BULLETIN No. 123

Further Midwater Trawl Developments in British Columbia

By **W. E. Barraclough** *and* **W. W. Johnson**
Fisheries Research Board of Canada
Biological Station, Nanaimo, B.C.

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INTRODUCTION

The success of the two-boat midwater trawl developed by Robert Larsen in Denmark in 1948 aroused the interest of British Columbia trawl fishermen in the possibility of trawling for herring for reduction purposes. These fishermen requested the Government of Canada to provide assistance in developing a herring trawl which would suit fishing conditions in the British Columbia waters. Accordingly, a program for the development of a midwater trawl was initiated in 1954 by the Fisheries Research Board of Canada Biological Station, Nanaimo, B.C., under auspices of the Industrial Development Service of the Canada Department of Fisheries.

Some British Columbia trawl fishermen had experimented independently with the two-boat midwater trawl as early as 1950 but had met with only moderate success. This type of gear proved very difficult to operate in strong tidal currents, which are common in the British Columbia fishing areas. Vessels engaged in these early trials were typical Canadian west coast otter trawlers (Fig. 1). Other experiments were made with single-boat midwater trawls, either of original design or similar to the Swedish Karl-Hugo Larsson *Phantom* trawl. Neither the two-boat trawls nor the single-boat trawls caught quantities of herring consistently enough to compete successfully with the purse seines in the fishery for reduction purposes.

With assistance from experienced fishermen, a trawl was designed at the Nanaimo Station and its success was demonstrated in 1955. The complete description of the design and construction of the net and gear, its method of operation and the results of the experimental fishing tests have been published as Bulletin No. 104 of the Fisheries Research Board of Canada. The main features of this midwater trawl were: (1) light nylon construction, (2) the attachment of specially designed otterboards by "pennants" to the towing warps in such a manner as to keep both otterboards and towing warps away from the mouth of the net, and (3) a provision for the removal of the herring with the codend still in the water.

Although herring were caught in commercial quantities during the fishing tests, two difficulties were apparent in operating the midwater otterboards on "pennants". The plywood otterboards were designed for use strictly in midwater and the lower vertical fin on each otterboard became bent or damaged if it struck firm bottom. Difficulty was also experienced in controlling the depth of the net or even in determining it accurately, particularly in fishing herring schools close to the bottom. It was desirable to operate the midwater trawl close to the bottom because in daytime, during the winter, herring school in dense concentrations on or near the bottom. These schools are the ones most suitable for midwater trawling. Continual changes in tidal currents altered the distance of

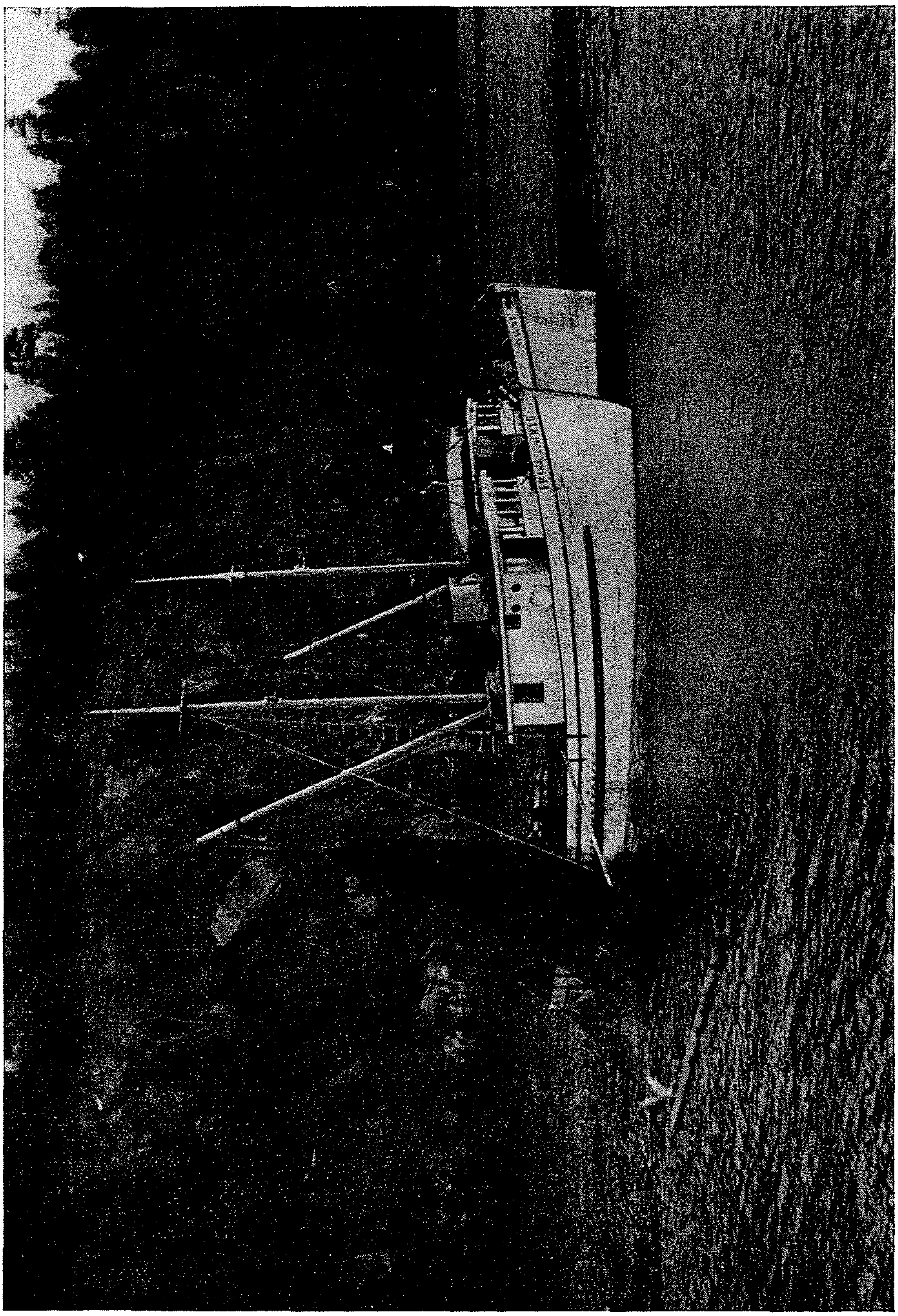


FIGURE 1. Two-boat midwater herring trawlers, Northumberland Channel, 1951.

the net from the bottom and its horizontal position astern of the trawler. Variations in the contour of the bottom and the height of the herring schools off the bottom at times necessitated adjustments to the speed of the vessel and length of the warp to keep the net at the correct depth. It became evident that modification of the otterboards and of the "hook-up" of the otterboards to the net, for fishing near the bottom, would be necessary before the net would be readily adopted by commercial fishermen.

In England the application of the midwater trawl gear for pilchards off the Cornish coast has shown encouraging results. For this fishery, curved otterboards suspended on pennants were modified to operate from vessels with stanchions or gallows mounted on the side, and to meet other conditions encountered in that fishery. The catches of pilchards compared very favourably with those made by drift nets in the same area (May and Bridger, 1958).

The present Bulletin describes the different nets, hydroplane floats and otterboards which were constructed and tested after the development of the No. 1 midwater trawl described in Fisheries Research Board of Canada Bulletin No. 104. A new method is described of operating these nets and associated gear close to the bottom with conventional otterboards. Some of the models used were designed to suit trawlers of different types and sizes, while other nets were designed for experimental studies aimed at increasing the speed of towing.

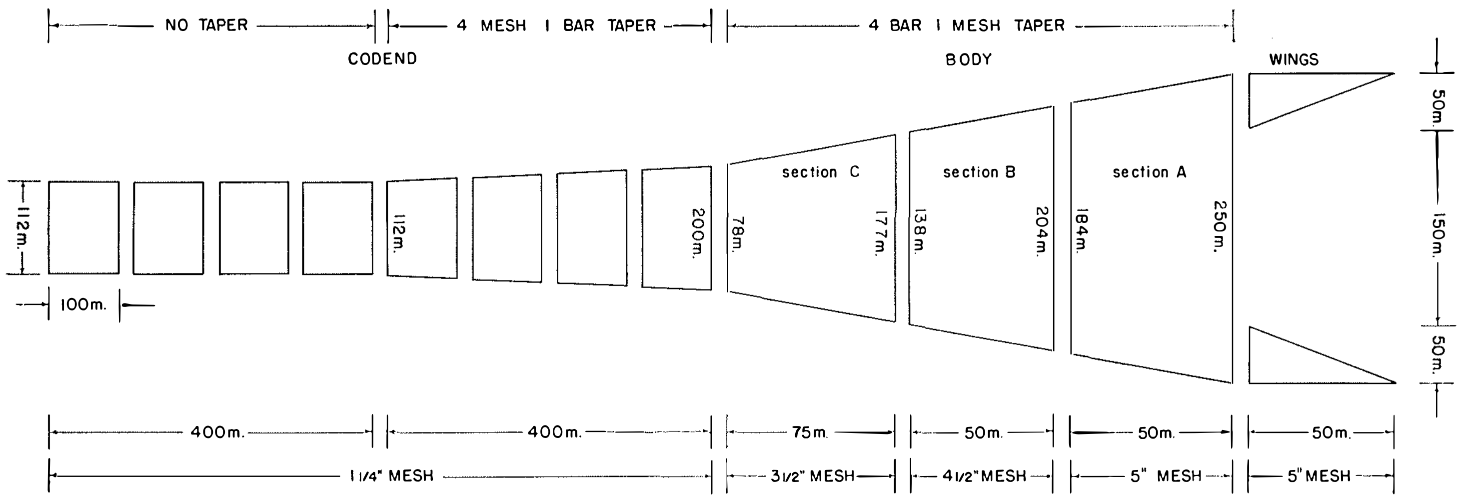
HERRING TRAWL NO. 3

In constructing a net for use close to the bottom with conventional bottom otterboards, a lighter yet stronger net was required than the strictly midwater net No. 1, described in Bulletin No. 104. A reduction was made in the number of meshes in the wings and body sections; the ribline and headline construction were changed; and an improved method for closing the zipper was developed. The dimensions of this net and the number of meshes used are shown in Fig. 2.

Net Modifications

The meshes on the front edge of the body section at the square[1] were hung farther apart than in Net No. 1, but the size of the mouth opening was kept about the same. This was accomplished by shortening the wings from 75 to 50 meshes, forming a base of 100 meshes for each of the 4 triangular wings instead of 150 meshes. In one experimental net the inside edge of each wing was cut with a 6-bar 1-mesh reverse taper from the base to the tip. This formed a base of 80 meshes for each of the 4 triangular wings and shortened the wings still further to 40 meshes. It is optional whether or not a reverse taper is used on the inside edge of the wing, but this type of taper does form a continuous seam projected in a straight line from the outside edge or seam of the body to the wing tip. Thus, with less netting in the wings and body and with the meshes hung farther apart on the square of the body, there was less resistance to the flow of water. The net could therefore be towed faster and lifted off the bottom.

[1]The square is that section of the net between two wings.



MATERIAL REQUIRED

NYLON SEINE NETTING

	THREAD SIZE	MESH SIZE	DEPTH	LENGTH
WINGS	9	5"	50m.	200m.
BODY section A	9	5"	50m.	868 m.
section B	9	4 1/2"	50m.	684m.
section C	9	3 1/2"	75m.	510m.
CODEND	6	1 1/4"	100m.	4,440m.

FIGURE 2. Plan of No. 3 midwater herring trawl, dimensions are shown in meshes.

The codend was lengthened from 6 to 8 strips of $1\frac{1}{4}$-inch mesh, each 100 meshes long. This additional length provided the space to retain the herring found necessary in previous experiments. Otherwise they tend to escape through the large meshes in the body.

Ribline Modifications

Two different types of ribline construction were tried to strengthen this net. One type was used in Net No. 3A (Fig. 3) and the other in Net No. 3B (Fig. 4). In Net No. 3A the riblines commenced at the corners between the wing and the square of the body, then extended outward down the meshes of the first two sections of the body to meet at the seams.

In Net No. 3B the riblines ran diagonally across the body along the bars of the meshes (Fig. 4), crossed each other, and joined the seams of the third section of the body (Section C). This latter type of ribline construction proved to be very satisfactory and enabled the nets to withstand the more rugged conditions found in midwater trawling in offshore waters. This type of ribline construction was used in all other midwater nets constructed.

Headline Modifications

The headline on each of four sides of the mouth opening of nets 3A and 3B was made in three separate lengths instead of one continuous length. Each length was joined by a metal thimble to a 3-inch galvanized ring at the corners of the square. The riblines which started at the corners of the square were also attached by a thimble to this ring. This method of headline construction was found to reduce considerably the twisting that occurred with a single 75-foot headline.

Originally the headlines were made of "belflex cable", a manila clad wire rope. However, this did not prove entirely satisfactory because of the alternate stretching and shrinking of the manila rope and the gradual weakening of the wire cores by corrosion.

A new type of nylon sheathed headline was constructed of $\frac{3}{8}$-inch diameter 6×19 (12-6-1) galvanized preformed alternate right and left lay wire rope, clad with a braided spun-nylon sheath (Barraclough and Johnson, 1957). This headline proved to be very satisfactory in the midwater trawl and ocean perch nets tested during the summer of 1957. Headlines of this rope were as easy to handle as other headlines and remained flexible. No twists, kinks, or signs of shrinkage were observed during three months of experimental fishing.

Zipper Modifications

In net No. 3B, the galvanized metal jib rings on the zipper opening were replaced by 8-inch lengths of $\frac{1}{2}$-inch diameter plastic pipe (Fig. 4). This zipper was closed by threading a $\frac{3}{8}$-inch braided nylon rope through the pipe sections, forming a continuous tube, and preventing gaps in the zipper when the net was being fleeted aboard.

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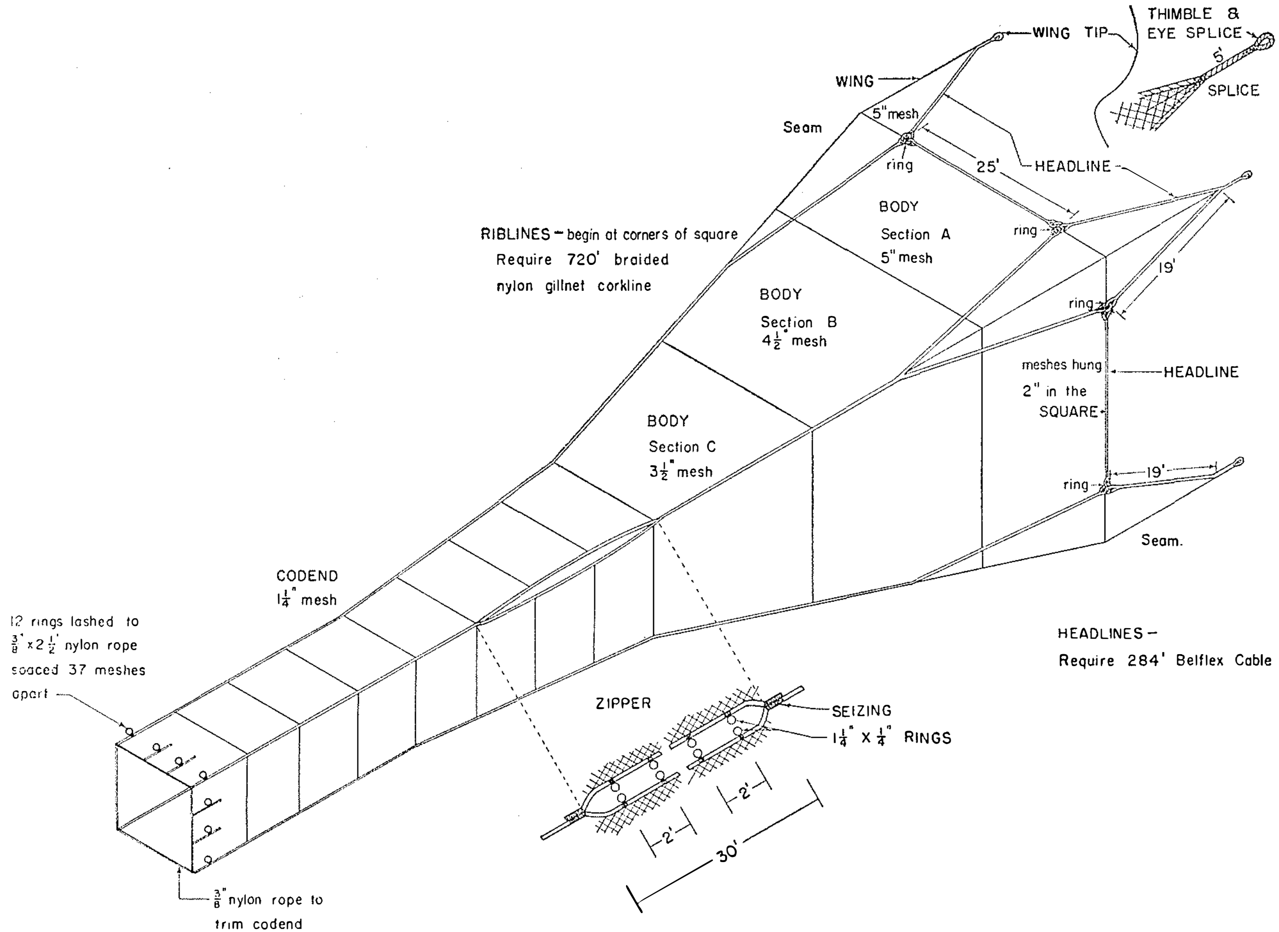

FIGURE 3. Ribline and zipper construction, No. 3A midwater herring trawl.

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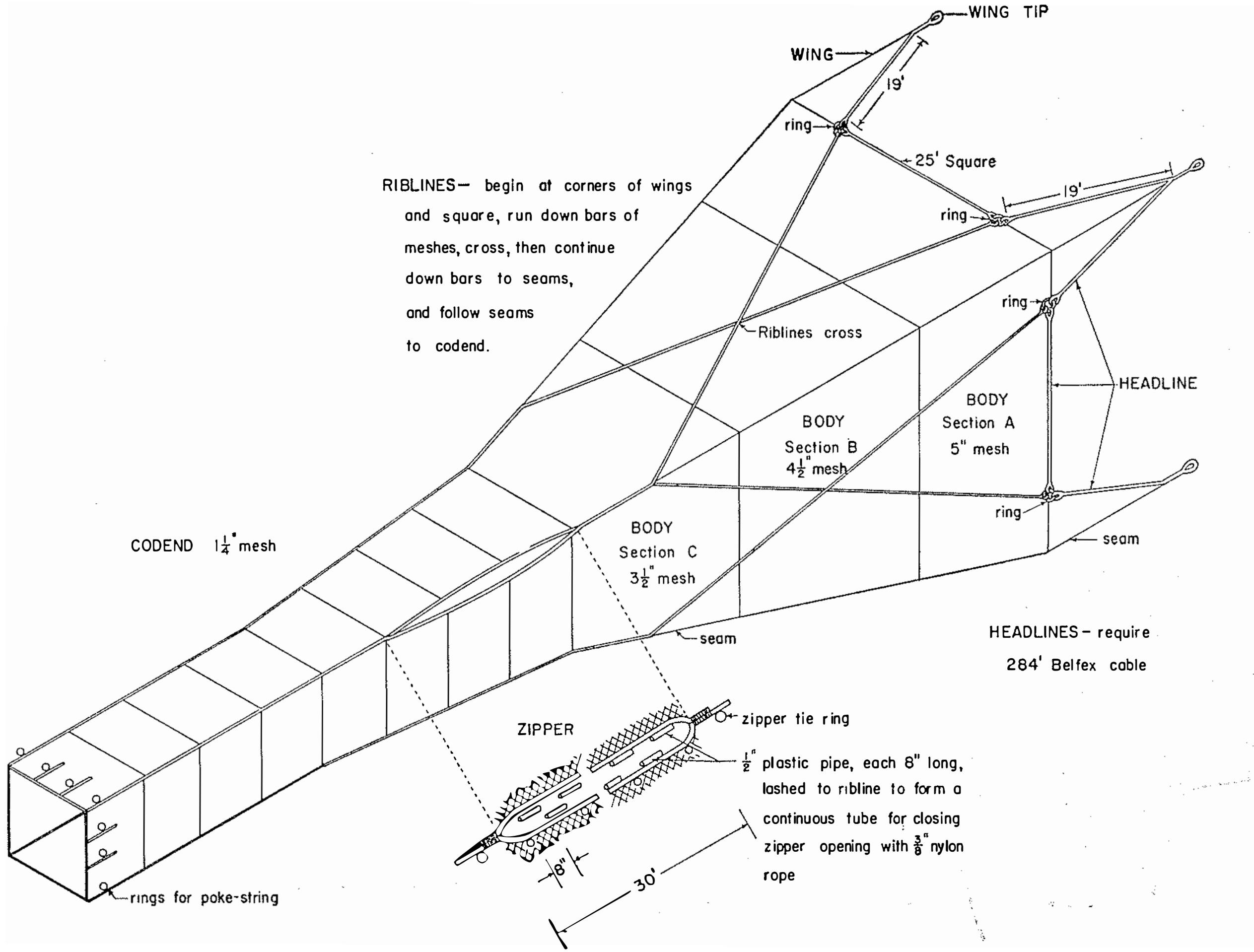


FIGURE 4. Ribline and zipper construction, No. 3B midwater herring trawl.

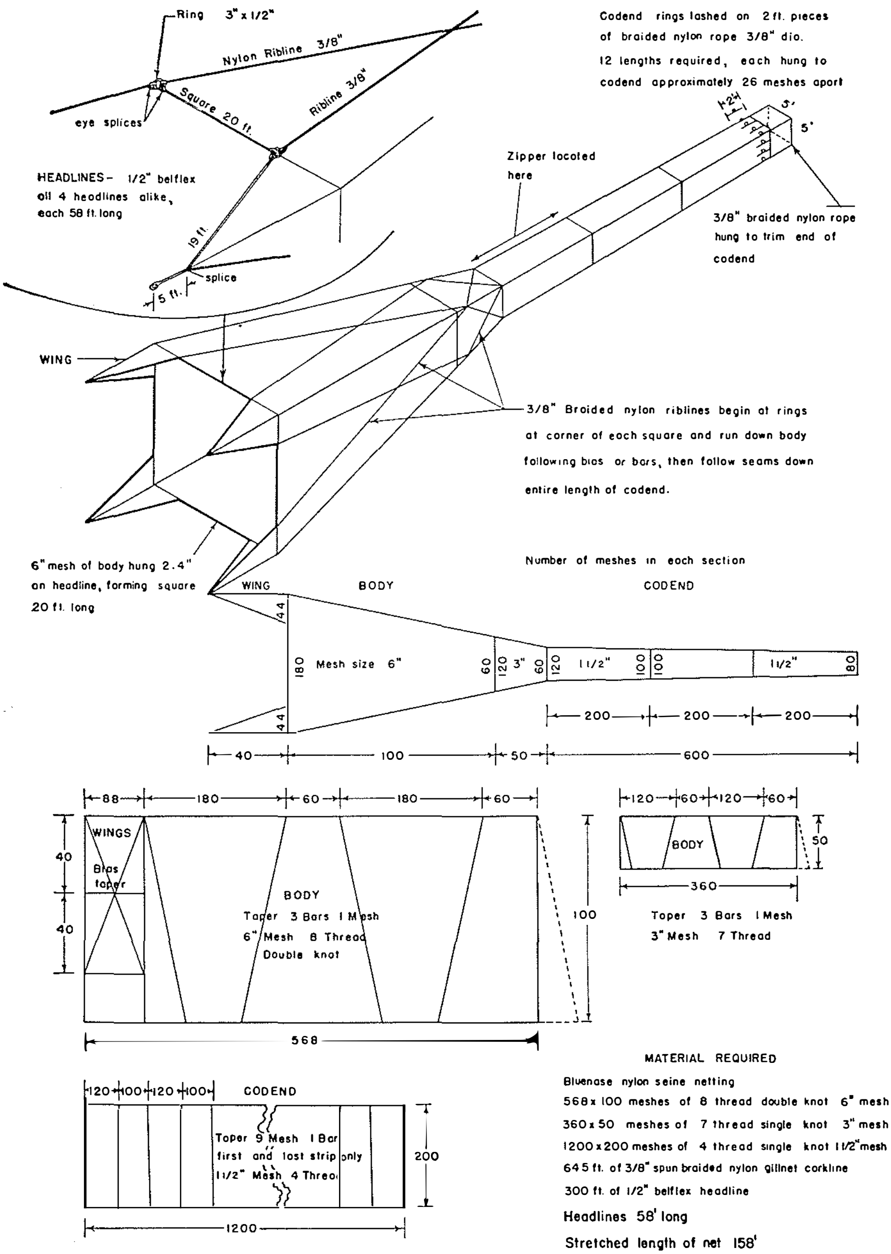


FIGURE 5. The details of construction of No. 4 midwater herring trawl.

Herring Trawl No. 4

This smaller net was developed for use on small trawlers (45 to 50 feet long), particularly those equipped with the "single-gear" rig (illustration in *Pacific Fisherman*, *42*(10), August, 1944). Details of construction are given in Fig. 5. This net was first tested successfully in offshore waters in the summer of 1956. Used with aluminum dual purpose otterboards (Fig. 24), its effectiveness in catching herring in commercial quantities, both in midwater and at the bottom, was demonstrated in the autumn of 1956 aboard the chartered "single-gear" trawler *Phyllis Carlyle.*

Herring Trawl No. 5

With the growing demand for nylon netting for herring trawls, a standardization of mesh and twine sizes was suggested by net manufacturers and their agents to enable them to stock sufficient quantities of nylon netting for the

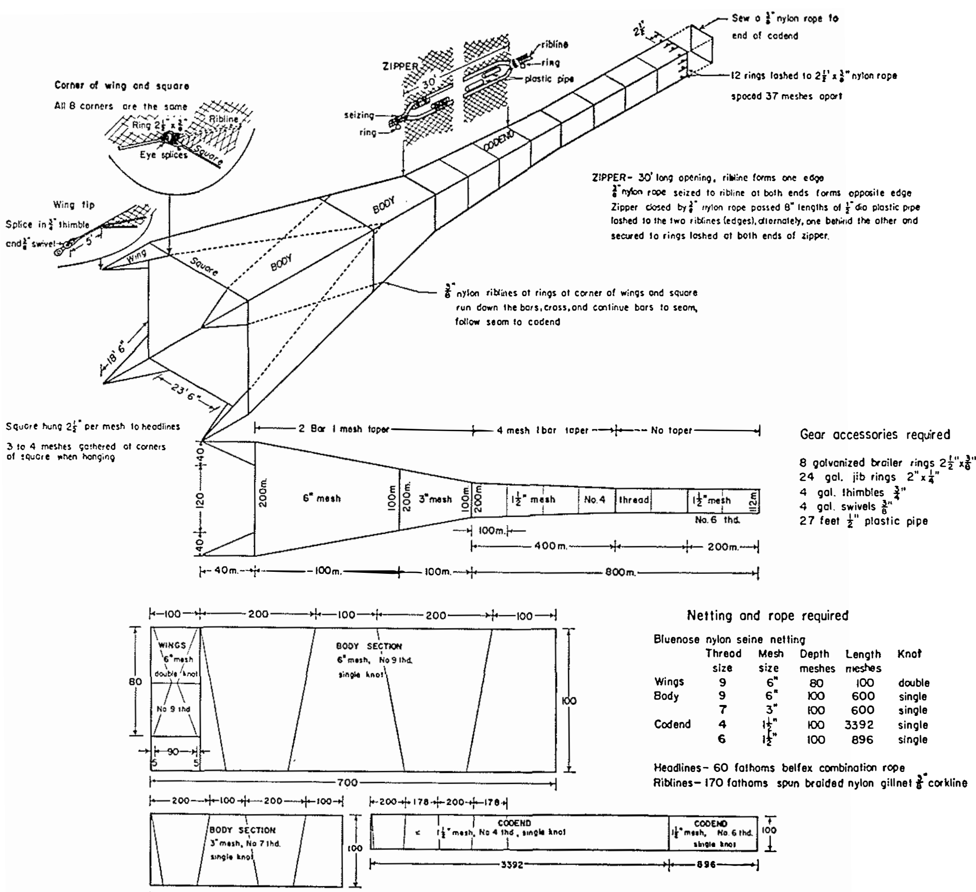


FIGURE 6. The details of construction of No. 5 midwater herring trawl.

fishermen's use. Net No. 5 (Fig. 6) was designed to meet these requests and its specifications were based upon the results of experimental fishing tests with nets of different design and size. These experimental nets were constructed of different twine and mesh sizes formed with single and double knots. Net No. 5 is essentially the same size as Net No. 3B (Fig. 4), but is more easily constructed because the 6-inch mesh in the wings and body, 3-inch mesh in the aft section of the body, and the 1½-inch mesh in the codend, being multiples of each other, are easily laced together. Net No. 5 proved to be efficient when used commercially.

Herring Trawl No. 6

This trawl was developed to test the idea that a strong net of light construction with a very large mouth opening might be suitable for catching herring in offshore waters, where they tend to occur in small, fast-moving schools. After many experimental tows, it was found that this net was too large for the type of herring trawler used in British Columbia at present. A pair of otterboards, each with a surface area of 40 square feet, was necessary to spread the mouth of the net sufficiently. To assure adequate towing speed, a vessel of no less than 400 hp would be required.

Details of the construction and number of meshes of nylon netting required to build the net are given in Fig. 7. The meshes in the square of the net were hung close together (1½ inches apart) in an attempt to decrease the escapement of herring through the large meshes. This questionable benefit was probably offset by the added drag of the net in the water by the large number of meshes (1,360) on the circumference of the mouth opening. A more suitable net with less drag would be obtained with the same circumference (170 feet), but with the meshes on the square of the headline hung out to 2 inches instead of 1½ inches, giving 1,002 meshes around the circumference of the mouth opening.

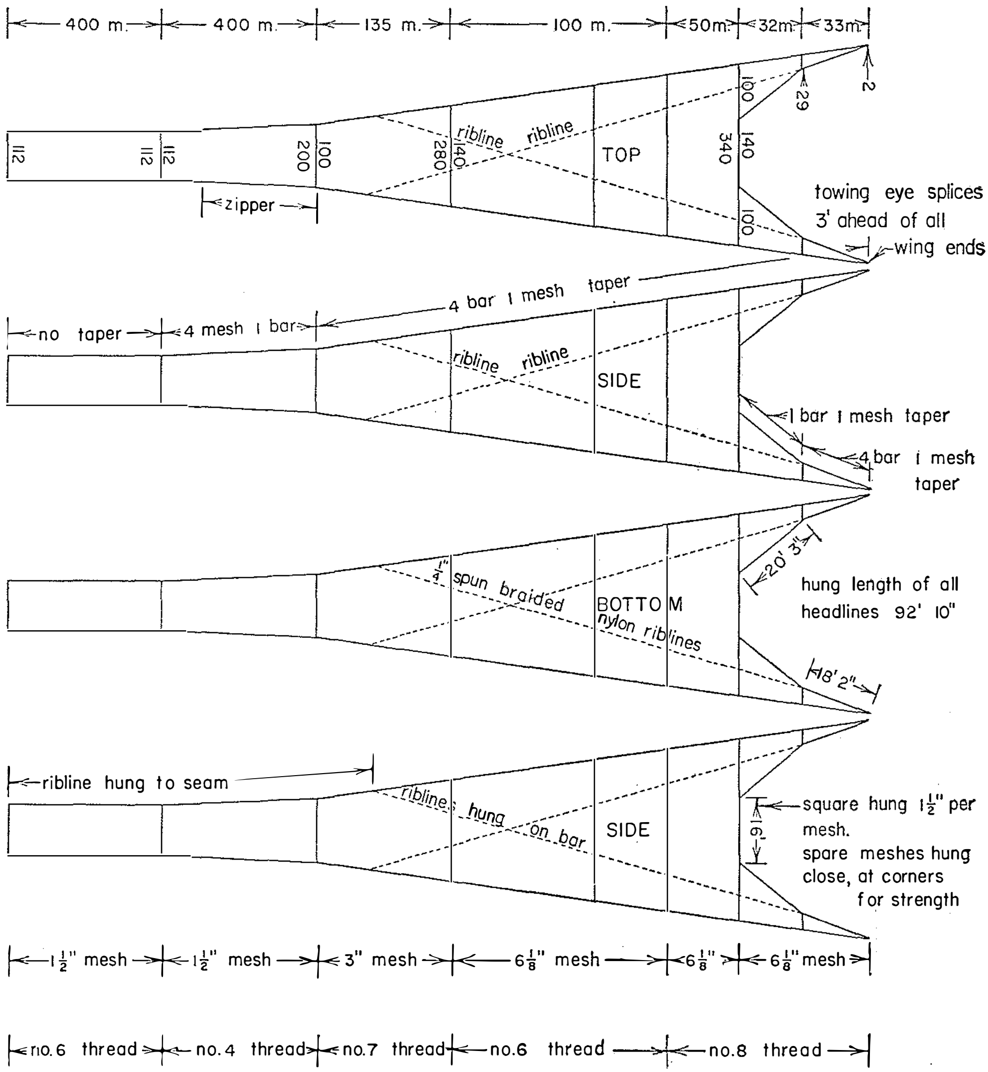
EXPERIMENTAL WATER BY-PASS TRAWLS

Many attempts were made in the design of the midwater trawl nets to solve the problem of the water resistance of the net, the greatest problem in midwater trawling. Two nets were constructed and tested which embodied the same principle as a high-speed plankton net (Gauld and Bagenal, 1951); that is, a passage for water was provided through the center of the net.

Funnel or Tunnel Net

The first of these nets (also referred to as Net No. 2) was designed to direct the herring through two tunnels to an attached codend, at the same time by-passing a portion of the water flow directly through the center of the net (Fig. 8).

Experimental water flow tests with model nets in the hydraulic laboratory at the University of British Columbia indicated that the water by-pass reduced the water resistance of the codend by 25% to 30%. Advantage was taken of



MATERIAL REQUIRED

Netting – filament nylon

1228m. x 50m. x $6\frac{1}{8}$" x No.8 thread, double knot
640m. x 33m. x $6\frac{1}{8}$" x " " , " "
828m. x 100m. x $6\frac{1}{8}$" x No.6 " , " "
700m. x 135m. x 3" x No.7 " , " "
2144m. x 200m. x $1\frac{1}{2}$" x No.4 " , single knot

Rope – 1040' x $\frac{1}{4}$" spun braided nylon

Headlines – 396' x $\frac{3}{8}$" x 6/19 alternate lay cable, sheathed with spun braided nylon rope

HOOK-UP REQUIRED

Sweepline lengths, upper – 40 fa. plus 1 fa extension
lower – 40 fa.

Floats – 20, standard 8" diameter

Leadline – 30 lbs approx.

Hydroplane floats – 2, aluminum

FIGURE 7. The details of construction of No. 6 midwater herring trawl, with 1,360 meshes around the mouth opening.

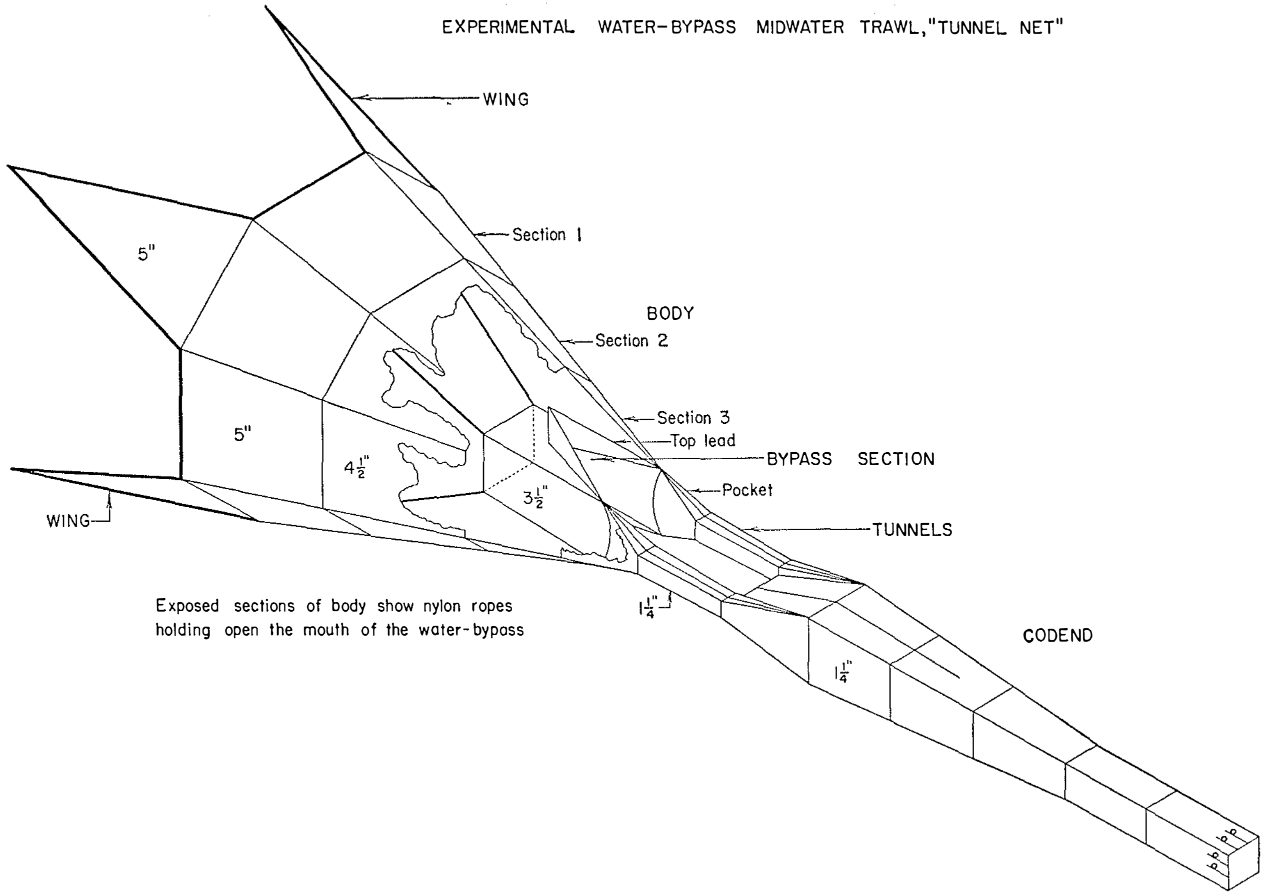


FIGURE 8. Plan of the water-bypass "tunnel" midwater trawl.

the decrease in water resistance in the codend to increase the size of the mouth opening proportionally. The mouth opening of the net was made about one-third larger in area than in Net No. 1 (Bulletin 104).

The body and mouth opening were constructed with 8 sides in an attempt to obtain as nearly a circular opening as possible when towing the net through the water. The 8-sided body section and headline helped to maintain the correct position for the attachment of the ropes which held the mouth of the water by-pass open. For this purpose, four braided $\frac{9}{16}$-inch diameter nylon ropes were attached to the upper and lower sections of the headline at the points where the corner of the square of the top and bottom sections of the body meet the lower corners of the wings. The complete details of the size and number of meshes and the construction of this net are shown in Figures 9 and 10.

Trouser Trawl

The second of the water by-pass nets was considerably smaller than the large tunnel net and of different design. In the trouser trawl the herring were funnelled directly into two separate codends instead of through two tunnels to a single codend. Because of its smaller size and its water by-pass this net could be towed at higher speeds than the other midwater trawls. Details of the amount of netting and of the construction are shown in Fig. 11. This net was used with 30-fathom sweeplines, with $3\frac{1}{2}$-foot extension pieces in the upper lines.

EXPERIMENTAL CONICAL "HIGH SPEED" TRAWL

This small version of Net No. 5 was built for comparative fishing tests with the small high speed trouser trawl. Details of the amount of netting and plan of the net are given in Fig. 13. The hook-up of this net to standard bottom otterboards for use either in midwater or near the bottom is shown in Fig. 12.

OCEAN PERCH TRAWL

At certain times of the day some species of fish, including herring and ocean perch (*Sebastodes alutus*), rise in schools off the bottom to a height at which they cannot be reached by the limited vertical opening of bottom trawls. The schools are too deep to be taken by conventional drift nets or purse seines and too close to the bottom to be taken by midwater trawls without damaging the net.

An experimental ocean perch net (Fig. 14, 15) was designed so that it could be towed at a regulated and constant height off the bottom when operated in conjunction with standard otterboards or with the dual purpose aluminum otterboards (Fig. 24) sliding or skimming along the bottom. The height at which the net fishes off the bottom is controlled partly by hydroplane floats on the sweeplines and partly by the length and adjustment of these lines. The increased vertical mouth opening of this net, as compared with standard bottom trawls, greatly assists in capturing fish that are off the bottom.

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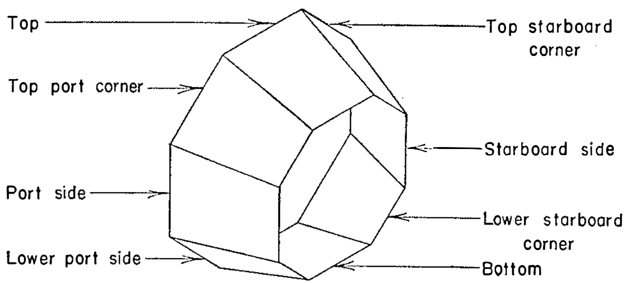
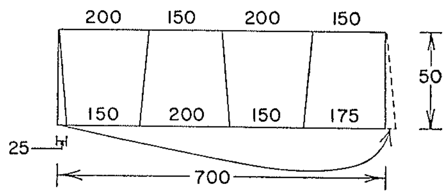
BODY SECTION NO. 1

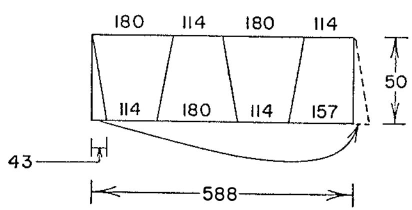


NETTING- mesh 5", 700 x 50 meshes, taper 2 bars 1 mesh.

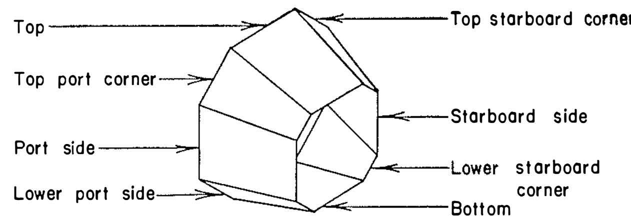
Top
Sides (2)
Bottom



Corners - mesh 5", 588 x 50 meshes, taper 4 bars 1 mesh.

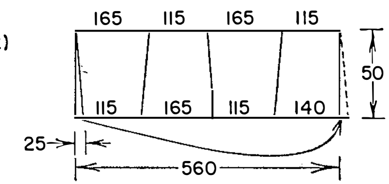


BODY SECTION NO. 2

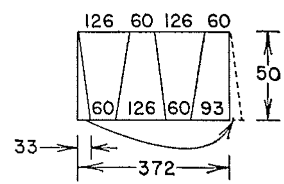


NETTING- mesh $4\frac{1}{2}$", 560 x 50 meshes, taper 2 bars 1 mesh.

Top
Sides (2)
Bottom



Corners - mesh $4\frac{1}{2}$", 372 x 50 meshes, taper 4 bars 1 mesh.



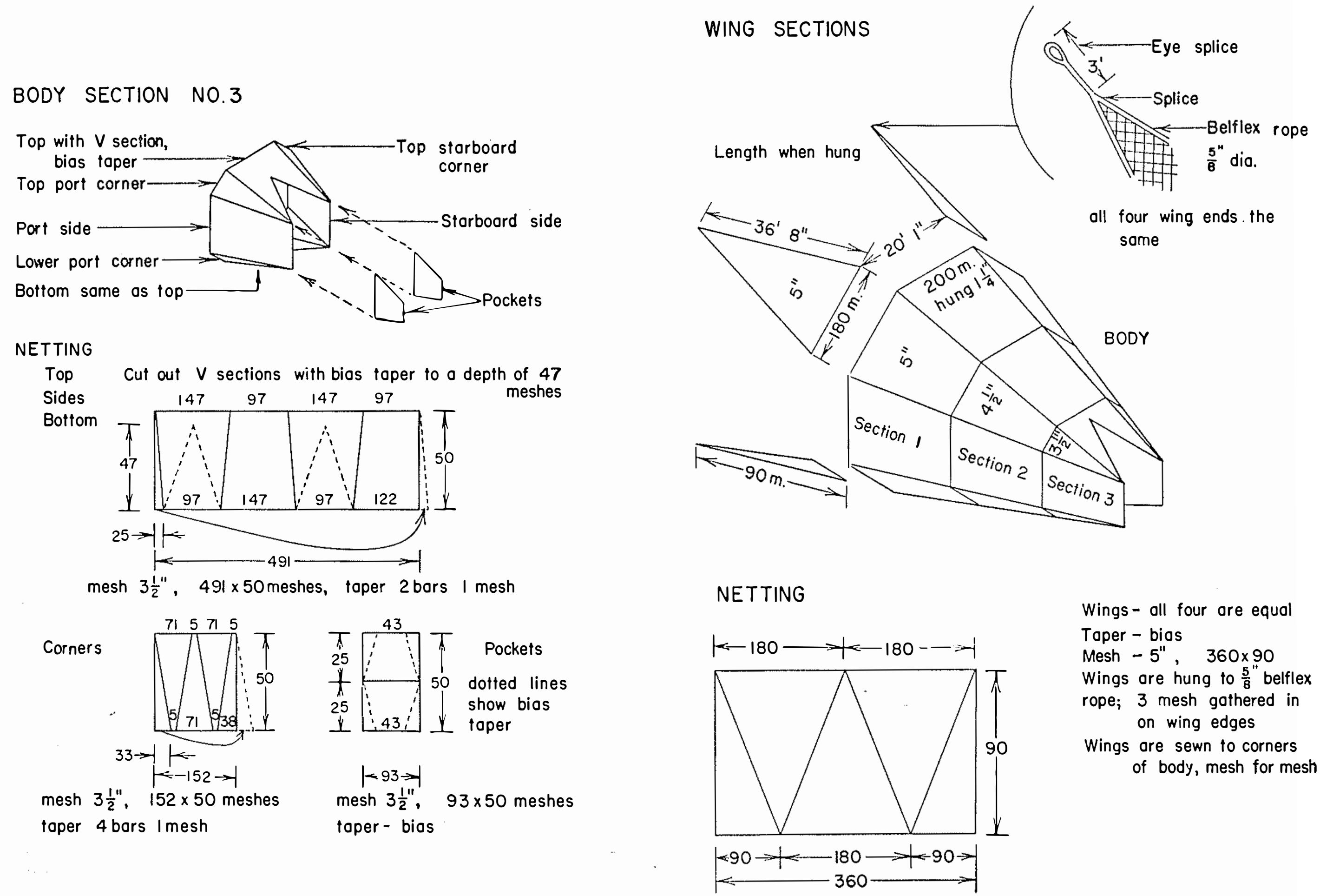


FIGURE 9. The details of construction of the wing sections and body sections No. 1, 2 and 3 of the water-bypass "tunnel" midwater trawl.

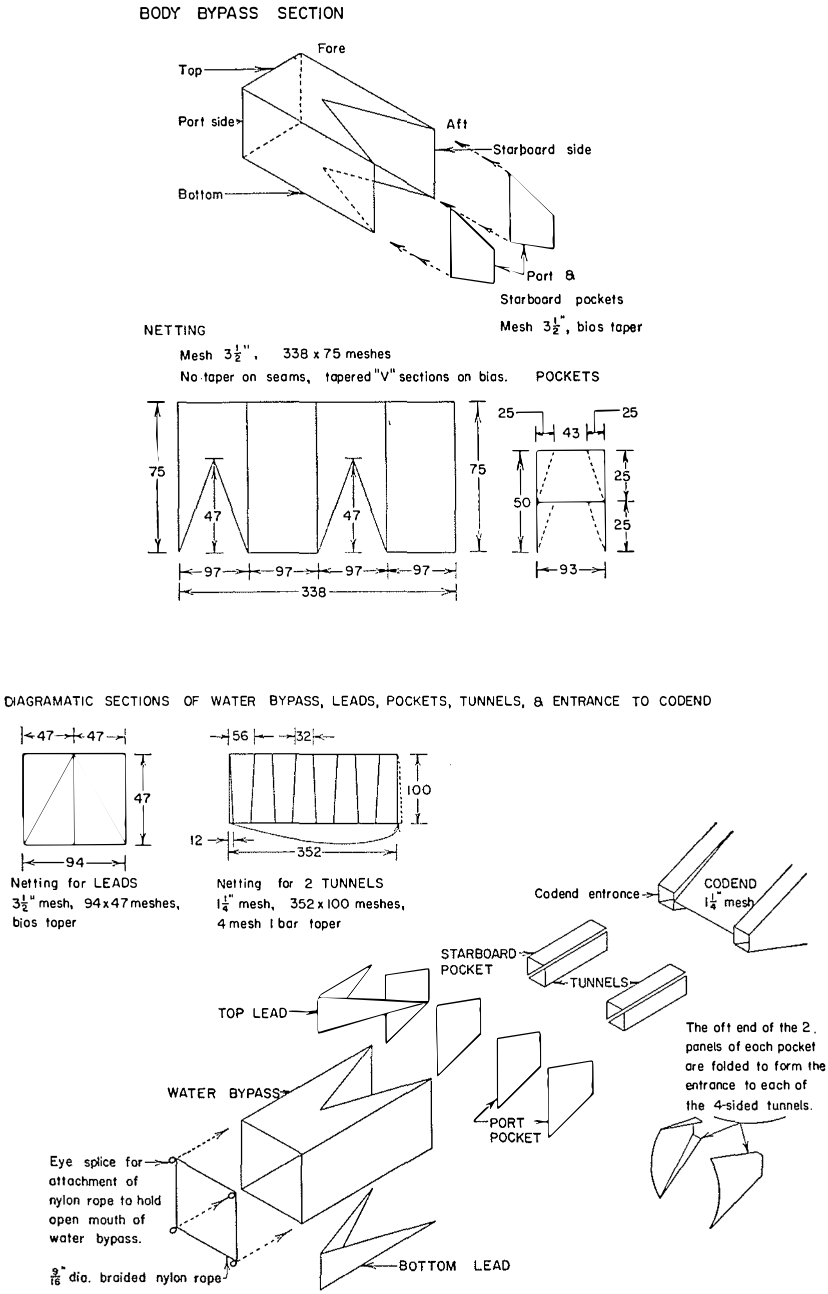


FIGURE 10. The details of construction of the body bypass section, and of the water-bypass, leads, pockets, tunnels and codend sntrance of the water-bypass "tunnel" midwater trawl.

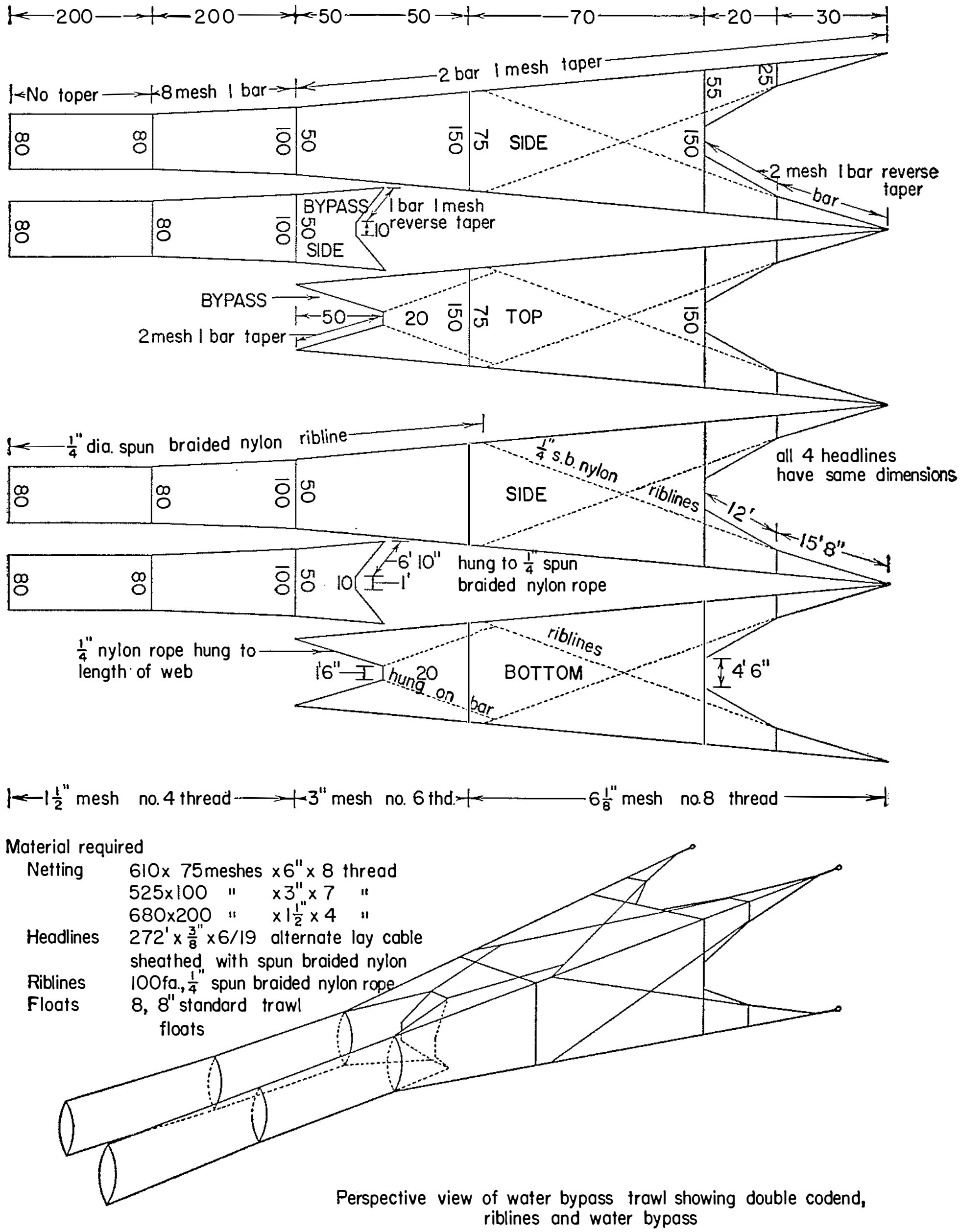


FIGURE 11. The plan and details of construction of the water-bypass "trouser" trawl.

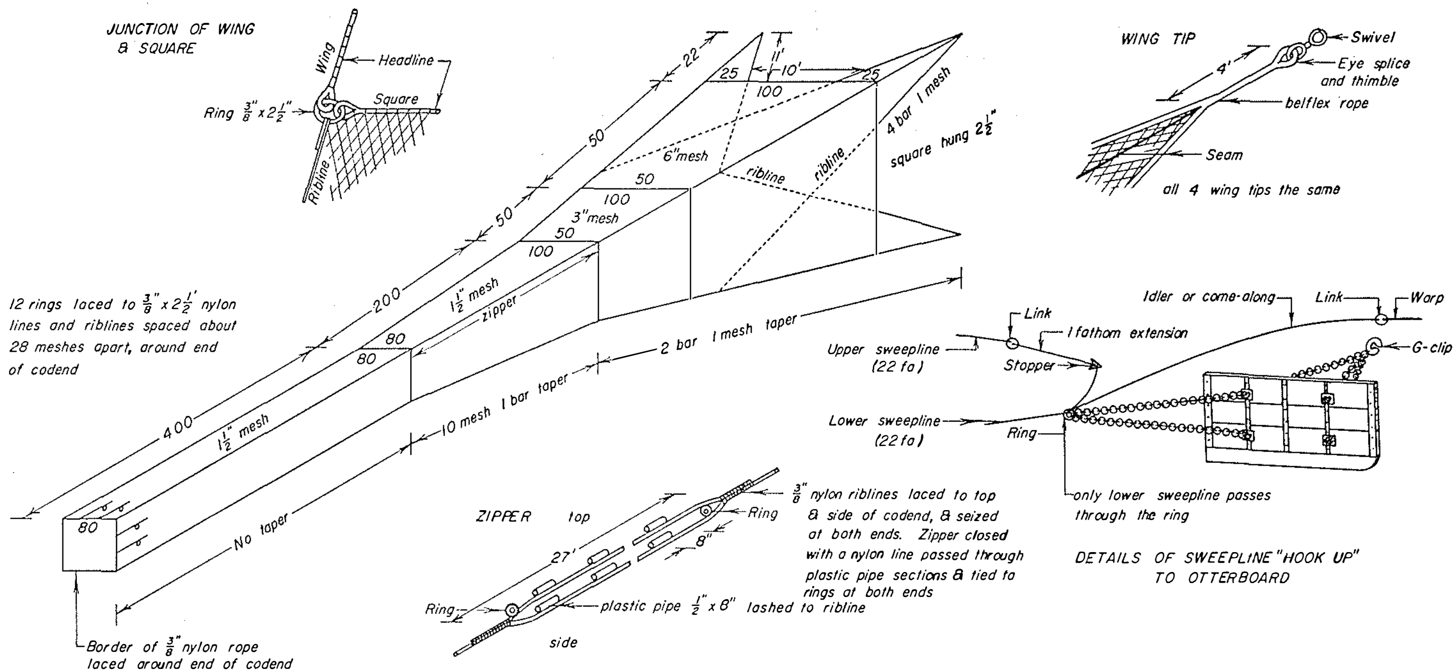


FIGURE 12. The plan and details of sweepline "hookup" of the experimental conical "high speed" midwater trawl.

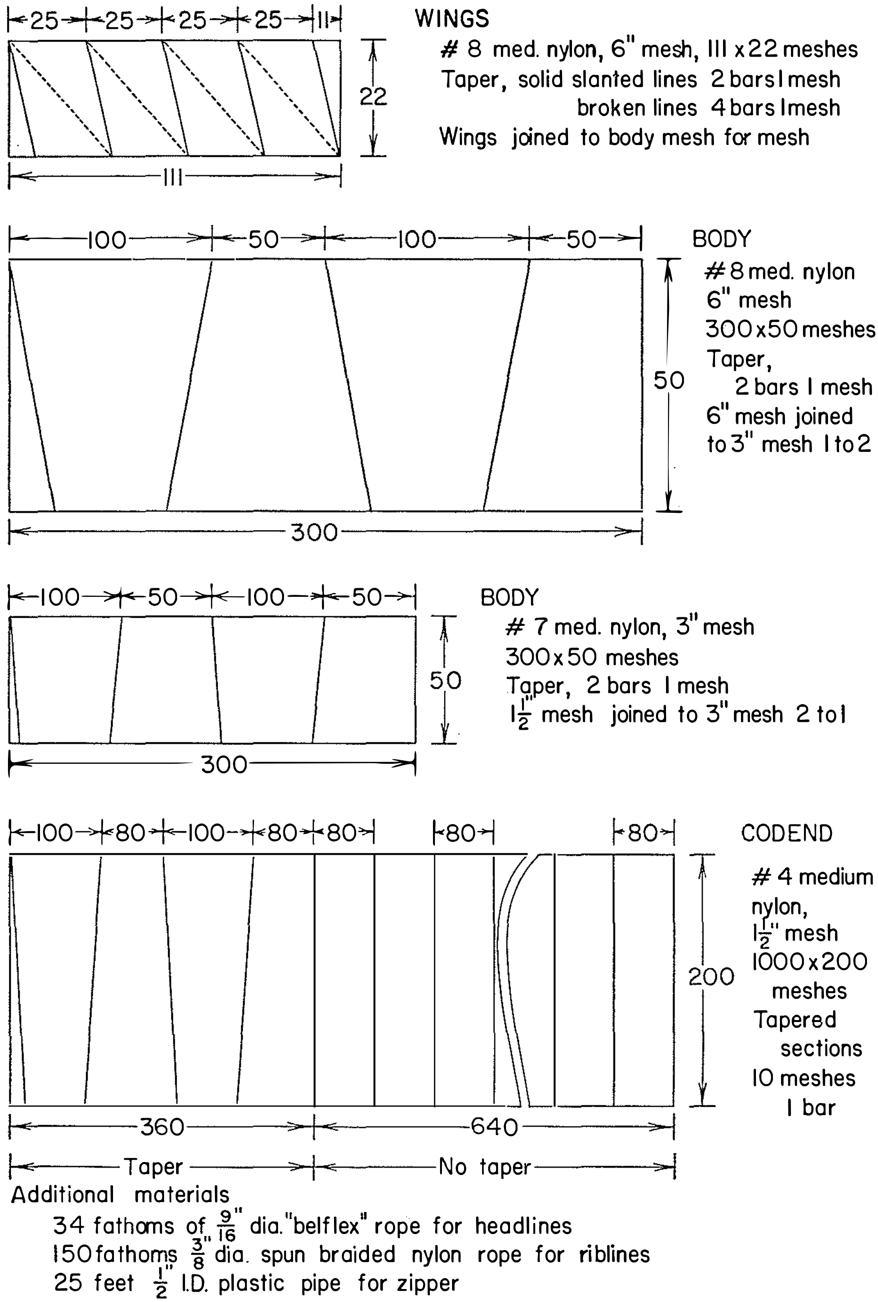


FIGURE 13. The details of construction of the experimental conical "high speed" midwater trawl.

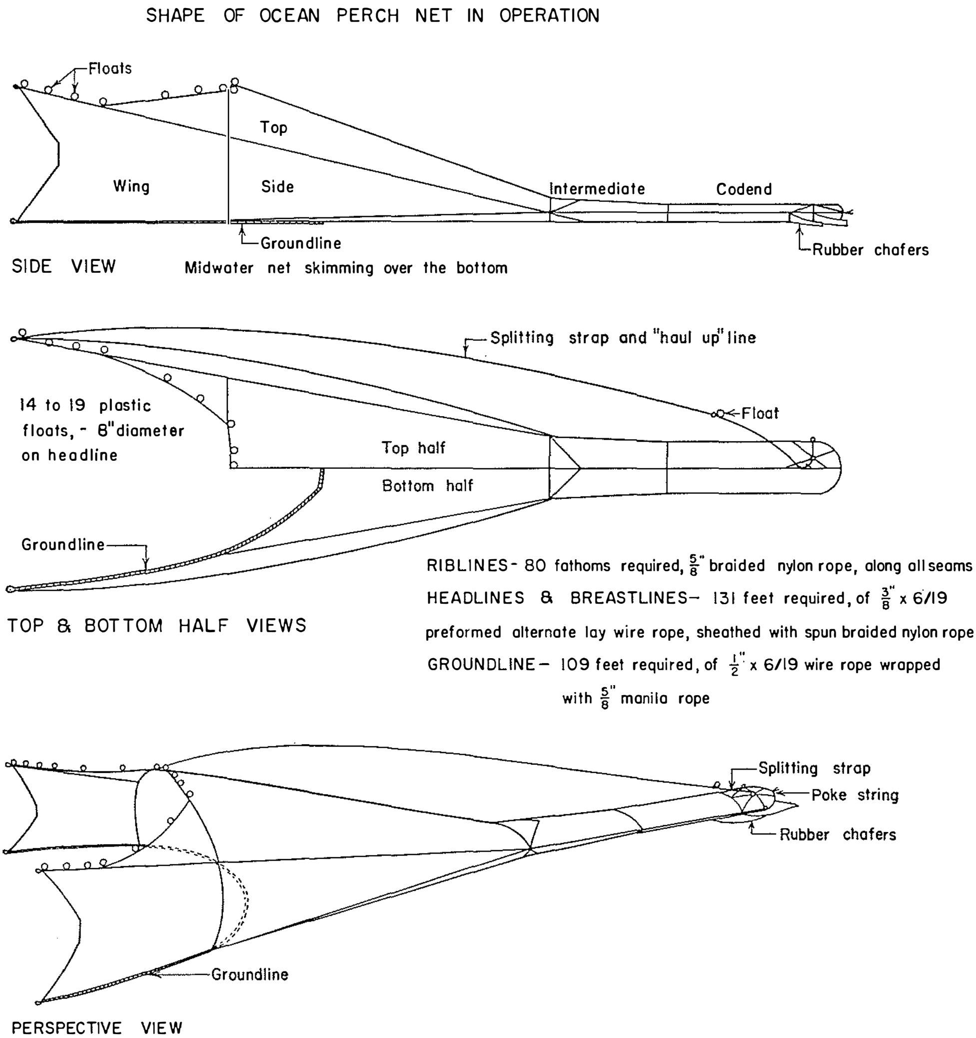


FIGURE 14. Perspective view and plan of the ocean perch trawl.

The component sections of this net are the same as those found in a standard bottom trawl; i.e., the wings, body, intermediate and codend (Fig. 15). However, it is distinguished by a greater frontal area and a higher vertical mouth opening. For this purpose a box-shaped or rectangular construction was used in the body rather than the conventional two-piece (top and bottom) construction.

Even more important was the introduction of wings which followed the same increasing taper as the sides completely through to the wing tips (Fig. 15). This taper provides a greater frontal area of the mouth of the net (Fig. 16).

By tapering the top edge of the wings and sides of the body section only, the short lower edge of the wings and sides becomes tighter when the net is under tow. The riblines lashed to the lower edge of the net thus carry the load of the codend. The longer tapering upper edge of the wings permits enough slack in the rest of the net to ensure an increased vertical opening. The wing ends were cut back in a shallow taper to prevent any sag in the breastline.

The gap between the top of the wings and top section of the body was closed by the insertion of wedges of netting, tapered on both edges toward the wing. The edge of the wedge that was hung to the headline was cut with a reverse taper. The usual type of wedge distorts and pulls in or "hogs" the front end of

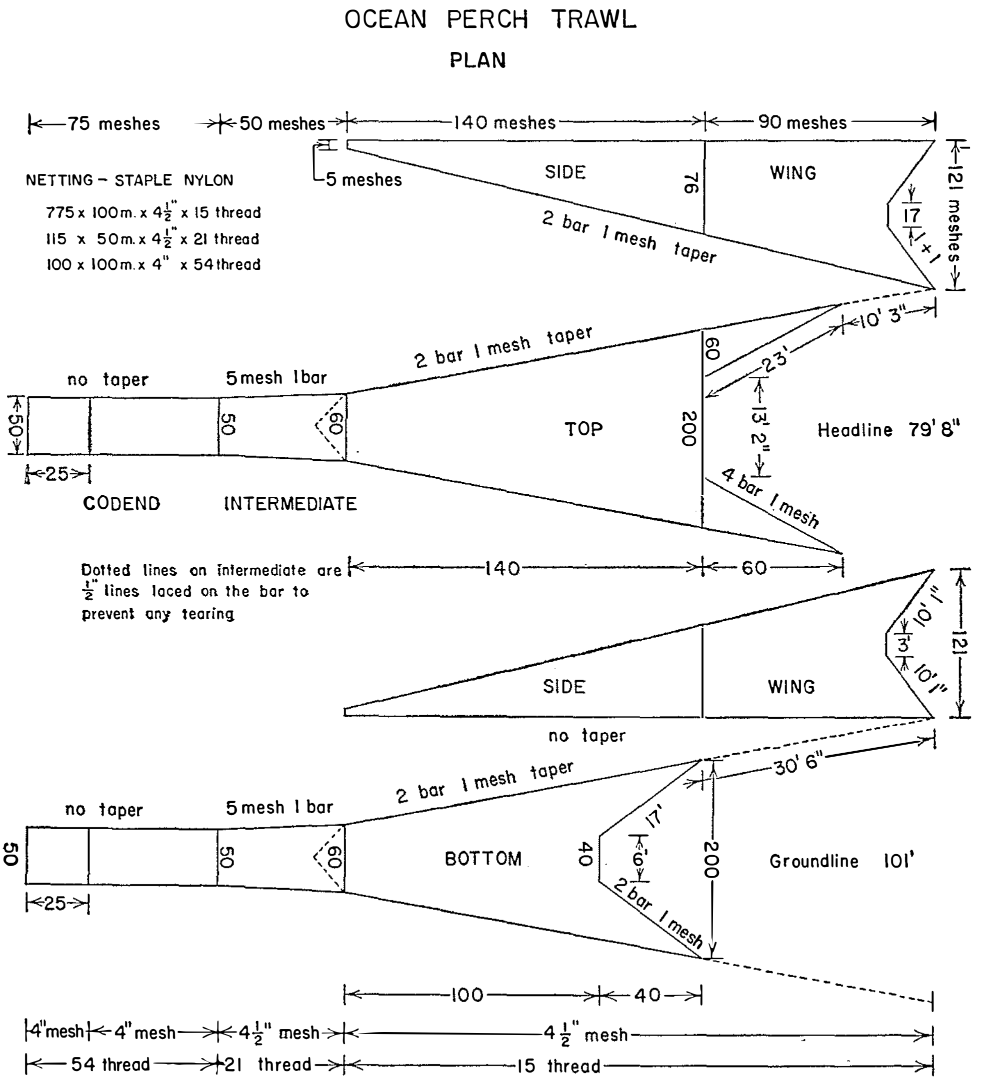


FIGURE 15. The details of construction of the ocean perch trawl.

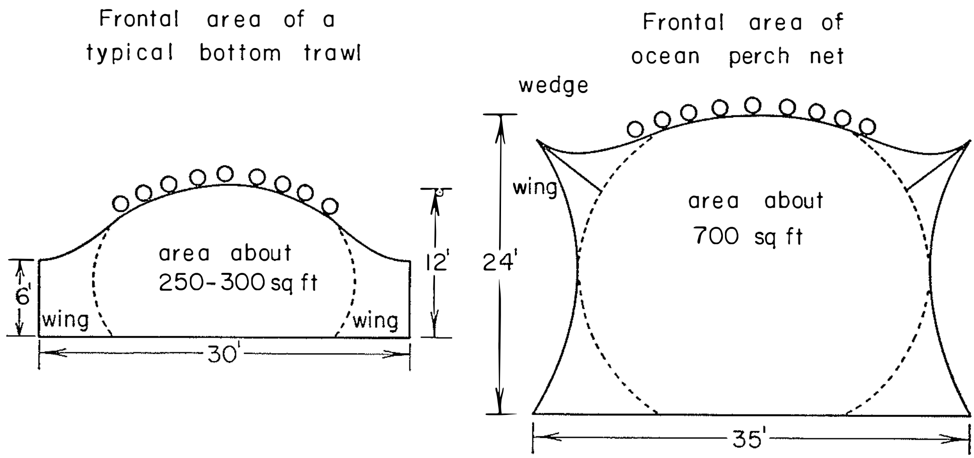


FIGURE 16. A comparison of the frontal areas of a typical bottom trawl and of the ocean perch trawl.

the trawl. By tapering the wedge on both edges toward the wing the taper in the body section is carried straight through on the seam edge to the wing tip. This permits the meshes on the headline to be hung to their full natural length.

A wedge with two tapers, one of them a reverse taper (fast taper) is more difficult to hang to the headrope than the conventional type of wedge. This difficulty can be almost completely overcome by lacing the edge with double twine in the manner described below before hanging the meshes to the headrope. In lacing the edge (Fig. 17), the section of the mesh referred to as the "step" is pulled almost to the "preceding bar", leaving a space between the step and the preceding bar of about 1 inch. This laced edge of the wedge is then divided and marked in quarter lengths and tacked to the required length of headline. When hung, this extra netting in the wedge gives the trawl a sag in the forward sections of the net when fleeting it aboard. However, the net opens to its full extent

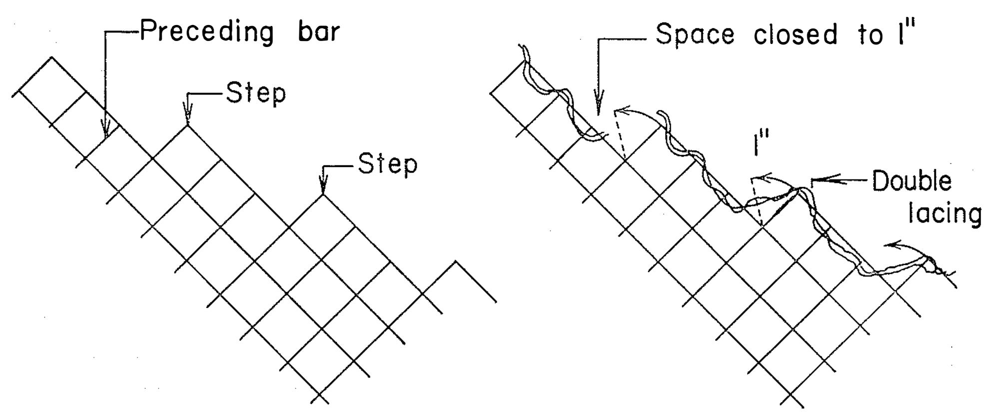


FIGURE 17. The method of lacing the edge of the wedge before hanging to headrope.

without any sag when in operation. To prevent the sag in the forward sections of the net (when fleeting it aboard) from straining and distorting meshes in the intermediate and codend, $\frac{1}{2}$-inch diameter braided nylon lines were sewn down the bar of the meshes on the top and bottom of the intermediate, beginning at the front corners of the intermediate and the riblines.

Staple or spun nylon twine was used throughout in the construction of the net. A considerable reduction in the weight of the netting and riblines and increase in the breaking strength was achieved by using nylon instead of the conventional cotton netting and manila ropes. The headline was constructed from the new nylon-sheathed, preformed, alternate right and left lay, galvanized wire cable.

HYDROPLANE FLOATS

It was found that the normal number of trawl plane floats lashed to the upper headline was not sufficient to lift the No. 3 midwater trawl net completely off the bottom when it was used in conjunction with standard bottom otterboards. A hydroplane float was therefore developed to provide the additional lift necessary, without unduly increasing either the weight on the headrope or the water resistance. Altogether 4 different types of hydroplane floats were developed in the course of the investigation.

Wooden Hydroplane Float on a Steel Mount

The first hydroplane float developed (Fig. 18, 19) consisted of a wooden aerfoil float section bolted to a steel bracket. This bracket was formed by welding two cross bearers on a triangular shaped mount. Both the cross bearers and the mount were cut from $\frac{1}{4}$-inch thick steel plate. The steel mount was cut so as to provide an angle of attack of about 18°. It was found that this angle of attack was adequate when the wooden hydroplane float was shackled freely to the upper sweepline. It could be increased by using additional shackles in the forward connection of the float to the sweepline and decreased by using additional shackles in the rear connection. A trawl plane float attached to a ring bolt on the upper surface of the wooden aerfoil section provided the stability required to keep the hydroplane float upright in the water when setting the gear.

A cable clamp was placed on each of the upper sweeplines, 3 to 4 feet from the wing tips. This clamp acted as a stopper for the hydroplane float, which was shackled so as to slide freely on the upper sweepline. Water pressure against the float holds it in its correct position against the stopper, which must be far enough in advance of the wing tips so that the float will not foul in the netting. This method of attachment allows the floats to be sent down the sweepline after the net is in the water. In hauling the gear, after the warp and sweeplines are in, the floats may be secured to ring bolts on the bulwarks or the stanchions *before* the net is fleeted aboard. This procedure eliminates the hazard of heavy trawl plane floats swinging above the heads of fishermen stacking the net on deck.

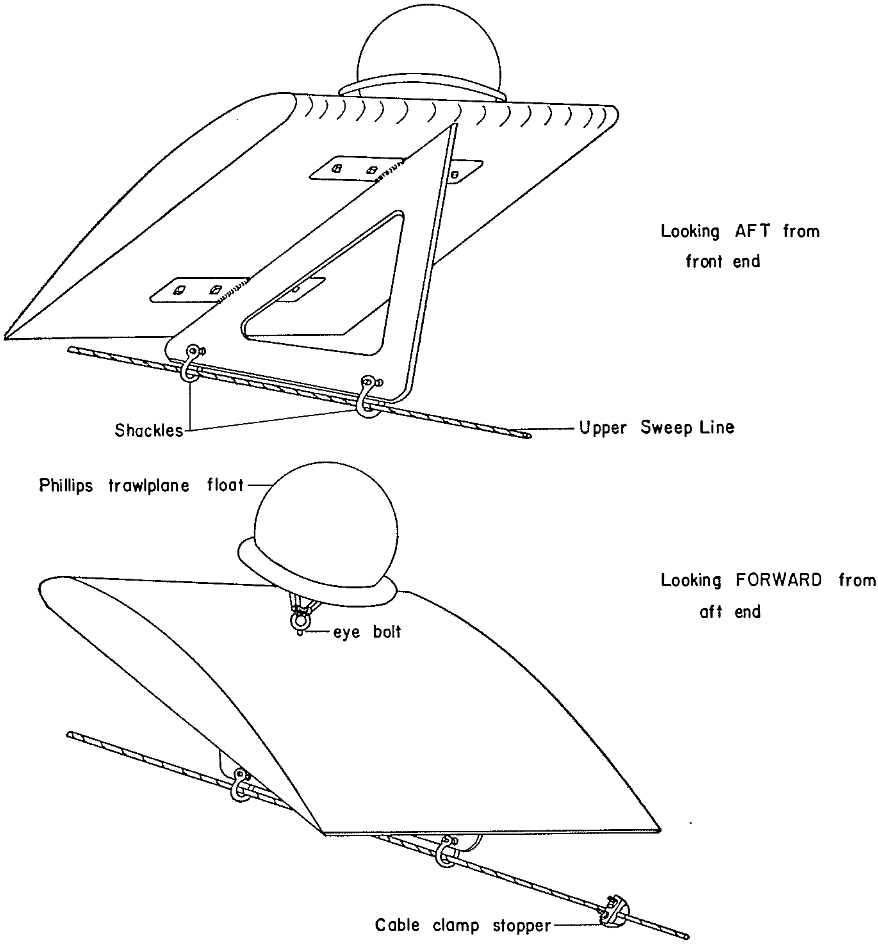


FIGURE 18. Perspective views of wooden hydroplane floats.

PRESSURIZED ALUMINUM HYDROPLANE FLOAT

In this float (Fig. 20) the aerfoil section and mount were made entirely of corrosion resistant $\frac{5}{16}$-inch thick aluminum–magnesium alloy (Type 57S or 65ST). This hollow aerfoil float was reinforced inside with four longitudinal aluminum cross members or ribs to enable the float to withstand pressure at depths down to 100 fathoms. It proved to be light and easy to handle. However, the cost of construction was very high compared to the production cost of other floats.

WOOD–ALUMINUM HYDROPLANE FLOAT

A third design (Fig. 22) incorporated a wooden aerfoil float section secured to a bracket of aluminum–magnesium alloy. The dimensions of this float are the same as in the aluminum hydroplane float (Fig. 20). Instead of using

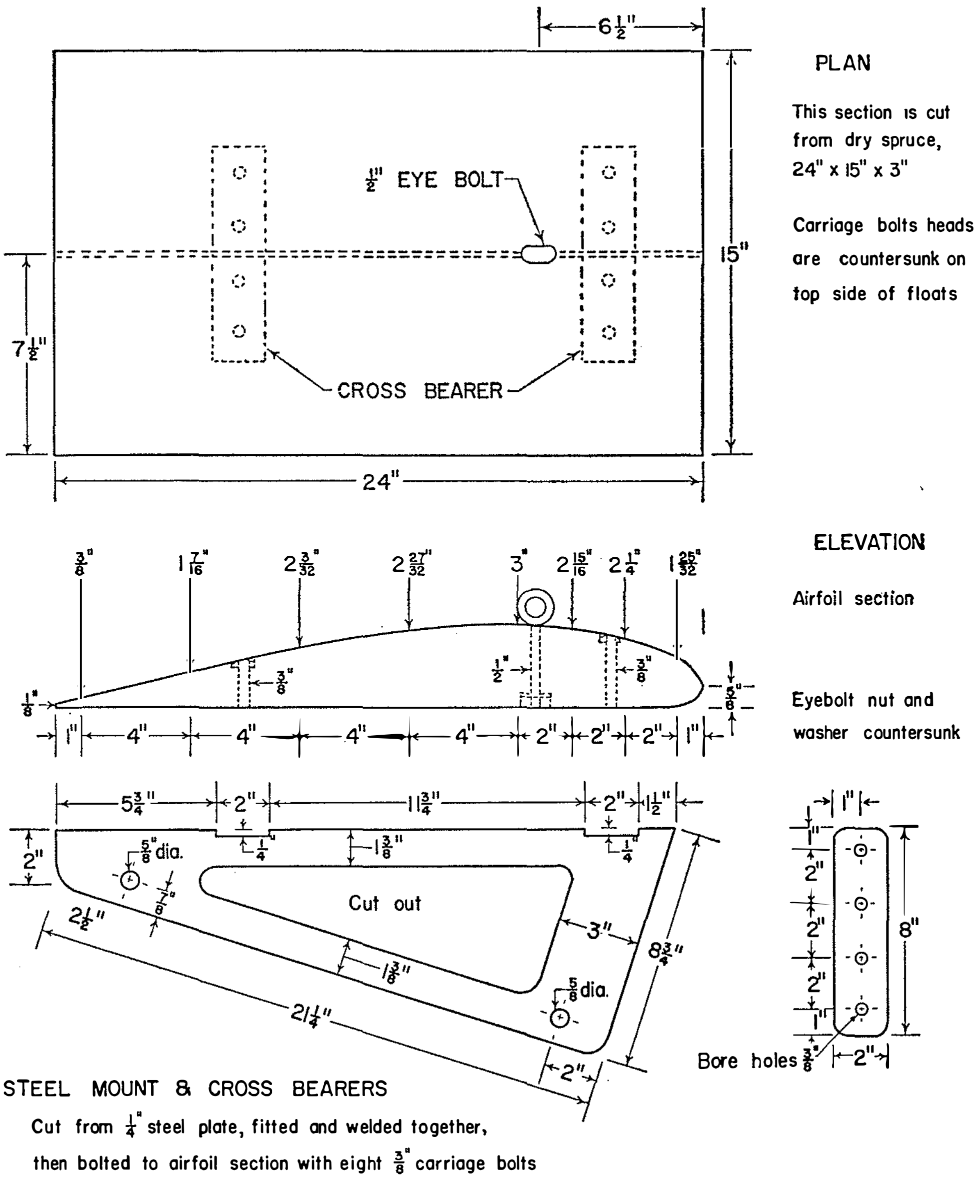


FIGURE 19. Details of construction of wooden hydroplane floats.

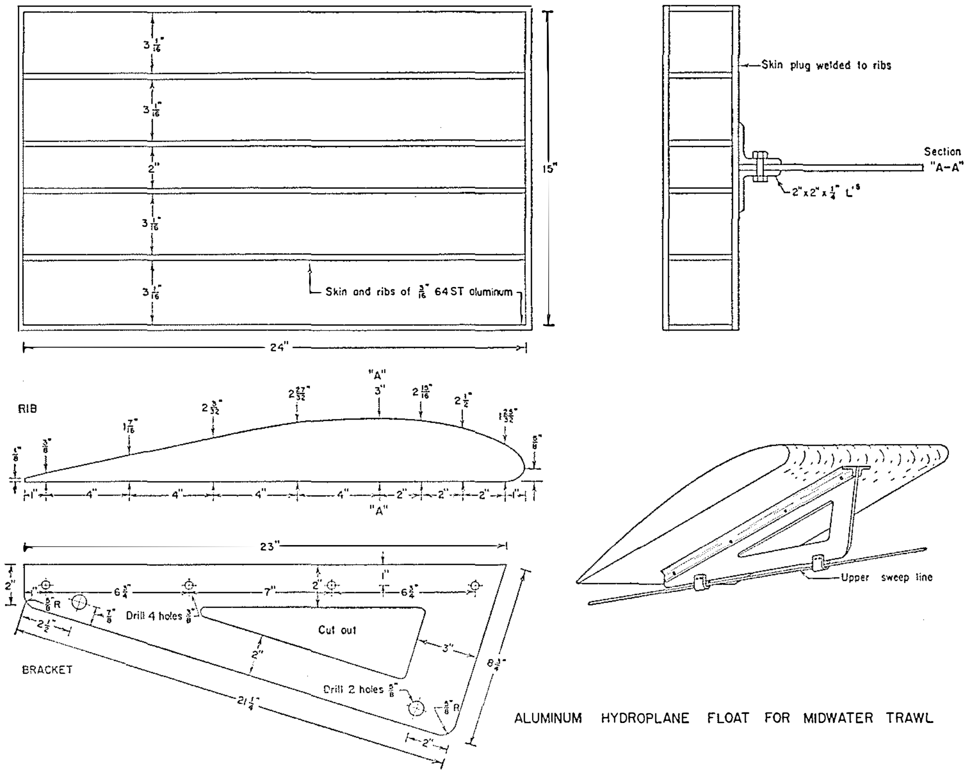


FIGURE 20. Details of construction of the pressurized aluminum hydroplane float.

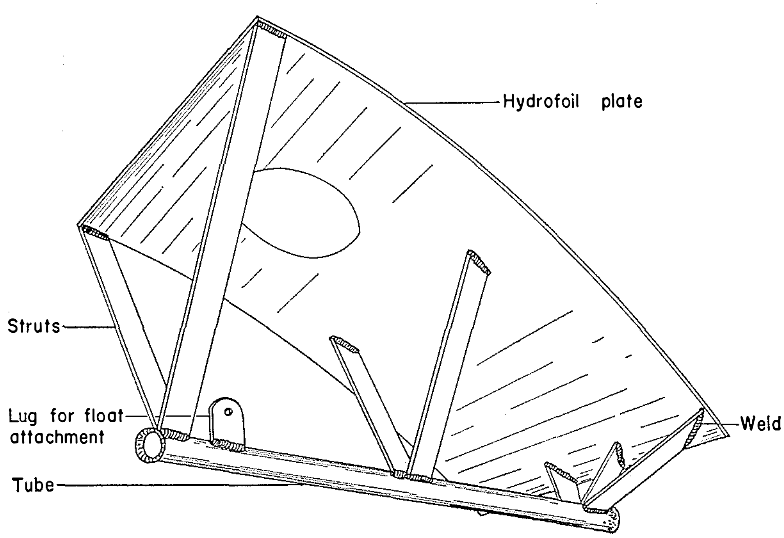


FIGURE 21. The sheet aluminum hydroplane float.

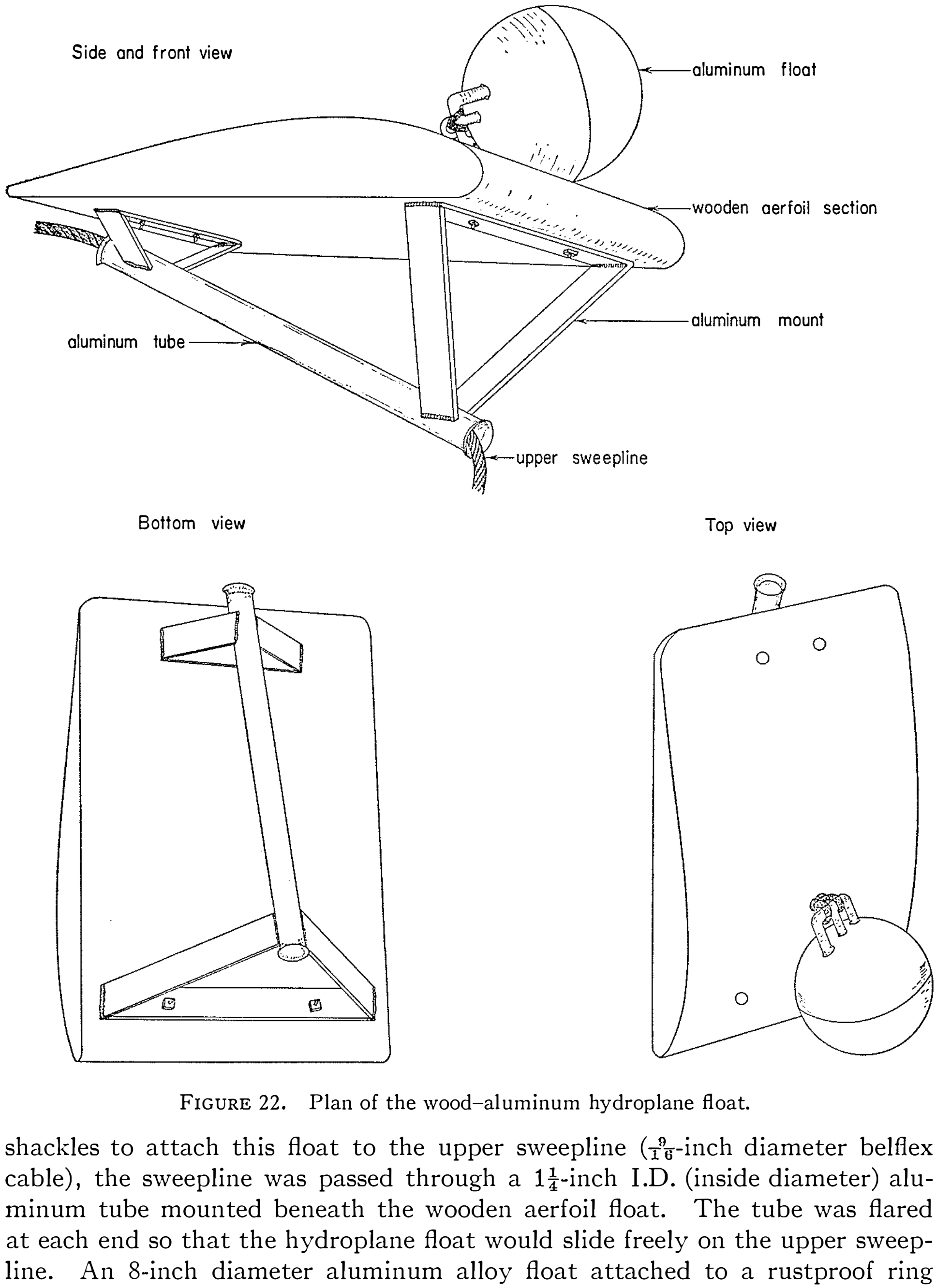


FIGURE 22. Plan of the wood–aluminum hydroplane float.

shackles to attach this float to the upper sweepline ($\frac{9}{16}$-inch diameter belflex cable), the sweepline was passed through a $1\frac{1}{4}$-inch I.D. (inside diameter) aluminum tube mounted beneath the wooden aerfoil float. The tube was flared at each end so that the hydroplane float would slide freely on the upper sweepline. An 8-inch diameter aluminum alloy float attached to a rustproof ring bolt on the upper surface of the wooden aerfoil section assisted in keeping the hydroplane upright in the water when setting the gear. This type of hydroplane float was used successfully in the midwater herring trawl experiments aboard the "single-gear" trawler *Phyllis Carlyle* during the period October to December 1956.

Sheet Aluminum Hydroplane Float

A fourth type of float was designed in an attempt to reduce the weight of the float still further, to simplify construction and to reduce the cost (Fig. 21, 23). This hydroplane float consisted of a sheet of non-corrosive aluminum alloy curved in an aerfoil section with a hole 6 inches in diameter cut through the sheet near the forward end, to seat an 8-inch diameter aluminum float. The aerfoil sheet, $29\frac{1}{2} \times 18$ inches, was attached by welded struts to a $1\frac{1}{4}$-inch I.D. aluminum tube, flared at both ends. The 8-inch aluminum float was secured in its seat by lashings fixed to a lug welded on top of the aluminum tube. If more buoyancy was required another float was secured in the space between the aerfoil section and the aluminum tube.

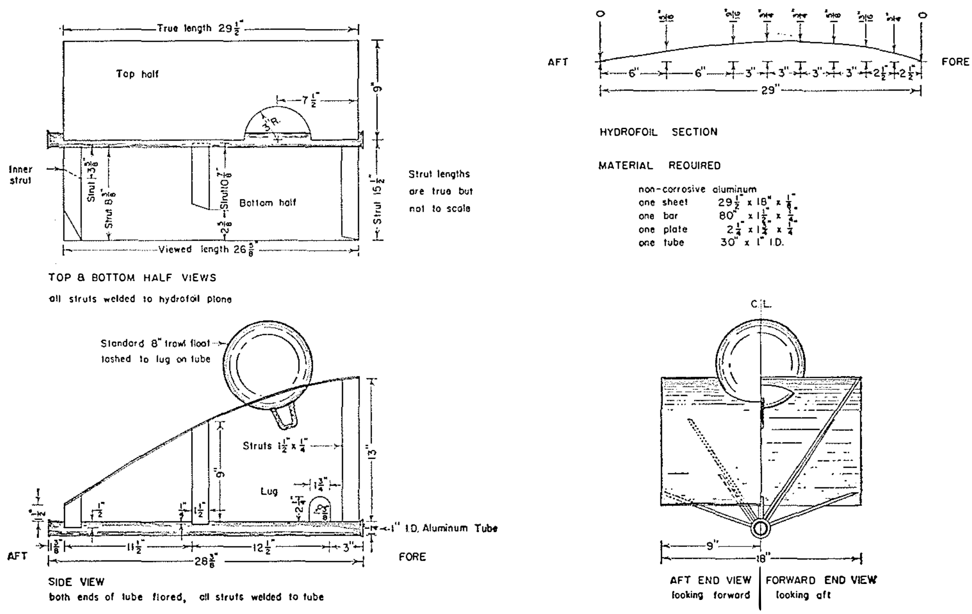


Figure 23. Details of construction of the sheet aluminum hydroplane float.

A DUAL PURPOSE MIDWATER-BOTTOM OTTERBOARD

In 1956 a dual purpose aluminum otterboard was developed which could be used either in strict midwater trawling, with or without "pennants", or in the same way as conventional bottom otterboards. The need for such otterboards became evident during the experimental fishing tests. The original otterboards were not designed to be towed along the bottom; the lower fins became damaged if they struck hard bottom.

The otterboard (Fig. 24) was constructed from aluminum–magnesium alloy sheets (Type 57S or 65ST) resistant to corrosion by salt water. The V-shaped or longitudinal dihedral of the otterboard provided stability when towed either at slow speeds (for example, 2 knots) or at high speeds (for example, 6 knots). Vertical stability in setting the otterboard was provided by securing a buoyant member to the outer edge of the plate. For this purpose a pressurized air ballast tube was welded to a recessed section on the top edge of the otterboard. Horizontal stability was improved by the provision of two horizontal stabilizer fins, which projected from the inside surface of the V-shaped plate near the after end. These fins served to minimize oscillatory movements of the otterboard. A vertical stabilizing fin was provided to assist in controlling the angle of attack of the otterboard when under tow. It was conveniently mounted

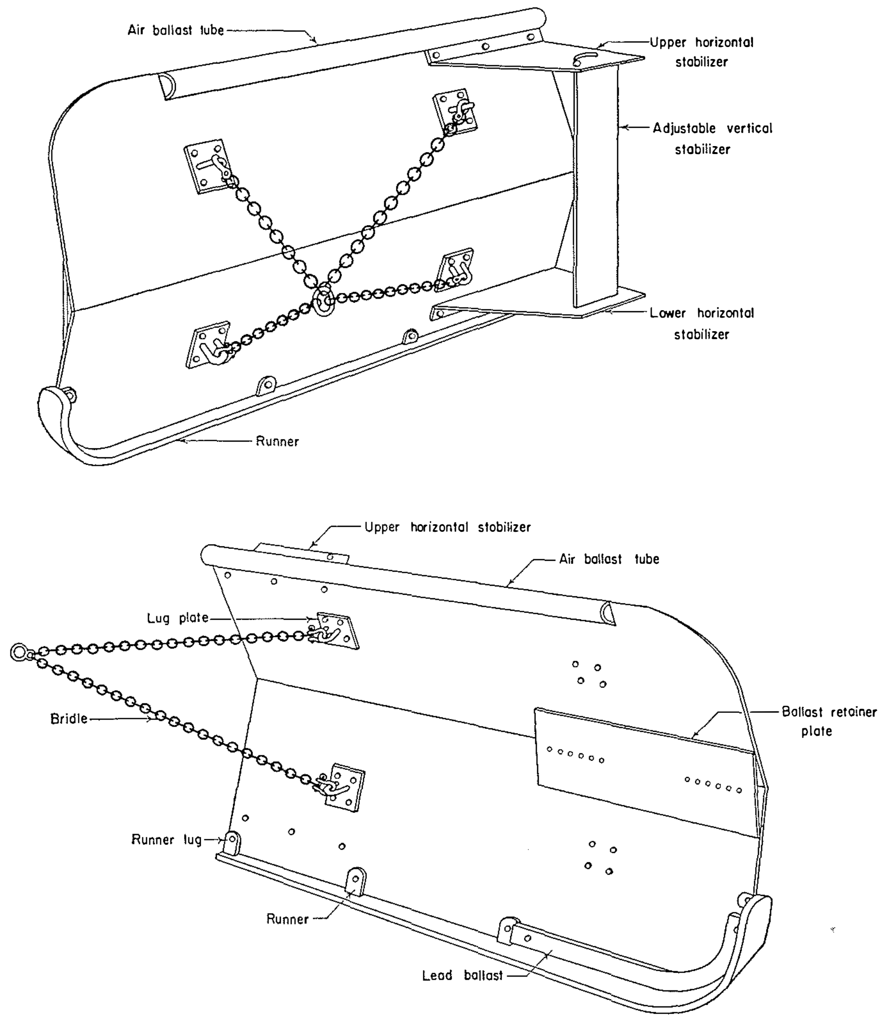


FIGURE 24. The front (top diagram) and back (bottom diagram) view of the starboard aluminum otterboard. Chain bridle as shown in front view is towing bridle; in back view as when otterboards are hooked up in conventional bottom trawl manner.

between the horizontal stabilizing fins in such a manner that the angle between the vertical stabilizing fin and otterboard could be adjusted. The vertical angle of tow was controlled by the attachment of a suitable weight in the form of small lead bars bolted to the lower edges of the otterboard and the adjustment of lead ballast fitted near the front central axis of the otterboard. A conventional galvanized chain bridle was shackled to the otterboard for towing. This type of otterboard could be used either in midwater with or without pennants, or on the bottom. Detailed descriptions of various parts are given below.

Sheering Surface of Otterboard (Port)

Each otterboard (Fig. 24, 25) was cut from a sheet of $\frac{5}{16}$-inch aluminum–magnesium alloy measuring 36 × 65 inches, and bent along the longitudinal axis to form a plate with a dihedral of 140°. The oblique angle between the plates may be varied within wide limits. The smaller the angle the more water is permitted to slip over the outer edges of the otterboard, and hence the higher the speed at which it can be towed. However, as the angle between the plates decreases there is a corresponding decrease in outward thrust. For most purposes, the angle between the plates should be between 110 and 170°, preferably about 140°.

Part of the top edge was recessed $2\frac{1}{2}$ inches to accommodate the air ballast tube welded into place (Fig. 24). The two front corners were rounded on a 10-inch radius. Holes $\frac{3}{8}$ inch in diameter were drilled in the positions indicated in Fig. 25 to house the machine bolts to hold: (1) the upper and lower horizontal stabilizer fins, (2) the four lug plates on the inside surface for the attachment of the four-piece chain towing bridle, (3) the two lug plates on the outer surface for the attachment of the two-piece chain bridle, used when the otterboard was "hooked-up" in the conventional bottom trawling manner, (4) the four pairs of runner lugs for attachment of the armour plate runner or shoe on the bottom edge of the otterboard.

Horizontal Stabilizers

The dimensions of the two horizontal stabilizing fins were the same (Fig. 26). They were cut from aluminum sheets $\frac{5}{16}$ × $13\frac{1}{4}$ × $45\frac{1}{2}$ inches in size. The edge of each fin, which was bolted to the inner surface of the after end of the otterboard, was bent at an angle of 110° along a line $1\frac{1}{4}$ inches from the edge. Each fin was held in position by three $\frac{3}{8}$-inch bolts. A curved slot $\frac{3}{8}$ × 4 inches with a radius of $5\frac{1}{2}$ inches was cut through the surface of both horizontal fins (Fig. 26). This slot permitted the adjustment of the vertical stabilizer for controlling the correct angle of attack of the otterboard in the water.

Air Ballast Tube

The aluminum air ballast tube had a wall $\frac{1}{4}$ inch thick, an outside diameter $2\frac{1}{2}$ inches and a length of 52 inches (Fig. 24, 27). It was sealed at both ends and would withstand pressures of about 20 atmospheres.

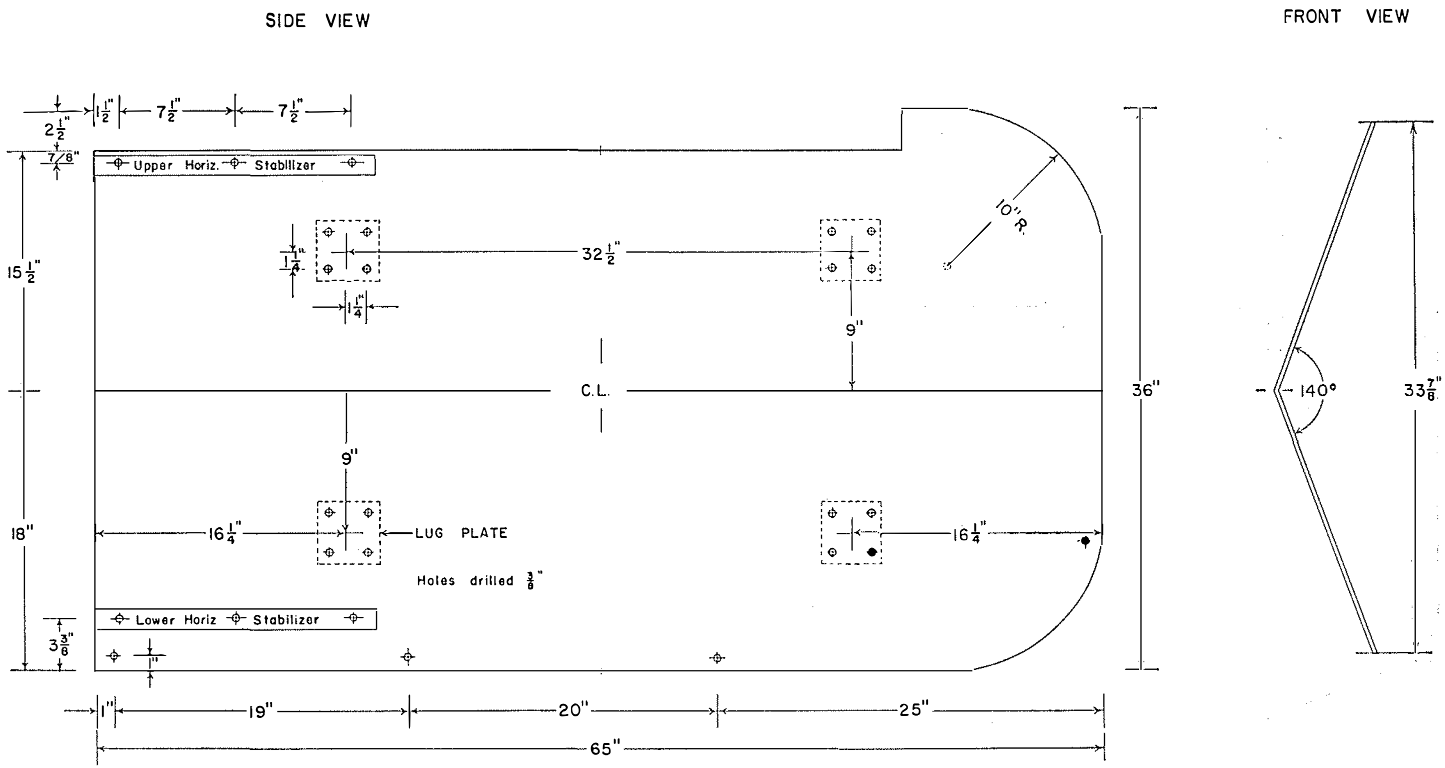


FIGURE 25. The details of construction and dimensions of the aluminum otterboards.

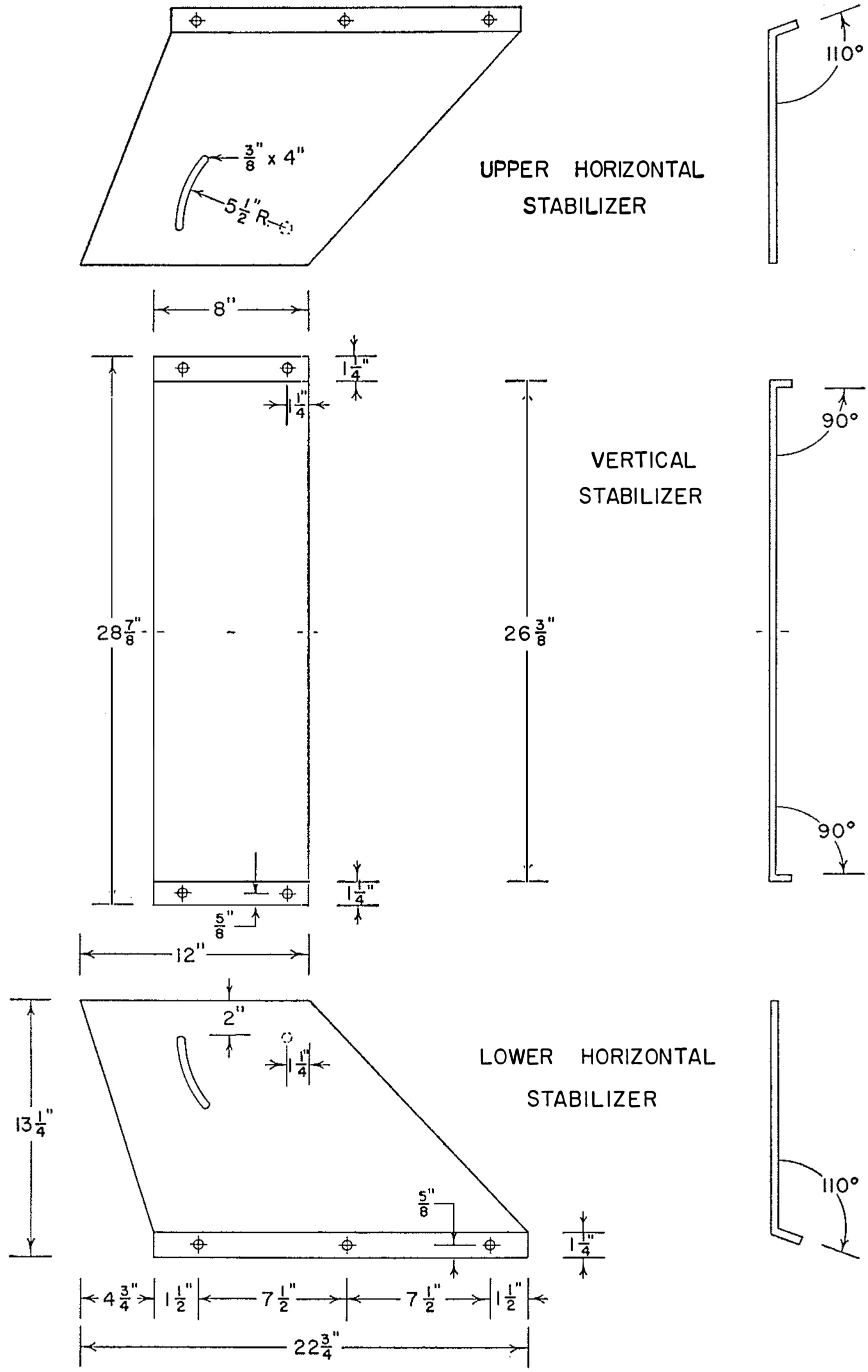


FIGURE 26. The details of construction of the horizontal and vertical stabilizer fins for the aluminum otterboard.

Runner or Shoe

The runner was cut from $\frac{5}{16}$-inch thick armour plate (Fig. 24 and 27). It measured $70\frac{1}{2} \times 4$ inches wide at the front end tapering to 2 inches wide at the after end. The forward end was rounded on a 2-inch radius and bent in an offset 10-inch radius to fit the same curvature and angle of the lower front edge of the otterboard. Eight runner lugs were welded in pairs to the upper surface of the runner, each $\frac{5}{16}$ inch apart, and at an angle of 20° outward from the perpendicular axis. The four pairs of runner lugs were spaced along the upper surface of the runner at intervals indicated in Fig. 27. Four $\frac{3}{8}$-inch holes were drilled along the lower edge of the otterboard, in line with the holes in the runner lugs, for bolting the runner to the lower edge of the otterboard.

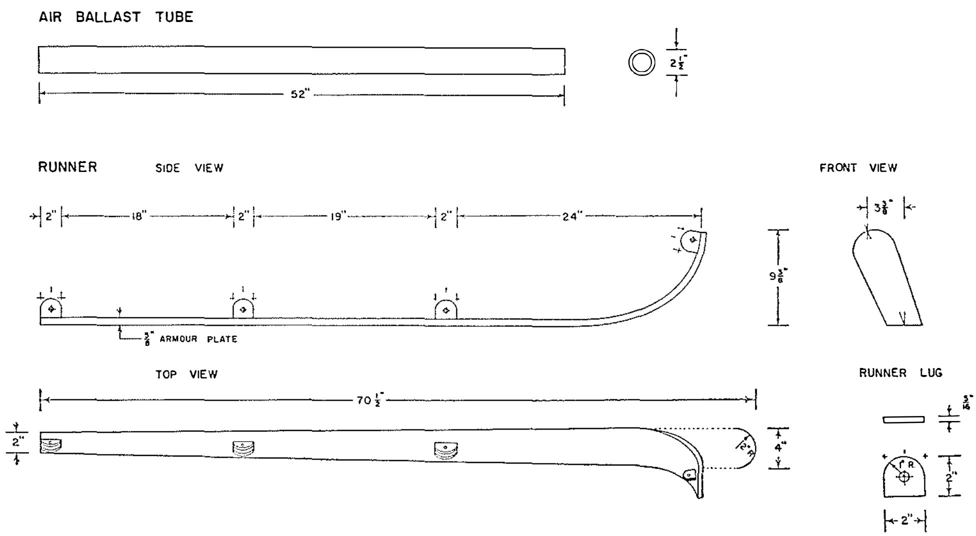


Figure 27. The details of construction of the air ballast tube and runner for the aluminum otterboard.

Lug Plates

For each otterboard 6 lug plates, 4×4 inches, were cut from $\frac{3}{8}$-inch steel plates (Fig. 24, 28). Four lug plates were bolted to the front of the otterboard and 2 to the back at the points opposite the two after lugs on the front side (Fig. 24).

A U-bolt was formed from a steel rod $6\frac{3}{8}$ inches long by $\frac{1}{2}$ inch in diameter. The ends of the U-shaped rod were placed through the 2 holes $\frac{1}{2}$ inch in diameter in the 4×4-inch steel plate and welded in place to complete each lug plate.

Ballast Retainer Plate

The $\frac{5}{16}$-inch thick aluminum plate measured $7\frac{1}{2} \times 24$ inches (Fig. 24, 28). It was spot-welded to the outside of the otterboard at the front end and straddled the concave central axis to form a V-shaped pocket or open chamber in which lead ballast could be placed. Twelve holes, $\frac{1}{4}$ inch in diameter, spaced 1 inch apart were drilled along the center line of the plate. Galvanized nails, driven through these holes into the lead ballast, held it in place.

Lead Ballast

A lead bar, 6 × 13 inches, 1 inch thick along the center axis, flat on one side and bevelled on the other side was inserted behind the retainer plate (Fig. 24, 28). This weight was easily moved into different positions for adjusting the balance of the otterboard in the water. The ballast was secured in place behind the ballast retainer plate as described in the previous paragraph.

An additional lead bar, 28 × 1 × $1\frac{1}{2}$ inches, was bolted in place along the lower front edge of the otterboard (Fig. 24). It was bent to conform with the curved shape of the steel runner upon which it rested.

List of Materials

A list of materials for a single midwater bottom otterboard is as follows:

Number of pieces	Material	Position
1	No. 57S aluminum sheet $\frac{5}{16}$ × 36 × 65 inches	Otterboard
1	No. 57S aluminum sheet $\frac{5}{16}$ × $13\frac{1}{4}$ × $45\frac{1}{2}$ inches	Horizontal fins
1	No. 57S aluminum sheet $\frac{5}{16}$ × 8 × 30 inches	Vertical fin
1	No. 57S aluminum sheet $\frac{5}{16}$ × $7\frac{1}{2}$ × 24 inches	Ballast retainer plate
1	No. 57S aluminum tubing $\frac{1}{4}$ × $2\frac{1}{2}$ O.D. × 52 inches	Air ballast tube
1	Armour plate steel $\frac{5}{8}$ × 4 inches tapering to 2 × $70\frac{1}{2}$ inches	Runner or shoe
6	Plate steel $\frac{3}{8}$ × 4 × 4 inches	Lug plates
8	Plate steel $\frac{5}{16}$ × 2 × 2 inches	Runner lugs
6	Steel rod $\frac{1}{2}$ inch diameter × $6\frac{3}{8}$ inches long	Eye lugs
1	Lead bar 1× $1\frac{1}{2}$ × 28 inches	Ballast
1	Lead bar 1 × 6 × 13 inches	Ballast
18	Machine bolts $\frac{3}{8}$ × $1\frac{1}{2}$ inches	To hold lug plates and ballast
14	Machine bolts $\frac{3}{8}$ × $1\frac{1}{4}$ inches	To hold runner and stabilizers
168	Galvanized chain links $\frac{3}{8}$ inch	Towing bridle
8	Galvanized shackles $\frac{3}{8}$ inch	Towing bridle
1	Steel ring $\frac{1}{2}$ × 4 inches	Towing bridle

Modified Otterboard

Prior to the construction of full sized otterboards, a number of model otterboards of different design were constructed and tested with model midwater trawl nets. One model which showed considerable promise is shown in Fig. 29. The plates of this otterboard forming the dihedral angle were not flat but curved transversely in the manner of aerfoils. An otterboard of this type gives a greater

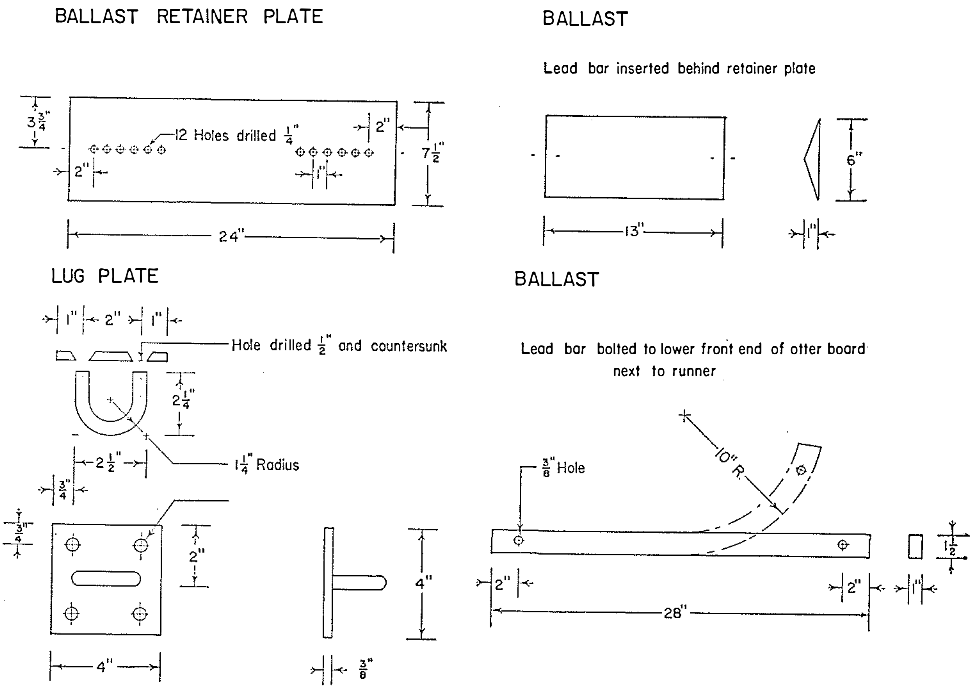


FIGURE 28. The details of construction of the lug plates, ballast retainer plate, and ballast for the aluminum otterboards.

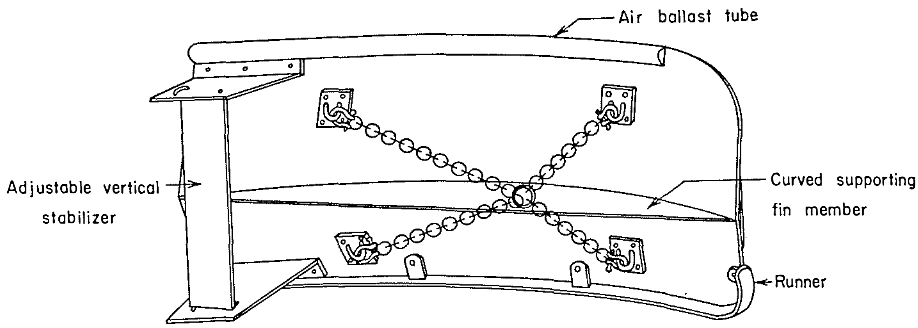
outward thrust than one comprising flat plates; the degree of outward thrust depends partly on the degree of curvature of the plates.

The otterboard of this type may, if desired, be constructed with a streamlined forward edge, for example by attachment to the forward edge of a suitably shaped member made of heavy hardwood or lead which would also serve as a ballast member.

METHOD OF USING THE MIDWATER NET CLOSE TO THE BOTTOM WITH STANDARD OTTERBOARDS

The nets described in this bulletin can be fished close to the bottom by hooking the sweeplines to conventional bottom otterboards, by eliminating the use of depressors and by providing additional lift for the net with special hydroplane floats (Fig. 30).

The method for hooking the sweeplines of the midwater trawl net to standard otterboards differed from that used with a normal bottom trawl and also from that used with No. 1 midwater trawl described in Bulletin 104. To enable the mouth of the net to open vertically to its full capacity and to permit the net to be towed horizontally (Fig. 30), the upper sweeplines were made 5 feet longer than the lower. Then, to keep the headline taut, particularly when setting and



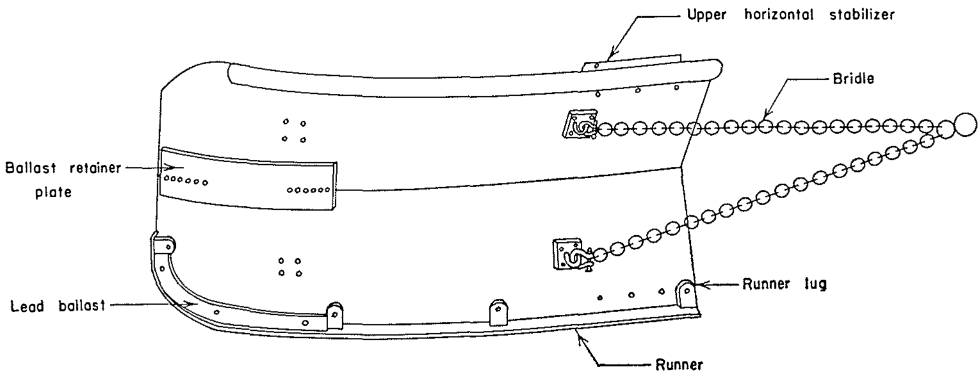


FIGURE 29. Front (top diagram) and back (bottom diagram) views of a curved otterboard for the portside. Chain bridle as shown in back view is used when otterboards are hooked up in conventional bottom trawl manner.

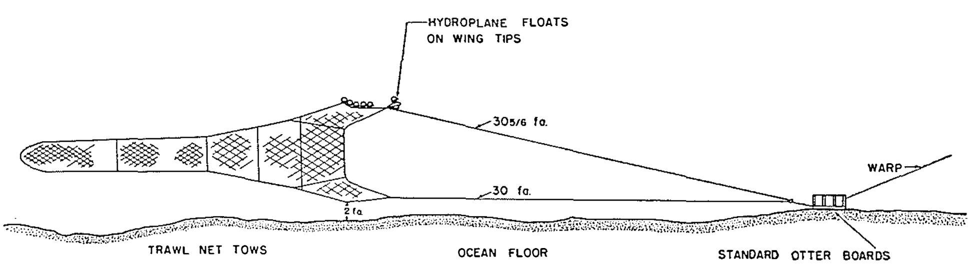


FIGURE 30. No. 3 midwater trawl fished just off the bottom with standard otterboards.

hauling the gear in rough water (so as to avoid fouling the trawl plane and hydroplane floats in the headline and leadline) a come-along or idler (Fig. 31) was inserted between the towing warp and the upper sweepline.

In setting the gear with the new method of "hook-up", the net and sweeplines are paid out until the kelly-stopper on the lower sweepline strikes the ring or kelly-eye attached to the chain bridle behind the otterboards. In this "hook-up" only the lower sweepline passes through a ring, whereas, in conventional bottom trawls the upper and lower sweeplines pass through their respective rings. The otterboards are attached by a G-hook to the special receiver link at the end of the towing warp. This link is flattened in the middle section on each side to permit passage of the opening in the G-hook. The kelly-stopper, kelly-eye, G-hook and receiver link are all standard types used on British Columbia trawlers. The come-along is attached from the receiver link to the link joining the upper sweepline and the 5-foot extension cable (Fig. 31).

In setting the net when the warp is first payed out, both the 5-foot extension cable and the come-along are tight. At this stage the 5-foot extension cable forms part of the lower sweepline. When the kelly-stopper has engaged in the kelly-eye, the 5-foot extension piece switches into the upper sweepline, which now in effect will be 5 feet longer than the lower. The come-along now becomes slack and remains so after the otterboard is attached to the warp. The procedure for hauling the gear is shown diagramatically in Fig. 31; it is the reverse of the procedure used in setting the gear.

EXPERIMENTAL FISHING TESTS

Midwater Net with Bottom Otteroards

The midwater net with conventional bottom otterboards and the sweeplines adjusted so that the net was about 2 fathoms off the bottom made excellent herring catches off the lower east coast of Vancouver Island. During November 1955, 5 to 10 tons of herring per haul were caught with Net No. 3A (Fig. 3) in 15-minute tows on typical herring schools lying near the bottom. Some catches of 20 tons and one catch of 75 tons of herring were made in 20 to 30 minute tows at depths from 40 to 55 fathoms during daylight hours in Trincomali Channel, Swanson Channel and Satellite Channel. As a result, the gear was immediately applied on a commercial basis during the winter herring fishery of 1955-56.

Trawling in Midwater with Dual Purpose Aluminum Otterboards

Experimental midwater trawling with these otterboards was first undertaken from the *San Tomas* during August and September 1956, off the west and north coasts of Vancouver Island. This 65-foot trawler was equipped with conventional Pacific-type double-gear winches, hydraulically operated and powered with a 220-hp engine.

The dihedral in the first pair of otterboards was 110°, and although these operated satisfactorily, their efficiency was increased after the dihedral was

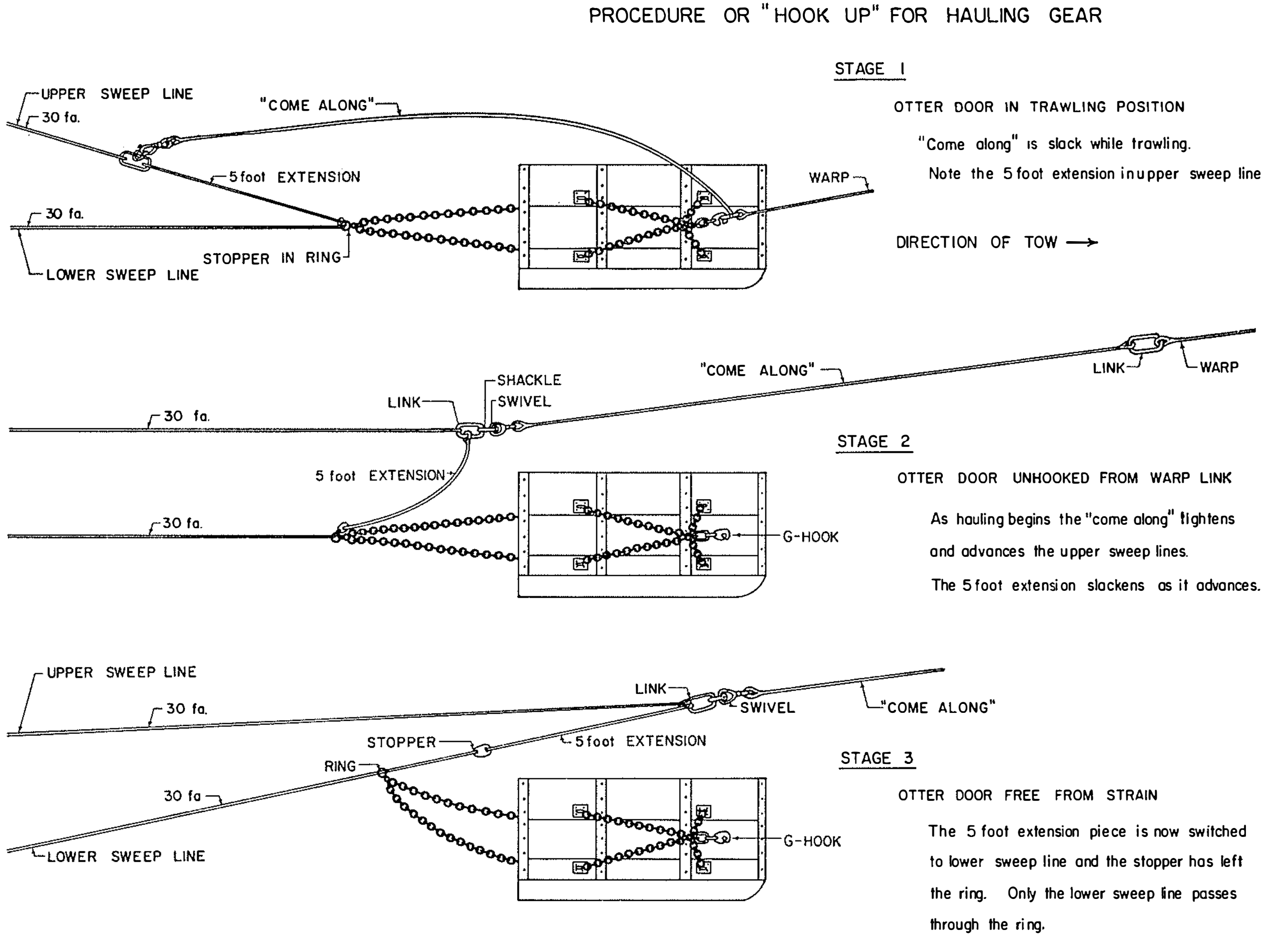


FIGURE 31. The method of attachment of sweeplines, otterboards and towing warp.

altered to 140°. The tests in midwater were conducted in two ways: (1) with the otterboards suspended on pennants as described in Bulletin 104, and (2) with the otterboards hooked up to the sweeplines by the method described in the previous section (Fig. 31). The latter "hook-up" was preferred for trawling even strictly in midwater, because it enabled the otterboards to be towed along the bottom, if necessary, without danger of damaging the net on the bottom. This method was easier to operate, and was just as effective in catching herring in midwater.

Further midwater trawl fishing experiments for herring with these otterboards were conducted from the 47-foot single-gear trawler *Phyllis Carlyle*, during October and December, 1956. They were slightly superior in performance to the typical conventional, flat, heavy, rectangular otterboards, which were also used at that time.

During June and July, 1957, aluminum otterboards measuring 48 × 87 inches were operated successfully in offshore waters from the *San Tomas* with the Ocean Perch Trawl at a depth of 110 fathoms.

Midwater Trawling from "Single-Gear" Trawlers

From October 22 to December 6, 1956, the *Phyllis Carlyle* was used to try midwater trawling for herring from "single-gear" trawlers. These trawlers are equipped with one trawling winch, a single davit in the form of a short boom on the starboard side and one warp with a bridle (Fig. 32). At that time over half of the trawlers in British Columbia had gear of this type. Net No. 4 had been made especially for use on these vessels, and was used in these tests.

Experimental fishing with this trawl was confined to the waters off the east coast of Vancouver Island where herring were known to school in large numbers. These areas included Deep Water Bay, Nanoose Bay, Trincomali Channel, Satellite Channel, Swanson Channel and Tumbo Channel. The V-shaped aluminum otterboards (Fig. 24) were used for nearly all the tests, and were rigged for midwater trawling as in Fig. 31, without the use of pennants.

It should be noted particularly that when these otterboards do touch the bottom, the net is fishing 1 to 2 fathoms off the bottom. Thus the net is never exposed to damage on the bottom, as it is with conventional bottom trawling.

Midwater Trawling for Summer Herring in Offshore Waters

These experiments were first tried during the summer of 1956 from the vessel *San Tomas*, and were expanded during 1957. The main fishing effort was concentrated in waters where purse seiners were actively engaged in offshore fishing for herring, including the Juan de Fuca Strait, Queen Charlotte Straits, Queen Charlotte Sound, Hecate Strait and Dixon Entrance. Six different types and sizes of midwater trawls were used, in exhaustive fishing tests at different times of the day and night. Catches up to 3,000 pounds of herring were made (Table I). However, the average catch was small in comparison with what was being taken by purse seiners operating in the same area (5 to 30

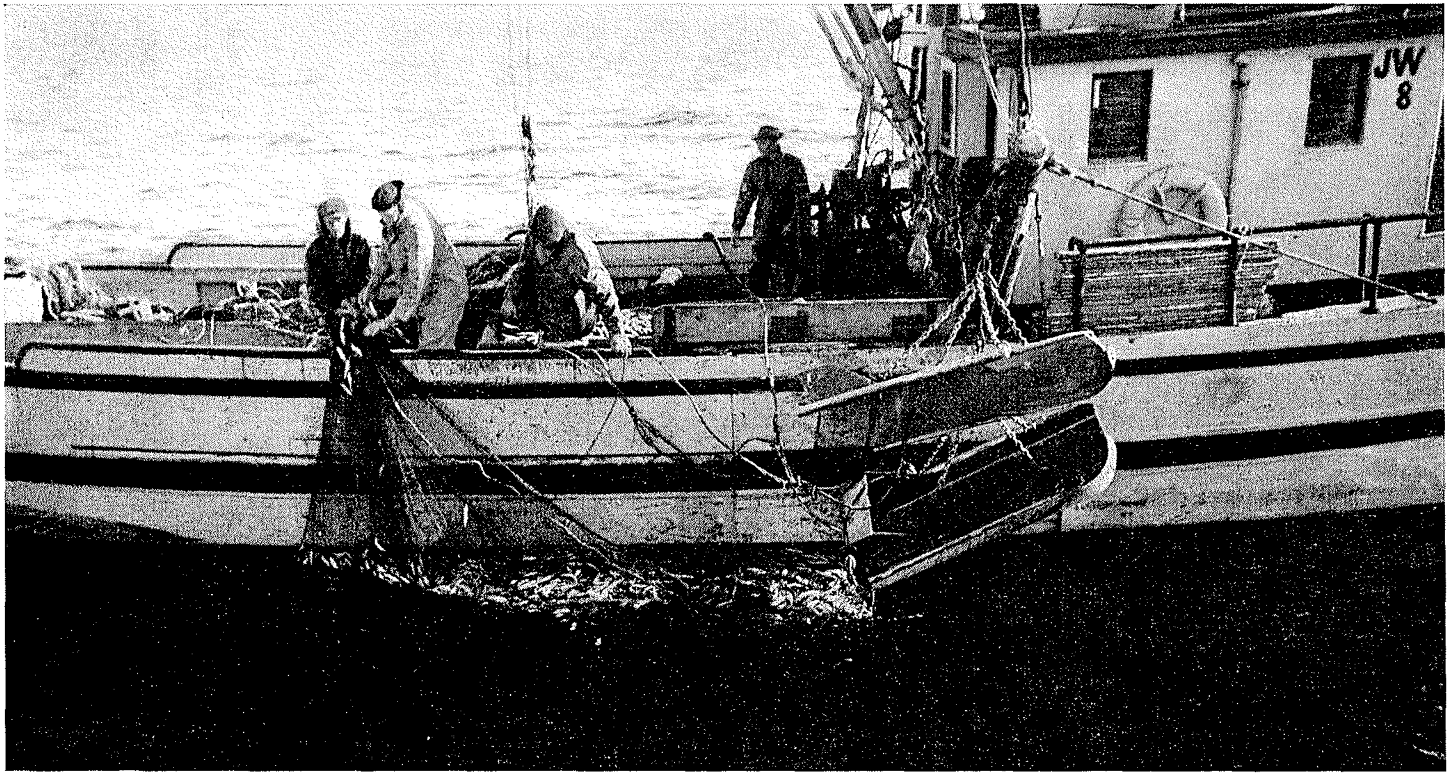


FIGURE 32. The "single-gear" trawler, *Phyllis Carlyle.*

TABLE 1. Selected series of representative tows on summer herring schools off the British Columbia coast in 1957 using different midwater trawl nets.

Date 1957	Time set	Time hauled	Catch of herring	Area fished	Depth to bottom	
			lb		*fath*	
TOWS MADE WITH NET No. 3B						
June 18...	1535	1615	1500	South flat grounds, Hecate Strait	17	10 "plumes" recorded on echo-sounder.
June 20...	0700	0800	nil	Caamano Sound	25	Snagged net on bottom in strong tide and rough weather.
June 30...	1053	1115	150	Mouth of Active Pass on east coast of Vancouver Island	50	Scattered herring recorded in tide streaks from surface to 8 fath.
July 12...	1200	1220	1200	11 miles NW Mexicana Point at the north end of Vancouver Island	17–30	3 "plumes" recorded on echo-sounder.
July 13...	0910	0945	2500	11 miles NW Mexicana Point at the north end of Vancouver Island	17–25	Small herring caught (see Fig. 33).
July 13...	1040	1130	1000	11 miles NW Mexicana Point at the north end of Vancouver Island	20–30	4 "plumes" recorded.
July 14...	1005	1100	4000+	11 miles NW Mexicana Point at the north end of Vancouver Island	20–26	8 "plumes" recorded. Lost many herring through zipper as net rolled over.
TOWS MADE WITH NET No. 4						
May 24...	0700	0726	nil	Off Cape Lazo, Strait of Georgia	35	2 "targets" recorded. Catch 200 lb of dogfish and sandlance.
June 11...	1510	1530	100	Off Point Grey, Strait of Georgia	20–30	Thin streak of herring 1 fath deep at a depth of 5 fath.
June 11...	1620	1645	2000	" "	25–30	Streak of herring 2 fath thick at a depth of 4 to 6 fath (Fig. 33).
June 17...	1430	1525	3000	Off Seal Rocks in Hecate Strait	17	Scattered herring patches from 3 to 10 fath.
June 18...	0655	0730	50	South flat grounds in Hecate Strait	13–17	3 scattered "plumes" recorded.
TOWS MADE WITH HIGH-SPEED CONICAL NET						
June 18...	1300	1355	250	South flat grounds, Hecate Strait	13–17	7 scattered "plumes" recorded.
June 18...	1000	1115	150	South flat grounds, Hecate Strait	15–17	A few scratches recorded on echo-sounder.
July 14...	1145	1215	2500	12 miles NW Mexicana Point	20–25	5 "plumes" recorded on sounder.
TOWS MADE WITH WATER BY-PASS TROUSER TRAWL						
July 11...	1430	1525	700	11 miles NW Mexicana Point	25	4 small "plumes" recorded on echo-sounder. 300–400 lb in codend.
July 12...	0800	0820	200	" "	17–20	9 "plumes" recorded on echo-sounder (Fig. 33).
July 14...	1515	1530	350	" "	20	9 "plumes" recorded on echo-sounder. 1 coho salmon in catch.
July 15...	0910	1040	50	" "	20	1 "plume" recorded, catch in 1 codend.

TABLE I—*Concluded*

Date 1957	Time set	Time hauled	Catch of herring	Area fished	Depth to bottom	
			lb		*fath*	
			Tows made with Net No. 6			
June 14...	0915	0935	150	Estevan Sound, Hecate Strait	33–36	3 "plumes" recorded on echo-sounder.
June 14...	1850	1940	2000+	South flat grounds, Hecate Strait	17	6 large "plumes" recorded.
July 3...	1745	1800	300	Trevor Channel, Barkley Sound	20–30	4 small "plumes" recorded at a depth of 3 to 10 fath. Catch was juvenile herring; most escape through 1½-inch mesh in codend.
July 4...	0903	1030	nil	17 miles SW Amphitrite Point on west coast of Vancouver Island	40	Recorded targets interpreted as plankton. Catch 3 horse mackerel and 1 bucket sandlance 1½ inches long.
July 5...	2125	2150	500	Off Clo-oose	30	2 "plumes" recorded. Catch juvenile herring; most passed through meshes in codend.
July 11...	1035	1110	300	12 miles NW Mexicana Point	23–25	5 "plumes" recorded. Small herring.
July 11...	1145	1215	100	" "	17	No herring recorded on sounder.

tons per set), and was too small for a profitable operation. It was estimated that for a profitable operation, a small trawler of 15 to 20 tons capacity should land 30 to 40 tons a week. Since 2 to 3 days would be spent in travel and in unloading, and since there is a 48-hour closure, only 2 days could be spent fishing a week. To make the estimated required catch of 15 to 20 tons a day, each tow should yield 4 to 5 tons.

The difficulty in catching herring in offshore waters during summer, as compared with inshore waters in winter, appears to be directly related to differences in schooling behaviour. In summer, the herring were recorded on the echo sounder paper as scattered "plumes" or inverted "cones" of tightly packed fast-moving schools (Fig. 33). (In winter, in the inshore waters of the Strait of Georgia, herring are often found densely schooled in layers 5 to 20 fathoms deep.) Strong tidal conditions, and the lack of suitable landmarks for bearings in offshore waters hampered the work in setting the gear on scattered, travelling schools of herring. Marker buoys were dropped over located schools and assistance was received from seine boats scouting nearby. In spite of these measures, it was difficult to tow the gear effectively through the schools, for they were moving too quickly.

The largest of the nets (Fig. 7) could not be towed quickly enough to keep up with the travelling schools. The relatively high speed nets (Fig. 11, 12), towed at 4.5 to 5 knots, had too small a mouth opening to enclose a sufficiently large number of fish from the plume-like schools. It was observed on the echo

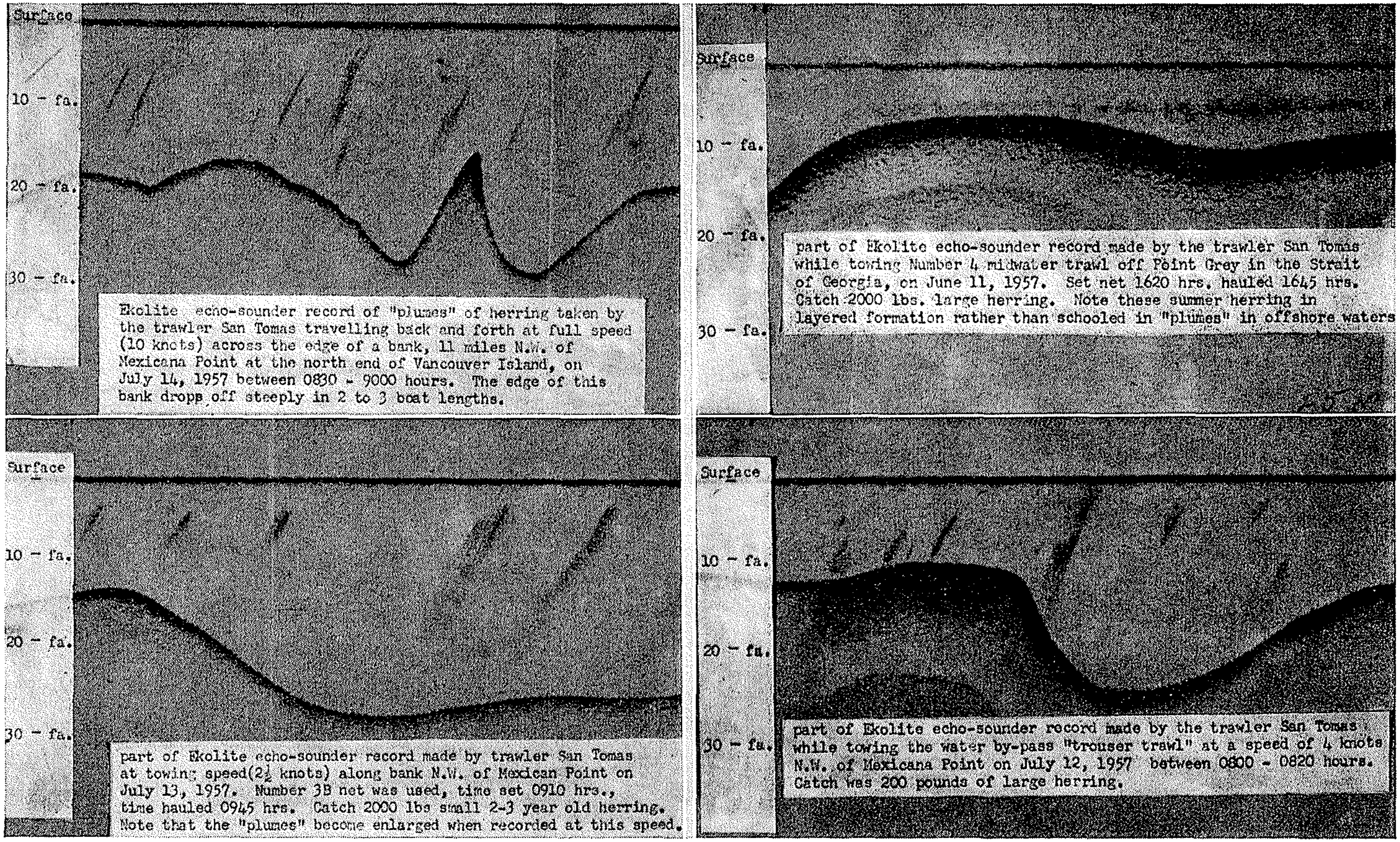


FIGURE 33. Echo-sounder records of herring fished with midwater trawls, June and July, 1957.

sounder recordings that even when the gear was not in the water a whole school of herring would sometimes suddenly rush downward as a closely packed unit, or scatter upwards and outwards. The sudden scattering or "exploding" of tightly packed schools is observed frequently by fishermen engaged in summer purse seining in offshore waters, and appears to be a typical response to disturbance.

Although the catches of summer herring taken by the small conical midwater trawl (Fig. 12) and the water by-pass trouser trawl (Fig. 11) were not of commercial quantity, they were large enough (250 to 2,000 lb) for sampling purposes for research projects. The sizes and ages of herring caught by both these trawls were the same as those in samples taken from purse seine catches.

COMMERCIAL USE OF THE MIDWATER TRAWL GEAR

In the late fall and early winter of 1955–56 seven trawlers used the midwater net with conventional otterboards in the British Columbia commercial herring fishery. Their average catch per 15-minute tow was 2 to 4 tons, and as many as 5 to 7 tows were made per day, a satisfactory performance considering that the average hold capacity of the trawlers operating was 10 to 15 tons. The largest trawler, the *Sea Pride II* with a 60-ton hold capacity, caught 622 tons of herring during a 5-week fishing period in December 1955 and January 1956. The total trawler catch for the season was about 2,000 tons of herring.

In the 1956–57 season, 19 trawlers took part in the fishery along the lower east coast of Vancouver Island. The total trawl catch was small, only about 2,000 tons again, as the major herring schools were unusually late in appearing on the most favourable trawling grounds. When the schools did appear the quota of 40,000 tons for the area was caught quickly, in 3 to 4 weeks, by the highly efficient purse seine fleet.

Although a smaller number of trawlers operated in 1957–58, the total catch of nearly 2,800 tons was greater than in any of the previous seasons.

There is a considerable range in the length (38 to 67 feet), hold capacity (10 to 60 tons) and horsepower (34 to 175 hp) in the trawlers that operate in the winter fishery. To a large extent the horsepower available in each trawler determines the size of the net that can be towed. However, the different trawl skippers have been able to build their nets to meet the requirements of each vessel and operate the gear on a commercial basis. The actual catch of 5 different trawlers fishing off the lower east coast of Vancouver Island in the past two winter herring seasons is given in Table II. To make the comparison as complete as possible Table II also shows the number of days fished each month, the number of tows made, the total trawling time, the average time per tow and the average catch per tow, for the benefit of fishermen considering entering this fishery.

TABLE II. Catch of herring taken by 5 different commercial trawlers using a midwater trawl net with bottom otterboards, in the winter herring fishery of 1957–58.

Date	Days fished	Number of tows	Total towing time		Time per tow	Total catch	Av. catch per tow
	no.	*no.*	*hr*	*min*	*min*	*lb*	*lb*
BOAT A (48 FEET LONG, 120 HP)—							
December 1957	3	14	8	45	37	33,505	2,393
January 1958	16	111	43	40	24	236,000	2,126
February 1958	3½	28	10	30	23	32,000	1,143
November 1958	2½	14	5	20	23	6,500	464
December 1958	6½	19	5	55	19	66,500	3,500
BOAT B (39 FEET LONG, 34 HP)—							
December 1957	2	6	2	50	28	40,000	6,666
January 1958	8½	36	10	10	17	97,690	2,714
November 1958	2	9	3	—	20	32,518	3,613
December 1958	3	9	2	—	13	46,120	5,124
BOAT C (42 FEET LONG, 165 HP)—							
December 1957	½	1	—	10	10	8,000	8,000
January 1958	2	7	—	58	8	67,530	9,647
February 1958	3½	15	1	10	5	81,274	5,418
March 1958	1½	6	—	30	5	28,195	4,699
November 1958	4	14	1	16	5	114,572	8,184
BOAT D (38 FEET LONG, 60 HP)—							
February 1958	2	7	2	30	21	70,145	10,020
November 1958	3½	12	3	—	15	100,680	8,390
December 1958	1½	5	1	15	15	39,971	7,994
BOAT E (54 FEET LONG, 115 HP)—							
November 1958	5	14	3	45	16	119,570	8,541
December 1958	8	33	8	—	15	451,820	13,692

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