. Shark bottom gill net

Since the shark is caught by trammeling, the hang-in is big as 40 percent. (Fig. 8)

The boat of 7 to 10 gross ton with 25 – 35 p.s. operate in fishing grounds of about 150 to 300 meters depth. They use about 40 to 80 units of net by 8 persons aboard.

In the morning they reach the fishing ground and lay out the net which is kept almost a day until next morning. Some net haulers are used for hauling the net.

Once they haul up the net, it is laid out again in the same fishing ground after taking out the fish from the net body.

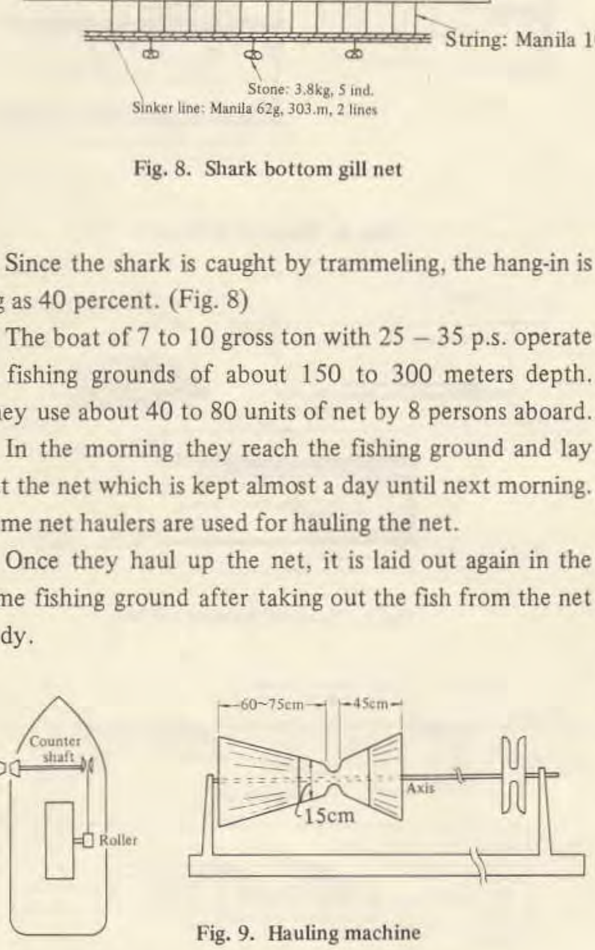


Fig. 9. Hauling machine

At the hauling the fishermen at first take up the anchor rope and the sinker line of bottom gill net are pulled up by hauling apparatus. (Fig. 9)

8. Trammel Net

Three sheets of net are constructed as trammel net. Small mesh size nets hang loosely in the middle and two net sides have big sized mesh.

According to the kinds and size of fish, the size of netting cord are different. Generally outside net is about 4 to 5 times in mesh size than the middle net. The stretch length of middle net is about two times that of outside nets.

Construction of this net is shown in Fig. 10 and the Table below.

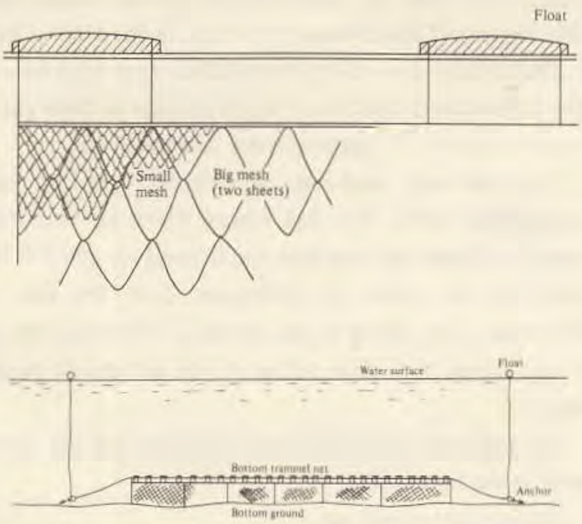


Fig. 10. Trammel net

Type	Middle net	Outside net
A	Nylon 210 d/2 50 mm	Nylon 210 d/4 210 mm
B	" 210 d/2 21 mm	" 210 d/4 180 mm
C	" 210 d/3 60 mm	" 210 d/4 210 mm
D	" 210 d/4 60 mm	" 210 d/6 240 mm

Net is set zig zag in the fishing ground around some reefs or set in circular shape.

Almost all dimersal fish are caught by this net and various sizes of fish could be caught by same sized mesh.

The difficulties encountered in this net is the troublesome removing of fish from the net. The efficiency of this net is always higher than ordinary one sheet gill nets. The selectivity of this net is not as strict as ordinary gill nets. Therefore some locality forbid to use this kind of net because it might effect the resources of fish in certain fishing ground.

Let us show some sample of trammel net which is used for catching dimersal fish.

Net, rope, accessories and others:

Middle net:

Nylon 210 d/2 yarns. 5.5 cm (Mesh size) 40 mesh (number of mesh in deep). 75.8 meters (stretched length of unit net)

Hang-in ratio 48 – 50% (buoy line), 44 – 46% (sinker line)

Length of complete net 37.9 – 39.1 m (buoy line)
40.9 – 42.4 m (sinker line)

Outside net (two sheets):

Nylon 210 d/4 yarns. 24.2 cm (mesh size), 17 meshes (number of mesh in deep), 57.6 m (stretched length)

Hang-in ratio 40 – 42% (buoy line)
26 – 30% (sinker line)

Complete length 33.3 – 34.9 m (buoy line)
40.9 – 42.4 m (sinker line)

String	: Kuralon 20's, 24 yarns length (39.4 cm) 82 pieces
Rigging twine	: Kuralon 20's 9 yarns
Buoy line	: Manila rope 5 – 6 mm (dia), 33.3 – 34.9 m (length)
Sinker line	: Manila twine 40.9 ~ 42.4 m length
Buoy	: Wooden buoy 33.3 cm × 1.2 cm × 1.5 cm 41 pieces 51.2 cm – 54.5 cm intervals
Sinker	: Unpolish earthern ware 11.3 gr (weight) 203 pieces 1.5 – 1.8 cm intervals
Main buoy	: Barrel
Main buoy line	: Manila rope 5.1 mm (dia) 2 – 2.5 times of length to depth of water
Anchor rope	: Manila rope 6 mm (dia) length twice depth of water
Anchor	: 2.6 – 3.7 kg
Boat	: 1.5 – 2 tons, 2 fisherman
Fishing ground	: 3 – 60 meters of water depth

Catch	Water depth
Flat-fish	15 – 60 m
Shrimp labste	21 – 23 m
Crab	15 – 23 m
Fish	3 – 15 m

9. Sweeping trammel net

The structure of this net is similar to that of the trammel net, but the method of operation is quite different. The efficiency of this gear is rather high if the fishing ground and fishes are proper for this operation. The expenses needed for this fishing gear is rather small with few fishermen required for operation.

Net construction

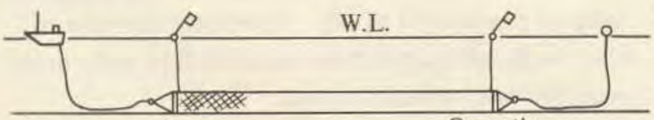
Trammel net

Middle net: Nylon 110 d/3 yarns 6.7 cm (mesh size) 38 meshes 75.8 m (stretched length)

Selvedge of middle net: Nylon 110 d/6 yarns. 6.7 cm (mesh size) 6 meshes

Outside net: Nylon 110 d/6 yarns 36.4 cm (mesh size), 4 meshes

Completed length 40.9m (Buoy line), 42.4m (Lead line)
Synthetic float 12 cm (length)



Operation

Rope

Buoy line	: Manila rope 7.5 mm (dia), 40.9 m (length)
Sinker line	: Manila rope

Accessories

Buoy	: Synthetic float 12 cm (length) 57 – 60 pieces
Sinker	: Unpolished earthern ware 37.5 gr (weight) 300 pieces

Number of units: 15 – 19 units

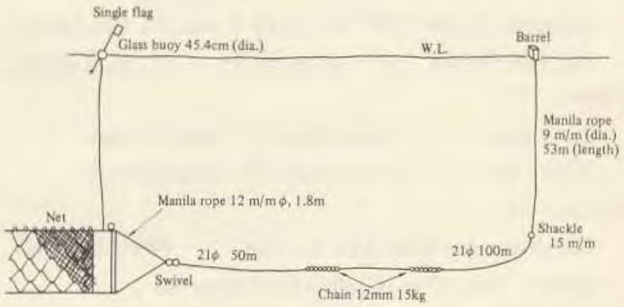


Fig. 11. Sweeping trammel net

Fishing method

Net is laid out in the morning. Barrel, rope, flag, net, flag, rope and barrel is the order of the throwing. After throwing the gear, the boat comes back to the place where they started from and take the barrel.

Then they pull up the manila rope of 9mm in diameter by drum. And after they reach the shackle, they take this off and join the towing rope to this shackle. Then the boat pulls this rope in a semi circle until the net is completely changed in direction. The speed of towing must be very slow, about 1h. 45m to 2 hours. After the net reverses direction, the boat takes the towing rope from shackle, and barrel rope and barrel are again joined with shackle. After that the boat goes another round and performs the same operation of towing. These operation of towing are conducted 4 to 5 times until 3 or 4 o'clock in the afternoon and then the fisherman take up the net with fish.

The net should be set along the current. Fish are caught mainly at the middle part of net.

Boat	: 8 – 9 tons, 35 – 40 p.s. 4 fishermen
Catch	: Bottom fish

Depth of fishing ground: 60 meters

10. Encircling gill net

This is the fishing gear which surrounds the fish in circle by net and forces the fish to gill in the mesh of the net. Schools of mullet which in habit reefs or near the shore are mainly caught by this fishing method. Sometimes fisherman use the gill net inside the encircling gill net. After they surround the fish, they put the single gill net inside. Thus the fish are caught both trammeled by encircling gill net and meshed by single gill net.

Net construction

Size	length of net	300 meters
	height of net	12 meters

Net

Main net: Nylon 210° 6 yarns, 5 cm (mesh size)

300 meshes (deep) 75 meter (length), 4 units

Shelvage: Nylon 210° 12 yarns 5 cm. 15 cm. (deep)

Bag net: Nylon 210° 12 yarns 15 – 18 cm, 2 sheets

Rope

Buoy line : 6 mm (dia) 300 meters 2 lines

Sinker line : 6 mm (dia) 330 meters 2 lines

Accessories

Buoy: wooden float 24 x 3 x 2cm 30 cm intervals

Sinker: lead 60 gr (weight) 6 cm intervals

Boat

Small boat 5 ton, 5 – 10 p.s., 2 boats

8 fishermen each

Catch : Mullet, shad, sea bass etc.

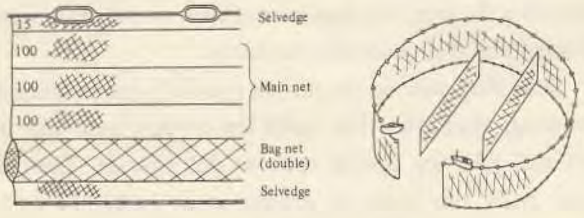


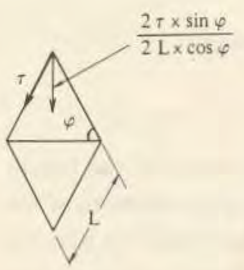
Fig. 12. Encircling gill net

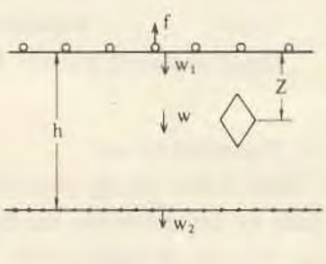
V. Some theorectical discussion on gill net.

1. Tension of netting cord.

If a gill net hypothetically stands still at any depth of water using such notations as f, buoyancy of float per unit length, w_1, weight in water of float line and upper salvedge of the net, w_2 weight in water of the lead line with lead and the lower selvedge of the net, w weight in water of the main net for unit length, the following formula is true.

$$f = w_1 + w + w_2$$





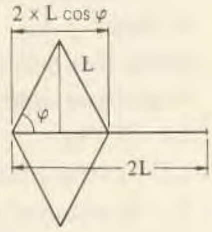
Vertical tension (tensility) for unit length of net for a part from the upper edge of the main net down to a depth z is formulated as;

$$f - w_1 - w \times z/h = w\,(1 - z/h) + w_2$$

If τ denotes the tension of netting cord, the vertical component of τ is τ x sin φ. If 2L is the size of stretched mesh, the width of a mesh is 2L x cos φ.

Therefore when the net has a hang-in ratio of (1-cos φ), vertical tension for unit length on the netting cord is $2\tau \times \sin\varphi/(2L \times \cos\varphi)$.

Here, the hang-in ratio is denoted as (1-cos φ) x 100 percent shows from the following figure.



$$\text{hang-in ratio} = \frac{2L - 2\cos\varphi \times L}{2L} = 1 - \cos\varphi$$

Therefore, in drift net the tension on the leg of mesh $\bar{\tau}$ is obtained from next formula as:

$$w\,(1 - z/h) + w_2 = \frac{\tau \times \sin\varphi}{L \times \cos\varphi}$$

$$\therefore \tau = [w\,(1 - z/h) + w_2]\ L \times \cot\varphi \qquad (1)$$

And bottom gill net the tension τ is obtained in the same process as:

$$f - w_1 - w \times z/h = \frac{\tau \times \sin\varphi}{L \times \cos\varphi}$$

$$\therefore \tau = (f - w_1 - w \times z/h) \times L \cot\varphi \qquad (2)$$

The maximum tension of τ is obtained when z = 0.

Thus, the maximum value are:

Drift Net → $\tau = (w + w_2) \times L \cot\varphi$ (3)

Bottom Gill Net → $\tau = (f - w_1) \times L \cot\varphi$ (4)

From these formulae we can calculate the tension τ of in both cases as intermediate value (Z=h/2) and maximum value of formula (3) or (4), if we know the value of f, w, w_1, w_2, L and φ. And those values could be easily found once net construction is decided.

As for f, the buoyancy of float is given by the tables supplied by float manufacturer. And also w, the weight of net in water is obtained from the weight of net in air W by affording the value of specific gravity of materials.

$$w = W\left(1 - \frac{1}{\rho}\right) \qquad \rho\text{: Specific gravity}$$

And w_1 and w_2 also could be calculated from the information of ropes and sinker.

The net which has big mesh for catching big fish has a bigger τ value than the net for small fish.

Particulary, in the case of bottom gill net which is mainly used to catch by trammeling is very small in τ value. When designing the gill net, these tables will be useful in calculation.

Drift Net

Value of τ

Specification / Name of fish	Mesh size (cm)		Number of yarns		Number of mesh in deep		Tension τ (gr.)	
	Range	Mode	Range	Mode	Range	Mode	Intermediate	Maximum
Herring	5.5 ~ 7.3	6.0	4 ~ 6	6	60 ~ 200	200	1.0	1.8
Yellow-tail	15.1 ~ 21.2	18.1		60	30 ~ 100		5.0	7.5
Young yellow-tail		9.1		9		100	1.8	2.5
Salmon	12.7 ~ 16.6	13.6	9 ~ 12		40 ~ 60		3.0	4.0
Trout	9.1 ~ 13.6	10.6	8 ~ 12		25 ~ 70		1.5	
Mackerel	7.0 ~ 9.7	8.5	4 ~ 12	6	70 ~ 480	100	2.5	3.5
Saury	3.0 ~ 4.0	3.3	4 ~ 6	6	75 ~ 200	100	1.0	1.2
Tuna	11.2 ~ 36.4	24.2			20 ~ 70	100	6.0	11.0
Shad	3.3 ~ 7.6	4.5		4	50 ~ 300	30	0.9	1.2
Bonito	6.1 ~ 10.3	7.6	6 ~ 18	6	40 ~ 500		1.3	2.0
Flying fish		5.2	4 ~ 6	4	30 ~ 200		0.5	0.8
Spanish mackerel	6.1 ~ 12.7	10.6	15 ~ 21	15	40 ~ 175		1.3	2.0
Shark	10.7 ~ 30.3	18.2			20 ~ 40	25	9.0	14.0
Horse mackerel	5.5 ~ 8.5	7.3	4 ~ 8	6	150 ~ 450		1.6	2.5
Sardine	3.9 ~ 4.8	4.3	4 ~ 6	4	140 ~ 700		2.3	3.0

Bottom gil net

Yellow-tail	16.7 ~ 22.4	18.2		60	10 ~ 30	20	4 ~ 17	5 ~ 19
Young yellow-tail	6.1 ~ 12.2	9.1	9 ~ 12		50 ~ 100	100	0.5 ~ 18	1 ~ 19
Alaska pollack	8.5 ~ 10.6		4 ~ 6	4	25 ~ 75	75	2 ~ 5.6	2 ~ 6
King crab	36.4 ~ 55	48.5	15 ~ 24	15	6 ~ 13	7	0.4 ~ 7	0.5 ~ 8
Crab	7.6 ~ 18.2		4 ~ 18		5 ~ 80		0.1 ~ 3	0.1 ~ 3.5
Shark	14.5 ~ 24.2	18.2	12 ~ 30		16 ~ 40	25	1 ~ 21	1 ~ 22
Cod	12.1 ~ 16.7	15.2	9 ~ 12	12	15 ~ 42	20	0.7 ~ 8.5	1 ~ 9
Bream	7.6 ~ 15.8			9	10 ~ 45		0 ~ 1.3	0.2 ~ 1.6
Shrimp	3.9 ~ 12.1		4 ~ 6	4	10 ~ 100	13	0 ~ 1	0 ~ 1
Flat-fish	8.8 ~ 24.2	15.2	4 ~ 12	4	10 ~ 50	20	0.3 ~ 4	0.3 ~ 4.5
Horse mackerel	6.1 ~ 8.5		6 ~ 8	6	80 ~ 130	100	1.9 ~ 4.9	2 ~ 5.3

In the case of the drift net, the tensility (tension) is determined by its sinking power of sinker and bottom gill net by its buoyancy of float.

From these two tables, the gill net which is main used to catch by gilling the fish, is bigger in τ value than the gill net mainly by trammeling.

The nets used to floating fish is smaller in τ value than the net used to catch dimersal fish.

2. Comparison of catch of gill net by different elements of net

   1) Different kinds of synthetic fiber nets were compared in the Sardine gill net, as shown in the following table.

Crehalon : Vinyliden Chloride
Saran : – ditto –

Tavilon : Vinyle chloride
Kyokurin : Nylon + Saran
Gurilon : Nylon

	Number of units	Number of operations	Total No. of fish caught	Average catch per unit	Comparative catch ratio
Cotton net	2	28	8.907	171	1.00 (as a base)
Crehalon	4	28	17.383	155	0.91
Saran	3	28	22.139	264	1.54
Tevilon	4	28	26.558	237	1.39
Kyokurin	2	28	21.326	381	2.23
Nylon	3	28	22.569	269	1.57
Gurilon	3	28	15.047	179	1.05
	21	196	133.929	237	

From the above table, the order of catch by kinds of synthetic fiber are Kyokurin, Nylon, Saran, Tevilon, Gurilon, Cotton and Crehalon.

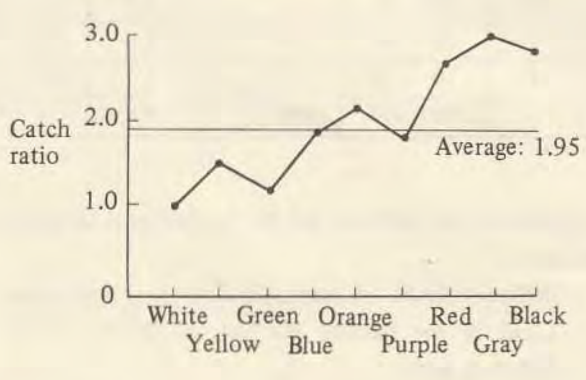
	Number of fish caught per unit, Sadine Gill Net									Ratio
	1	2	3	4	5	6	7	8	9	
Nylon (Blue colour)	130	238	109	983	440	108	188	380	860	1.52
Nylon (White)	75	104	83	716	255	23	113	230	175	1
Cotton (Brown)	76	147	27	872	340	87	158	296	890	1.15

White colour is not good for catching sardine by drift net operated at twilight.

2) Sardine drift net

Nine colours of net are used for trial fishing; viz, white, yellow, green, blue, orange, purple, red, gray and black.

The orders of the brightness of coloured net at a depth of 50 meters at midday are the same as the above.



The catch ratio increase it's value from lighter net to darker net in brightness shown above figure.

3.8.2 Trap net construction – Japanese type

1. Introduction

In such a country like Japan which is surrounded by the sea, with a warm current from the south and a cold current from the north along the coast lines. At nearly the center of the Japan Sea area these two currents mix where planktons are produced with nourishing water, small fish are aboundant taking food and bigger fish (both cold current fish and warm current fish) stop their migration and take plenty of food.

Thus, the coastal lines of Japan is very rich in fish migrating from north to south or from south to north. Furthermore the topography of coastal lines have many varieties with bays, gulfs, inlets and coves.

The fixed nets with trap (or without) from big scale to small, various types of nets, are set along such coastal lines to get migrating fishes along the coast. The situation is very favourable for such kind of trap nets, or fixed nets because of the moderate coastal current, moderate varieties of uneven lines in the coast, seasonable migrating fish depending on the conditions of water, moderate meteological stimulation which induce the fish school from off-coast areas to shore by variation of sea condition with lower atmospheric pressure.

2. Construction of trap net

1) Large size trap net

There are three kinds; fixed net of triangular shape ("Oshiki Ami" in Japannese), fixed net of box shape ("Daibo Ami") and fixed net with trap ("Otoshi Ami"). The last one is now most popular and the former two are not used now in Japan.

The "Otoshi Ami" are set in the main bays of Japan such as Sagami Bay, Kumano Bay, Tosa Bay, Toyama Bay and Wakasa Bay. The example of this type is shown in the following figure.

Otoshi Ami (example in Mie Prefecture, Japan)

Depth of operation : 30 meters

Nature of sea bottom : mud or muddy sand

Main species of fish: Yellow tail, tuna, sardine, mackerel, horse mackerel and other coastal species.

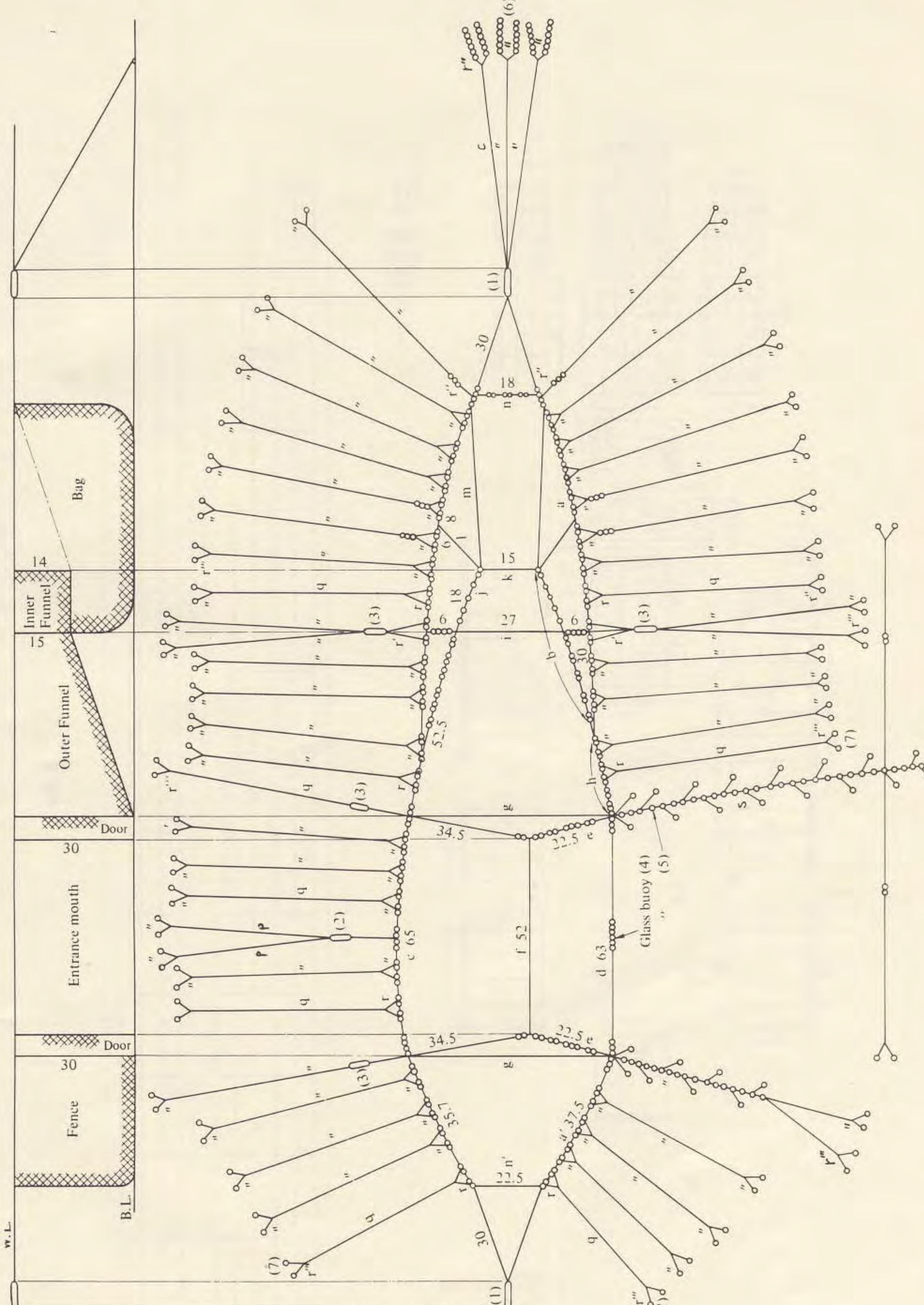
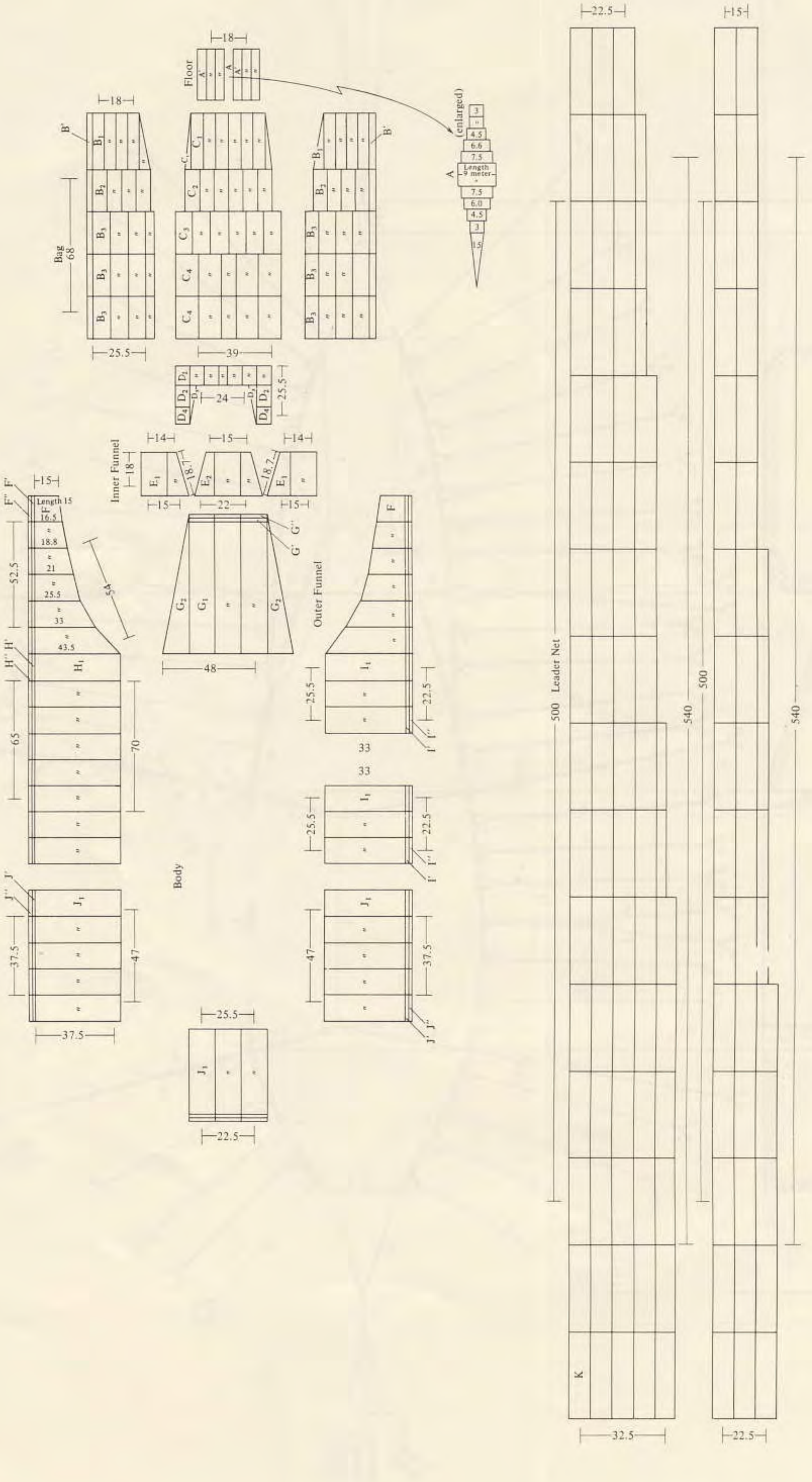

Bag
Inner Funnel
Outer Funnel
Entrance mouth
Fence
Door
Door
W.L.
B.L.
Glass buoy (4)

Fig. 1



Floor
Bag
(enlarged)
Length 9 meter
Inner Funnel
Outer Funnel
Body
Leader Net

Fig. 2

Specifications (explanation of Fig. 1 ~ 3)

Webbing

	A	A'_1	B_1	B_2	B_3	B'	C_1	C_2	C_3	C_4	D_1	D_2	D_3	D_4	E_1	"	E_2	"
Name	Bag	"	"	"	"	"	"	"	"	"	"	"	"	"	Inner Funnel	"	"	"
Name of of part	Cod-end	Floor	Side	"	"	sel-vage	Bot-tom	"	"	"	"	"	"	"	Side	"	Bot-tom	"
Mate-rial	Saran or Kureha-lon (1,000 D)	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Size (ply/No. of yarns)	3/39	3/36	3/30	"	"	3/60	3/30	"	"	"	3/36	"	"	"	3/24	"	"	"
Type of knot	Trawler knot	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
Mesh size	3.0cm	4.5	6.0	7.5	9.0	6.0	6.0	7.5	9.0	12.0	7.5	"	"	"	12.0	"	"	"
Depth (No. of meshes)	100	"	"	"	"	10	100	"	"	"	"	"	25	10	100	100-50	100	100-50
length of net	78.5m	27	30	22.5	22.5	120	30	22.5	"	22.5	15	15	22.5	7.5	22.5	22.5	22.5	22.5
No. of unit	1	6	9	8	21	2	6.5	6	6	9.0	6.5	2	1	"	2	2	1	2
Total length	78.5m	162	270	180	473	240	195	135	135	203	97.5	30	22.5	15	45	40	22.5	40

	F	F'	F''	G_1	G_2	G'	G''	H_1	H'	H''	I_1	I'	I''	J_1	J'	J''	K
Name	Outer Funnel	"	"	"	"	"	"	Right Fence	"	"	Door	"	"	Fence	"	"	Leader
Name of of part	Side	Sel-vage	"	Bot-tom	"	Sel-vage	"										
Mate-rial	"	"	"	"	"	"	"	Saran or Kure-halon	"	"	"	"	"	"	"	"	"
Size (ply/No. of yarns)	3/30	3/45	3/60	3/30	"	"	"	3/30	3/45	3/60	3/30	3/45	3/60	3/30	3/45	3/60	11.3 gr/fathom
Type of knot	"	"	"	"	"	"	"	Trawl-er	"	"	"	"	"	"	"	"	"
Mesh size	13.5	"	"	13.5	"	"	"	13.5	"	"	"	"	"	"	"	"	21
Depth (No. of meshes)	100	"	"	100	100-1	100	"	100	"	"	"	"	"	"	"	"	50
length of net	145	1.5	1.5	72	72	1.5	1.5	43.5	1.5	"	43.5	1.5	"	43.5	1.5	"	45
No. of unit	2	12	12	3	2	3	3	8	8	"	6	"	"	13	"	"	108
Total length	290	18	18	216	72	4.5	4.5	348	12	"	261	9	"	565.5	19.5	"	2430

Ropes & Lines

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	n'	a'
Name	Body	"	"	"	"	"	"	"	"	"	Body	"	"	"	"	"
Mate-rial	Wire	"	"	"	"	"	"	"	"	Manila rope	Manila rope	"	"	Wire	"	"
Size (Dia)	21mm	"	"	"	"	16mm	"	"	21	21	21mm	18	"	21	"	"
Length	98m	52.5	65	63	22.5	52	34.5	20	39	18	15m	18	43.5	18	22.5	67.5
No. for unit	2	2	1	1	2	1	2	2	1	2	1	2	2	1	1	2
Total length	196m	105	65	63	45	52	69	40	39	36	15m	36	87	18	22.5	135
Remarks	Bag side	Funnel side	Fence side	month side	Door	Door			Stretch-ing rope of Funnel month	inner Funnel side						Fence side

	c	p	q	r	r'	r''	r'''	s	t	u	u'	v	w			
Name	Anchor rope	"	"	"	"	"	"	Leader	"	"	"	Leader	"	Lines attach with net selvage	Haul-ing rope	Hanging rope
Mate-rial	"	"	Manila rope	"	"	"	"	Wire	Manila rope	"	"	Manila rope	"	"	"	Manila rope
Size (Dia)	18	12	24	24	"	"	"	21	18	24	18	18mm	"	18	"	6–9 thread
Length	66	66	66	15	24	7.5	7.5	1002	22.5	69	69	18	7.5	3600	30	1.2
No. for unit	6	2	44	35	2	2	55	1	102	10	22	2	146		4	1000
Total length	396	132	2904	525	48	15	302.5	1002	2295	690	1518	36	1095	3600	120	1200
Remarks	Anchor rope of main buoy												Foot of Anchor rope			Japanese name "Bottan"

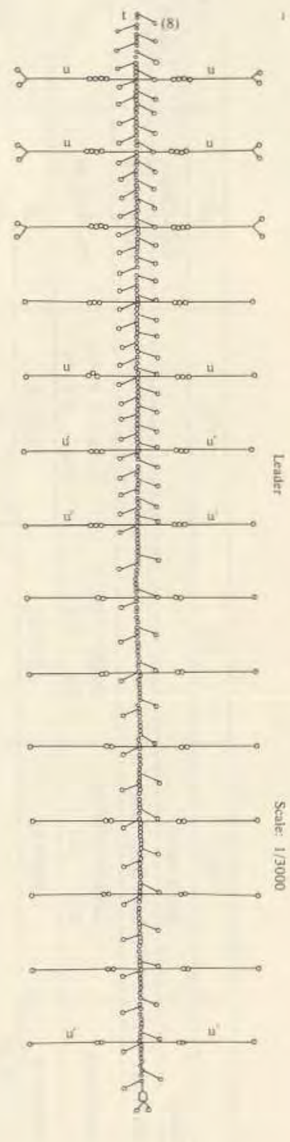


Fig. 3

Floats

	(1)	(2)	(3)	(4)	(5)
Name	Main buoy			Side float	Leader float
Material	Iron float tank	"	"	Glass buoy	"
Dimension	Length 6 meter Dia 0.7 "	Length 3 meter Dia 0.5 "	Length 3 meter Dia 0.4 "	Dia 0.45 m	"
Buoyancy	2000 kg	250 kg	150 kg	20	"
No. of floats	2	1	4	272	360

Sinker

	(6)	(7)	(8)
Name	Main bags	Side bags	Leader bag
Material	Sand or pebble bag made of strew cord	"	"
Dimension	Length 1.2 m, Dia 0.4 m	"	"
Weight in air	18 kg (1 bag)	"	"
No. of Sinker	1800 (= 25 bags × 72)	2350 (= 25 bags × 94)	3100

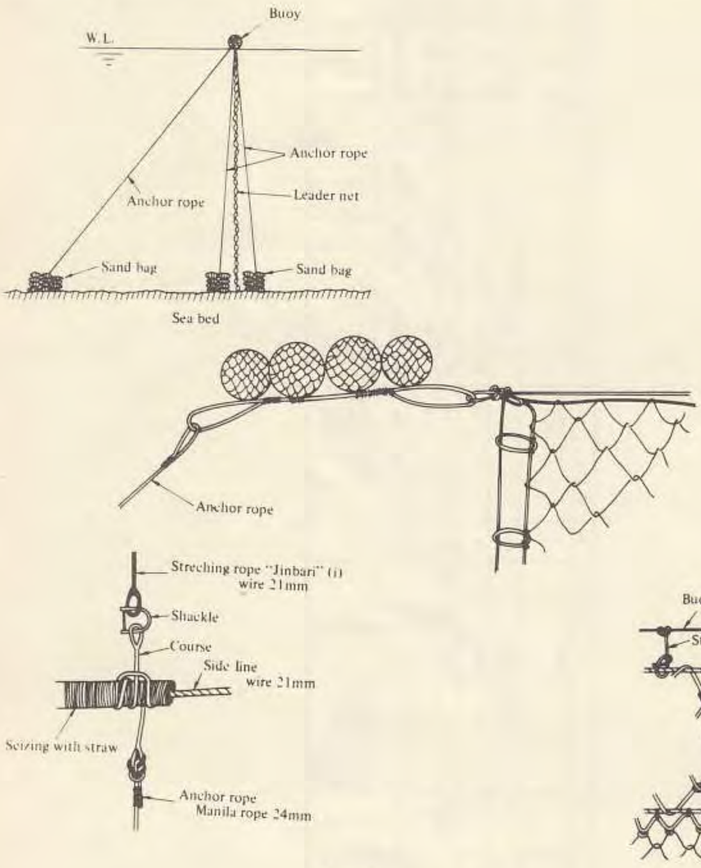


Fig. 4

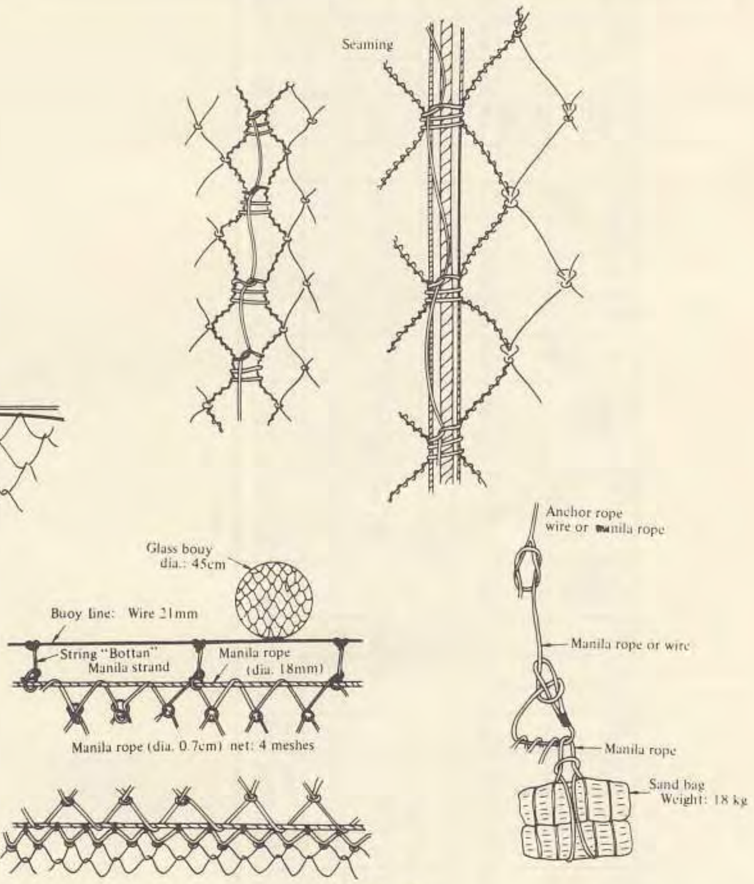


Fig. 5

2) Medium size trap net

a. Sardine trap net (*Hisago-ami*)

The pocket of this net measures some 18 m long and 50 m wide in the largest type.Three boats are necessary to operate the net. They capture the fish in the bag net. One boat raises the bag net entrance and the other boats lift up the whole bag net from one end to other end facing the flowing current. Mainly the fishing season is spring to summer. The species of fishes are sardine, mackerel, horse mackerel, squid and others. The fishing grounds of this kind are mainly in the coastal waters of middle part of Honshu on both the Pacific and Japan Sea sides. The whole view of this net is shown in Fig.6.

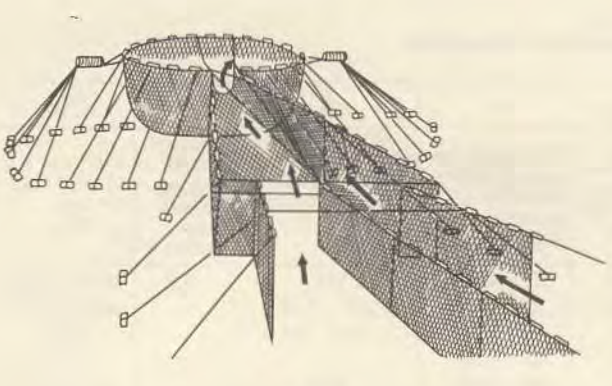


Fig. 6

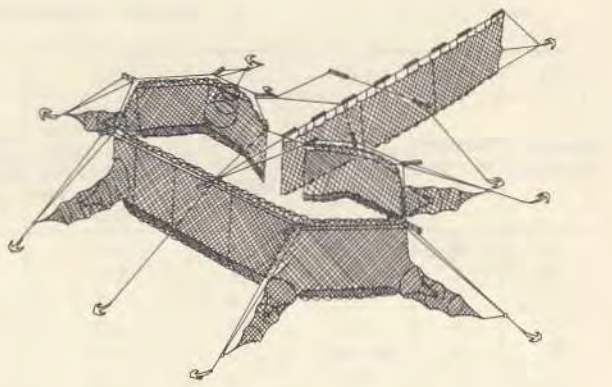


Fig. 8

b. Herring trap net

The net of this type is used only in the northern part of Japan, mainly along the coast of Hokkaido. This type usually measures about 45 m long and 20 m wide in the bag net, and some 150 m long in leader net. The net is operated with 3 boats, one for net-lifting and two for carrier. The bag net is lifted up from one end to another after the entrance had been closed. The fishing season is rather short, only 3 months, March to May, when the herring come for spawning. The whole view of this net is shown in Fig. 7.

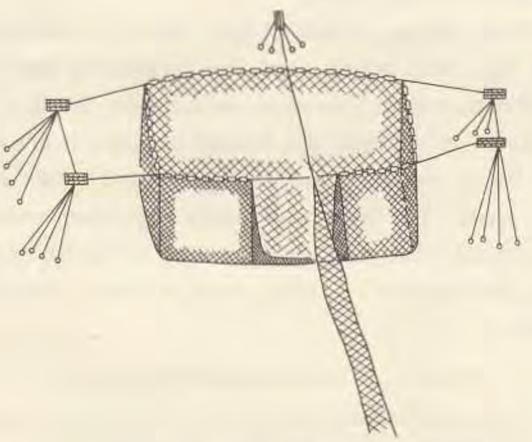


Fig. 7

3) Small size trap net (*Masu-ami*)

Almost all the year round this kind of small size trap net is operated in many small bays throughout the country. The gear consists of main net, leader net and bag nets with flappers. Several bag nets (pocket net) are loosened by ropes through pulley whose ends are pulled up to take the fish by boat. This operation is done by one small boat boarding 2 ~ 3 men. The species of fishes are sea bream, spanish mackerel, perch, cuttlefish, flat fishes, croaker, squid etc. The whole view of this net is shown in Fig. 8.

3.8.2 Estimated tension in the sand bag rope in trap nets

Medium sized trap nets in Japan used for catching sardine and horse mackerel called *"Hisago – ami"*, consists of ascending net, trapping net and fence net. The net is set very near, or 1 to 2 miles off shore, its length is about 120 meters, width 80 meters and depth of net 20 to 40 meters.

This type of trap net in "Kamakura" fishing ground, the conditions of which are shown in the followings, is experimented with as a sample for measuring the tensions of ropes connected to each sand bag. The results of the measurements and the estimations are tabulated in the followings also.

Conditions of fixing sand bags and the buoyancy of buoys

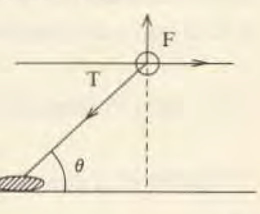
1) Fixing power of 1 sand bag: Bottom nature is sand, length of rope is 103 meters (average), and depth of water is 39 meters. Then, $n = 103/39 = 2.5$ and consequently the fixing power is calculated as 11 kilograms.
2) Buoyancy of glass buoy: Diameter is 36 centimeters and the buoyancy of buoy $F = V - W = 21 - 3 = 18$ kilograms.
3) Variation of buoyancy according to the floating appearance of glass buoy.

Percentage appearance of buoy above the water line of total volume	% 0	5	10	20	30	40	50
Buoyancy (kg)	18	18	17.6	16.2	14.4	11.7	9.0

4) Tension of rope calculated from the buoyancy

$$T = F \sin\theta + R \cos\theta = 0.4F + 0.9R$$

Here, R is distributed value of total net resistance by the number of anchor ropes.



Results of measurements and estimations

(1) Symbol of buoys	(2) Number of ropes	(3) Number of sand bags connected to rope	(4) Number of glass buoys	(5) Total buoyancy estimated from floating appearance above the surface of water (kg)	(6) Buoyancy on rope F=(5)/(2) (kg)	(7) Estimated tension of rope from the equation (kg)	(8) Directly measured tension of rope in water by tension meter (kg)	(9) Current speed during experiment v miles/h.	(10) Fixing power of sand bags on rope (kg)
A	4	50 – 80	14	252	63	25 + 0.9R	156	0.3	550 – 880
B	4	40 – 60	14	234	58	23 + 0.9R	110 – 136	,,	440 – 660
C	1	50	4	47	47	19 + 0.9R	96 – 136	,,	550
D	3	50	12	187	62	25 + 0.9R	–	,,	550
E	2	50 – 60	8	118	59	24 + 0.9R	110	,,	550 – 660
F	1	80	4	42	42	17 + 0.9R	140 – 160	,,	880
G	3	80 – 100	12	100	33	13 + 0.9R	95	,,	880 – 1100

If (7) and (8) in the table are same in the value, R, distributed net resistance to anchor ropes is approximately calculated 85 to 160 kg in case of 0.3 miles per hour of current speed.

The relation between the tension of rope and speed of the current studied by model experiment for "Hisago-Ami" is approximately expressed as $T = kv^{1.7}$, where, T is the tension and v is the speed.

Under this experiment, the speed of current is almost 0.3 miles per hour which is normal and average speed of current in the fishing ground for "Hisago-ami", but if the current increase 3 times this normal speed or 0.9 miles per hour, which is a "strong current" for this net, and impossible for operation of hauling the net, the tension of rope increases $(9/3)^{1.7} = 6.4$ times the tension in normal current of 0.3 miles per hour. Therefore the resistance of R becomes $(85\sim160) \times 6.4 = 540\sim1020$ kgs which is considered almost equivalent to the fixing power of sand bag (10) as seen in the table. In other words, the sad bags will be in danger of being washed away by the current in currents of more than 0.9 miles per hour in speed.

As the breaking strength of synthetic rope of 10 to 15 millimeter in diameter, is about 2.5 to 3.5 tons, the tension of a rope 100 to 150 kgs, is about 5 per cent of the above value. In other words, the *safety factor* is calculated as 20 in this case. Even in 0.9 miles per hour of current, the tension will occupy about 20 to 30 per cent of the breaking strength, that is 3 to 5 safety factor, so we could estimate the elongation of ropes which is always under stress from hydraulic resistance of net due to the current of about 0.3 to 0.5 miles per hour, and this is of no account in the practice.

3.8.4 Light Fishing (1), Characteristics of light fishing

1. Objectives of the study on light fishing

In order to clearly understanding light fishing, the following items of the research ought to be conducted.

1) Kinds of fishing operation with light, their techniques, problems of light fishing and future prospects.
2) Physical character of light in water, how the light intensity distribute according to the condition of environment.
3) Fish behaviour under the light, reaction of fish to the intensity of light and relation between behaviour of fish and specified gears.

2. History of light fishing

There are few records of light fishing in olden times. The light was mainly used for illuminating the work. During that time fishermen realized that the fish were attracted to the light and decided to utilize it as part of the fishing method. Thus, the light was only used above the water. The light used under the water was first introduced when electricity was used as the light source. The development of fishing lamp in Japan is shown in Table 1.

Table 1 The development of fishing lamp

Light source	Light intensity	Age of light source
Wooden torch	100 cd	Till the 1900^S
Kerosine lamp	400–600 cd	Till the 1930^S
Acetylene lamp	100–1000 cd	During the 1910 – 30^S
Electric white lamp		
12V 60 W	70 cd	
24 V 200 W	300 cd	
100 V 500 W	750 cd	At present
,, 1000 W	1600 cd	
,, 2000 W	3300 cd	
Mercury lamp		
150 V 270 W	1030 cd	From the 1950^S to present
Fluorescent lamp		
100 V 20–40W	1600–5500 cd	From the 1950^S to present Colored lamps are used.

In Japan, the application of electricity began from 1930, and the actual utilization of electric lamp for fishing since 1952. Sardine fishing for example had developed in the western part of Japan, Kyushu and specially in Nagasaki, using above and under water fishing lamp, the main species of fish caught by this light fishing are mackerel, sardine, horse mackerel, flying fish, sand lance, saury, squid, yellow tail, bonito, etc. Except squid and saury, other kinds of fish can also be caught using bait, but the weight of this fishing in coastal fishing in Japan has now become very important. The effective adaptation of light in fishing is, therefore, more and more important at present and it might be connected with the saving of fishing expense and reduction of fishing labour.

3. Some problems in light fishing

To enhance big catch attracted by light, technical efforts should be paid in the following points: to attract the fish widely horizontally and also deeper the vertically, and in the next step how to keep the fish longer in the limited small area for as long as possible, and to make the fish schol more compact.

The adaptability of fish according to the light intensity and colour of light which correspond to the scale of fishing and efficiency of gears should be studied scientifically.

From olden times, the fishermen understood by experience that if one try to get the fish from wide and deep area the intensity of light must be increased to cover as wide an area of water as possible. From the study, it is that the fish distribution, around the center of light in this case, is in inverse relation to intensity of light and the length of time shortens in accordance with the increasing intensity of light. From the above scientific base, the fishermen had already experienced technique in which they decrease the light intensity gradually to keep the density of fish constant. Some fish depart from the school, and this is realized by the fishermen.

At present the light fishing has become bigger and bigger both in quality and quantity. The intensity of light should be controlled by fishing boat in order not to interfere mutually. The most important problems in light fishing is to find the way of systematic operation under effective use of light, and also effective utilization of fishing ground.

The fishing operation, therefore, should consider proper physical and biological conditions and fishing method. Thus, the problems which will be raised in the light fishing could be considered as follows:

1) To obtain most adequate intensity of luminosity in the water for attracting the fish effectively and how to obtain it.
2) The way of controlling the intensity of light according to the condition of fishing ground, kind of fish and the degree of fish growth.
3) Lighting engineering on controlling of light intensity, wave length selection of light and its proper operation with proper fishing method.
4) Pattern of fish behaviour to the light especially the main position of fish school in underwater luminosity distribution of the light, and the variety of the position according to the elapse of time.

Basic understanding of light fishing requires fundamental research mainly on biological and physical points and on the basis of these informations the application of fishing method will be performed reasonably.

3.8.4 Light fishing (2), Fish gathering lamp and related fisheries

1. White electric lamp

The white electric lamp is most popular and widely used. The lamp is made by hard glass for anti-shock, water proof and rolling proof. The filament is made specially to have a life about 200 hours, but with big light intensity. Usually the life of lamp becomes short in accordance with the increasing the light intensity.The regular voltage used for the lamps are 6, 8, 12, 24, 100, 200 and 220, and the intensity of light are 20 W, 30 W, 1 Kw and 2 Kw.

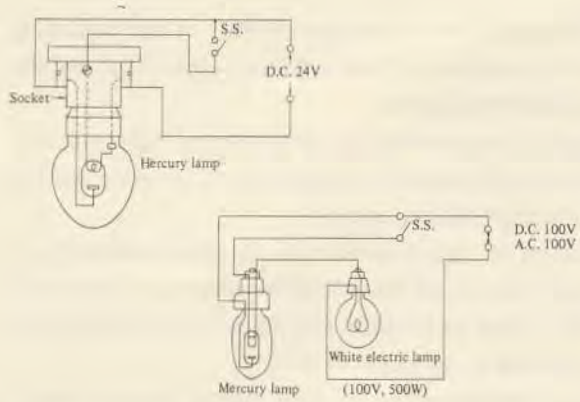
2. Fluorescent lamp

Recently it is said that the fish might have the selectivity to the wave length of light as well as light intensity. The colour of lamp, therefore, was adopted using fluoresent lamps. This could use any colour lamp and the electric consumption could be economized. Blue and green light particulary transmit well in water. The lamps used convert from direct current to alternating current. The intensity ranges from 4 watts to 40 watts. The reflecting lamp has 4 to 10 fluoresent lamps.

3. Mercury lamp

Recently the mercury lamp are used experimentally. As this lamp has spectrum characteristic maximum at the wave length of between 500 and 600 mμ, the rate of transmitance in the water is fairly high, and the lighting effectiveness to the amount of electric power consumed is also big. But the price of the lamp is very high and life of the lamp is not so long because of variation of voltage. And it will take about 2 to 5 minutes until the lamp attain proper intensity of light after putting the light on which may cause some trouble for fishing operation.

Commercial application of this lamp in fishing is not developed yet. This is because of the reason mentioned above.



4. Kind of fisheries with light

The kinds of fishing with light are follows: saury stick held dip net, sardine purse seine, mackerel and horse mackerel purse seine, lift net, squid angling and mackerel angling. Fishing operation in night time fishermen widely use fish gathering lamp which are used above water and underwater. The illumination of the lamp are shown in the table although there are many varieties.

Kinds of fishing	Electric power of fishing unit (Watt)	Light intensity of a lamp (Watt)
Squid angling	100– 8,000	100–1,000
Horse mackerel and mackerel pole and line	100– 2,000	100– 500
Sardine purse seine or lampara net fishing	100–10,000	100–1,000
Sarine, horse mackerel and mackerel lift net	100– 4,000	100–1,000
Saury stick held dip net	5,000–30,000	500–1,000
Sand lance stick held dip net	500– 1,000	100– 300

3.8.4 Light Fishing (3), Squid fishing with light

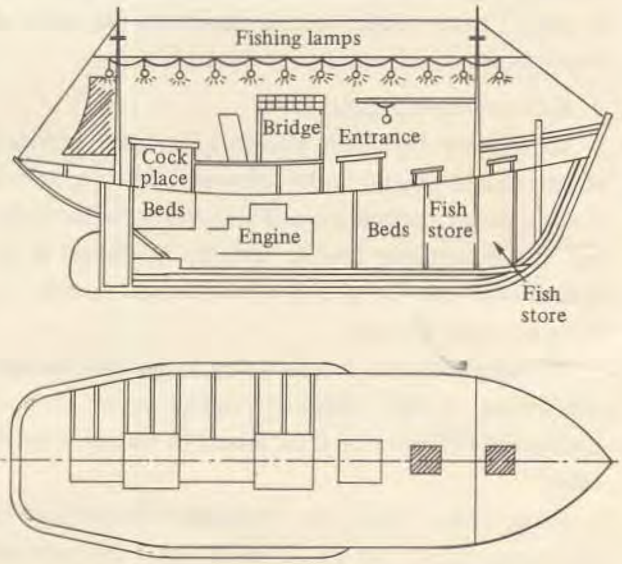
1. Squid fishing

Common squid, *Ommastrephes sloani pacificus,* are very important species in Japan, ranking third to Alaska pollack and mackerel in catch. In the catch of squids, 90% is obtained with common squid and 95% of common squid is gained by the angling fishing with light. Other are caught by trawl, trap net fishing. The size of angling boat has increased year by year in tonnage. Particularly the number of 10 to 50 tonnage fishing boat has increased rapidly and big boats such as more than 100 tonnage boat are also in fashion for fishing in southern area of the Pacific.

Very recently the scale of squid fishing has become big in size; the boats attain 300 gross ton and total intensity of light in big boat reach 200 KW maximum. So the arrangement and proper use of light intensity are required in not to interfere with other operations. Catching method become to be mechanized in some extent. Sea anchor is used in the fishing operation to keep the boat at the position of school. The intensity of light has enlarged.

2. Luminosity of light in squid angling

The fishing light used both from above water and underwater. The intensity of a lamp ranges from 50 W to 1KW. The number of lamps are usually from 1 to 8. The lamps above water are mainly arranged along with side of the boat as shown in the figure and underwater lamp is used as auxiliary to induce the schools of squid to come up to the surface of water.



The distribution of luminosity have been tested in the following examples:

1) 3Kw (500 W x 6) fishing light above the water show remarkable decreasing of luminosity from the surface to 6 meter in depth but from that depth the decreasing tendancy is not so sharp, and 4 lux at 6 meter, 0.15 lux at 25 meter in depth. At 34 to 45 meters it is estimated order of 10^{-2} lux.
2) Another experiment shows that 2 Kw luminosity is 15 lux at 0.5 meter, 5 lux at 3 meters and 1 lux at 6 meters, and 5Kw is 21 lux at 0.5 meter, 10 lux at 3 meters and 3 lux at 6 meters. The difference of luminosity between 3 and 5 Kw is big within 3 meters in depth.
3) The school of squids come up to the surface of water when the luminosity is 0 to 100 lux after sunset at about 1900 to 2000 hours in the Japan Sea. The fishing is very active during this time. If luminosity of the surface is over 100 lux, squid could not be lured by angling.

3. Effective fishing by the light

1) Intensity of light and fishing effectivenss

Before fully examining the proper intensity of light for squid fishing, there has been a recent trend to increase the intensity in squid angling. According to fishermen's experience, good fishing is expected under big intensity of light and high voltage. Among two fishing boat if the difference of light is bigger than 5 Kw there is apparently a difference of catch. For 15 ton boats the boat with 2.5 Kw per ton has most effective fishing and it decreases even if the intensity increases.

2) Arrangement of fishing lamp and fishing effectiveness

Most squid angling boats have one or two lines of fishing lamps along the center line of boat. Some research boat tested the effectiveness of the arrangement of lamps. If the intensity of light is big at mid-part of ship, the fishing is better in the mid section than in bow or aft. If the intensity is big at bow or aft of boat, fishing is good at fore or aft of boat. And the latter arrangement caught much squid in the experiment. Some experiments report that the lamp arrangement in central line are not so stable in fishing, sometimes the squids go off and are caught by other boats. So, the lamps were tried to starboard side in order to use the shadow of the body of the boat in the water then the fishing became stable.

The squid is said in general to be likely to assemble in shadow of the boat to avade the direct lighting area. According to the experiment, the result of fishing is better when the angling line is put in shadow area than bright area in the water. The barrier between shadow and bright are best in fishing. In order to utilize this barrier in fishing, the adjustment of the length of roller basement, the angling apparatus, is necessary to put fishing line in the barrier. The height of lamps is also related to the shadow of boat body as shown in the figure below.

Setting position of 3 lines (A, B and C), in a tentative way with the elongation of the roller-arm (R) of squid angling machine. B is the most effective line which is at the boundary of lighted and dark areas.

B shows a better catch than A which has her shadow area over water surface.

4. Under water fishing lamp

Generally, the lamp is used above the water for squid fishing. But some experiment on underwater lamp had been carried out; the effectiveness of attracting the squid is much better than above the water lamp but the fishing rate is not better. The result might be due to the brightness in the shadow which be formed when lamps above the water were used. This should be examined in more detail in future.

5. Effectiveness of mercury lamp

The experimental comparision was conducted between mercury lamp and electric white lamp. The former was more effective in attracting the squid but practical use of mercury lamp had difficulties such as electrical equipments, arrangement and the price.

6. Moon and fishing effectiveness

There were many reports on the relation between the phases of the moon and fishing effectiveness. One report says that if the moon rising time is during a.m. the total moon shining hours will be short and it bring better catch of squid. The feeding habit of squid are mainly around sunrise and sunset. And during the first 17 days of the moon the results of fishing is apparently good. Actual fishing operations are held without considering the moon. By biological observation, it is said that schools of squid in the night of moon shining swim actively for the sake of their sexual intercourse, but those in dark night are calm in this activity and seem to be more easily attracted by the fishing light.

7. Behaviour of squid to the fishing light

The study on the behaviour of squid has already been reported since 1828. The squid is easily attracted by light and go up near the surface of water, but if stronger light directly projected to the school, the feeding action decreases and therefore the fishing by angling is better operated in darker places or shadow made by the boat. Squids sometimes assemble near the white foam produced by the wave striking the body of boat or by moving boat ahead or astern. If the light projected to the surface of water, squid immediately swim toward the source of light and it sometimes jump out from the surface of water but only once, it never repeats.

According to the survey by fish finder on the school of squid, they exist mostly from 5 to 30 meters depth, sometimes up to 50 meters. The luminosity of the water is about 10^{-2} lux at the depth of 35 to 45 meters. They are, therefore, supposed to have light sensibility to luminosity of the order 10^{-2} lux.

How does the hook and line of squid angling gear look in the water? Through the underwater TV, the observation at the depth of 10 meters from the surface shows that only the steel hook which is special hook for squid having many hooks combined is realized as white object reflecting light and the plastic body directly connected to the hook could not be seen. Also, the observation by scientist through deep sea underwater boats report that the squid coming near the hook, stop once for a moment about one meter in front of the hook and then with quick action fly at the hook and catch the hook with two long legs.

Some consideration was given to the relation between the fishing activity and the records by fish finder. About 3 to 5 minutes after putting the light on the fishing is commenced and soon get into most excited fishing, and then catching activity slows down gradually. This tendency of fishing activity looks like a poisson distribution.

If the fishing is stopped and commeced again, the tendency mentioned above is also repeated.

3.8.4 Light Fishing (4), Saury fishing with light

1. Fishing lamp

The stick held dip net for catching saury fish is the most representative light fishing in Japan, which covers big fishing ground with a large number of associated fishing boats. Also, the number of fish gathering lamps in a boat is big, having quite big total light intensity. So, this is a very popular type of light fishing and the most big size of fishing comparing other kinds of light fishing.

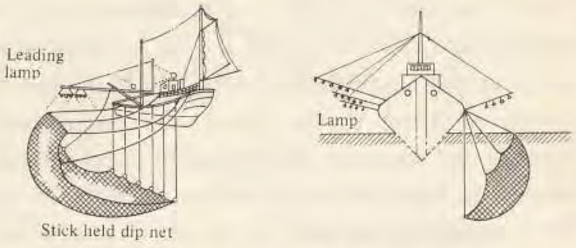


Fig. 1. Saury fishing gear

The lamps are fish gathering lamp, fish leading lamp and search light. At the fishing ground the net is opened to wait fish coming at one side as shown in the figure. Then, in the first step the fish will be attracted widely by using fish gathering lamps. Next, out of two fish leading lamps of both sides of boat, one lamp at the side which is the opposite side to the net is put off, the fish group will go excitely under the other leading lamp which is set above of the net as shown in figure. By controlling the intensity of the light, a masterfishermen once judge the fish school just on the net and being concentrated into close density of school, he will make order to take up several lead lines which are attached to the edge of one side net as shown in the figure. It needs very fast operation in order not to escape the fish outside the net. The search light is used for searching the fish school by projecting freely on the sea surface a little distance from the boat. The intensity of light is about from 500 watt to 1 kilowatt. Several fish gathering lamps are kept in the lamp shade which reflect the light of lamps and make scattering to the sea. The several lamp shades are held on the beam or bamboo which are projected from the side of boat. These are used for giving strong light widely to the surface of water around the boat. The fish leading lamp is put on just above the net by which the fishes once attracted by fish gathering lamp will go up near the surface and in the net, the intensity of light, therefore, is not necessary so strong and the reflecting light shade is deeper than that of fish gathering lamp. The intensity of light is controlled and colours have some varieties as red or orange in order to make fish concentrate in the net. The total intensity of all lights summing up is restricted within 30 kilowatts in one boat.

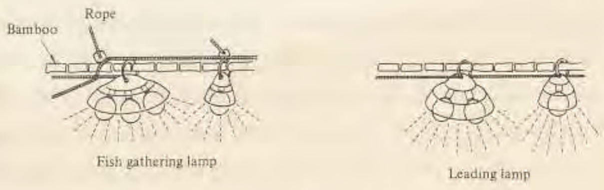


Fig. 2. Lamps

2. Saury fishery with lamps,

The total amount of catch of saury per year is from 50,000 to 500,000 tons. In most flourishing year of fishing in 1958 more than 2,000 fishing boats with fishing lamps made fishing getting 500,000 tons, but since then the catch have been decreasing and the number of boats dropped to 500. In 1973 the catch rapidly goes up more than 400,000 tons. As the light is restricted 30 kilowatts in the intensity in one boat, but actually some boats might be over this limitation. According to the scientific report, the saury fish could be attracted even in the brightness of 10^{-2} Lux in minimum. So, the lights are used only above the water surface and even the effectiveness of underwater lamp for saury fish is somewhat realized the actual fishing do not use it.

3. Reaction of fish with light

According to the observation on actual state of fish assembling around the light, the following types of characteristics could be classified.

1) "Nagashi" school type: This is the school swimming at the surface of water. This school of fish will give good fishing and almost 40 to 60 percent of all schools were found as this type particurally in the flourish year of fishing, 1958, but only 10 percent is in poor catching year.
2) "Shirami" school type: This is the school swimming deeper than "Nagashi" school type. The colour appearance of the school from the boat looks white. The tendency of attracting to the light is not so good as "Nagashi" school type.
3) "Soko" school type: This type was specially found after the utilization of fish finder and fluorescent lamp.

Before, we could not use this type, because the swimming layer is deeper. Sometimes fish finder catch the existense of school at about 30 to 60 meters. About 10 percent are found in the total fish school every year. The attraction by light of this type is rather good.

When entering spawning season, the saury fish become to show bad reaction to the light. The optimum water temperature for saury fish are from 14 to 18 centigrade.

According to scientific paper it is said that if the water temperature is low the rate of catch will show good fishing in general. That is why "Soko" school type which swim at low water temperature of deeper layer is good as attracted by the light. If there is no different water temperature between upper and lower layer of water, "Soko" school type could not be seen any more.

During attracting by the light, the fish has little quantity of food in its stomach.

4. Distribution of light in water

The equi-illumination which observed under such condition using ordinary capacity of light for a commercial boat as fluorescent lamp (20W x 6 x 8, Green colour and Blue colour) and white electric lamp (500W x 6 x 5) are illustrated in the Fig. 3.

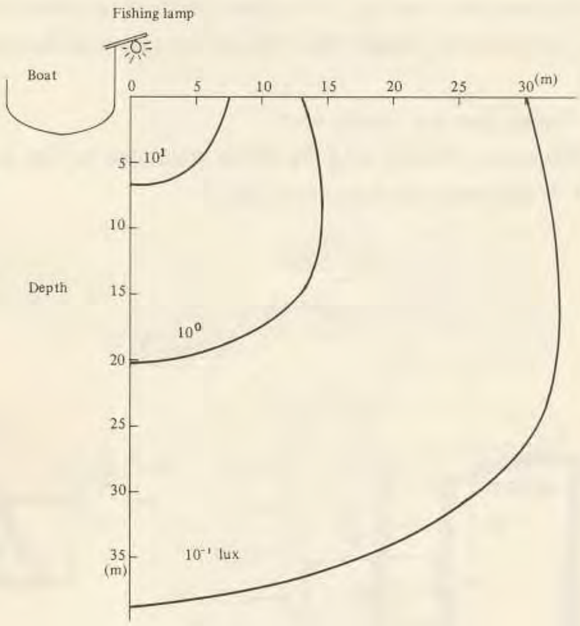


Fig. 3 Equi-illumination

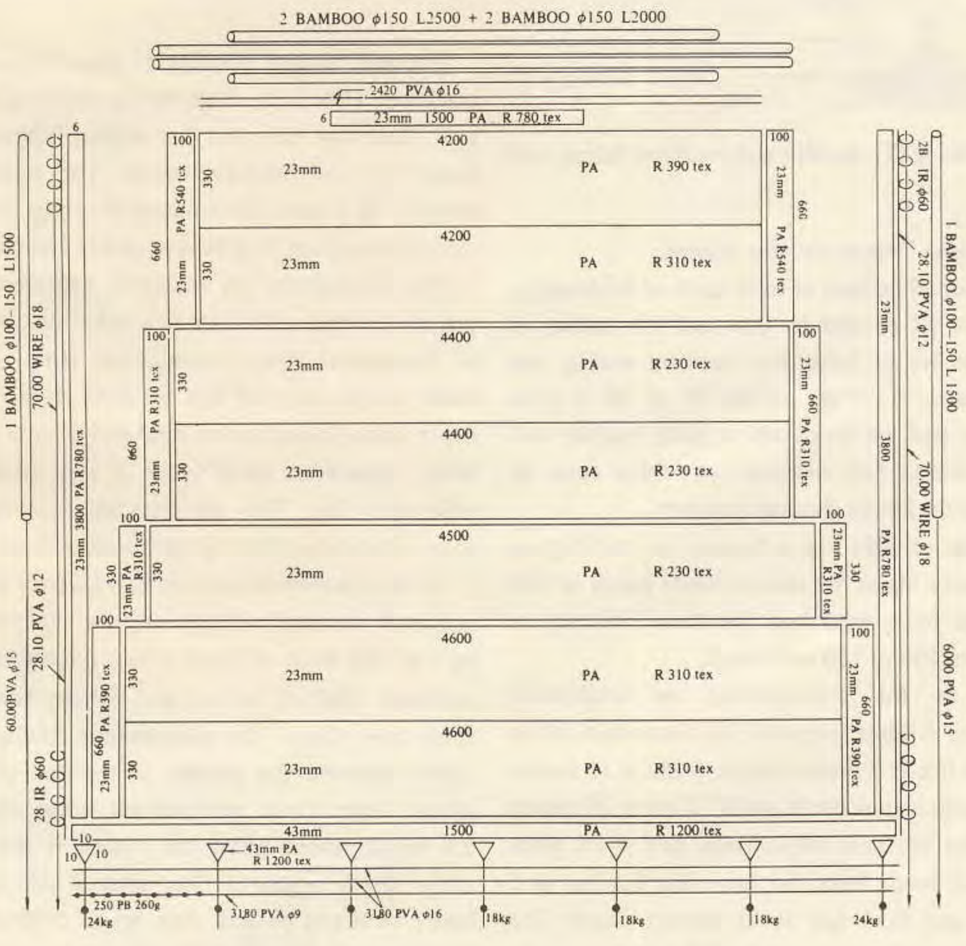


Fig. 4 A sample design of stick held dip net

According to the survey by Sonar most of saury fish are assemble at the place where the range of brightness are about 10^0 to 10^1 lux. Once they are attracted they will be concentrated and led to desirable position by controlling the intensity of light when the net operation is carried out.

5. Fishing gear and fishing boat

Structure of stick held dip net is illustrated in Fig. 4. and fishing boat with lamps is in Fig. 5.

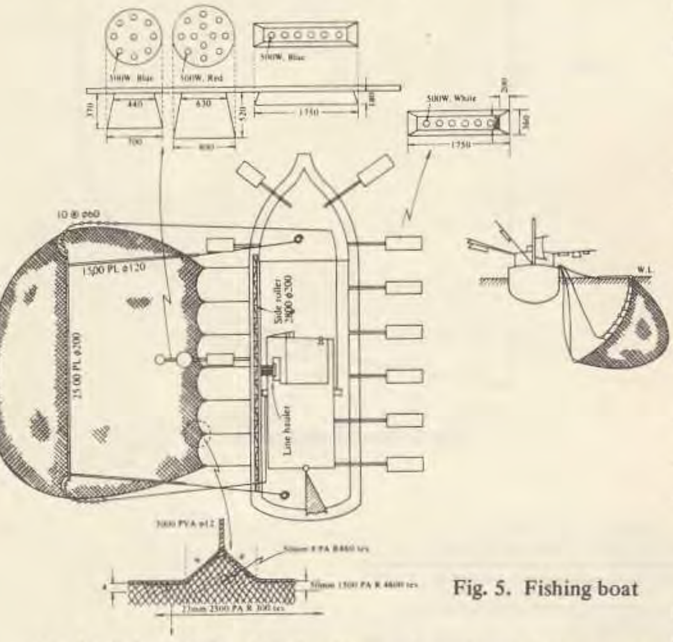


Fig. 5. Fishing boat

3.8.4 Light Fishing (5), Sardine and mackerel fishing with light

1. Mackerel fishing by pole and line angling.

In 1970 about 65 percent of total catch of mackerel by purse seine and 12 percent by pole and line angling in Japan. The number of boats for mackerel angling was about a thousand which are almost 30 to 50 in gross tonnage. Some trial on automatic angling machine and automatic scattering bait machine have been done recently owing to the labour shortage problem.

The intensity of light for a boat of 30 to 50 gross tonnage is usually about 13 electric white lamps of 500 watts each, and for a small boat less than 3 tonnage is about 5 lamps of 100 to 150 watts each.

According to the measurement on underwater luminosity using 6 white lamps of 500 watts each in the experiment, 44 lux at 5 meters depth, 8 lux at 10 meters depth, 2 lux at 20 meters depth and 0.13 lux at 25 meters depth just under the boat respectively. But at the place where 5 meters apart from the boat side 5.5 lux at 5 meters depth and 0.14 lux at 10 meters depth. The mackerel school at that time situated 15 to 25 meters in depth.

According to the fishermen, the lamps are better to hang at about nearly same height or a little heigher as the height of fisherman's head position when he is sitting for fishing. The intensity of light per a person that means the total intensity of light divided by number of fishermen is better about 300 watts in maximum in view of fishing effieiency. The result of comparison of light shown in the table indicates that the fluorescent lamp is better than incandescent lamp, but the former one is still exceptional in using for mackerel fishing based on the same reason as in saury fishing.

Table 1. Fish gathering effects of fluorescent lamp

	Incandescent lamp	Fluorescent lamp
Consumption electric power (watt)	840	200
Time required from lighting to catching (minutes)	19	16
Continuous catch time (minutes)	60	66
Catch per man (kg)	49	48
Catch per watt (kg)	0.06	0.25

Mackerel is less phototaxis than sardine and horse mackerel. They have much strong tendency to attract by bait. Therefore, pole and line angling fishermen use both lamps and bait simultaneously. The mackerel behave actively in bright surroundings forming schools but in dark surroundings they behave calmly and individually.

The experiment on mackerel behaviour with lamp reports that the school are dull behaviour in the reaction to fluorescent lamp, incandescent lamp. Through fish finder image mackerel fish are from surface to 20 meter depth under incandescent lamp and from 3 to 30 meters under fluorescent lamp which is very similar tendency with saury fish. They are attracted more by blue-white colour fluorescent than by green colour fluorescent.

In the experiment when several kinds of fishes as horse mackerel, mackerel and anchovy are combined under the light of 300 watts of green colour fluorescent lamp, only mackerel float to surface and behave circulately apart from other fishes. The experimental fishing through fish finder reported the process of reaction of fish against lamps. Under 26 of incandescent lamps which are hung 2.5 meters above water the school at about 20 to 40 meter depth began to float after 2 minutes when the lamps were put on and came up till 5 meters depth and kept its depth about five minutes.

In such condition when the baits were scattered 2 minutes after they floated up near the surface and after 3 minutes more were on the surface and fishing was done. The schools at the depth of 45 to 90 meters depth behaved almost same pattern. When the school were at 80 to 100 meters depth, firstly small bags in which the bait inside were put at their migrating layer, they began to float up after two minutes and 18 minutes later many fishes float up to the surface and fishing was done. This suggests that mackerel fishing is effective if both lamps and baits are used simultaneously. The amount of bait is about 10 to 15 percentage of total catch mainly used sardine.

2. Sardine, horse mackerel purse seine with fishing lamp

A fleet of purse seine boats consists one net boat of 50 to 100 tonnage, 2 to 3 carrier boats and 2 to 3 fishing lamp boats which equip also fish finders. The lamp boat firstly seek fishing ground operating lamps and fish finders. When fishermen notice the existence of fish school they put in underwater fishing lamp in the sea and try to make fish attracted. If the depth of school are deeper than the depth of purse seine they operate the lamps intensively to make fish coming up. After 10 to 60 minutes when lamps are put on net boat will make the fishing of purse seine. The net are laid out surrounding both lamp boat and school as well. The lamp boat is small boat of 3 to 15 gross tonnage and drive dynamometer by main engine for electric source. They can catch sardine, horse mackerel and mackerel school separately according to the fishing season and fishing ground.

3.8.4 Light fishing (6), Light sources for fishing and their concernings

Illumination used for fishery which is playing an important role along with various kinds of oceanic developments have been rapidly expected at present. Although many technical achievements have been accomplished, there still remain many fields in need of development. Among them the characteristics of oceanic illuminations are very important to be clarified for technical development.

1. History of light source

The word "light source" was presumed from the application of light by the fire. Ancient people held the fire in reverence like God that has power of ruin, and they utilized the fire in their daily lives. Thus fire serves three functions for human beings: cooking, warming and lighting. In olden time people used resin for the light and then they used fish oil, animal oil, plant oil and recently mineral oil and electricity.

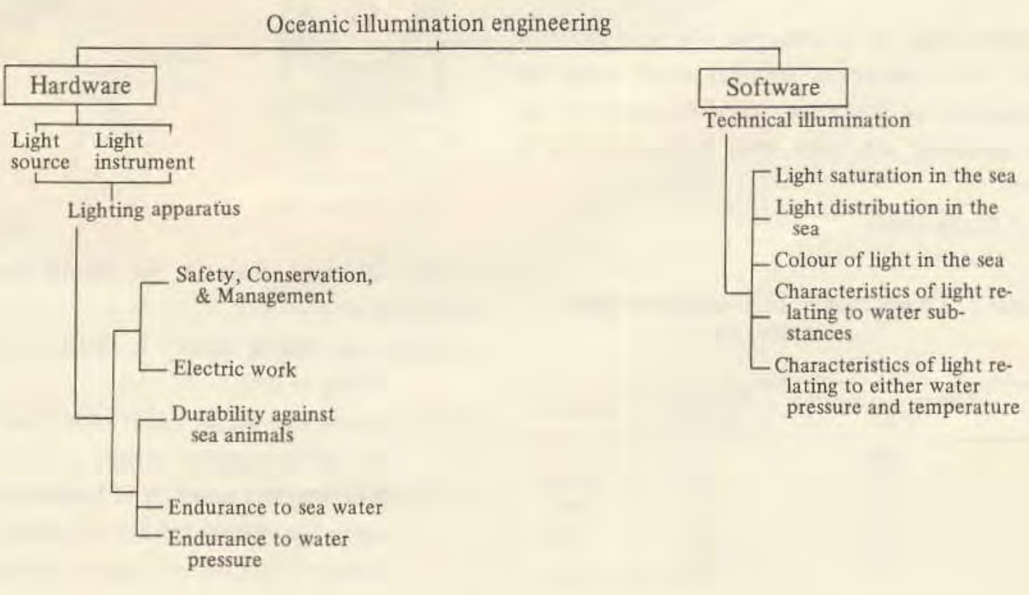
As for fishing light, Kerosene, Carbide were first used but these are not so convenient for the light source. The reason are inconveniency of handling at sea, unbalance of light intensity, impossible to use under water light, bad smell, etc. Thus the electricity could overcome these defects.

2. Oceanic illumination and characteristics of underwater light.

In general the main different points of light behaviour between in air and in sea are indicated as follows:

In air, the light penetration is hardly influenced by the thickness of air atmosphere. On the other hand, in sea water it varies according to the water depth, physical condition of water and water substances. Thus, the decreasing rate of light penetration is large in sea water.

Almost all of the visual light wave length could fully penetrate in air, but in sea water decreasing rate of light penetration are remarkable particularly at the longer



length of light wave.

In natural condition, fish in the sea live rythmically according to the daily changes of sun light from day to night, that is they live in natural surroundings of light. Once the artificial light is used in the night, the fishing light produces unnatural bright atmosphere at once. The performance of the light which attract the fish to the light, therefore, is quite different from natural light such as sun light and moon light.

Some fish are easily attracted by artificial light stimulation which will be proportion to quality and quantity of light and projecting hours. But in the fishing, fishermen should make the fish concentrate so as to catch in limited area of fishing net by controlling the quality and quantity of light.

In fishing in the night, the brightness of moon light is delicate influence to the fishing efficiency. As it is understood in the Table 1 which shows underwater luminosity of sun, moon and artificial light, the light fishing in time of full moon is not so effective because about 20 meters deep the luminosity is the same value for both full moon and fishing light.

Table 1. Comparison underwater luminosity of sun light, moon light and fishing lamp

Depth of water (m)	Intensity of light (lux.)		
	Sun light	Moon light (Full moon)	Fishing lamp (100 W)
0	100,000	0.240	–
2	81,900	0.197	20.5
5	60,700	0.146	2.43
10	36,800	0.088	0.368
20	13,500	0.032	0.033
30	5,000	0.012	0.005
	Here, light absorption rate by sea water is 0.10		

When light is put on at first, fish will be attracted in proportion to the amount of stimulus which means the value of intensity of light times stimulate hours but this attractive tendency will vary with projected time of fishing lamp.

3. Kinds of fishing lamps

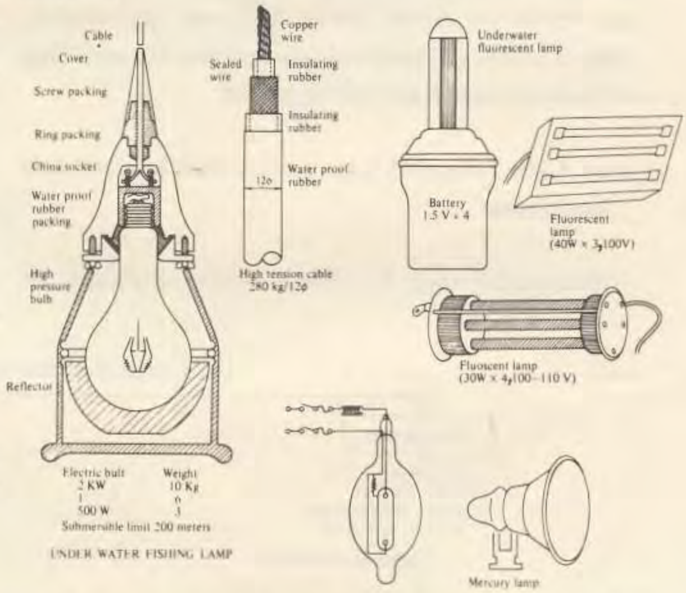
Table 2. Characteristics of incandescent lamp (60W, 100V)

Voltage	Colour temperature (°K)	Efficiency (lm/W)	Life hour
70	2400	503	–
80	2540	722	33400
90	2650	960	4700
100	2780	1220	1000
120	3000	1765	–

Table 3. Items on various light sources

Light source	Effi-ciency (lm/W)	Max. brightness (Sb)	Colour temper-ature (°K)
Natural light source			
Sun light at zenith	113	224,000	6,500
Sun light at horizon		600	1,850
Full moon light		0.26	4,125
Blue sky at night		0.8	12,000
Cloudy night		0.22	7,000
Combustion light source			
Candle light flame		1.0	1,930
Acetylene flame		10.8	2,360
Incandescent lamp			
Elect. lamp 10 W	7.5		2,395
100 W	14.0	652	2,835
500 W	19.2	1,083	3,015
1,000 W	21.0	1,286	3,080
Fluorescent lamp			
White colour 40 W	53	0.61	4,500
Day light co. 40 W	47	0.54	6,500
Discharge lamp			
Low pressure mercury lp.	14	2.1	
High pressure mercury	37.5	140	
Neon sign (red)	10	0.19	

The kinds of fishing lamps shown in the figure below are incandescent lamp, fluorescent lamp, mercury lamp, iodine lamp, sealed beam type headlight lamp, sodium lamp, etc.



The necessary character of fishing lamp could be sumarized as follows:

(1) Shape of fishing lamp : It should be proper shape fitting to boat.

(2) Brightness and colour : It is most essential factor to decide the capacity of lamp.

(3) Beam of light and necessity of lamp shade: It depends upon the demand from operation whether the light is required to project in wide range or

concentrate to limited area.

(4) Time required between the time of putting light on and the time of attaining normal intensity of the light : This is very important for fishing, so instant operation of lighting is required.

(5) Controlling light intensity : It should be simplified.

(6)Relation between fishing lamp and general electric sources of boat's own use: Direct current or alternative current will be discussed accordingly.

(7) Safety to high voltage, vacuum and high pressure : Extreme high voltage for neon light is not usual.

(8) Easy handling related to the shape of light, weight and outfit.

(9) Durability of light relating to life, surface temperature.

(10) Efficiency and economical price : Actually these factors are very important for commercial boat in case of management of fisheries.

3.8.4 Light Fishing (7), Outline of fish reaction against light

The fishing lamp is used for chatching fish by utilizing the phototaxis of fish. Some of fish attracted by light, but there are many varieties among the behaviour of fishes. Some fish are attracted by light and the other are not. Even very easily attracted fish sometimes show negative behaviour to it under specific environmental conditions.

There are some different views on the reasons why fish can be attracted e.g. incentive of fish, optimum luminosity, attraction by feeding, compulsory movement by phototaxis, etc.

1. Behaviour of fish attracted by the light

The kinds of fish which are attracted by the light are saury fish, sardine, anchovy, round herring, jack mackerel, horse mackerel, squid, mackerel, shad, herring, Alaska pollack, bonito, flying fish, etc.

Table 1. Lobus opticus relating with degree of phototaxis on typical fishes catching by light fishing

Degree of phototaxis to white light

Strong phototaxis (caught by light fishing)		Weak or non phototaxis (Scarcely caught by light)
Type of fish that has Fovea	Type of fish that has Lateralen Einschnürung	Type of fish that has no Fovea and Lat. Einschnürung
Engrauls japonica (Anchovy)	*Etrumeus micropus* (Round herring)	*Mugil cephulus* (Mullet)
Cololabis saira (Saury)	*Sardinops melanosticta* (Sardine)	*Coryphaena hippurus* (Dolfin)
Scomber japonicus (Mackerel)	*Harengula zunasi* (Big-eyed herring)	*Seriola quinquerdiata* (Yellow tail)
Leiognathus nuchalis (Slip mouth)	*Hemiramphus sajori* (Halfbeak)	*Lateolabrax japonicus* (Sea bass)
Trachurus japonica (Horse mackerel)	*Sphyreena japonica* (Barracuda)	*Chrysophrys major* (Sea bream)

According to Uchihashi[1] the fish which possess the positive phototaxis has a big Lobus opticus which is essencial function of sight sense in the brain of fish. On the side of Lobus opticus there exist some form of Fovea or Lateralen Einschnurüng. The relation between the existence of the two mentioned above and the phototaxis is shown in Table 1.

Some fish having positive phototaxis show the habit of feeding on plankton by aid of sight in bright surroundings where fishing light are put on. But generally fish once attracted by light is in the state of loosing sense direction – disorientation. Verheijek[2] conclude that under natural light self controlling system of nerve center will act naturally and fish can select appropriate degree of intensity of light. On the other hand, under artificial light as it is extrordinary stimulus to fish, the self controlling system will be deluded and fish loose his directing sense thus being easily attracted by artificial light by action of compulsory phototaxis.

Blaxter & Parrish[3] report in the experiment that fish has some differences in their preference to light intensity between the conditions of day time and night time. The school of Whiting swim in a layer of brightness at 0.17 lux which is almost the same luminosity of 0.06 to 0.22 lux where the fish are attracted by artificial ight. But it is not always so. It can be said that Whiting adapt with low intensity of light in night and adapt with high intensity of light in day time. The arrangement of such difference will be done by their movement of up and down in the sea.

The one condition of the theory of optimum light intensity is that the fish will stay longer in their own favorite luminosity zone. But according to the observation by Imamura[4] about horse mackerel experiment it is said that the fish do not stay steadily under bright surroundings projected by fishing light, but they always make such movement coming near to the light source and going off to darker place. And after some interval of time they are again attracted by the light. This is repeated by several groups of fish.

Kuroki and Chuma[5] deduce the behaviour of anchovy under artificial light by aid of sonar observation that the images of fish school in sonar vary time to time. The school of anchovy, therefore might make active movement with rather fast swimming speed forming group and sometimes dispersing.

According to visual physiology study, Tamura[6] express his opinion that for the sake of forming group by visual sense of fish the minimum brightness will be from 10^{-2} to 10^{-5} lux. Practically it is experimented that minimum luminosity is measured as 10^{-2} lux when fish darkness than hum being, but capacity of identification to shape of object seems to be only one-tenth of that of human being. Moreover, the visual distance is limited by physical condition of water particularly by the turbidity of water.

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3.8.4 Light Fishing (8), Specified fishing gear of squid angling

1. Fishing amount of squid in Japan during these ten years.

Almost five percent of total catch of fisheries is occupied by squid. The fishing mainly by angling are conducted all over along various coastal areas in Japan and also bigger boats go to high sea for fishing in big scale.

The number of fishing boats engaged in squid fishing is shown in Table 1., and catch amount of squid is shown in Table 2.

Table 1. Number of squid fishing boats

Year	Total number		Less than 10 tons		10–30 tons		30–50 tons		50–100 tons		More than 100 tons		Non-engine boat out of total	
1962	40,783	100%	26,913	100%	1,524	100%	373	100%	50	100%	4		11,919	100%
1963	36,565	90	25,916	96	1,441	95	440	118	93	186	4		8,626	73
1964	35,695	88	26,609	99	1,093	72	418	112	124	248	8		7,513	63
1965	36,070	88	27,570	102	1,680	110	484	130	202	404	6		6,128	51
1966	36,128	88	28,830	107	1,693	111	503	135	255	510	5		4,842	41
1967	35,993	88	29,332	109	1,696	111	509	155	318	636	9		4,059	34
1968	33,320	81	27,686	103	1,825	120	639	171	377	754	8		2,785	23
1969	33,867	83	28,444	106	1,790	117	711	191	509	1014	18	100%	2,395	20
1970	34,153	83	28,756	107	1,732	114	741	199	803	1603	61	339	2,060	17
1971	33,828	83	28,740	107	1,799	118	696	187	985	1970	86	478	1,522	13

Table 2. Catch amount of squid

(Unit: ton)

Year	Total		Less than 10 tons		10–30 tons		30–50 tons		50–100 tons		More than 100 tons	
1962	533,158	100%	158,168	100%	224,624	100%	126,065	100%	14,107	100%	35	
1963	580,209	109	217,663	138	202,181	90	126,349	100	31,183	221	25	
1964	237,163	44	111,526	71	74,122	34	27,745	22	21,197	150	267	
1965	386,955	73	138,205	87	122,328	54	74,577	59	49,644	352	626	
1966	378,502	71	134,521	85	101,372	45	77,411	61	63,479	450	550	
1967	471,958	89	159,811	101	114,793	51	99,740	79	95,697	678	695	
1968	649,056	122	188,788	119	154,682	69	165,512	131	138,499	982	833	
1969	467,491	88	122,548	77	97,969	44	125,859	100	117,526	833	2,857	100%
1970	403,692	76	116,048	73	68,796	31	88,268	70	120,675	855	9,275	325
1971	364,576	68	100,480	64	48,677	22	57,410	46	140,465	996	16,683	584

2. Samples of squid fishing boat installed with light

District	Tonnage	Number of screw	Dynamo (KW)	Fishing lamps	Number of light line	Remarks
Hokkaido	2.20			$500^W \times 2, 250^W \times 3$		Survey at 1965
Aomori	3.00			$1^{KW} \times 4$	1 line (center)	at 1968
Hokkaido	3.00		2	$500^W \times 2,\ 300^W \times 2$		at 1964
	4.00		3	$500^W \times 5$		at 964
	3.00		3	$500^W \times 5$		at 1964
	5.00			$500^W \times 10$		at 1968
	5.00			$1^{KW} \times 5,\ 500^W \times 3$	1	at 1968
Aomori	4.80			$1^{KW} \times 13$	1	at 1971
	4.80			$1^{KW} \times 12$	1	at 1971
Hyogo	7.50		10	$1.5^{KW} \times 6$	1	at 1971
	8.20	2	15	$1.5^{KW} \times 6$	1	Angling machine 6 (direct driving from engine)
	15.00	4	30	$2^{KW} \times 11$	1	Ang. Ma. 7 (electric drive)
Aomori	19.70		10	$1^{KW} \times 10$	2	at 1968
	20.00			$1^{KW} \times 12$	1	
Hokkaido	20.00			$1^{KW} \times 8$	1	
	28.60			$1^{KW} \times 13$	1	
Aomori	29.90			$1^{KW} \times 12$	1	
Fukui	15.00			$1^{KW} \times 18$	2	at 1971
Hyogo	31.70	7	60	$2^{KW} \times 20$	1	Ang. ma. 9 (electirc drive)
Aomori	70.00			$1^{KW} \times 16$	2	at 1971
	80.00			$1^{KW} \times 18$	1	
	84.90			$1^{KW} \times 20$	2	
Hyogo	89.64	8		$2^{KW} \times 10,\ 3^{KW} \times 20$	1	Ang. Ma. 12 (electric drive)
	99.80	8	130	$2^{KW} \times 44$	2	Ang. Ma. 13 (electric drive)
	85.00	8	140	$3^{KW} \times 33$	1	Ang. Ma. 13 (electric drive)

3. Fishing gear and operation

1) Squid angling by hand (Fig. 1)

District : Kyushu (kagoshima), fishing in summer, surveyed in 1957

a: Leader line, Tetoron, No.18, 100 meter

b: Main line, Nylon, No.10–12, 15–22 meter

b': Main line, Nylon, No.7 – 8, 3 meter

c: Branch line, nylon, No.7 – 8, 10 cm

d: Swivel, brass

e Artificial bait hook, material is lead, covered with nylon or silk cloth, the colour of cloth are white, red, pink, blue, etc., weight is 30 – 60 grams, length 8 – 10cm.

f: Reel of line, wooden made, length 40 cm, width 20 cm.

Fig. 1

g: "Hanego", gear used when squid come up and float on the surface, two hooks and line with bamboo poles of 50 – 60 cm. long, which are fastened to wooden handle like a fork so-called "Hanego" of 30 – 40 cm. long.

Operation: Mainly by hand on board small boats ranging 0.5 to 3 tonnage. In summer, in this district, squid migrate during 3 to 4 months, in which fishing are concentrated. The numbe of crew are 1 to 3 persons. Some boats have transceiver, dynamo meter and windlass. The sources of light is from battery and lamps are illuminated in series in the center line of boat. Fishing are mainly done in the night, but sometimes it is done even in daytime angling at the bottom.

In night time when they arrive at fishing ground they put on fishing lamps and lay down the line in the sea. At first the fishermen fish by angling line as shown in the figure. But when a big school begin to float up near the surface, particularly in lunar time, the fishermen use "Hanego". He holds one set of gear in either hand, 4 hooks are used at one time, and it is effective method in such condition of fish school.

2) Squid angling (roller system by hand) (Fig. 2)

District: Niigata (facing Japan Sea), surveyed in 1961.

Gear:

a. leader line, cotton 60 yarns – 90 yarns, 35 meters.

b. Branch line, nylon 12 mm, 30 hooks each 30 cm.

intervals.

c. Weight, made of lead weights 500 grams.
d. Hooks, made of plastic, bone or horn with the colour of red, green, pink.
e. Roller, made of special plastic.
f. Roller platform, made of wood.
g. Reel by hand.

Dynamometer: 1kw to 5 kw

Fishing lamps : 1kw x 3

Sea anchor: This is used to keep boat up-stream. Hemp cloth are seamed as shown in the figure.

Operation: Before sun set, boat arrive at fishing ground. The boat keep its position by the action of sea anchor. The roller platforms are projected along both sides of boat and are fixed to bulwark. The line with hook are pulled down in the sea. Number of fishermen are about 2 to 10. In good fishing day they get about 4 tons.

3) Squid angling (Roller system by mechanical drive) (Fig. 3)
   District: Shikoku (Ehime), surveyed in 1960
   Fishing Boat: 10 gross tonnage, 30 horse power
4) Squid angling (Automatic angling machine system) (Fig. 4)
   District: Iwate, north east of Japan, surveyed in 1972.
   Outline: About 80 boats of squid angling exist. Average earning by fishing by a boat of 10 gross ton is from 5 to 6 million yen (17,000 – 20,000 US$). Recently owing to the lack of labour at sea, automatic angling machine come to be used. Most boats now have 1 to 2 machines at least and a few have full automatic machines in place of fishermen.

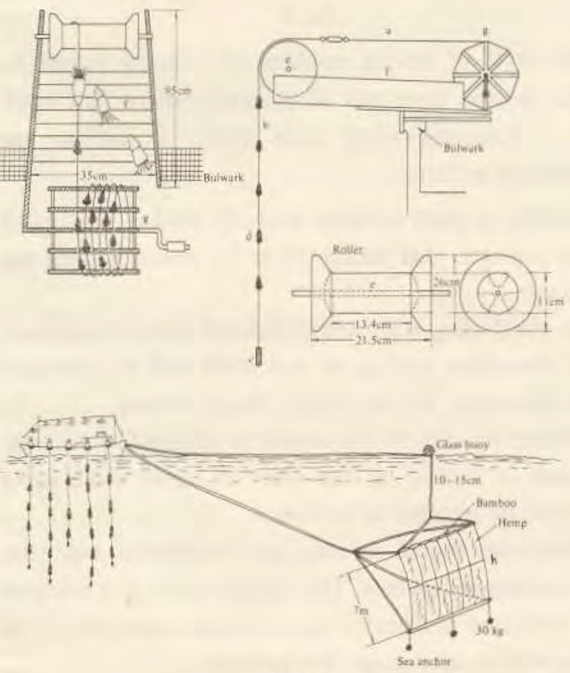


Fig. 2

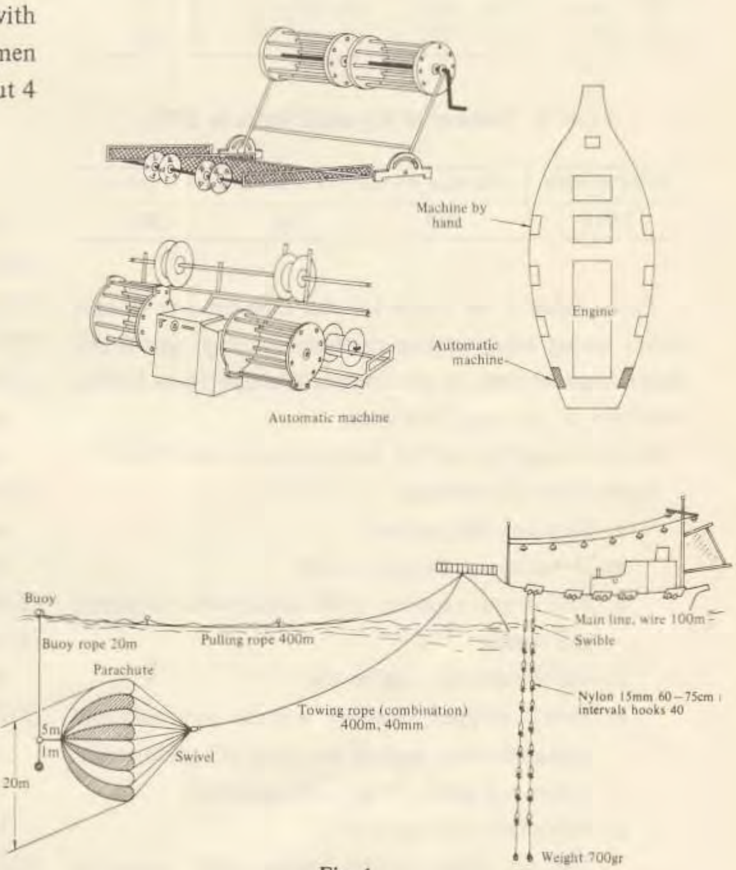


Fig. 4

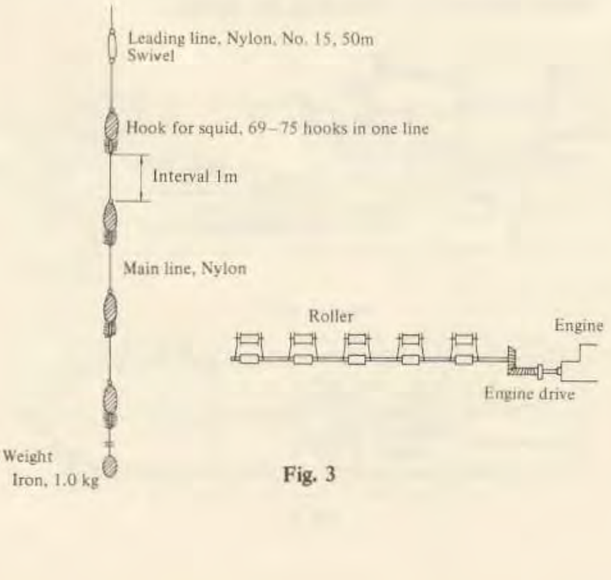


Fig. 3

Operation: Judging from previous day's fishing condition as well as their long period of fishing experiences, the fishermen decide the place of fishing ground of the day. In the evening at 14:00 to 17:00 they leave from the base port and arrive before sun set. At night they put on fishing lamps, put anchor into sea to keep ship's position and they respectively take one's position with machine and make fishing. During operation many boats exchange their fishing conditions by wireless telephone and move fishing place if necessary, sometimes 4 or 5 times transition in maximum. Fishing boat is 10 gross tonage with 60 horse power engine, crew 7 on board, with fish finder, 1 W wireless telephone and 20 KW dynamo meter. Fishing season is from June to December. Fishing ground is less than 200 meters in depth. The average catch is about 50 kg to 5 tons in a night.

4. Squid angling machine and it's operation.

The number of crew in a boat between 1967 when threr were no angling machines and the present with angling machines are compared in Table 1.

Table 1. Comparison of number of crew on board

Boat	In 1967	In 1973	
		Number of screw	No. of angling machine
10 – 30 ton	14 – 15	6 – 7	2 – 3
30 – 50 "	18 – 20	12 – 13	6 – 7
50 – 100 "	25 – 30	14 – 15	10 – 20

Table 2. Number of big squid boats in 1973

Total number	Less than 40 ton	40 – 50 ton	50 – 100 ton
3,019	567	546	1,906

From Table 1 we could see the effectiveness of man power saving using angling machine although this is still under improvement in mechanism and operation for the condition of sea, squid and boat.

1) Kinds of angling machine now currently used. (Fig. 5)

Explanation of machine:

a: Gear box (oil packed)

b: Motor switch (water proof)

c: Reel drum; capacity of 45 hooks with 50 meters line reeling

d: Guide roller for angling line

e: Safety stopper: stopper will be automatically operated when angling line goes off guide roller.

f: Roller and platform of hand operation.

g: Automatic slip apparatus;

This can adjust variable tension which occurs by irregular pitching and rolling of the boat. When too much strain of angling line, automatic slip will act and when too much looseness of line, automatic speed up reeling will act.

h: Variable gear motor or torque motor; Electric source are single phase 120 voltage, 250 – 300 watts or three-phase 220 voltage, 250 – 400 watts.

i: Brake apparatus; When laying out the line, free degree of braking will be imposed to the line so as to make smooth operation of fishing gear.

j: Depth arrangement meter; Once setting 50 meters in depth, the repeatance of hauling up and down motion are operated in the range of 50 meter length of line.

k: Clutch handle:

Other kinds of machines such as "Sun-power" (MA-R), "Kasahara" (KA-100), "Seki" (CHM), "Uematsu" (UN-1), "Uroko", "Honda" "Hamade", etc are used for commercial boat.

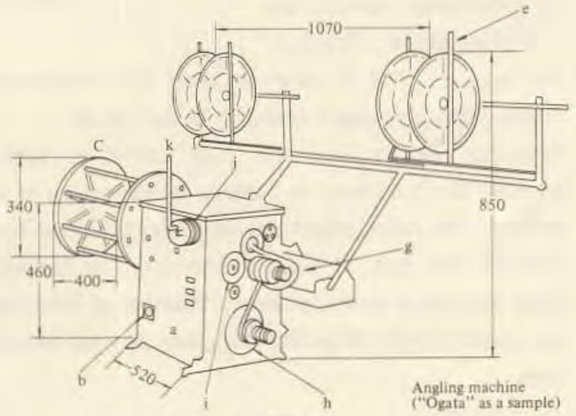


Fig. 5

The style of driving machine are directly joined to engine, electric drive and oil pressure system. The opinions of fisherman using these kinds of machine are summarized as follows:

(1) Number of shaft rotation normally used is 370 to 420 per minutes, that means 70 to 75 meters hauling per minute.

(2) To avoid cling with neighbourhood line, arrangement of alternative hauling up and down will be necessary for operation, and sea anchor should be used.

(3) Sinking velocity of line should be adjusted by braking.

(4) Speed of hauling up line when all hooks catch squid should be arranged to be slow.

(5) Fisherman should entirely get acquainted with the operation of machine. The fishing ability of a machine is evaluated as from 0.7 to 2.0 persons capability. If he has skill he can manage five machines.

(6) Even though school is slight in density the machine can repeat its work for detecting the squids.

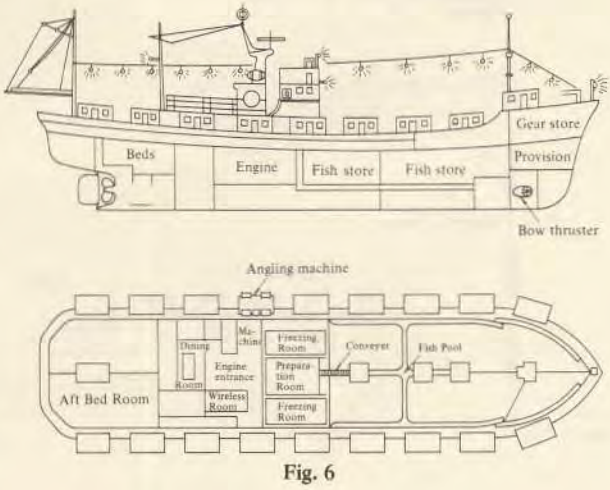


Fig. 6

(7) The machine is particularly benifit for old fishermen.

2) Modern fishing boat with machine (ideal standard style recommended) (Fig. 6)

Main engine 800 p.s.

LOA (m)	33.3	Length of boat overall
LWL	28.5	Length of boat on the water line
B	6.07	Maximum beam of boat
D	2.65	Depth of boat
d	2.30	Draft
Δ (t)	269	Displacement
C_b	0.663	Block coefficient
C_p	0.705	Prismatic coefficient
C_m	0.940	Midship section coefficient
Dynamometer	190 KW	
Fishing lamps	4 KW x 30, 3 KW x 12	
Instrument	lader, loran, direction finder, wireless telephone fish finder, freezing machine, electric thermometer.	
Number of fishermen		15 persons

3) According to the FAO Statistics, total catch of molluscus in the world is in the range of between seven hundreds thousand to one million metric tons.

In 1970, Japan got 510,000 metric ton which occupies almost seventy percent of total catch. Following Japan, ten percent by Korea, three percent by Spain, two percent by Italy and two percent by Taiwan.

Eighty-five percent of total catch which coincide with 610,000 tons are got from Pacific Ocean area in which north west of Pacific around or near Japan island are predominant. Following this, in Atlantic Ocean area 77,000 tons are recorded in catch in which middle east of west coast of Africa, North Sea, Newfoundland are main fishing ground.

Some of Japanese big boats nearly 100 tons or more in tonnage of squid angling go fishing to south Pacific around New Zealand fishing ground.

This is the most modern far sea fishing boat of squid angling fishing as it is explained in the last figure above.

Fishing Boat

Fishing Boat

4.1.1 Outline of Fishing Boat

1. Introduction

There are so many kinds of fishing boats, i.e. from big fishing boats as the mother boat of whale fishery to very small boats such as coastal non-engine boat which is carried out by only one fisherman. So many kinds and numbers of fishing boats could be found in the world.

At any rate, even a small fishing boat, the boat is used for particular use of fishing, so the capacity of the boat depends upon the kinds and scale of fisheries itself. Sometimes, the scale of fishing and the fishing plan are regulated by the capacity of boat, but in both cases the boat itself is the means of production, therefore, it can be said that the fishing boat is part of the fishing gear in a broad sense.

The person in charge of planning and designing of building the fishing boat should make an effort to fit the technical requirement on the side of fishing and proceed its plan with the adjustment of techniques, capital and legislation. But ordinarily almost such requirements are inclined to the fishery management and space of accomodation of the members aboard, etc., and on the contrary the enforcement of enterprising, techniques and legislation are less which bring some trouble to the designer of constructing fishing boat.

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

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

Unnecessary luxury articles and unuseful instrumentations should be excluded from the view point of essential objectives of fishing itself.

Recently the technical development of modernized fishing boat have progressed remarkably not only in the hull construction and engine but also in the way of preservation of catches, facilities, communication means, navigation instrument, fishing apparatus, etc. Consequently, ship builders are quite natural being asked to have full knowledge and experience in all parts of fishing boat when new boat are planned to be built.

In many sea places in the world where various kinds of fisheries are conducted, anticipated development of fisheries in future are very difficult, even though the fishing boat are indispensable where the fisheries exist so the technical development of fishing boat are very essential matter for the fisheries expansion.

Actually, the fishing boat is the most valuable thing among fishing gear so that vigorous attempt for the improvement and investigation on boat efficiency is very important matter for fisheries management as well as shipbuilder.

2. Meaning of fishing boat

In simple saying, the fishing boat is the boat engaging in fisheries. It is engaging in the activity of catching marine and inland porductions or of aquaculture management, and also is engaging in such activities as investigation, guidance, training and inspection.

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

1) Those boats which mainly engage in fisheries as trawl boat, whale catcher, tuna long liner, bonito angling boat, danish seiner, etc.

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

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

4) Those boats which mainly engage in survey, research, guidance and training activities or engage in inspection activity having fishing facilities. These boats mainly belong to fishery government, fishery research institute, fishery school and fishermen cooperative association.

3. Kinds of main engine

Steam engine, diesel engine, semi-diesel engine, gasoline engine are mainly used for fishing boats. Among them diesel engine is predominantly used.

4.1.2 Kinds of fishing boat

1. General requirement

The general requirement for fishing boats to operate fisheries are as follows;

1) Stoutness of hull structure:

In view of the performance of a fishing boat which is required not only to navigate on water, but also to make fishing operation in the fishing ground and to carry its catch back to home port, the stoutness of hull structure must be stressed more than anything else so that the boat may carry its crew safely during its operation and carry its catch back home in their best condition.

2) Successful operation of fisheries:

The fishing boat must take in various types of fishing gear and other necessary materials, sail to its fishing ground in safety, then harvest fish school by effective use of the fishing gear. So as to fulfill the fishing objectives mentioned above, the fishing boat should be well facilited in various points such as fishing machines, navigational instruments, radio apparatus, freezing machine etc.

3) High stability:

Since the fishing boat must often operate fisheries even in stormy weather and handle fishing gear and catches broadside, its stability is required to be high in value.

4) Complete facilities for storing:

In order to carry back the fish catches to its home port in their best condition, the fishing boat must be equipped with best storing facilities, such as ice-making, refrigerating and cold storing facilities, especially in case of large type of fishing boat setting out on ocean fisheris.

2. Types

There are the following types of employments on the operation of fishing boats.

Drift-net fishing, stick-held dip net fishing, harpoon fishing, trolling fishing, Danish seine trawling and other drag net fishing, lift-net fishing, purse seine fishing, driving-in net fishing, trap fishing, diving-machine fishing, floating drag-net fishing, skipjack pole and line fishing, cod line fishing, tuna long-line fishing, salmon and crab gill net fishing, tuna gill-net fishing, coral fishery, pearl oyster and troohoid fisheries, furseal, sea otter, sea lion and seal leopard hunting, other sundry fisheries.

In regard to big boat used for large scale type fisheries are: Otter trawling fisheries, factoryship whaling, transportation of fish catches and their products from fishing grounds, experiment, research, guidance, training or inspection relating to fisheries.

3. Classification by water operated

1) Fresh water fishing boats comprise those boats used for fishing purpose mainly in rivers and lakes. Almost all of them are wooden boats of small size. The fishery types operated by these boats include various small fisheries in fresh waters.

2) Sea water fishing boats

Sea water fishing boats are various in size and operation ranging from very small boats in coastal waters to giantic motherships of whaling expeditions in the high seas. The following boats belong to this category: fishing boats used for inland water fisheries, those used for shellfish and seaweed gathering, those for fixed-net fisheries, pole and line fisheries, long-line fisheries, gill-net fisheries, purse seine, lift-net fishery, Danish seine trawling, otter trawl fisheries, skipjack and tuna fisheries, whaling fisheries, government fishery research boats, fish carriers and sport fishing boats.

4. Classification by size and engine

The classification of fishing boats may be made by style of structure, building materials, propulsion method or types of fisheries in regard to a boat.

1) Small boat: Generally small boats are made of wood. They have been used from old days for coastal fisheries, and most of them were open boats. Nowadays many of them are deck covered.

The size of hull indicated by the beam at the widest part boat measured in the horizontal distance between the two side boards. The small boat is called a junk which is operated by rod, scull or oar. Many of them are sailing boats, but with the latest development of engines, they have been converted to powered boats.

The wooden small boat (e.g. Japanese small boat) which include the simplicity in structure and equipment has a merit of cheapness of its building cost, the expediency of handling, handing or setting on land which makes it to be provided with a base of operation even in places where no proper fishing port or port of distress exists, as well as the lightness in weight, light draft, little rake or rolling and easy navigation.

2) Wooden and steel boats: The medium boats are divided into wooden and steel boats. Most of them being very stout are used for off-shore and deep-sea fisheries. Otter trawling boats, tuna long line fishing boats, Danish seine trawling boats, skipjack fishing boats, drift-net fishing boats, whale catchers, whale factories, etc. belong to this category.

The merits of wooden boats mainly consists of the simplicity in their building and repairs and the cheapness in their building cost. But steel boats are far superior to wooden ones in regards to stoutness and durability as a result of use of steel which is strong and uniform in quality.

3) Powered and non-powered fishing boats: By the method of propulsion, fishing boats are classified into powered and non-powered ones. The non-powered boat is operated by means of scull, oar or sail, while the powered boat, by means of steam power or engine.

The development of powered fishing boats has brought about the operation of deep-sea fisheries. It may safely be said that the invention of ship's engine has marked a new epoch in the history of fishing craft of the world. However, there still a number of non-powered boats operating inland or coastal water fisheries of small scale. But they are gradually being converted to powered boats with the recent development of engines of small type.

There are various types of engine used for fishing boats. For small boats, oil engine are mostly used. This type of engine can be handled with ease and is fit for small boats. Before, the semi-diesel engine or hotbulb engine was used for fishing boats of medium or small size, while the diesel engine was used for fishing boats of larger size. Now, the diesel engine is popularized and a great deal of small boats are also using this type. In fact, the diesel engine is an essential propulsion means to deepsea fishing boats such as skipjack and tuna boats, trawlers of larger size, catcher-boats and others.

4.1.3 Characteristics of fishing boat

The necessary qualification of fishing boat are almost similar with ordinary passenger boat or cargo boat in general. More over, the fishing boat should have particular functions different from ordinary boats such as fishing operative works, preservation works for the catch, etc.

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

1. Speed

The fishing boat is required to have high speed so as to search and trace the fish school, and to carry the catch keeping fresh within possible short time. About 700 tonnage whale catcher is 18 miles per hour and 300 tonnage tuna long liner is 12 miles per hour and 100 tonnage trawler is 11 miles per hour in speed.

It should be careful that sometimes the fishing boats are not so efficient when fishing because of having too much high power engine for their exaggerated requirement.

On the contrary fishing boat sometimes requires dead slow speed in the fishing operation such as in tuna long line fishing and this is also one of characteristics of fishing boat.

2. Manoeuvring and engine

The fishing boat is required to have good manoeuvring specially under such operations as tracing and detecting fish school, operation of fishing gear, etc. For the fulfilness of fishing operation the rudder should work efficiently, turning circle should be small, the operation of start, stop, ahead and astern in propel engine should be simple, swift and sure, the rotation of engine should be smooth even in mid-speed, low-speed or slow-speed.

For instance, bonito fishing boat always has to move with the same speed of bonito school when angling. It should be smoothly conducted in the operation of engine speed variation when the tuna long line of about 15 kilometers is taken up from the sea continuously with slow speed ahead. Otherwise the fishing efficiency might be influenced very much. For the sake of this, recently, some of big fishing boat has variable pitch propeller.

3. Resistance

The fishing boat is specially requested to have full resistance against strong forces of wind, wave, etc. For this purpose, fishing boat should be constructed in good stability, fully buoyancy and less rolling and pitching.

4. Navigational distance

The distance only depends upon environmental condition of fishery as the movement of fish school, fishing ground and so on. So it needs long distance. Tuna long line fishing boat, for instance, has remarkable long distance navigation from Pacific to Atlantic via Indian Ocean without any stopping.

5. Construction

Construction of boat should be strong because the fishing boat occassionary encounter sever sea condition, and endure the vibration caused by engine operation.

6. Propulsion of engine

The engine is preferably small in size although it is requested powerful enough. Usually diesel engine is adopted for fishing boat because it could be rather smaller in size as compare with steam engine. Both high speed and low speed engine are applicable for fishing boat.

The steam engine could stand for severe running and long durability but is rather big in size. On the contrary high speed engine such as automobile engine has recently been used with the benifits of simplicity of handling.

7. Preservation and processing facility

Fishing boat ordinary has to carry the catch to fishing port. In order to keep the fish fresh, ice keeping room, cold room and freezing room are necessary to be isolated from outside. The processing machines – canning, fish meal plant – are also equipped when they are necessary. These are also the characteristics of fishing boat.

8. Fishing machines

Fishing boat naturally should be equipped with fishing apparatus, as angling machine, line hauler, net hauler, trawl winch, purse winch, power block etc. There are so many varieties according to the kinds of various fishings.

4.1.4 Basic calculation for deciding elements of boat

1. Speed of boat

L.B.D, coefficient of finess, displacement, body shape under draft line, trim, selection of engine kind, etc. are the elements for deciding speed of boat. Ordinarily ship builder estimate navigational speed and maximum speed approximately from the past experiences. The navigational speed ordinary use the power of three-fourth 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 the application of Admiralty coefficients as:

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

2. Fuel and lubricating oil

Normal consumption of fuel oil are based on the following factors.

Necessary consumption of oil
= Rate of fuel consumption × Number of Horse power × Time consumable

Rate of fuel consumption
Diesel Engine 0.22 (kg/HP/hr)

Number of Horse power to maximum continuous house power
for Naviation (go & back): 70 to 80 percent
for Fishing: 50 to 80 percent (depends upon operative condition.)

Time consumable
Calculate summing up the time requiring going and back to fishing grounds, operation in fishing ground, etc.

Weight of oil

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

Necessary quantity of lubrication oil
Diesel Engine 0.03 × fuel oil

3. Fresh water, provisional and hand luggage

All necessary water per person are:
20 liters/day/person for sea fishery
20 ~ 30 liters/day/person for off shore fishery
30 liters/day/person for coastal fishery

Provisional is 1.7 ~ 2.0 kg/day/person
Hand luggage is 100 kg/person.

4. Ice

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

Weight of ice 136 kg (0.3m × 0.57m × 1.15m)
Weight of sliced ice 625 kg/m^3

5. Weight of catch

Weight of unit in fish store:

Fish	835 kg/m^3
with sliced 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. Load condition

	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
Provision	–	100	40	10
Fishing gear	–	100	100	100

4.1.4 Fishing boat and its engine

Fishing technique involves a wide meaning that not only fishing methods, disposal of catches, etc. that should be rationalized, but also the developing techniques on optimum fishing method, optimum boat size decision, optimum style of boat by various kind of fishing gears.

Furthermore, economical circulation mechanism for fishery and fishing administration by which such synthetic techniques mentioned above could be practically carried out, are important. By such efforts of improvement the fishery management will be stable.

The problems of fishing boat should also be overcome along with such endeavors.

The main kind of fishing engine is diesel engine. It has passed already 50 years since diesel engine began to be applied in fishing boat.

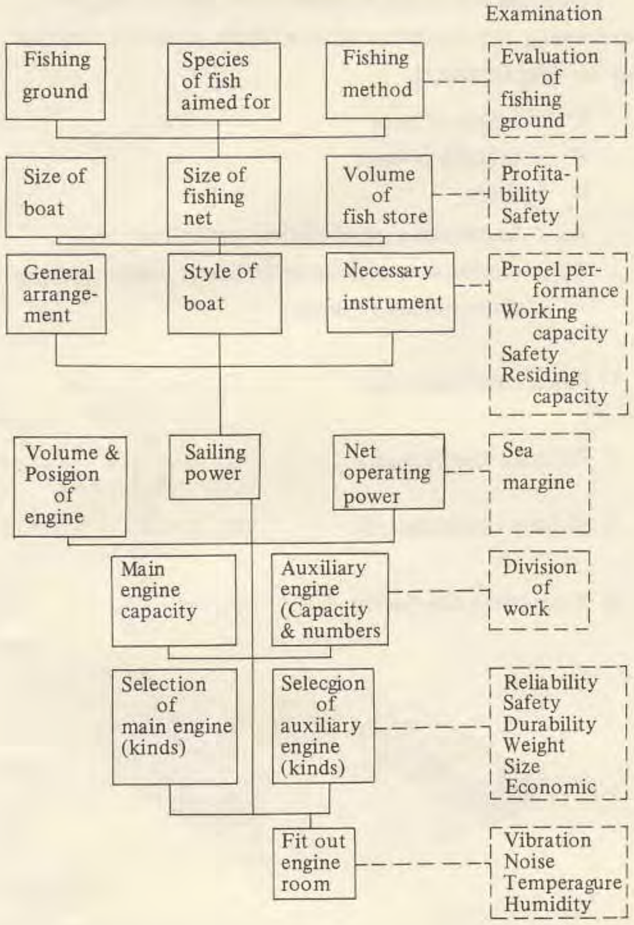
The improvement of engine efficiency can be promoted by the effort of increasing the engine rotation (average piston speed) and supercharging capacity (mean effective pressure).

As for small engine of fishing boat, most improvements have been in engine rotation. Usually it is 6 m/s, but now it attains even 12 m/s in rotation.

Medium size engine were about 5 kg/cm^2 in its mean effective pressure about 20 years ago are now attaining about 15-20 kg/cm^2.

Thus, the engine capacity nowadays has increased by about five times with that of 20 years ago.

Orders in plan of engine



4.1.5 Principal dimension

Definition of principal dimension

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

1. Length

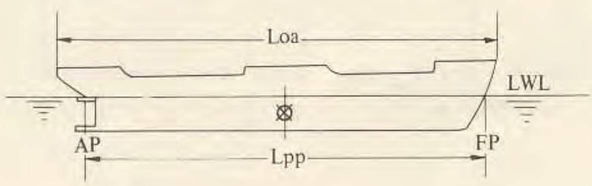
a) Length over all, LOA. or Loa

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

b) Length between perpendiculars, LPP or L

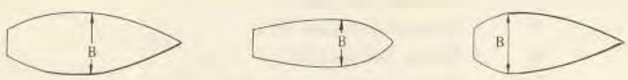
This is the horizontal distance from fore perpendicular, FP to after perpendicular, AP at the designed load waterline, LWL.

The center of Lpp is called midship of the body.



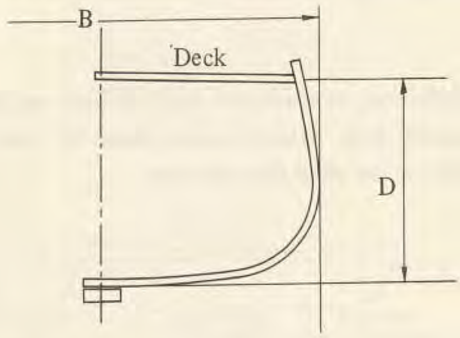
2. Breadth (Extreme breadth) B

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



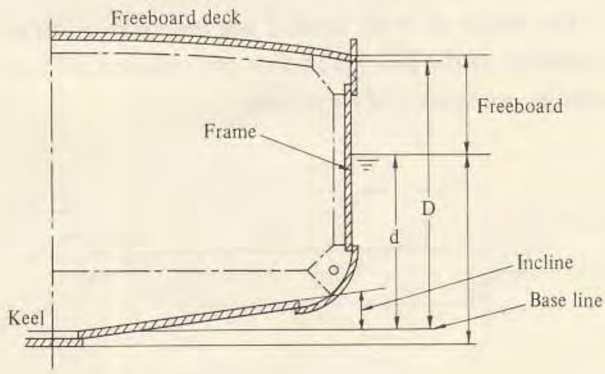
3. Depth, D

This is the vertical distance from the base line to freeboard deck at the midship section.



4. Draft, (Draught, d)

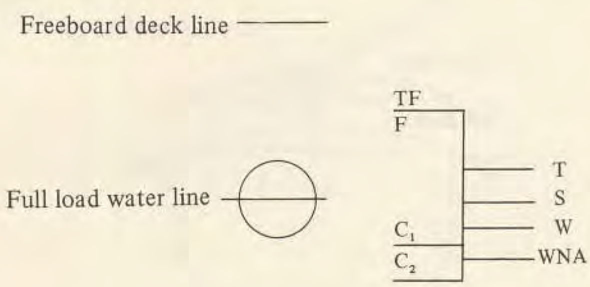
Moulded draught (d) is the vertical distance between load water line and the base line.



5. Freeboard

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

The indication shown as an example is marked on the side of boat body

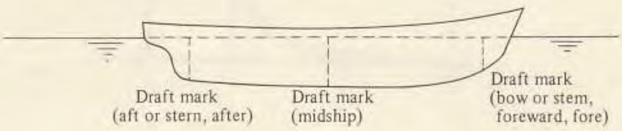


T F	:	Tropical fresh water full load W.L.
F	:	Fresh water : Summer : full load W.L.
T	:	Tropical full load W.L.
S	:	Summer full load WL.
W	:	Winter full load W.L.
WNA	:	Winter North Atlantic full load W.L.
C_1	:	Passenger boat full load W.L.
C_2	:	Passenger and cargo load W.L.

4.1.5 Terminology of boat

1. Trim

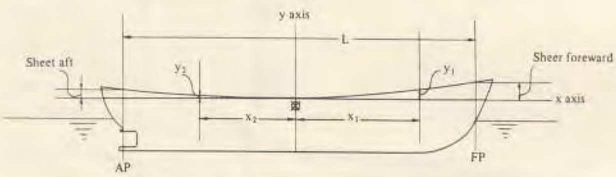
The difference between the draft of bow and that of stern is called trim. Trim by stern means the boat has a deeper draft in the stern than the bow.



2. Sheer

The word "sheer" in boat terminology is bend of freeboard deck side line.

The height of sheer forward and that of sheer aft are calculated at the position of fore perpendicular (FP) and after perpendicular (AP) seperately.



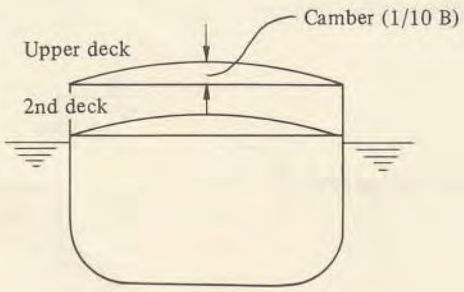
$$Y_1 = (6.664L + 203.2) \times \left(\frac{x_1}{L}\right)^2 \text{ (cm)}$$

$$Y_2 = (3.332L + 101.6) \times \left(\frac{x_2}{L}\right)^2 \text{ (cm)}$$

Here, L is the length of boat.

3. Camber

The camber is the curvature height of the deck beam at the center line of boat body.



4. Coefficient

Following the symbols shown here, several coefficients expressing the condition of boat shape could be denoted in the next formurae.

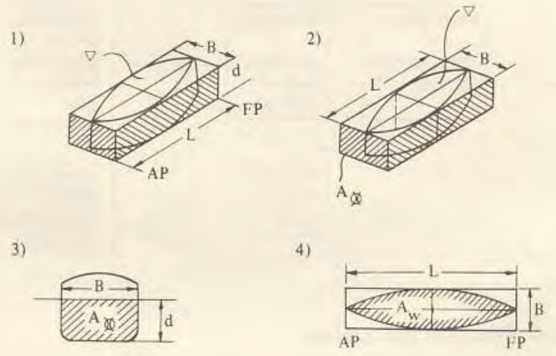
L	:	length of boat
B	:	breadth of boat
d	:	draft
A_w	:	horizontal area of boat in water line
$A_{⊠}$	:	section area of boat under water line at midship
∇	:	displacement (volume)

1) Block coefficient, C_b $\quad C_b = \dfrac{\nabla}{LBD}$

2) Prismatic coefficient, C_p $\quad C_p = \dfrac{\nabla}{A_{⊠} L} = \dfrac{C_b}{C_{⊠}}$

3) Midship coefficient, $C_{⊠}$ $\quad C_{⊠} = \dfrac{A_{⊠}}{Bd}$

4) Water plane coefficient, C_w $\quad C_w = \dfrac{A_w}{LB}$



4.1.5 Calculation for a volume of hull and speed calculation

1. Approximate method of integration

1) Shimpson's first rule[1)]

y, a function of x, denoting $y=f(x)$, the value of integration A which is calculated as the result of integration of y from x_0 to x_n as shown in Fig. 1 is as follows:

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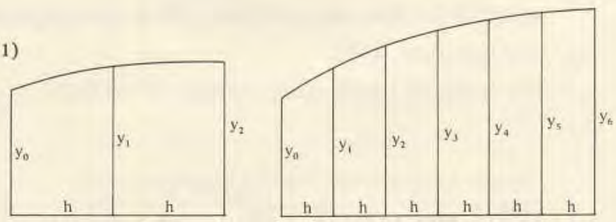
1)



$$\text{Area} = \frac{h}{3}(y_0 + 4y_1 + y_2)$$

$$\text{Area} = \frac{h}{3}(y_0 + 4y_1 + y_2) + \frac{h}{3}(y_2 + 4y_3 + y_4) + \frac{h}{3}(y_4 + 4y_5 + y_6) = \frac{h}{3}(y_0\ 4y_1 + 2y_2 + 4y_3 + 2y_4 + 4y_5 + y_6)$$

$$A = \frac{h}{3}(\frac{1}{2}y_0 + 2y_{1/2} + \frac{3}{2}y_1 + 4y_2 + 2y_3 + \cdots + 2y_{n-3}$$

$$+ 4y_{n-2} + \frac{3}{2}y_{n-1} + 2y_{n-1/2} + \frac{1}{2}y_n)$$

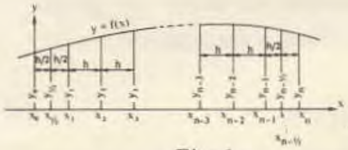


Fig. 1

Fig. 2

2) Tchebycheff rule

In the Fig. 2 the value of A denoting $A = \int_{-a}^{a} f(x)$ is expressed as :

$$A = \frac{2 \times l}{n} \sum^{n} y$$

In this case the value of x depending upon the number of n is tabulated in Table. 1.

Table 1

n	x_0/l	x_1/l	x_2/l	x_3/l	x_4/l	x_5/l
2	–	.5773				
3	0	.7071				
4	–	.1876	.7947			
5	0	.3745	.8325			
6	–	.2666	.4225	.8662		
7	0	.3239	.5297	.8339		
8	–	.1026	.4062	.5938	.8974	
9	0	.1679	.5288	.6010	.9116	
10	–	.0838	.3127	.5000	.6873	.9126

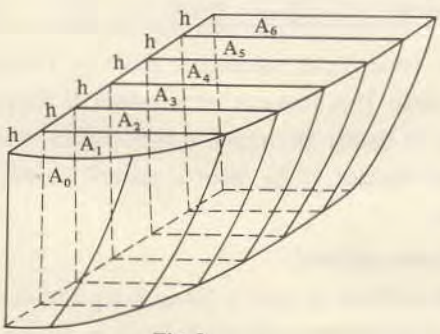


Fig. 3

3) Volume calculus

$$\text{Volume} = \frac{h}{3}(A_0 + 4A_1 + 2A_2 + 4A_3 + 2A_4 + 4A_5 + A_6) \quad \text{(see Fig. 3)}$$

2. Speed

1) Admiralty coefficient α

$$\alpha = \frac{\Delta^{2/3} \times V^3}{ps}$$

Here, Δ : Displacement (t.)
V : Speed (kt)
ps : Horse power

Example table

Kind of boat	Length of boat	Admiral coefficient
Whale catcher boat	68.20	160
Small catcher boat	19.80	64
Big trawler	78.27	210
Medium size trawler	41.69	123
Big tuna long liner	53.60	140
Medium tuna long liner	27.40	90
Small tuna long liner	19.85	66
Big skipjack angling boat	38.00	94
Two boat trawler (pair)	29.84	145
Big purse seiner	25.00	77
Salmon gill netter	26.00	73
Big fish carrier	131.00	300
Fishing inspection boat	51.00	130
"	25.00	75
Fishing training boat	66.00	220
"	20.55	83
Fishing survey boat	36.00	135

2) Speed to length ratio λ

$\lambda = V/\sqrt{L}$

Advantageous λ are 1.31, 1.52 and 2.01
Disadvantageous λ are 1.22 and 1.40

4.1.5 Measurement of tonnage of small fishing boats

1. Net tonnage (NT)

1) Net volume of space (m^3) is obtained by deducting volume of spaces of the followings 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, all those above the deck

Net tonnage = (net volume of space) × 0.353

2) In the case of the length of boat is less than 24 meters. Net volume of space (m^3) is obtained by deducting the 1/5 of the total volume of space and 7/4 of substantial space of engine room from the total volume of space.

Net tonnage = (net volume of space) × 0.353

2. Displacement tonnage (Δ)

The displacement of boat expressed by the weight (unit = 1 ton) of boat being varied according to the quantity of fuels, water, crew, is called displacement tonnage. This is the weight of boat. Ordinarily in the case of 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 case of light loaded from the displacement tonnage in the case of full loaded. In other words this is the total weight of load by loading until the load water line attains full load water line.

4. Gross tonnage (GT)

Ordinarily the fishing boat is expressed by GT.

There are several formulae for GT measurement of small fishing boats in exsitence which are similar in so far as each formula in some way combines several liner measures of the boats' dimensions. As in GT measurement of large fishing boat, the method of the tonnage measurement has differed considerably from country to country. To establish an international standard on this matter, so far several international meeting have been convened. At present, the "International Convention on Tonnage Measurement of Ship, 1969" which was agreed upon in a conference held in London under the sponsorship of the Intergovernmental Maritime Consultantion Organization (IMCO) is coming into force.

1) International formula for GT measurement of fishing boat 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.

$K = 0.2 + 0.02 \log_{10} V$ (as tabulated in the Table 1)

Enclosed spaces are all those spaces which are bounded 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 a space, or in the partitions or bulkheads of a space, nor the absence of a partition or bulkhead, shall preclude a space from being included in the enclosed space.

2) Current practice for GT measurement of small fishing boat

For the measurement of GT, 100 cubic feet (or 2.83 cubic meters = 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 the 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,

$GT = (a + b) \times 0.353$ (metric system)

or

$GT = (a + b) \times 1.0$ (British system)

To the circular by FAO replies 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)

(1) 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 of streamline but not cubic, a coefficient is multiplied by the cubic number to derive an actual volume of the hull of a boat. Thus, a formula commonly in use is as follows:

$GT \text{ of } a = L \times B \times D \times C \times 0.353$

coefficient C = Volume of enclosed sp./$L \times B \times D$

(2) Moorson method No. 2

This method is adopted only in South Vietnam and Thailand. A particular feature of this method is that in the formula for the measurement of GT, periphery (P), which is the measure around the section of the hull at the mid-length, is used. The formula in use in these countries is as follow:

$$GT = \left(\frac{P+B}{2}\right)^2 \times L \times C$$

In South Vietnam, 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.) = $\begin{cases} 0.85 \text{ for displac. hull} \\ 0.90 \text{ for flat bot. hull} \end{cases}$

In both countries, metric system is used for the measurement of dimensions, and C is defined as follows:

	Wooden boat	Steel boat
South Vietnam	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 a variety of boats. Therefore, it is advisable to avoid using C_b and replace it by such a general coefficient as K instead.

(3) 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 unified among countries concerned to keep an international comparability of GT. Although it seems more reasonable to include enclosed space above upper deck, it should be clarified which space is to be included and which space is not to be included.

For example, at present Japan excludes from GT measurement the following enclosed spaces above upper deck:

(1). Space used to accommodate steering equipment, mooring equipment and anchor winch.

(2). Engine casing, wheel house and galley.

(3). Space used for ventilation and for skylight and toilet.

(4). Companion ways and small hatch ways.

It is likely that at present these kinds of exemption are not always uniform among countries.

3) Standardization of measurement in the case of small boat below 24 m in length

Definitions of L, B and D

Even if a unified formula is used by all countries, different GT will be obtained for the same boat if the definition of L, B and D differs among countries. IMCO is therefore considered that this is the right time to make the bset use of the difinitions given in the paper for solving the problems before us.

The following specific dimentions are suggested by FAO for the formula:

Length Loa; Overall length; horizontal distance between the extreme ends of the boat;

Breadth Boa; Overall breadth: extreme width of the boat measured to the outer surface of the hull;

Depth Dmin; 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 most 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.

Beside this, the shape of fishing boats differ 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 1 Coefficinet 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	0.3183
800	0.2581	150 000	0.3035	490 000	0.3138	830 000	0.3184
900	0.2591	160 000	0.3041	500 000	0.3140	840 000	0.3185
1 000	0.2600	170 000	0.3046	510 000	0.3142	850 000	0.3186
2 000	0.2660	180 000	0.3051	520 000	0.3143	860 000	0.3187
3 000	0.2695	190 000	0.3056	530 000	0.3145	870 000	0.3188
4 000	0.2720	200 000	0.3060	540 000	0.3146	880 000	0.3189
5 000	0.2740	210 000	0.3064	550 000	0.3148	890 000	0.3190
6 000	0.2756	220 000	0.3068	560 000	0.3150	900 000	0.3191
7 000	0.2769	230 000	0.3072	570 000	0.3151	910 000	0.3192
8 000	0.2781	240 000	0.3076	580 000	0.3153	920 000	0.3193
9 000	0.2791	250 000	0.3080	590 000	0.3154	930 000	0.3194
10 000	0.2800	260 000	0.3083	600 000	0.3156	940 000	0.3195
15 000	0.2835	270 000	0.3086	610 000	0.3157	950 000	0.3196
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	0.3098
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 meters. Coefficients K at intermediate values of V shall be obtained by linear interpolation.
(derived from: N. Fujinami et al. Measurement of gross tonnage of small fishing vessels. IPFC/IOFC/ST 26, Nov. 1971)

Table 2. Test calculation of GT by different countries

A test calculation was made using four different formulas, namely, Japanese formula as representative of those based on cubic numbers, Hong Kong, South Vietnamese and Thai. 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 (loaded condition)	–	0.85

(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

$$P = (B + 2D)\, C_b = 7.50 \qquad \text{Here, } C_b = 0.85$$

$$GT = \left(\frac{P+B}{2}\right)^2 \times L \times 0.058 = 41.50$$

(iv) Hong Kong Formula

$$GT = \frac{(L - B) \times B \times \tfrac{1}{2}B}{94} \text{ (in ft)} = 48.2$$

(derived from: same as Table 1)

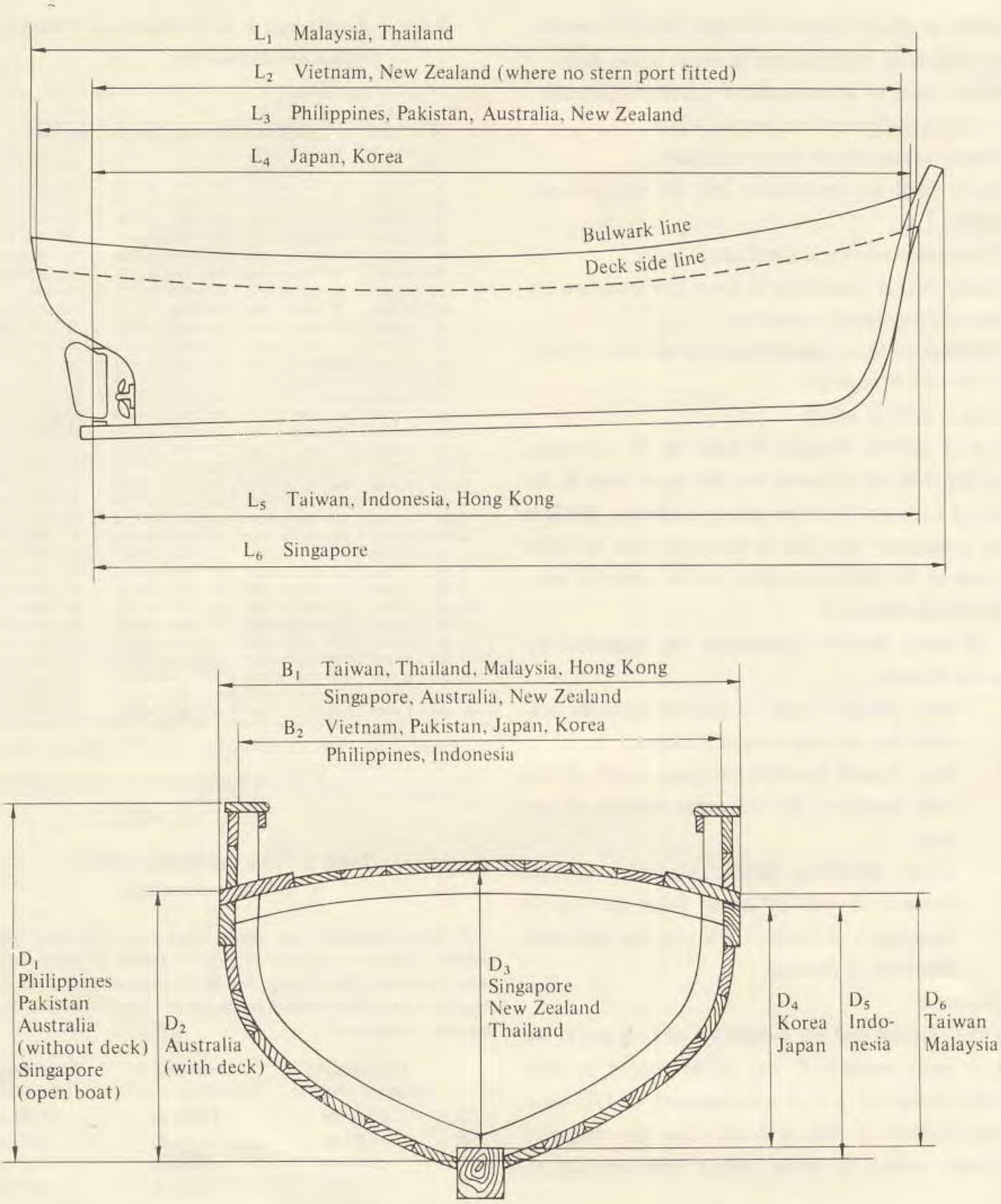


Fig. 1. L, B and D used in different countries

4.1.6 Stability of boat (1)

The water displaced by a ship is known as the buoyant force. The forces of ship weight and buoyancy are equal and opposite direction to keep balance upward force (B) and downward force (W).

A proportion of the buoyant volume is normally immersed in the water and this is called her "buoyancy". The proportion of the buoyant-volume which is not normally immersed in the water is called the "reserve of buoyancy". The freeboard is the distance between the uppermost watertight deck and the waterline and it is a measure of the reserve of buoyancy. A good freeboard should be maintained because any reduction in freeboard means a reduction in reserve of buoyancy.

1. Center of Gravity

This is the point at which the whole weight of the ship acts. It is the point at which the total weight of a rigid body may be assumed to be concentrated. The weight is a force which acts vertically downwards through or from *the center of gravity G.* The position of the centre of gravity G entirely depends upon the distribution of weight in the ship. The height of G is affected by topweight and by ballast. The actual effects can easily be calculated if the original position of G is known. This position can be found by conducting an inclining test. This test will be discussed later.

2. Center of Buoyancy

This is the centre of gravity of the displaced water B i.e. the underwater volume of the ship and is the point through which the resultant upthrust of the water surrounding the boat may be considered to act. The position of B is entirely dependent upon the geometric form of the ship's underwater body. (See Fig. 1)

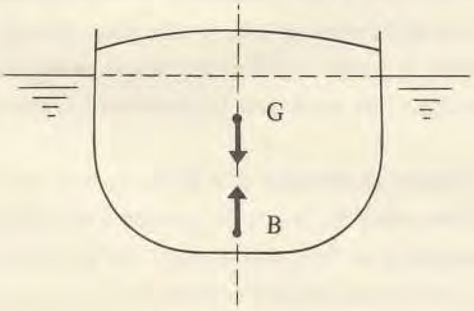


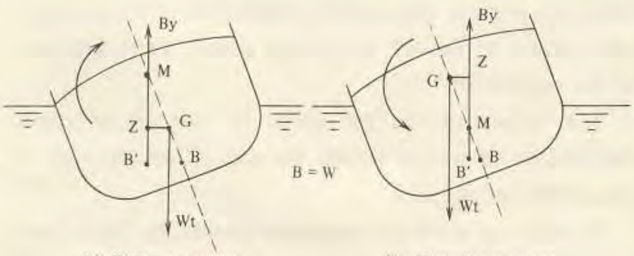
Fig. 1

If the ship is heeled by some external force the weight does not change and therefore the position of G will remain unaltered, but the centre of buoyancy B will move from the middle towards the lower side of the ship because the shape of the submerged part of the ship will be changed. G and B will no longer be in line.

When two equal and opposite forces acting on the same object are not in line they produce a moment tending to rotate the object, this moment is calculated by multiplying the horizontal distance between the points at which the two forces act by the force of one of them (See Fig. 2)

3. Metacentric stability

The ship is considered in static condition and is assumed to be freely floating upright in still water.



(a) Righting moment (positive – stable)

(b) Upsetting moment (negative – unstable)

Fig. 2

Fig. 2 shows the *righting moment* which is calculated by multiplying the weight W by the horizontal distance GZ. This horizontal distance GZ is called the *arm* or the *righting lever.*

Consider a ship floating freely in still water and slightly inclined by some external and temporary force from the upright. The weight and centre of gravity are virtually unaltered as the vessel is heeled, her stability, therefore, can be measured by the length of this arm or righting level.

We should now be clear that the shape of the watertight portion of the ship's hull, part of which is normally under water and part of which may go under water as the ship heels, determines the position and movement of the center of buoyancy B.

The positions of B and G in relation to each other and to the ship will determine her degree of stability.

The arm or righting lever may be used as a measure of the stability of the ship but the more usual measure is metacentric height of GM.

Righting moment W x GZ is thus formed which tends to rotate the ship either back to its initial position i.e. upright, or further from it in the direction of the original inclination.

Equilibrium will not be regained until the righting moment has disappeared and B and G are once more in the same vertical line.

A ship with a large righting moment will roll quickly, while a ship with a small righting moment will roll slowly.

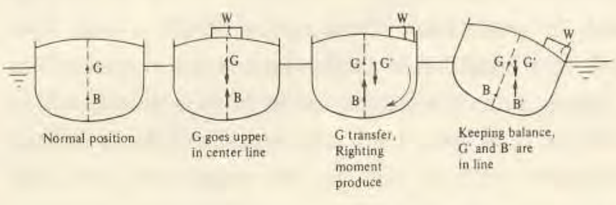
In fact, a ship with a large rightning moment and excellent stability may roll so rapidly as to endanger the crew and fittings, while a ship that rolls sluggishly may be unsafe in heavy weather because her righting moment is small. A compromise in these respects must be achieved by the designer.

If the vessel does not return to the upright, but heels until B and G are in the same vertical line then the ship will heel to some permanent angle of roll. When heel is permanent it is called *list.*

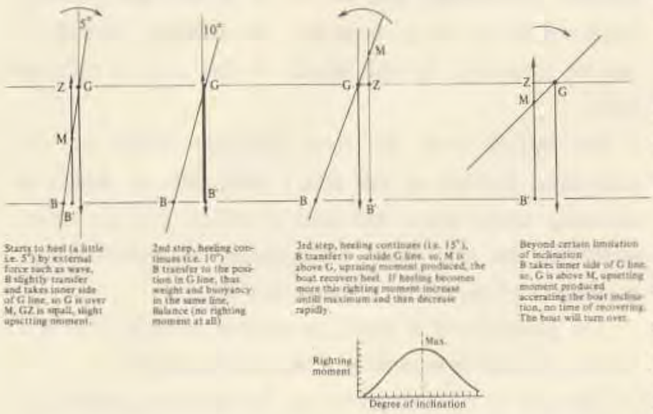
It is important to note from an inspection of the diagrams that the direction of rotation of the ship subsequent to initial inclination is dependent upon the relative positions of the centre of gravity G and the *metacentre* M.

4. Relative position of G and M

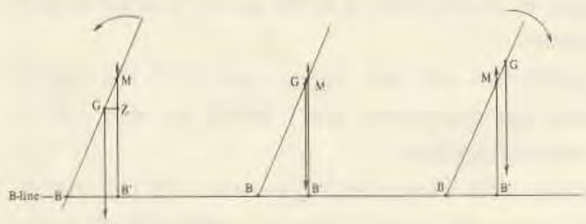
1) Point G transfer outside from the center line by loading weight to one side of boat.

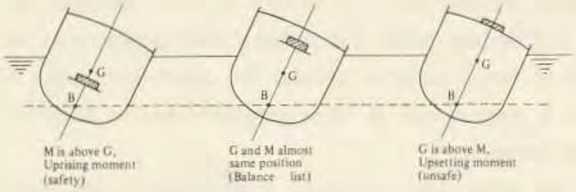


2) Normal rolling by wave– in the case of no change in loading



3) G transfer upward and downward in the center line by loading weight up and down (In the case of same inclination, no change of B' position).





4.1.6 Stability of boat (2)

The following conditions are necessary for stable equilibrium in still water:

1) Buoyancy must equal Weight

$W = B$

2) B must be in the same vertical line as G.

In the case of inclination of boat, the restoring force by righting moment should be in such condition as:

G must be below M (GM is positive).

The amount of metacentric height GM, bears an important relationship to the period of roll of the ship and the acceleration of the motion. If GM is small there will be a condition of tenderness and the motion will be sluggish. From the stability point of view the ship will be referred to as being crank. The opposite of this is stiff and excessive stiffness due to too much GM, not only extremely uncomfortable but could result in damage to fitting. Inadequate GM is extremely dangerous as it could result, in the worst case, in over-rolling of the ship in seas. Inadequate GM means the case that G is above M or GM is negative.

1. *Negative metacentric height*

A ship with a negative GM is not necessarily in imminent danger of capsizing. In calm water the condition is not usually dangerous, but it is certainly a most undesirable condition.

In such a condition the ship will have a list. It can not remain upright. The ship will heel to some permanent angle of roll. With a few centimeters of negative GM the ship will list at its angle of roll. At this point the ship will have picked up positive GM when incline more. In any further analysis this must now be considered as the initial position.

Fig. 1 shows an unstable ship at its angle of roll. The centre of buoyancy B_1 is not on the ship's centerline but on the upright line. The centre of gravity will still be in the same position on the ship's centerline but the position of metacentre M will not on the center line.

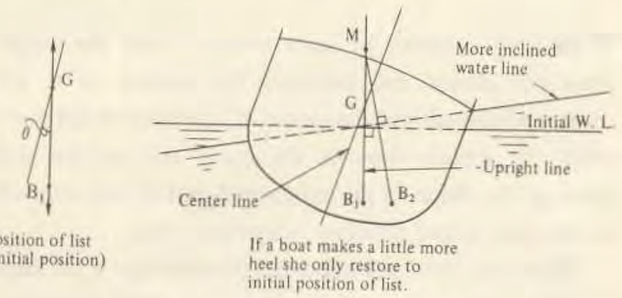


Fig. 1 Positive GM at angle of roll

It is required to find the new position of M. M lies at the intersection of a vertical line through B_1 (now B_1 the initial center of buoyancy) and the vertical line to the last water line through the centre of buoyancy B_2 in a slightly inclined position.

It is seen that the new metacentre M is above G, i.e. the vessel has positive metacentric height and restoring couple will operate to return it to its angle of roll in the direction of the original list.

The causes of the list might be due to improper distribution of weight within the ship either too high or excessively on one side.

In order to avoid the suspected instability the following advice should be acted upon:

1) Do not empty any fuel or water tanks below the waterline on the low side.
2) Lower movable weights if possible, e.g. trim down fish in the hold and fishing gear.
3) Secure suspended weights and derricks and do not attempt to haul on the derricks.

4) As a resort, ballasting may be attempted.

2. Effect of weight on ship condition

The effect of weights can be considered in the followings.

1) Raising or lowering weight which is already aboard

If a weight of w is raised a distance d, the centre of gravity of the whole ship will also be raised to a new position G_1. The metacentric height GM will decrease by an amount GG_1. Now the force w multiplied by the distance through which it is moved d is called the moment. This is equivalent to the weight or displacement of the ship multiplied by the effect (distance GG_1) on G.

That is, $w \times d = W \times GG_1$

Where W (often disignated by Δ) is the displacement of the ship. Note there is no change in either draft or trim when a weight already aboard is raised. Lowering a weight has the reverse effect by increasing the GM.

2) Weights added or removed

Weights added or removed from a ship will cause:

Increase or decrease of displacement,

Increase or decrease of draft,

Alteration in trim fore-and-aft unless added amid ships,

Raising or lowerting of G,

Alter the position of B and M,

and

List, unless added on the centreline, but this is not significant for weights of moderate amount.

Although the position of M and G will change there may, in fact, be no change in their relative positions in which case GM value would remain the same.

Example

On departure from the fishing grounds for home a trawler is found to have 30 tons of fish in the hold at a height of 8 ft. above the keel. Since leaving port the trawler has consumed 13 tons fuel – 3 ft. above Keel, 8 tons of fresh water – 6 ft. above keel, 2 tons of stores – 10 ft. above keel and lost 3 tons of nets and fishing gear – 14 ft. above keel. Before leaving port the trawler had a displacement of 500 tons and the height of its centre of gravity above the keel KG was 7 ft. Calculate the new position G_1, above the Keel. If in this condition the height of M i.e. KM is 9 ft, what is the metacentric height on leaving the fishing grounds and the value of the righting lever at 10 degrees inclination.

Item	Weight (tons)		Lever (ft.)	Moment (tons)	
	+	–		+	–
Trawler	500		7	3,500	
Fish	30		8	240	
Fuel		13	3		39
Fresh water		8	6		48
Stores		2	10		20
Nets etc.		3	14		42
	530	26		3,740	149
	504			Mom. of Δ = 3,591	

$$\text{(New lever) } KG = \frac{\text{Moment of } \Delta}{\Delta} = \frac{3{,}591}{504}$$

$$= 7.14 \text{ ft.}$$

$$\text{But} \quad GM = KM - KG$$

$$= 9 - 7.14$$

$$= 1.86 \text{ ft}$$

This is on departure from fishing grounds.

$$\text{Also, righting lever } GZ = GM \sin\theta$$

$$= 1.86 \sin 10^\circ$$

$$= 1.86 \times 0.1736$$

$$= 0.323 \text{ ft. approx.}$$

That is to say at 10° inclination the righting lever will be nearly 9.6 cm (= 0.323 × 0.3).

3. Angle of heel due to moving a weight transversely

It is assumed here that the weight to be moved is already aboard the ship. If not, and the weight is to be added or removed from one side of the ship, then the problem is in two parts, viz, the weight, if first considered, to be added at the centerline (in this case the metacentric height decrease on the centerline) and then moved transversely.

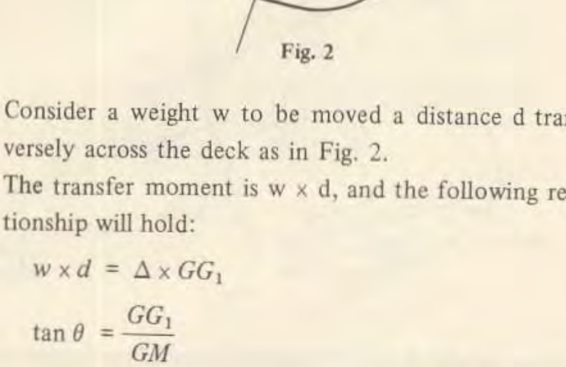


Fig. 2

Consider a weight w to be moved a distance d transversely across the deck as in Fig. 2.

The transfer moment is w × d, and the following relationship will hold:

$$w \times d = \Delta \times GG_1$$

$$\tan\theta = \frac{GG_1}{GM}$$

$$\tan\theta = \frac{w \times d}{\Delta GM} \quad \text{and} \quad GM = \frac{w \times d}{\Delta \tan\theta}$$

This is important because it means that if the angle of heel can be measured as a result of moving with a known weight and a given distance, then GM can be found. This formula is therefore made use of in the stability investigation known as an *Inclining Experiment.*

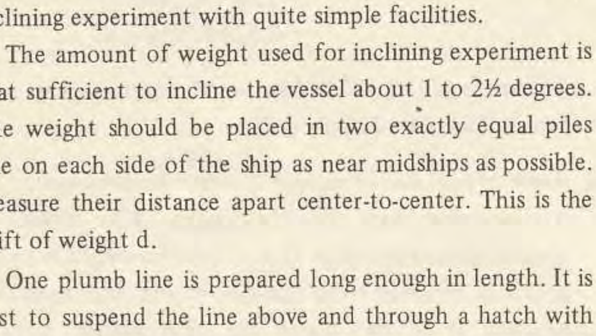
4.1.6 Stability of boat (3)

Inclining Experimnt

The object of this inclining experiment is to determine the position of the centre of gravity. The position of G is the fundamental position of the centre of gravity from which other positions in any condition of loading of the ship can be determined by the calculation if the loading information is known. From the view point of the ship's stability the main interest is an inclining test by which the value of metacentric height is found. Any officer of boat could check a boat's stability by means of a rough inclining experiment with quite simple facilities.

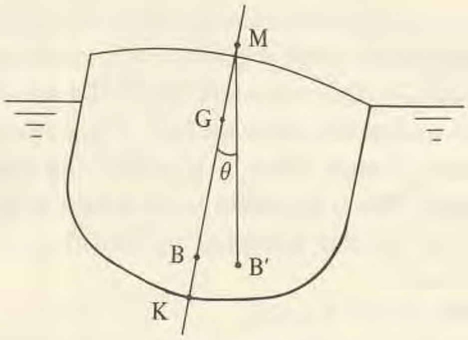
The amount of weight used for inclining experiment is that sufficient to incline the vessel about 1 to 2½ degrees. The weight should be placed in two exactly equal piles one on each side of the ship as near midships as possible. Measure their distance apart center-to-center. This is the shift of weight d.

One plumb line is prepared long enough in length. It is best to suspend the line above and through a hatch with the bob immersed in a wide bucket. A horizontal wood batten is fixed above the bucket so that the plumb line very lightly rubs its edge. The length of the plumb is accurately measured from point of suspension to the top edge of the batten. Take the drafts fore-and-aft. Mean draft will give the ship's displacement in tons from an inspection of the ship's displacement curve supplied with the builder's particulars. Mark the centerline of the plumb line on the wood batten with a pencil. Proceed as follows.



1. Move weight A to B. Note deflection of pendulum and mark on batten
2. Move weight A back to original position.
3. Move weight B to A. Note deflection
4. Return weight B to original position
5. Repeat moves 1 to 4.

In the statical stability the length of GM is almost constant under the angle θ ranges below 10~15°. As M is almost immovable, the point of M is called as transverse metacenter.



Here the following symbols are used and calculated.

Δ = Displacement of ship in tons (from mean draft)

w = Inclining weight (half the total) in tons

d = Shift of inclining weight

l = Length of pendulum (plumb line)

s = Deflection (average) of pendulum across batten

Now $\frac{s}{l} = \tan\theta$, where θ is angle of inclination, and

$$GM = \frac{w \times d}{\Delta \tan\theta}$$ as it was already discussed.

If the height of the centre of gravity (KG) of the ship in the inclined condition is required, it is necessary first to find the height of the metacentre GM from the builder's particulars at the draft (d) or displacement ($\triangle$) obtaining. Then $KG = KM - GM$.

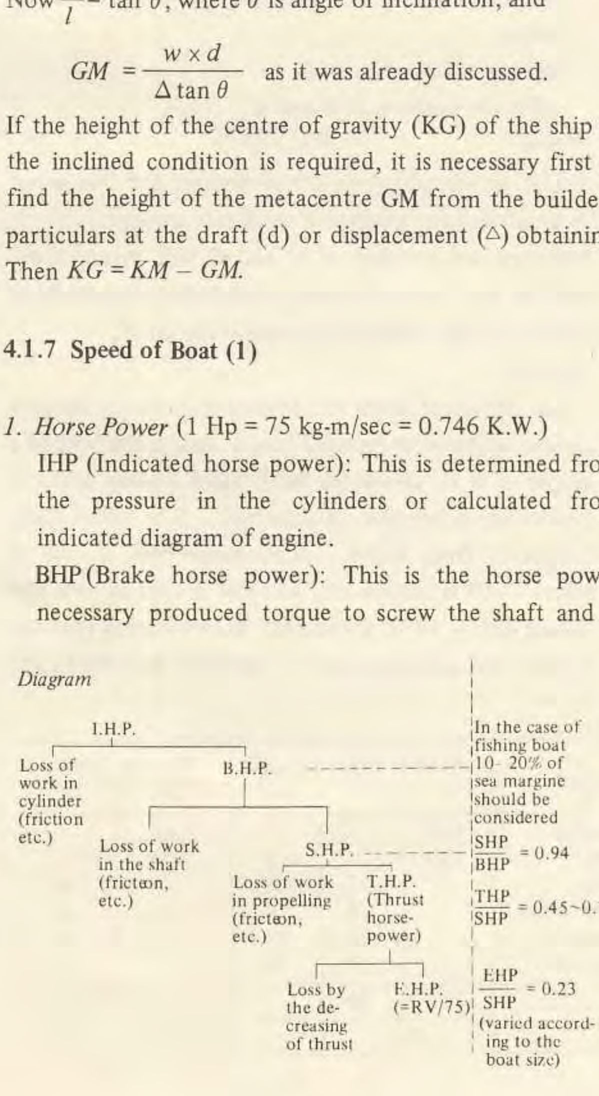
4.1.7 Speed of Boat (1)

1. Horse Power (1 Hp = 75 kg-m/sec = 0.746 K.W.)

IHP (Indicated horse power): This is determined from the pressure in the cylinders or calculated from indicated diagram of engine.

BHP (Brake horse power): This is the horse power necessary produced torque to screw the shaft and is

Diagram



less than IHP because of the loss of work in the cylinders.

SHP (Shaft horsepower) or DHP (Drived horsepower) or PHP (propeller hosepower): This is decided by torsion meter in rotate shaft.

EHP (Effective horsepower): Horsepower which needs for moving the boat substantially. The value will be measured by model experiment of boat.

$EHP \fallingdotseq SHP \times 0.23$

In fishing operation, about 20% sea margine is prefarable for the *EHP*.

So, $EHP = BHP \times 0.8 \times 0.94 \times 0.23$

Normally, from the direct measurement, *EHP* of the boats ranging from 300 to 5,000 tonnage is expressed as:

$EHP = (0.15 \sim 0.30) \times BHP$

2 Relation between speed and length of boat

1 knot = 1852 m/hr

speed length ratio: $\dfrac{\text{Speed (knot)}}{\sqrt{\text{length of boat (ft)}}} = \dfrac{V}{\sqrt{L}}$

Normal Speed boat: (economical speed) $\dfrac{V}{\sqrt{L}}$ is nearly 1.00

Low speed boat: Less speed than $\sqrt{L} \times 0.8$

High speed boat: More speed than $\sqrt{L} \times 1.2$

High speed boat could not be obtained infinitively, it will probably attain $1.5 \times \sqrt{L}$, if taking care of special style of boat or using particulary big power of engine. But it is almost impossible to get $\sqrt{L} \times 2.0$ speed. The necessary length of boat is obtained as follows if we make the boat cruising with economic speed. (use $V/\sqrt{L} = 1.0$)

Required speed	Necessary length of boat
6 knot	6 x 6 = 36 ft
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 speed of boat he had better increase the length of boat rather than installing an engine of higher power.

For example:

M. V. Queen Merry

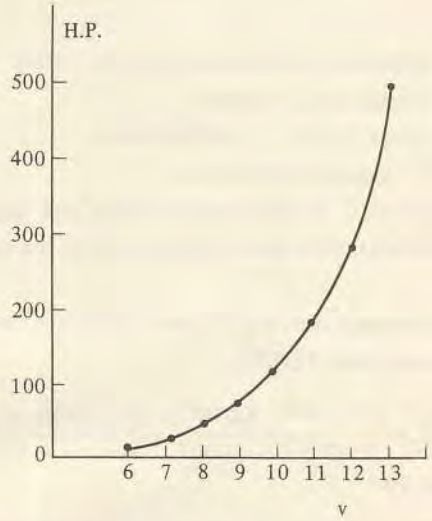
Gross tonnage 80,000 ton. Length 975 ft., speed of boat 31.6 knot. The value of $\dfrac{V}{\sqrt{L}} = \dfrac{31.6}{\sqrt{975}} = \dfrac{31.6}{31} =$ 1.02. So, 31.6 knot is economical speed for such huge length of boat.

3. Relation between speed and horse power

Ex. M.V. Takachiho-Maru, Gross ton 50, Length 76 f.

$\sqrt{L} = \sqrt{76} = 8.72$

	Speed v (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



The horsepower required to increase speed by 1 knot will become bigger according to number knot increase. It is impossible from the fiture of v – HP to get the speed more than 13 knot whatever we increase the horse power. Because the value of $\dfrac{V}{\sqrt{L}}$ will be more than 1.5.

4. Approximate calculation from speed to horsepower or the opposite

The resistance of boat are classified frictional resistance R_f, wave making resistance R_w, eddy making resistance and air resistance. The following formula is realized.

$$R_f = \rho\lambda \left\{ 1 + 0.0043\,(15-t) \right\} A V^{1.825}$$

Here

R_f : frictional resistance (Kg)

t : water temperature (°C)

ρ : 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 boat is clean the value of λ is about from 0.13 to 0.16.

The length of wave produced by the boat foreward moving is denoted as:

$$s = \frac{2\pi}{g} \cdot V^2$$

g : acceleration of gravity (980 cm.sec)

As, $\frac{V}{\sqrt{L}} = \sqrt{\frac{g}{2\pi} \cdot \frac{s}{L}} = f \times \sqrt{\frac{s}{L}}$, if the value of $\frac{V}{\sqrt{L}}$ become large, the length of wave will become large which accompany with big wave making resistance.

Approximate calculation formula between speed and horse power is denoted in the following.

$$\text{I.H.P.} = \frac{\Delta^{2/3}\, V^3}{C} \text{ or } V = \sqrt[3]{\frac{IHP \times C}{\Delta^{2/3}}}$$

Here,

C : admiralty coefficient (about 60 – 100)

Δ : displacement tonnage

V : speed (knot) · · · · normal speed

I.H.P. : indicated horse power

The value of C is small in bad design and large in good design of boat. Ordinarily it is about 80 in the value.

ex. 1

Δ is 440 tonnage, speed is 11 knot and C is 80 in value. Find horse power (I.H.P.).

$$\text{I.H.P.} = \frac{\Delta^{2/3} \times V^3}{C} = \frac{440^{2/3} \times 11^3}{80} = \frac{57.85 \times 1331}{80}$$

$= 965$ HP

ex. 2

Δ is 270 tonnage, I.H.P. is 500 HP, C is 80. Find the speed.

$$V = \sqrt[3]{\frac{500 \times 80}{270^{2/3}}} = \sqrt[3]{957.5} = 9.85 \text{ Knot}$$

4.1.7 Speed of boat (2)

1. The application of $\frac{\text{B.H.P.}}{\Delta} \sim \frac{V}{\sqrt{L}}$ curve is useful for finding speed horse power or length of boat.

ex.1

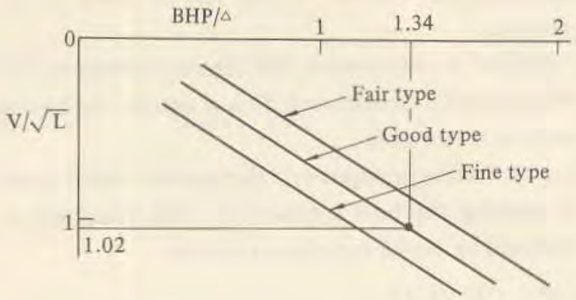
Gross tons is 154., L is 97 ft., B is 19.4 ft., D is 10.8 ft., (1 ft is 3.28 meter). $\sqrt{L} = 9.87$, Δ are 224 tonnage in light load and 354 tonnage in full loaded. B.H.P = 300 HP

How are the speed of light and full loaded condition?

In light loaded condition,

$$\frac{B.H.P.}{\Delta} = \frac{330}{224} = 1.34$$

In the curve, if we take the value 1.34 in the transverse and taking the curve of good type, then we will find the value 1.02 of $\frac{V}{\sqrt{L}}$



So, $V = \sqrt{L} \times 1.02 = 9.87 \times 1.02 = 10.0$ knot

In full loaded condition,

$$\frac{B.H.P.}{\Delta} = \frac{330}{354} = 0.848. \text{ From the curve we get}$$

$$\frac{V}{\sqrt{L}} = 0.91$$

So, $V = \sqrt{L} \times 0.91 = 9.87 \times 0.91 = 8.9$ knot

2. Displacement curve could provide any displacement of boat according to the draft. If we don't have displacement curve, the outline of displacement $\triangle$ should be calculated in order to get necessary calculation for speed and horse power of engine.

The following table of elemental coefficients relating to the coefficient of displacement is used for the calculation speed or horse power. (See in next page)

Ex. 2

Tuna long line steel boat. Good type, $L = 31$ meters. Want to take 9.5 knot as full load condition. Find required horse power.

$L = 31$

$B = L/5.568 = 5.57$

$D = L/10.92 = 2.84$

$L \times B \times D = 31 \times 5.57 \times 2.84 = 490$

Gross ton $= L \times B \times D \times 0.3 = 490 \times 0.3 = 147$ ton

Displacement $= L \times B \times D \times 0.349 = 490 \times 0.349$
$= 171$ ton

Displacement at full load $= L \times B \times D \times 0.592$
$= 490 \times 0.592$
$= 290$ ton

$$\sqrt{L\text{ (feet)}} = \sqrt{31.00 \times 3.28} = 10.14$$

$$\frac{V}{\sqrt{L}} = \frac{9.5}{10.14} = 0.937 \text{ (Normal Speed)}$$

When $\frac{V}{\sqrt{L}} = 0.937$

The value of $\frac{B.H.P.}{\Delta}$ in Good type is found from the figure as 0.94. So, $B.H.P.$ (at full load) $= 290 \times 0.94$
$= 273$ horse power

	L/B	L/D	B/D	Gross ton / L.B.D.	△ / L.B.D.	△ (full load) / L.B.D.
Inspection or research boat (steel)	5.436	10.69	1.97	0.263	0.353	0.452
- ditto - (wood)	4.55	10.00	2.21	0.25	0.365	0.536
Whale catcher	5.788	10.56	1.85	0.254	0.376	0.477
Fish carrier boat (steel)	5.83	11.40	1.95	0.32	0.377	0.673
- ditto - (wood)	4.68	9.60	2.04	0.27	0.353	0.522
Tuna long liner (steel)	5.568	10.92	1.96	0.30	0.349	0.592
- ditto - (wood)	4.56	9.16	2.01	0.255	0.361	0.570
Skipjack boat (steel)	5.33	10.40	1.95	0.29	0.376	0.598
- ditto - (wood)	4.80	9.07	1.89	0.256	0.345	0.549
Trawler (steel)	5.95	11.15	1.87	0.27	0.363	0.500
2-boat trawler (steel)	5.13	10.34	2.01	0.263	0.362	0.540
- ditto - (wood)	5.20	9.30	1.79	0.245	0.337	0.552
Danish seiner (steel)	4.83	10.22	2.12	0.258	0.405	0.575
- ditto - (wood)	4.78	9.88	2.05	0.236	0.369	0.565
2-boat purse senior (steel)	4.274	9.27	2.16	0.21	0.360	0.473
Purse seiner (steel)	4.21	8.52	2.02	0.28	0.383	0.585
- ditto - (wood)	4.28	9.63	2.24	0.235	0.370	0.540
Stick held dip net boat (wood)	4.66	9.90	2.12	0.265	0.433	0.537
Long liner (wood)	4.68	9.70	2.07	0.242	0.325	0.468
Mackered angling boat (wood)	4.27	9.74	2.06	0.276	0.361	0.535
Squid angling boat (wood)	4.94	9.99	2.02	0.224	0.334	0.472
Spearing boat (wood)	4.67	9.80	2.10	0.234	0.344	0.487

Ex. 3

Wooden skipjack angling boat. Good type, L = 27 meters. If setting 300 horse power, how much the speed in full load condition?

$L = 27$

$B = L/4.80 = 5.63$

$D = L/9.07 = 2.98$

$L \times B \times D = 27.00 \times 5.63 \times 2.98 = 453$

Gross ton $= L \times B \times D \times 0.256 = 453 \times 0.256 = 116$ ton

Displacement $= L \times B \times D \times 0.345 = 453 \times 0.345$
$= 156$ ton

Displacement at full load $= L \times B \times D \times 0.549$
$= 453 \times 0.549 = 249$ ton

$\sqrt{L\ (\text{feet})} = \sqrt{27.00 \times 3.28} = 9.4$

As $\dfrac{B.H.P.}{\Delta} = \dfrac{300}{249} = 1{,}205,$

so, from the figure the value of $\dfrac{V}{\sqrt{L}}$ is 1.0 (normal Speed).

Required speed $V = 1.0 \times 9.4 = 9.4$ miles/hour

3. Suppose there is a plan to built new research boat for skipjack pole and line fishing, purse scine fishing and gill net fishing (multi purpose boat).

The principal dimension of the boat are

$L.B.D.$ = 75 ft × 19.5 × 9.25

Displacement (Δ) = 120 tonnage

Discuss the necessary elements of the boat.

1) Normal speed boat

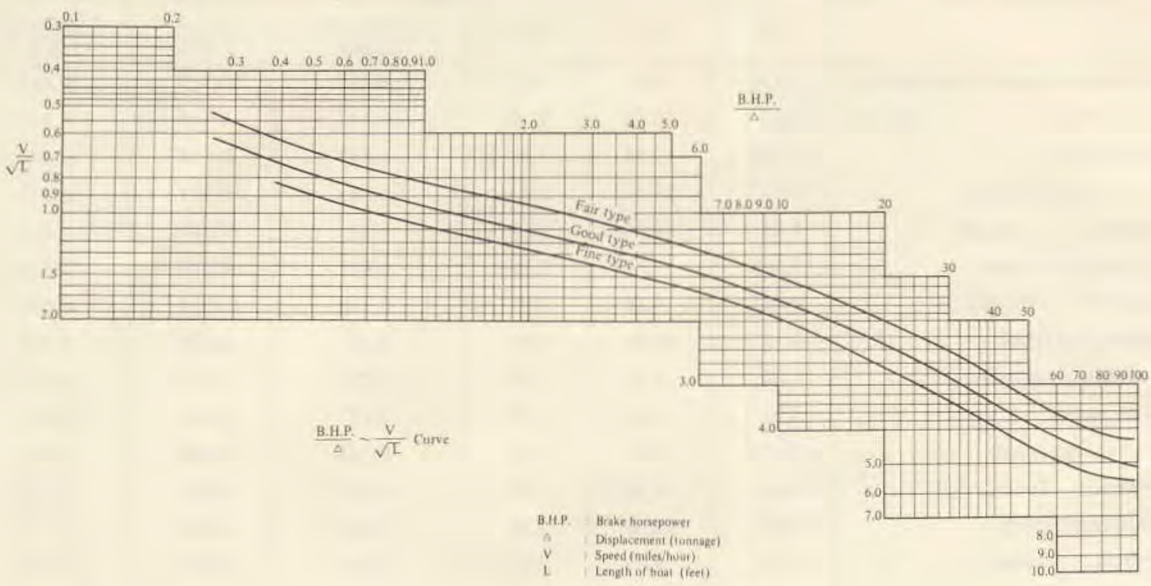
$V = 1.0 \times \sqrt{L} = 1.0 \times \sqrt{75} = 8.7$ knot

2) $IHP = \dfrac{\Delta^{2/3} \times V^3}{C}$, using $C = 80$

Speed	IHP	$\frac{V}{\sqrt{L}}$	Remarks
9 knot	$\frac{120^{2/3} \times 9^3}{80} = 210^{ps}$	$\frac{9}{8.7} = 1.03$	Normal speed boat
10 knot	287	$\frac{10}{8.7} = 1.14$	
11 knot	382	$\frac{11}{8.7} = 1.26$	High speed boat
12 knot	496	$\frac{12}{8.7} = 1.37$	

3) B.H.P calculation. Using Good type of boat. △ = 120

Speed	$\frac{V}{\sqrt{L}}$	(from the figure) B.H.P./△	B.H.P.
9 knot	$\frac{9.0}{8.7} = 1.03$	1.40	168
10 knot	1.14	2.20	264
11 knot	1.26	3.00	360
12 knot	1.37	4.50	540



4.1.8 Basic plan of building boat

1. Nomenclature and decision of coefficients

The main items denoting elemental capacity of boat FAO indicated are as follows:

GT – Gross registered tons, regardless of the difference of measurement by countries.

LOA – Length of the vessel measured parallel to the loaded water line, from the extreme end of the bow to the extreme end of the stern.

LWL – Length of the vessel on the water line.

B – The maximum beam of the vessel measured horizontally.

D – Depth of the vessel, namely the distance from the top of the deck planking to the bottom of the keel excluding a possible bar keel (for steel vessels), or the rabbet bottom line of the keel (for wooden vessels), measured vertically to the loaded water line at the ship side (normally the beam is cambered and the ship side is lower than the ship centre) at the midship.

d – Draft, namely the distance from the water line to the bottom of the keel excluding a possible bar keel (for steel vessels), or to the rabbet bottom line of the keel (for wooden vessels), or the extended line of it, measured vertically to the water line; draft-fore at the fore end of the water plan; draft-aft at the end, draft mean at the midship.

F – Freeboard, namely distance from the top of the deck plank to the water line measured vertically to the water line; freeboard-fore at the fore end of the water plan; freeboard aft at the aft end; freeboard mean at the midship.

C_w – Water plane coefficient, or water line coefficient, namely the ratio between (the area of the water plane) and (the length of the water plane) x (the maximum width of the water plane).

$C_{⊗}$ – Midship section coefficient, namely ratio between (the area of the immersed transverse section of the vessel at the midship measured vertically to the water line) and the area made by (the maximum width of the immersed transverse section) x (draft at the midship).

C_{max} section – Same ratio as $C_{⊗}$ but not at the midship section but at the maximum immersed transverse section.

C_b – Block coefficient, namely the ratio between (the volume of the vessel under the water plane) and the volume made by (the length of the water plane) x (the maximum width of the maximum transverse immersed section) x (draft at the maximum immersed transverse immersed section).

C_p – Prismatic coefficient, namely the ratio between (the volume of the vessel under the water plane) and the volume made by (the length of the water plane) x (the area of the maximum immersed transverse section). Therefore $C_b = C_p \times C_{max}$.

$½\alpha_\theta^\circ$ – The angle which the water line makes with the centre line of the vessel at the stem. Normally, this is the average angle for the first 1/20 of the dimension LWL, but when measuring care is taken to disregard excessive rounding or hollowing near the stem.

$\frac{1}{2}\alpha_{\gamma}^{\circ}$ – The maximum angle of run of any water line up to and including the water line, measured at a section 5% LWL foreward of the extreme end of the water line. This measurement is made relative to the centre line of the vessel in a plane parallel to the water line.

α_{BS}° – The maximum slope of the buttock line drawn in the afterbody at a section 25% of the beam B, measured relative to the water line.

LCB – Position of the longitudinal centre of buoyancy in relation to the midship expressed as a percentage of LWL, "+" or "f" indicate the position foreward the midship, and "–" or "a" indicate the position aft of the midship.

LCG – Position of the longitudinal centre of gravity expressed in the same manner as LCB.

$\overline{KM}$ – Distance of the metacentre above the bottom of the keel excluding a possible bar keel (for steel vessels) or above the rabbet bottom line (for wooden vessels), measured vertically to the water line.

$\overline{KB}$ – Distance of centre of buoyancy above the bottom of the keel exculding a possible bar keel (for steel vessels), or above the rabbet bottom line (for wooden vessels), measured vertically to the water line.

$\overline{GM}$ – Height of the metacentre above the centre of gravity.

$\overline{KG}$ – Distance of center of gravity above the bottom of the keel excluding a possible bar keel (for steel vessels), or above the rabbet bottom line (for wooden vessels), measured vertically to the water line.

S – Wetted surface area of the vessel under the water line.

$\overline{KG}/D$ – Ratio between $\overline{KG}$ and depth of the vessel D.

TPC – Tons per cm immersion.

MTC – Moment to change trim 1 cm.

Coefficient of finess

$$C_b = \frac{\nabla}{L \times B \times d} \quad \text{or} \quad C_b = 1.07 - 0.41 \frac{V}{\sqrt{L}}$$

$$C_{\otimes} = \frac{A_{\otimes}}{B \times d}$$

$$C_p = \frac{\nabla}{L \times A_{\otimes}} = \frac{C_b \times L \times B \times d}{C_{\otimes} \times B \times d \times L} = \frac{C_b}{C_{\otimes}}$$

$$C_w = \frac{A_w}{L \times B}$$

$$C_u = \frac{\nabla}{A_w \times d}$$

Table 1

C_b	C_p	$C_{\otimes}$	C_b	C_p	$C_{\otimes}$
0.40	.554	.722	0.60	.623	.968
0.42	.554	.758	0.62	.639	.970
0.44	.554	.794	0.64	.656	.975
0.46	.556	.827	0.66	.674	.978
0.48	.560	.857	0.68	.693	.981
0.50	.566	.883	0.70	.712	.983
0.52	.574	.906	0.72	.731	.985
0.54	.583	.926	0.74	.750	.988
0.56	.595	.942	0.76	.769	.988
0.58	.608	.954	0.78	.788	.990

Example

Length 34m, Width 7m, Depth 3.4m

Cruise speed = 9 knot

Displacement (design) 500 ton, BHP = 350 Ps

$L = 34\text{m}, \; V = 9, \; \sqrt{L} = \sqrt{34 \times 3.28} = 10.5$

$B = L/4 \times 0.82 = 7\text{m}$

$D = B/2 \times 0.97 = 3.4\text{m}$

$F = D \times 0.12 = 0.4\text{m}$

$d = D - F = 3.0\text{m}$

Designed displacement 500 ton

$500 = L \times B \times d \times C_b$

$\therefore C_b = 0.7$ or

$$C_b = 1.07 - 0.41 \frac{V}{\sqrt{L}} = 1.07 - 0.41 \times 0.90 = 0.7$$

* decision of coefficients

$C_b = 0.70$ from Table 1

↓ $C_p = 0.71, \; C_{\otimes} = 0.98$

$C_v = 0.85$ (Fig. 1) ⟶ $\frac{KM}{B} = 0.43$ (Fig. 2)

↓ $\therefore KM = 3.0$

$\frac{KB}{d} = 0.54$ (Fig. 3) $\therefore KB = 1.6$

$\therefore BM = KM - KB = 1.4$

↓ $\alpha = \frac{BM \times d \times C_b}{B^2 \text{ (full load)}} = 0.06$

↓ $C_w = 0.85$ (Fig. 4)

↓ $TPC = \frac{L \times B \times C_w}{100} = 2.0 \text{ t}$

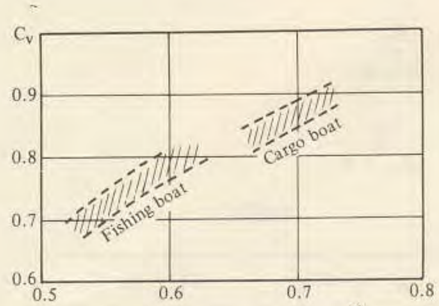


Fig. 1

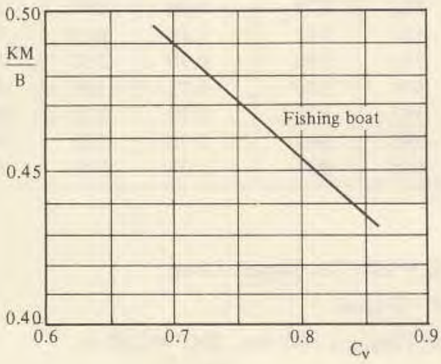


Fig. 2

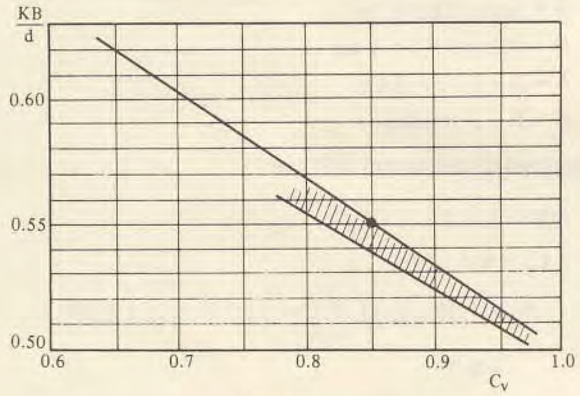


Fig. 3

* decision of dead weight

$L \times B \times D = 34 \times 7 \times 3.4 = 809$

Full loaded displacement 500 ton

$C_b = 0.70,\ d = 3.0\text{m}$

Light load displacemnet = 1) + 2) + 3) + 4) = 170 t as shown in the follows.

1) Weight of hull: taking the coefficient
   $C_h = 0.12 \sim 0.16$, then,
   $L \times B \times D \times C_h = 809 \times 0.144$
   $= 116.5$ t

2) Weight of engine: taking the coefficient 0.11, then,
   $BHP \times C = 350 \times 0.11 = 38.5$ t

3) Weight of equipment is 12 t.

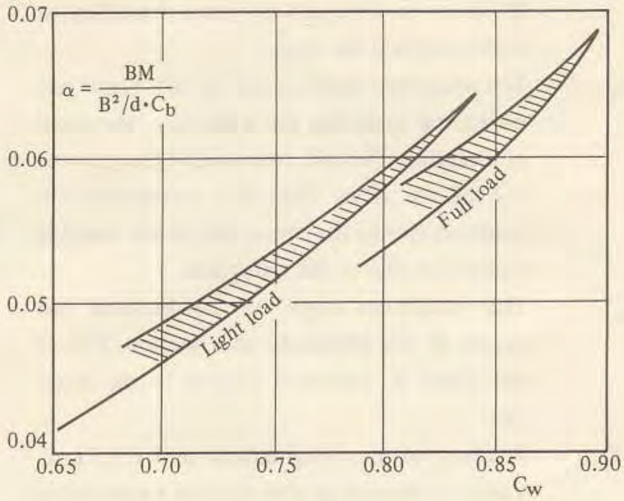
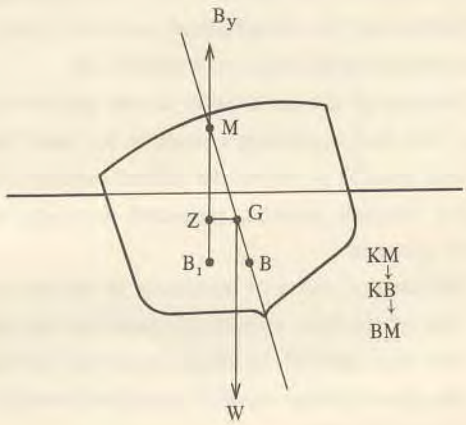


Fig. 4



4) Others is 3 t.

Thus,

Dead weight $D.W.$ = Full load − Light load
= 500 − 170 = 330 t

If, actual draft 3.1m,
the corrected $D.W.$ = 330 t + 2 t × 10 = 350 t

GM is already expressed in the explanation of inclining experiment, finding the value of GM as:

$$\text{GM} = \frac{w \times d}{W \times \tan\theta}$$

The stability is closely related to the shape of boat, loading, draft and the size of GM value.

The position of M is nearly constant according to the style of boat, center of buoyancy B is movable by the draft and center of gravity varies its position by loading.

The M is fixed with relation to shape of boat, namely width of boat and depth of boat. If the width become large, position of M become high and this increasing rate elementarily influences stability very much.

Even though with the increasing of depth of boat, M does not drift in position very much, and the value of GM become small because of the position of G becomes high. So, this might give the most adequate value of B/D.

Nevertheless, boat is not necessarily safe by the action of making the width large. There should be limitation in the value.

Initial stage arm GZ is large which means safety when the width is large and M is high in position, but if angle θ beyonds maximum inclination angle the length of GZ become decrease and this causes capsizing of boat.

On the other hand, if M is high and GZ is large excessively, the forces of restitution is too much in heavy rolling and is called a stiff ship.

If the depth of boat D is too big, the GZ become minus which causes the ship list. In this case if we move some load in lower part of boat in order to get G down then the boat recovers safety because the maximum inclination angle become very large. Generally speaking, in the small value of stability the boat come crank ship in which the rolling is big but slowly and onboard feeling is easily.

If boarding the weights on deck that make the position of G high and GM becomes small, it is called top heavy or crank boat, and is very dangerous.

Once the hull is completed, the position of M and G are fixed.The stability of boat, therefore, could be adjusted in the following ways: changing G position by moving the weights in lower part, and changing B position by draft and balast.

So, again we could say that within the range of angle θ between 10 to 15 degree, the position of M would scarcely move.

In order to find the length of GM, the position of B should be mathematically calculated from displacement curve as described above and the position G is found by inclining experiment as stated already or it is estimated by informal formula.

2. Review the stability conclusively

1) States of elements and stability

Righting moment : $GZ \times W$

Righting arm : $GZ = GM \times \sin\theta$

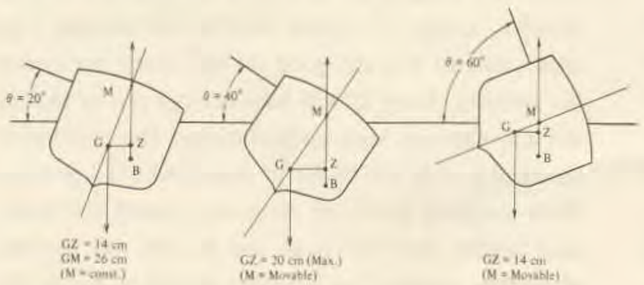
From inclining experiment : $GM = \dfrac{w \times d}{W \times \tan\theta}$

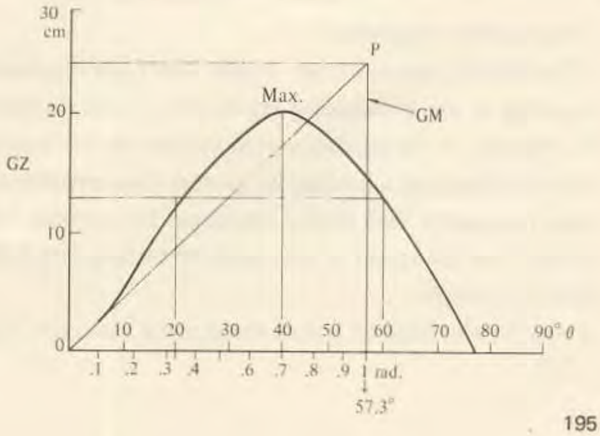
The stability is connected with :

Shape of boat, loading, draft and GM

		G (position)	B (position)	M (position)	GM	GZ	Stability
In general	If change draft	–	Movable	$\theta < 15°$ nearly const.			Changeable by W (GZ × W)
	If Change loading	Movable	–	- ditto -	Changeable	Changeable	Changeable
Normal condition changes	If width B becomes large	–	–	Becomes high	Becomes big	Initially it is big, but according to the θ increase, decreases after max. angle.	Large value of stability
	If depth D becomes large	Becomes high		Nearly const.	Becomes small	Becomes small	Small value of stability: crank ship, rolling is big but slow, comfortable feeling
Excessive condition	If width B excessively increased	–		Excessively high		Excessively big	Heavy rolling, stiff ship, aboard feeling is bad.
	If depth D excessively increased	G become above M			Becomes minus	Becomes minus	Ship list. (In order to adjust list, loading in lower part is necessary)

2) Find $GZ \cdot \theta$ curve (Example: how to draw)





If we denote θ as radian, then $GZ=GM \cdot \theta$ (1 rad.=57.3°)

(1) To make boat incline at $\theta = 20°$ and to find the position of B in the drawing by mathematical calculation. G is already found by inclining experiment, M will be found in the drawings. Thus GZ = 14 cm and GM = 26 cm are found for example.

(2) Fixing point P in such a manner, then make straight line through P and O. Take GM = 26 cm at 1 radian point as shown in the figure.

(3) Up to 0.1 rad., GZ and OP line are on the same line.

(4) In the same way we could find GZ in each angle so that the curve will be drawn as shown in the fiture. Again we get GZ = 14 cm at the angle 60°, thus the angle at the maximum GZ, is found as 40° or 0.7 rad.

4.2.1 Particulars of boat – 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 requested that they should be provided with steel hull, strong structure and solid fishing equipment.

In addition to the requirements for general high sea fishing boats, trawlers must establish 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 operation.
3) Stability must be great; seaworthiness must be excellent; and oscillation must be little.
4) The boat should have good buoyancy and big towing power, and at the same time they must be easily operated in fishing.
5) The trim is not easily changed.
6) The boat must have enough and complete storing facilities for the catch.
7) The boat has such special features as great rise of floor and large sheer; namely, large warp of the side line of upper deck.

2. Shipbuilding regulation

The fishing boats, (types shown later) are regulated according to the shipbuilding regulations of own country. The purpose of the regulation is to improve the buoyancy of fishing boats by adjusting the general characteristics of boats to expedite their fishing operation. The trawlers, for instance, are requested or stipulated by the regulation of Japan as example.

1) Any trawler shall be a steel vessel of 1st class over 200 GT.
2) Its dimensions shall be over $L \times B \times D = 30{,}000$
3) It shall be equipped with exclusive oil tanks durable for more than 2,000 miles, and its maximum speed shall not be less than 11 kt.
4) Although there are trawler's main elements as shown in the latter table, the adequated balancing, if the boat around 40 m in length, will be as:

L/D = less than 10.5, L/B = less than 5.8
B/D = more than 1.75

3. Type of fishing boats

The trawler is one of the fishing boats, and each type of fishing vessels has it's own particular elements for the fishing purpose. It of course depends 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.

The type of 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
Long lining :	Bottom long liner (sharks, red fish.........) Surface long liner (tuna, mackerel...........)
Harpoon fishing:	
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) General speaking, trawl boat has long L, a narrow width B and big draft d. The block coefficient C_p should be small as possible, and aft draft be deep as possible. Longer L means benefit for keeping high speed, narrow B is also good for high speed but uneasy for stability. Deep D will have enough power to drag net and also can keep good stability. The position of center of gravity G is better to place lower in any cases. When dragging trawl net with slow speed the resistance involve both by boat and by net will increase more than usually, the propeller should be big in size

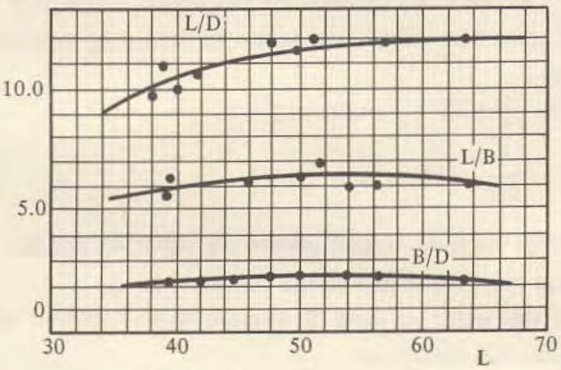
to enhance enough thrust for dragging net. In this point of view, low speed rotated engine and pitch propeller are profitable.

2) Characteristics

Value of ratio

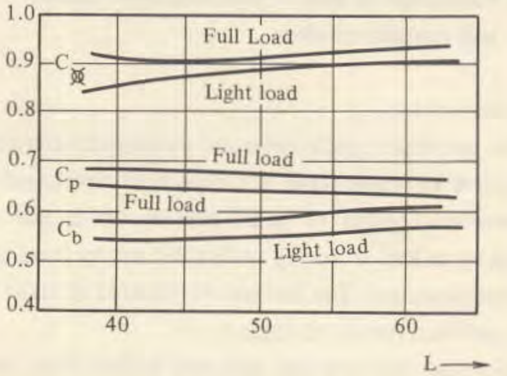
L	L/B	L/D	B/D
40 M	5.5 – 5.8	9.7 – 10.3	1.7 – 1.9
45	5.6 – 6.0	10.5 – 10.9	1.7 – 2.0
50	5.8 – 6.2	10.8 – 11.6	1.7 – 2.1
55	5.8 – 6.2	11.2 – 11.8	1.7 – 2.2
60	5.8 – 6.2	11.4 – 12.0	1.8 – 2.3

The value of Gross ton/$L \times B \times D$ is between 0.24 to 0.30.



Coef. of finess in trawler

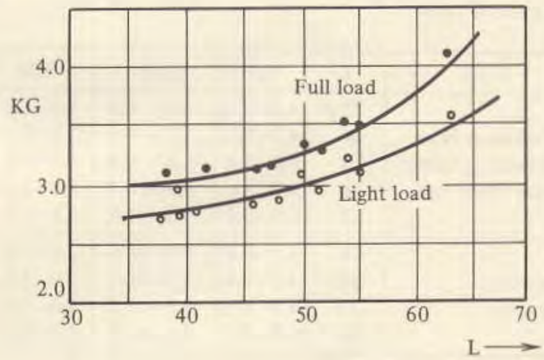
Coef.	Light load	Full load
C_b	0.52 – 0.62	0.58 – 0.67
C_p	0.61 – 0.68	0.66 – 0.72
$C_{⊠}$	0.85 – 0.92	0.88 – 0.93



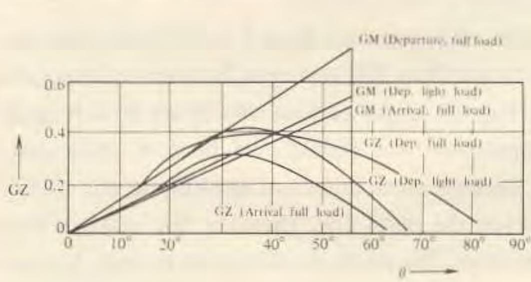
Stability: Generally the position of center of gravity should be lower as possible, draft should be deeper. Although the initial stability is not so big, dynamical stability should be taken big giving big draft.

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
40	0.72 – 0.80	0.64 – 0.73



Condition	▽	d	F_{bd}	KG	GM	θ (Range of stability)	GZ (Max)	θ×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°



5. Fishing machine

The machines and fishing apparatus are 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 × 14.5 ~ *40 m/min.	* 50 p.s
300 ~ 500	4.5 × 21 ~ 42	75
600 ~ 1,000	5.0 × 14 ~ 31	90
1500	5.0 × 14 ~ 48	120

$* \, ps = \frac{3000 \times 40/60}{75} = 26.6$ (Loss of work and sea margin should be taken into consideration)

4.2.1 Particulars of boat – Two-boat type trawler and medium trawler

1. Introduction

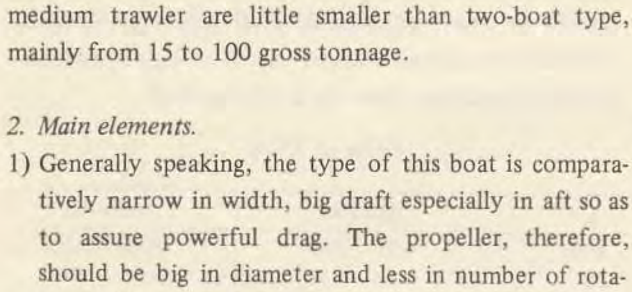
The two-boat type trawler and medium trawler are one of typical Japanese trawl net type boat developed from conventional design of small trawler which had made fishing by sailing or rowing and hauled net by hand since a hundred years ago. The number of this kind of trawl boats are more than twenty thousand.

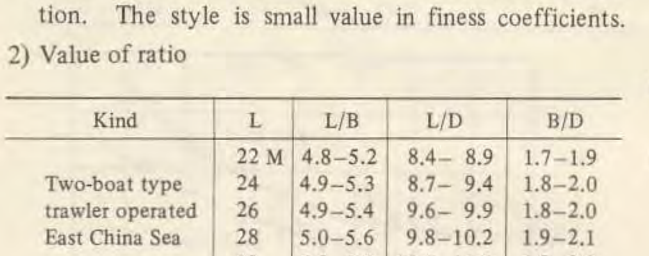
Two-boat type trawlers operated in East China Sea are mainly 75, 95 and 130 gross tonnage. On the other hand medium trawler are little smaller than two-boat type, mainly from 15 to 100 gross tonnage.

2. Main elements.

1) Generally speaking, the type of this boat is comparatively narrow in width, big draft especially in aft so as to assure powerful drag. The propeller, therefore, should be big in diameter and less in number of rotation. The style is small value in finess coefficients.
2) Value of ratio

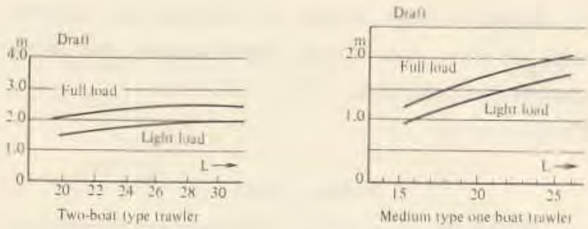
Kind	L	L/B	L/D	B/D
Two-boat type trawler operated East China Sea	22 M	4.8–5.2	8.4– 8.9	1.7–1.9
	24	4.9–5.3	8.7– 9.4	1.8–2.0
	26	4.9–5.4	9.6– 9.9	1.8–2.0
	28	5.0–5.6	9.8–10.2	1.9–2.1
	30	5.0–5.8	10.5–11.0	1.9–2.2
Medium trawler	18	4.1–4.6	9.5–10.0	2.0–2.6
	20	4.2–4.8	9.5–10.1	1.9–2.5
	22	4.4–5.0	9.6–10.2	1.8–2.3
	24	4.5–5.2	9.7–10.3	1.7–2.3





Coefficient of finess of trawler

Coef.	Two-boat type trawler		Medium trawler	
	Light load	Full load	Light load	Full load
C_b	0.50 – 0.58	0.58 – 0.67	0.52 – 0.60	0.58 – 0.64
C_p	0.58 – 0.65	0.66 – 0.71	0.58 – 0.67	0.63 – 0.71
$C_{\otimes}$	0.83 – 0.92	0.87 – 0.95	0.88 – 0.91	0.90 – 0.93



Two-boat type and medium trawler sometimes meet sea accident because of bad weather, lack of stability and over load (fish). Also they lay fishing gear and fish boxes on upper deck and this makes the position of G high. Recently navigational instruments such as direction finder, loran, rader, etc. are all put into more higher position than deck level. Some regulation (in case of Japanese trawl fishing boat) requires the metacentre height GM to be bigger than calculating values of following two formulas.

$$B \times \frac{1}{25} + 12 \qquad \text{(unit: cm)}$$

$$L \times \frac{1}{150} + 12 \qquad \text{(unit: cm)}$$

This formula is also applied to other fishing boats except purse seiner and bonito angling boat.

If the width of boat B is more than 7 meters, the formula will change as:

$$(B - 700) \times \frac{1}{12} + 40 \qquad \text{(unit: cm)}$$

$$(L - 4200) \times \frac{1}{72} + 40 \qquad \text{(unit: cm)}$$

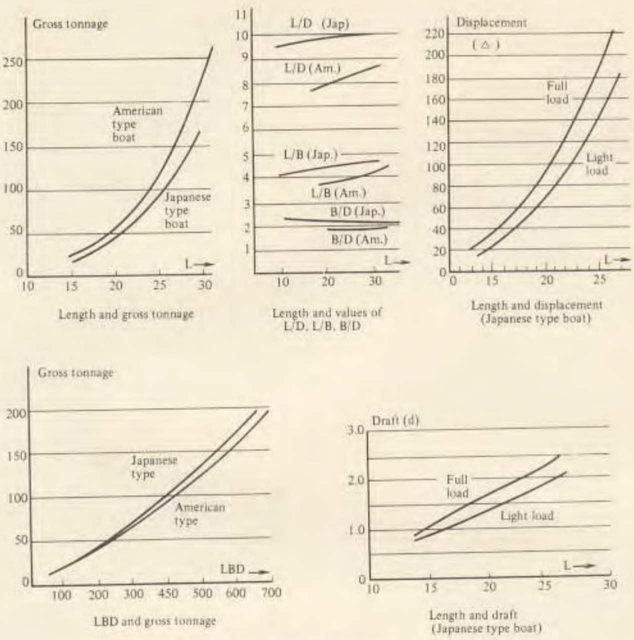
As for freeboard, F should be greater than $(D \times \frac{1}{25} + 15)$ centimeter in case of steel boat and $(D \times \frac{1}{15} + 20)$ centimeter in case of wooden boat.

4.2.2 Particulars of boat – Purse seiner

1. Purse seiner's main elements

The size of boat ranges from 5 to 250 tons. But normally, it is less than 100 tonnages. In order to keep good maneuvering, the length of boat should not be so long. In fishing operation, the stability of boat is particularly required because most fishermen assemble in one side of deck and reel the purse line. Therefore the width of boat should be large. The depth should not be so deep, because small freeboard is preferred by fishermen for the operation.

And small freeboard is also good for preventing the position of G (center of gravity) being raised.



Characteristics index of purse seiner
(Japanese type purse seine and American type)

Table 1. Value of C_b, KG/D, GM

Item	Type	Light load	Full load
C_b	Japanese American	0.50 – 0.63 0.46 – 0.60	0.57 – 0.68 0.54 – 0.64
KG/D	Japanese American	0.73 – 0.90 0.74 – 0.87	0.75 – 0.91 0.73 – 0.90
GM (cm)	Japanese American	40 – 100 61 – 110	30 – 85 38 – 88

The value of GM should be bigger than calculating values of the following two formulars.

$$\frac{B}{23} + 27 \qquad \text{(unit: cm)}$$

$$\frac{L}{120} + 27 \qquad \text{(unit: cm)}$$

Table 2. Turning circle capacity

Length of boat (meter)	Time required for turning circle		Diameter of a circle to a boat length
	Up to 15° from initial course	Up to 360° from initial course	
22 >	8 sec	80 sec	3.0
22 <	10 sec	90 sec	3.5

Fish Behaviour Against Gears

Fish Behaviour against Gears

5.1.2 Fish behaviour in relation to drift and bagnet

1. Introduction

Quite different fishing gear may be used to catch the same species of fish under different fishing conditions and even, sometimes, on 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 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. Light 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 6m. Judging from studies of the eye, 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 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

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.

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 noise levels and turbulence. While a drifting net will tend to make rather little noise, in a bottom gill net noise may be a serious factor; in a leader net vibration could be advantageous

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 accord with the behaviour described in relation to illumination, i.e. an ascent towards evening when the fishing is good at depths of about 50m. At night the fish disperse, but move up to the surface again at dawn.

4) Colour of drift nets

In a fishing test of drift net colour (Nomura, 1961) in the southern Sea of Japan a large net 75m x 20m was divided into 60 differently coloured panels each measuring 7.5 x 2m. The colours used were (in order of brightness measured at 50m) White (W), Yellow (Y), Green (G), Blue (B), Orange (O), Purple (P), Red (R), Gray (G_y), and Black (B_k). This shows the order of the panels and the catch of sardines in the panels on each of 11 days. 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 adjacecent panels. In this way each coloured panel could be allotted a score.

The cases of combination (+) (+) and (–) (–) are more higher scores than the cases of combination (+) (–) and (–) (+). As the 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 said result indicates that the darker the colour of netting the better the catch in 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 catch-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.

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 was 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 in and around trap nets

Leader nets are set to lead fish into the trap net of which about 15,000 are to be found in the 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.

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 10m when they encounter the leader net.

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 15m 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.

3) Other behaviour

Schools of fish when frightened by other fish may swim through the meshes of the leader net while small schools 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 manilla 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 8mm diameter twine and 30cm mesh the schools move along it at a distance of 1 to 1.5m and rarely pass through the meshes.

Table 1.

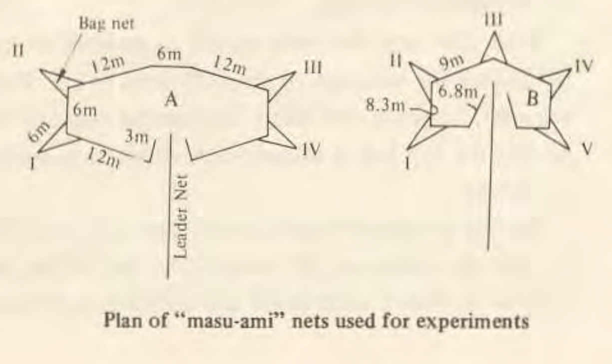
Relative value of catch in different positions of bag nets

Kinds of fish		Net A				Net B			
	Position of bag	I	II	III	IV	I	II	IV	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

Table 2.

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

Horse mackerel generally move at 5 to 20m from the net at a depth of about 10m; of about half the fish observed, 30 percent passed into the mouth of the trap net and 20 percent 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.

4) Catching positions in bag nets

About 4,000 small bag nets or "Masu-ami" now operate along the coast of Japan. A plan of them is shown in the figure. Miyamoto (1954) plotted the position of capture of fish within these nets. These are shown in Table 1, the results indicating that more fish were caught on the seaward side.

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 2. The coastal fish such as bream, perch, shad, yellow tail and flatfish were taken better by the light nets and nocturnal species such as the eel and sharp-toothed eel by darker nets. Crab and shrimp were not affected.

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5.1.2 Movement of fish in water, hydraulic resistance and propulsion

Propulsion

Fish produce the driving force which should overcome the hydraulic resistance of fish when swimming in water. The wave movement of fish body from right to left produce the swimming action. The back bone of fish which has joints is bent by extension and contraction of muscles located in both sides of fish body. The most violent movement is seen in the part of caudal or tail fin.

Primitive analyzation of propulsion of fish

From Figure 1 it is understood that the fish proceed straight foreward.

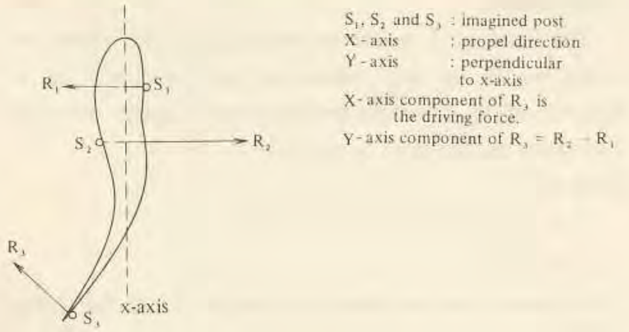

Fig. 1

Hydraulic resistance of fish and speed of fish

The propulsion of fish T produced when fish makes foreward movement under the constant speed U is equivalent to the water resistance of a fish D.

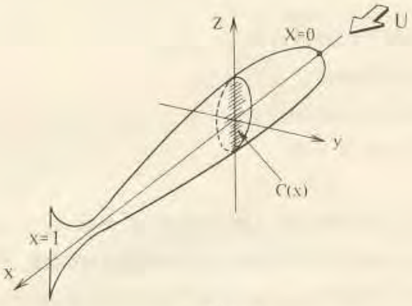

Fig. 2

There is the following relation between propulsion T and power of work P as $TU=\eta P$, where η is the propulsion efficiency. If T equals D as mentioned above, then the relation $DU=\eta P$ is satisfied. Therefore, approximate resistance of fish will be estimated if we know the speed of fish, power of work and propulsion efficiency. In aquariums there are some experiments on the measurement of speed of comparatively small size fish. According to the experiment, common freshwater small fish show that maximum speed is nearly proportion to the length of fish.

1. The running distance per second will be nearly 10 times the fish body length l. This speed is a special speed when the fish is frightened by outside stimulas; and may show maximum speed. Therefore, this speed does not last long; it could be called temporary speed.
2. The constant speed or normal speed U of fish which it can comparatively long time, is far smaller than the temporary speed. A special speed that will last as long as 20 seconds is called 20S' speed, is shown in Fig. 3. The 20S' speed will be proportional to $l^{2/5}$. This means that power of work is proportional to l^3 and

resistance D is proportional to $l^2 \times U^{3/2}$.

The speed of big fish is very difficult to measure, we scarcely know except rough estimation from fragmentary observations.

The salmon, 1 meter in length, jump out above the water by about two meters, so its speed will be as follows, when the angle between fish jumping direction and water surface is 45 degrees..

That is:

$$U = \operatorname{cosec} 45^\circ \times \sqrt{(2 \times 9.8 \times 2)}$$
$$= 9 \text{ m/s}$$

This is also nearly ten times the body length of fish l. The 20S' speed, according to up stream swimming in swift running rivers for spawning, will be estimated as 3 to 4 m/s.

The resistance of fish D is :

$$D = \tfrac{1}{2} \rho\, U^2 S C_f$$

where, the frictional coefficient $C_f = 0.455\,(\log_{10} R)^{-2.55}$ and,

R (= Reynold's number) = $U \cdot l/\nu g$,

ρ = density of water

ν = water kenetic viscosity

S = surface area of fish

Some data concerning the speed of fish is shown in Table 1. Here l is body length, W is weight of fish, P is the power of work which is calculated from DU/η and η is, in this case, taken as 0.75.

Table 1

	l (m)	W (kg)	U (m/s)	P (kg.m/s)	P/ (m/s)	Remark
1). *Salvelinus fontinalis*	0.6	4	4.5	10	2.5	Salmonidae
2). *Phocaena communis*	1.2	24	7.5	56	2.3	Dolphin
3). *Delphinus delphus*	1.8	90	19	250	2.8	"
4). Blue whale	27	120,000	10	40,000	0.33	Whale

The amount of muscle in whole meat of fish body is 40 percent. So, actual value of P/W should be multiplied 2.5 times that is 1): 6, 2 & 3): 6~7, 4): 0.8 m/s. The human being is said to be 1.5 m/s, so muscle of the fish is more powerful than human being.

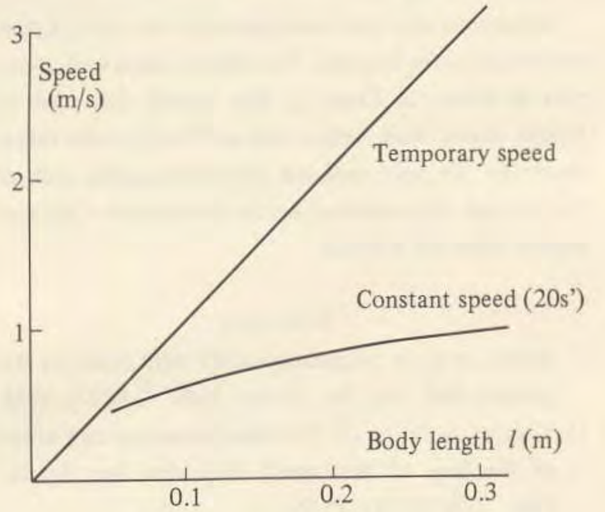

Fig. 3