ARTICLE

A PROGRESS REPORT ON THE DEVELOPMENT OF A SHRIMP TRAWL TO SEPARATE SHRIMP FROM FISH AND BOTTOM-DWELLING ANIMALS

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BCF has developed a trawl that separates, while fishing, shrimp from other marine animals. The design resulted from experiments aboard the 'John N. Cobb' and several cooperating Pacific Northwest commercial shrimp trawlers. Behavioral studies of the response of shrimp and associated marine animals to capturing gear contributed to the gear development.

The BCF shrimp-sorting trawl has long wings with double web panels. Shrimp pass through the large mesh inner panel and are retained by the small mesh outer panel, which leads to a cod end. Fish and other "trash" that cannot pass through the inner web lead aft, either passively or actively, to a trash chute that allows passage back to the sea bed. The shrimp-sorting trawl caught up to 2,000 pounds of shrimp per tow. This catch usually contained less than 1 percent trash, whereas conventional nets fished nearby had catches up to 80 percent trash.

Shrimp catch rates have been less when using the shrimp-sorting trawl than for conventional trawls. This problem is being studied. Time-consuming sorting, however, is nearly eliminated, and shrimp quality improved. The sorting trawl permits fishing during late evening and morning hours of darkness, and on grounds not now fished because of high trash catches. Research is continuing to further improve catch rates and separation, and to modify the trawl for other shrimp fisheries.

One major concern of commercial shrimp fishermen is the large amount of fish and bottom-dwelling invertebrates in the shrimp catches. Along the Washington and Oregon coasts, shrimp fishermen are particularly bothered with small flounders, Pacific hake, sablefish, smelt, and sea urchins.

In the Pacific Northwest, shrimp fishermen spill their pink shrimp catch from the trawl onto a large sorting table, where crew members handpick out all "trash" (unwanted fish and invertebrates caught incidentally). Because shrimp must be free of all trash and mud to be marketable, extra manpower is required to assist with this time-consuming task. If the sorting problem could be eliminated, only 3 men would be required in the crew instead of the present 4. Sorting time varies with the amount and kind of trash. A typical catch aboard a Pacific Northwest shrimp trawler might contain 1,500 pounds of pink shrimp and 5,000 pounds of trash, which would require about 3 man-hours to separate.

Some fish caught in shrimp trawls have market value but usually cannot be handled profitably along with shrimp. Moreover, some state laws prohibit large amounts of fish to be landed by shrimp trawlers.

Present trawl capture techniques damage both shrimp and fish. Shrimp are crushed by large volumes of fish, and fish are repeatedly punctured by shrimp rostrums. Broken sea

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U.S. DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
Sep. No. 836

urchins stain shrimp and are very difficult to sort from shrimp. Small-mesh shrimp trawls also capture large numbers of young fish; most of those that have air bladders, such as hake and rockfishes, do not survive when returned to the sea bed. Consequently, many fish die even when discarded.

Trash in shrimp catches reduces fishing efficiency. Vessels are often forced to cease fishing temporarily when the entire catch cannot be brought aboard at once. Part of the catch must remain in the trawl alongside the vessel until space is available on the sorting table. When the amount of trash is too great to make sorting feasible, the entire catch is dumped overboard and new grounds having less trash are sought. Shrimp trawling is not conducted during early morning and late evening because the catch is mainly trash, especially small flounders.

In May 1968, BCF's Exploratory Fishing and Gear Research Base at Seattle, Wash., began experiments and fishing trials to develop a method of reducing unwanted marine forms in shrimp catches. Experimental approaches presented in this report are based on a detailed understanding of trawl design tied closely to investigations of the behavior of shrimp and other animals.

BACKGROUND

Early Separator Shrimp Trawl Research in Europe

In 1963, French researchers experimented with a shrimp trawl designed to separate shrimp from flatfish (Boddeke, 1965). The trawl was designed on the principle that shrimp and flatfish respond differently to a stimulus--shrimp swim up into the water column whereas flatfish swim toward the ocean bottom. A conventional shrimp trawl was divided into upper and lower sections by a large-mesh curtain or panel of web. The upper section was completely closed off from the lower section. The separator panel was weighted so that it hung horizontally throughout the length of the trawl body and terminated at a junction of upper and lower cod ends. In theory, shrimp would swim up through the large-mesh separator panel and lead back into the upper cod end, while flatfish and other bottom-dwelling invertebrates would not swim through the panel and would pass out through the lower cod end, which is not tied.

The Dutch began experiments with the French sorting trawl in 1964 to determine its utility for the Dutch shrimp fishery. In their tests, the French sorting trawl had a lower catch rate than the control trawl, a traditional Dutch trawl. Consequently, a funnel-like separator was incorporated. This net had higher catch rates than the French-designed trawl and the control trawl.

Pertinent BCF Observations on Animal Behavior

Observations on the behavior or inferred behavior of shrimp to shrimp trawls was limited to data accrued during exploratory surveys and incidental "in situ" observations.

• Distribution of shrimp in trawls and inferred behavior.

When being fished, both 400-mesh Eastern otter trawls and 57-foot semiballoon trawls have large areas of closed meshes due to unequal distribution of strain on the web. Trawls have often been retrieved with hundreds of shrimp trapped in the forward top and wing meshes. Shrimp encountering the closed meshes passed through or were forced into the webbing, where they became lodged.

BCF scientists aboard the minisub 'Pisces' observed pink shrimp during dives in Puget Sound, Washington. Individual shrimp were seen both on the bottom and occasionally well up into the water column. Shrimp generally moved slowly across the bottom unless disturbed by near contact with the Pisces' skids. On these occasions, the shrimp usually jumped 1 to 2 feet sideways or upward away from the skid. Unless disturbed again, the shrimp usually made no further rapid movements.

Divers have frequently watched "broken back" shrimp (genus <u>Spirontocaris</u>) in their natural habitat. These shrimp are usually found near or beneath bottom debris, and seldom dart away unless nearly or actually touched. When the disturbing object gently contacts a shrimp, it swims a few inches away. Divers have captured individuals by hand. On one occasion, hundreds of "broken back" shrimp were on the bottom near a submerged log. When divers moved through them, the shrimp jumped up to 2 feet off the bottom or sideways using several snapping motions.

• Observed fish behavior.

A primary consideration in developing a sorting trawl is the behavior of fish which are to be sorted. Scuba diving scientists have observed smelt (Osmeridae) and Pacific herring (Clupea harengus pallasi) many times within the influence of a trawl. In most instances, these fish oriented and swam with the trawl near the uppermost side and top web panels. Escape was usually attempted through the top of the trawl (High and Lusz, 1966). These fish appeared content to swim for long periods in the trawl without tiring or exhibiting distress. But when subjected to sudden diver motions, many fish would dart through upper meshes of the net.

Flounders, on the other hand, invariably swim downward seeking an escape route out of a bottom trawl and seldom rise more than 3 feet from the bottom at any time. Only a small space is necessary between the trawl footrope and ocean floor to allow great numbers of flounders to pass beneath the trawl footrope and escape.

Other near-bottom species, such as Pacific cod (Gadus macrocephalus), sablefish (Anoplopoma fimbria), spiny dogfish (Squalus acanthias), surf-perches (Embiotocidae), some species of rockfishes (Sebastodes spp.), lingcod (Ophiodon elongatus), and cabezon (Scorpaenichthys marmoratus) respond in a manner between the two extremes. Individuals of all these species have been observed escaping beneath a trawl footrope that was 6 to 12 inches off the bottom. Rarely do any rise more than 15 feet after coming within the trawl's influence in an effort to escape. Usually these species swim ahead of the footrope 2 to 5 feet off the bottom. When the footrope eventually passes beneath them, they turn toward either side of the trawl and, sometimes, rise several feet. All species observed, except smelt and herring, move quickly back to the trawl intermediate or cod end after being totally enclosed by web. Salmon (Oncorhynchus spp.) and halibut (Hippoglossus hippoglossus) are the only species observed that swam forward and escaped out of the trawl mouth after being more than about 15 feet aft of the footrope.

PRELIMINARY RESEARCH

Limited trials were made by the BCF Juneau Exploratory Fishing and Gear Research Base, and later by the Seattle Exploratory Fishing and Gear Research Base, to determine if the French-type separator trawl was effective in the North Pacific pink-shrimp fishery. Following these limited trials, which produced inconclusive but encouraging results, an intensive trawl net development program was begun by the Seattle Base. Results of Seattle's program to date are described below.

Model Separator Panel

Two small trawls, a Gulf-of-Mexico shrimp try net, and a one-quarter scale model 57-foot semiballoon trawl were built with horizontal separator panels of 3-inch web leading to upper and lower cod ends. After underwater observations, both trawls were modified. The separator panel was shortened, additional leaded line was attached, and aluminum trawl floats were tied on the trawl top panel to ensure space between the separator panel and the trawl top.

Both nets were tested in Port Susan, Washington, on sparse populations of pink shrimp. Although catches were low, only about 40 percent of the shrimp were in the upper bag of the model and try nets.

57-Foot Semiballoon Separator Trawl

From experience gained with the model trawls, a standard 57-foot semiballoon trawl then was modified with a separator panel and a second cod end. Unfortunately, tests with this modified trawl aboard the trawler 'Tradewind' on commercial shrimp grounds off central Oregon achieved poor separation of shrimp from trash. These results suggested the need for a different method of separating shrimp from trash in the Northwest shrimp fishery.

DEVELOPMENT OF SORTING CONCEPT

Before a successful separator trawl could be developed, it was necessary to further understand the underlying reaction of shrimp and fish to webbing. Therefore, an experimental cruise was conducted with our research vessel John N. Cobb off central Oregon. The primary purpose was to test shrimp trawls with experimental devices for separating shrimp from trash, and to determine behavior patterns of shrimp relating to their capture.

Several trawl configurations were tested. Each was a step toward determining shrimp reactions and providing a basis for future commercial trawl design. These various configurations were not intended to operate as commercial trawls.

Retaining Covers

As noted earlier, shrimp had been observed hanging partially through wing and top meshes of conventional bottom trawls and 57-foot semiballoon shrimp trawls when retrieved. Their presence indicated that some shrimp escape through the net and that the rate of escape might be very high in areas where the meshes are fully open. Therefore, in an attempt to determine the degree of escapement, small covers were placed over the trawl in strategic places.

Nine-foot square pieces of $\frac{3}{4}$-inch mesh web were laced at 5 locations to the outside of a 2-inch mesh 57-foot semiballoon shrimp trawl. Each piece covered a $4\frac{1}{2}$-foot square area, thus creating a pocket to hold shrimp that passed through the larger web. Fig. 1 shows the location of these covers.

In four 30-minute tows, considerably more shrimp were captured in the side covers than in the top covers. The average number of shrimp in each pocket was: position 1--31.2, position 2--14.2, position 3--66.0, position 4--6.8, and position 5--3.0. The trawl cod end contained an average of 75 pounds of shrimp and 210 pounds of fish.

The results indicate that the greatest escapement occurred near the intermediate. The lack of fish or other trash in any pocket suggests that marine animals other than shrimp may lead along the trawl web, did not contact the trawl in covered areas, or were too large to pass through the webbing.

Side Panel Covers

The purpose of the second experiment was to assess the total amount of escapement through the side panels.

A large panel of $\frac{3}{4}$-inch mesh web was attached outside each 2-inch mesh trawl side panel from the wingtip to cod end. The panels were laced along the seams in the forward part of the net and departed from the seams aft to retain a constant vertical size (Fig. 2). Near the intermediate, the panels nearly circumscribed the net. Shrimp passed through the trawl web and led aft along the small mesh external cover to special cod ends

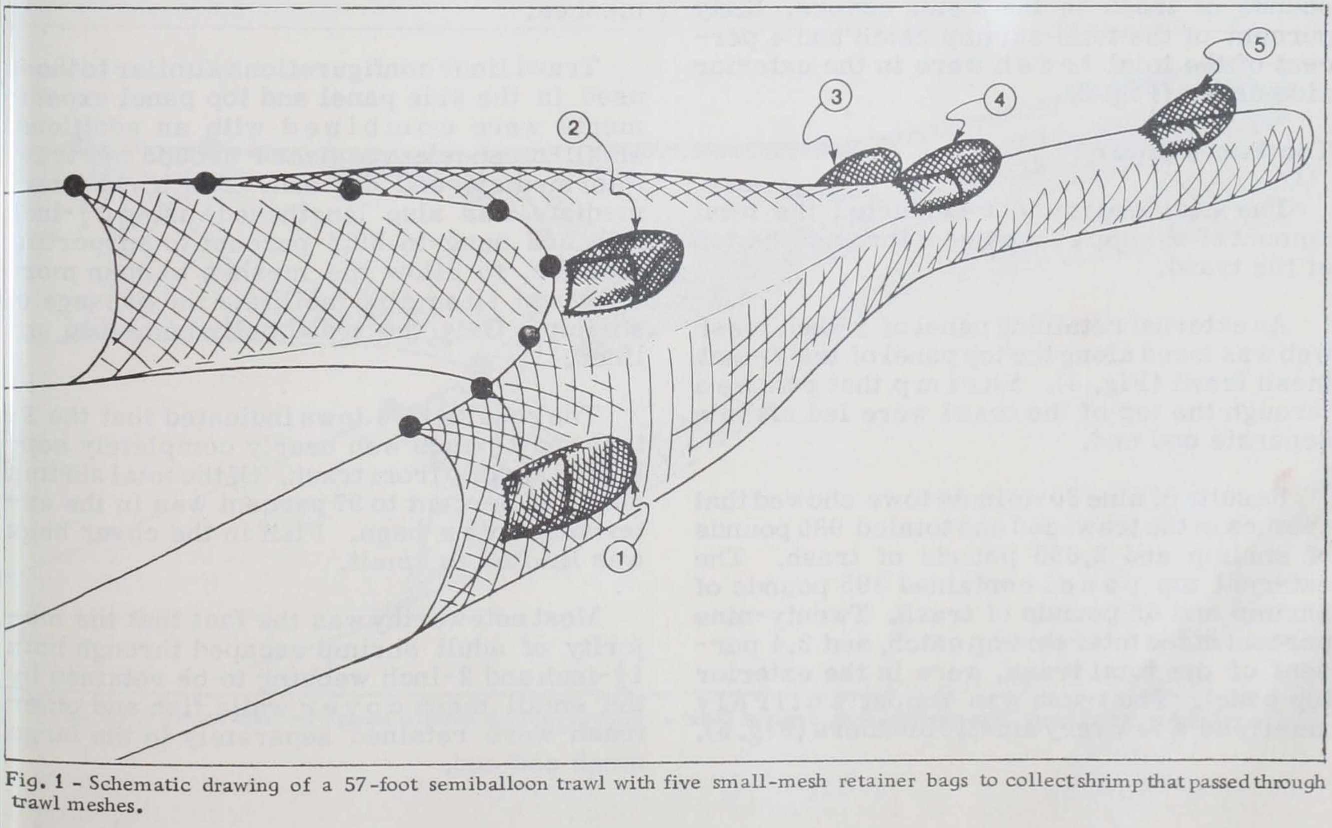

Fig. 1 - Schematic drawing of a 57-foot semiballoon trawl with five small-mesh retainer bags to collect shrimp that passed through trawl meshes.

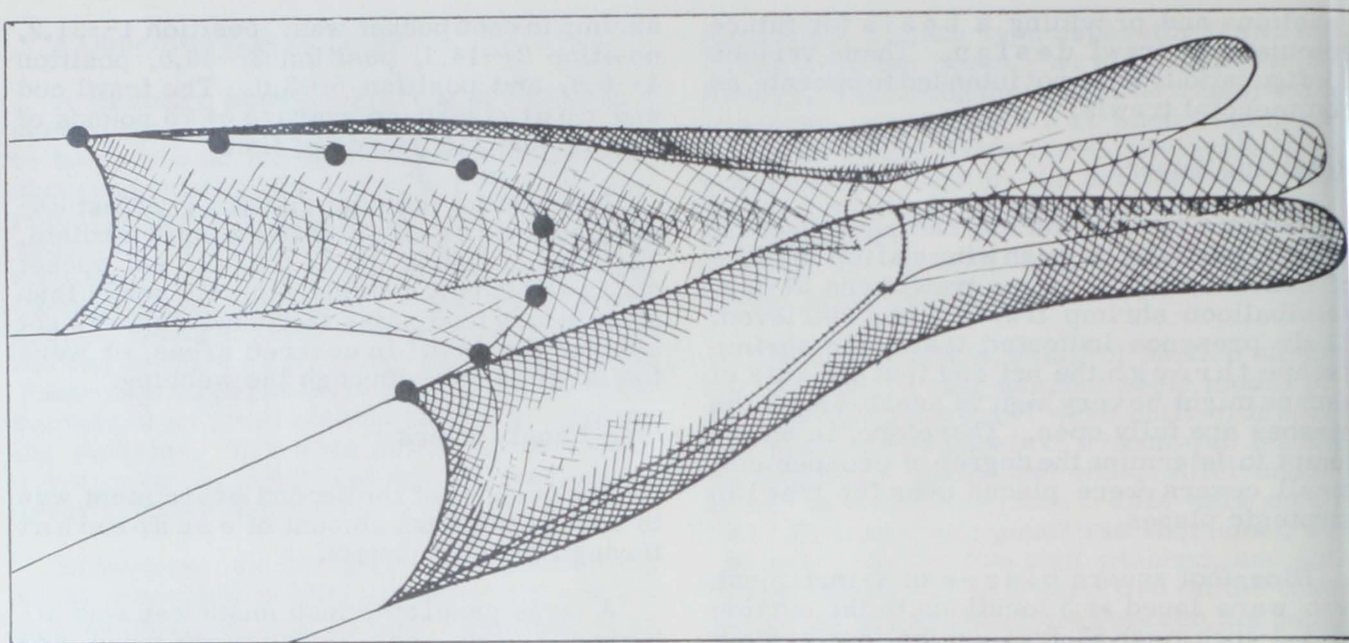

Fig. 2 - A 57-foot semiballoon trawl with exterior covers of $\frac{3}{4}$-inch web along the side panels terminating in individual cod ends.

terminating each cover panel. Organisms that did not pass through the 2-inch web were lead into the $1\frac{1}{2}$-inch mesh trawl cod end.

Six 30-minute tows produced 530 pounds of shrimp and 870 pounds of trash in the trawl cod end--and 805 pounds of shrimp and 35 pounds of trash in the 2 side covers. Sixty percent of the total shrimp catch and 4 percent of the total trash were in the exterior side cover (Fig. 3).

Top Panel Cover

The next experiment evaluated the total amount of shrimp escapement through the top of the trawl.

An external retaining panel of $\frac{3}{4}$-inch mesh web was laced along the top panel of the 2-inch mesh trawl (Fig. 4). Shrimp that passed through the top of the trawl were led aft to a separate cod end.

Results of nine 30-minute tows showed that catches in the trawl cod end totaled 980 pounds of shrimp and 2,655 pounds of trash. The external top panel contained 395 pounds of shrimp and 65 pounds of trash. Twenty-nine percent of the total shrimp catch, and 2.4 percent of the total trash, were in the exterior top panel. The trash was almost entirely smelt and a few very small flounders (Fig. 5).

Combined External Trawl Cover

Catches of nearly pure shrimp in the exterior covers were great enough to suggest this dual web concept as a means to separate shrimp from trash. Consequently, this experiment was designed to enclose all trawl meshes.

Trawl liner configurations similar to those used in the side panel and top panel experiments were combined with an additional small-mesh sleeve placed around the trawl intermediate and cod end. The trawl intermediate was also lengthened, using $1\frac{1}{2}$-inch web and hung-in 29.3 percent to supporting riblines, to allow the meshes to open more fully and thereby facilitate the passage of shrimp. Only the trawl belly remained unlined.

The results of 4 tows indicated that the 2-inch and $1\frac{1}{2}$-inch web nearly completely separated shrimp from trash. Of the total shrimp catch, 87 percent to 97 percent was in the external cover bags. Fish in the cover bags was limited to smelt.

Most noteworthy was the fact that the majority of adult shrimp escaped through both $1\frac{1}{2}$-inch and 2-inch webbing to be retained by the small mesh cover while fish and other trash were retained separately in the large mesh cod end.

Fig. 3 - The combined catch in two covers attached to trawl side panels made up 60 percent of the total shrimp catch. Note the many fish in the trawl cod end, whereas only a few smelt are scattered in the separated catches.

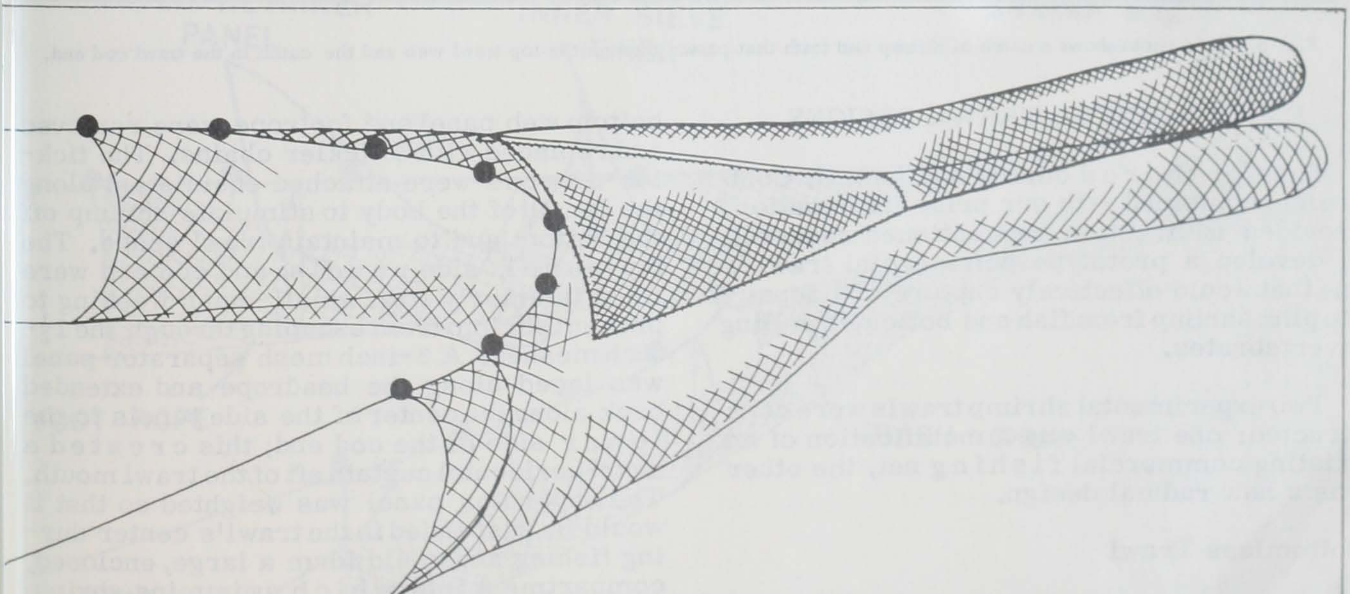

Fig. 4 - A $\frac{3}{4}$-inch mesh web panel covered the top portion of a trawl to retain shrimp that passed through the trawl web.

Fig. 5 - This photo shows a catch of shrimp and trash that passed through the top trawl web and the catch in the trawl cod end.

EXPERIMENTAL TRAWL DESIGNS

Data gathered during the John N. Cobb cruise, combined with our prior information, provided a direction for continued research to develop a prototype commercial trawl--one that would effectively capture and separate pink shrimp from fish and bottom-dwelling invertebrates.

Two experimental shrimp trawls were constructed: one trawl was a modification of an existing commercial fishing net, the other was a new radical design.

Bottomless Trawl

This trawl was designed to allow trash species to escape under the trawl, and to stimulate shrimp to pass upward through a large mesh separator panel into the cod end.

A 57-foot, conventional, semiballoon shrimp trawl was modified for testing. The bottom web panel and footrope were removed and replaced with 3 tickler chains. The tickler chains were attached equidistant along the length of the body to stimulate shrimp off the bottom and to maintain trawl shape. The top panel, side panels, and cod end were lined interiorly with small-mesh webbing to prevent shrimp from escaping through the $1\frac{1}{2}$-inch meshes. A 3-inch mesh separator panel was laced along the headrope and extended back along the center of the side panels to the lower side of the cod end; this created a near-horizontal curtain aft of the trawl mouth. The separator panel was weighted so that it would be suspended in the trawl's center during fishing and would form a large, enclosed, compartment into which swimming shrimp could enter easily. The lower section of each side panel served as a skirt to prevent shrimp from escaping horizontally. The bottom of each side panel was weighted to keep the trawl on bottom.

Fishing trials of the prototype bottomless trawl were conducted on shrimp grounds near Newport, Oregon. To test the efficiency of the experimental trawl, the John N. Cobb made 2 tows adjacent to a commercial trawler, the M/V 'Jaka-B,' which was using a conventional, 57-foot, semiballoon trawl. The comparative tows produced about the same amount of shrimp for each vessel. Owing to low availability of shrimp during the testing period, shrimp catches were very small; therefore, results were not conclusive. Further testing is planned.

BCF Shrimp-Sorting Trawl

In design this new trawl departs radically from conventional shrimp trawls. It has neither a top nor bottom panel but a double wall of webbing in the wings to separate shrimp from fish and bottom debris (Fig. 6). The inner panels of the double-walled wings are of meshes large enough for shrimp to pass through, and the outer panels are of meshes small enough to retain the sorted catch. Size of shrimp contained in the outer bag would naturally be governed by mesh size. Smelt and other fish that tend to swim upward could pass over the top of the new trawl.

Fish and debris that did not pass through the large meshes of the inner panel in the wings eventually pass through a trash chute out of the trawl unharmed. Because all shrimp were not expected to pass through the wing sieve web, the trash chute was constructed of large-mesh web, which would allow some of these shrimp to go into the retainer bag. Those shrimp that continued through the chute without passing through any meshes would eventually be captured in the trash bag, or deposited back onto the sea bed if the external portion of the chute was not closed.

After construction of the new trawl, diver observations determined that the overall configuration was adequate for testing.

Fishing Trials

Initial field trials of the BCF shrimp-sorting trawl were conducted on shrimp beds off Newport, Oregon. These were reported to have small-to-moderate amounts of shrimp but large amounts of trash fish and sea urchins. The John N. Cobb made 9 tows with the net. In every tow, the trash content of the separated shrimp catches was less than 3 percent by weight, and no sea urchins were

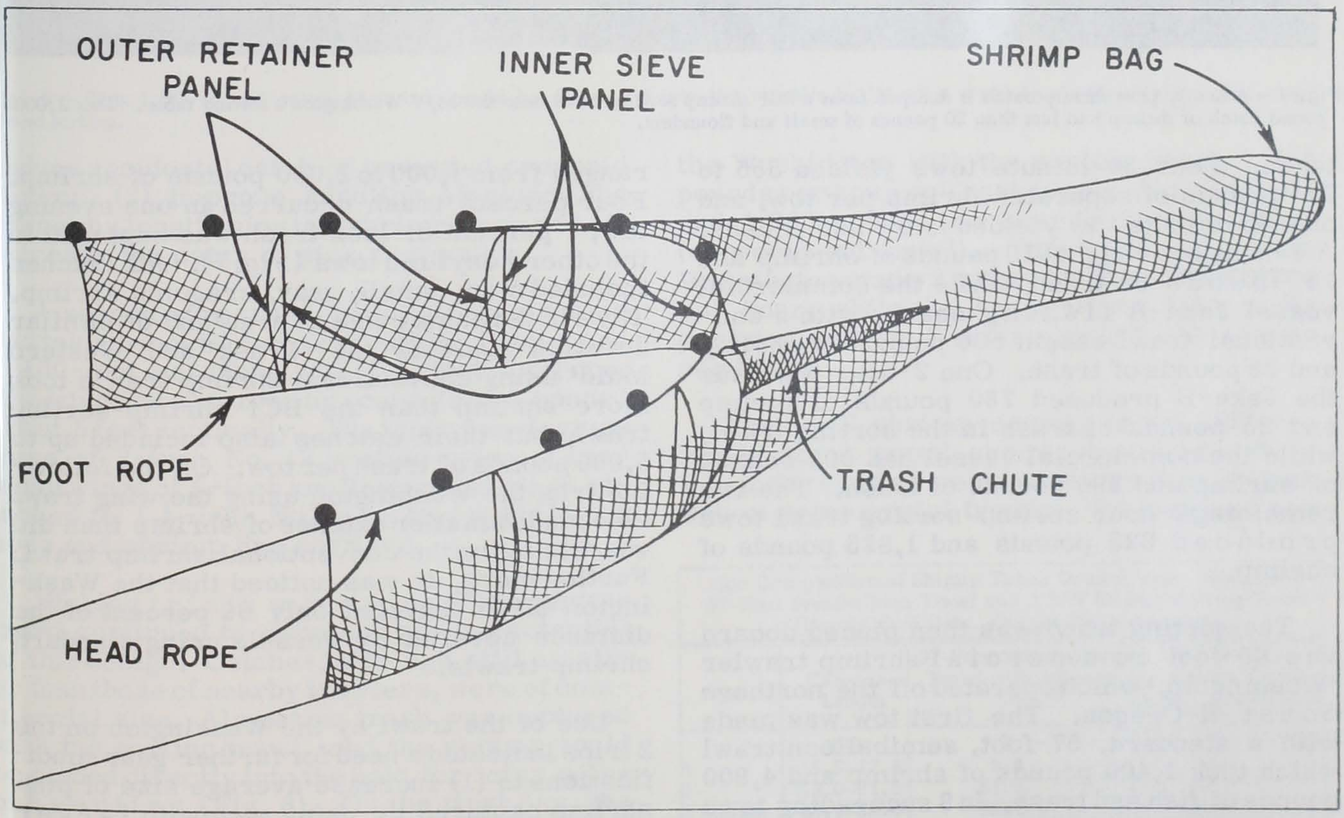

Fig. 6 - Schematic drawing of the BCF shrimp sorting trawl featuring long double panel wings and a short trash chute.

Fig. 7 - A nearly pure shrimp catch is dumped from a BCF shrimp sorting trawl onto the M/V Washington's sorting table. This 2,000-pound catch of shrimp had less than 20 pounds of smelt and flounders.

taken. Four 30-minute tows yielded 555 to 735 pounds of separated shrimp per tow, and one 30-minute tow yielded only 265 pounds. A 1-hour tow caught 610 pounds of shrimp and 15 pounds of trash, while the commercial vessel Jaka-B fishing nearby with a conventional trawl caught 500 pounds of shrimp and 55 pounds of trash. One 2-hour tow near the Jaka-B produced 780 pounds of shrimp and 25 pounds of trash in the sorting trawl, while the commercial vessel had 800 pounds of shrimp and 390 pounds of trash. The two remaining 2-hour shrimp-sorting trawl tows produced 625 pounds and 1,825 pounds of shrimp.

The sorting trawl was then placed aboard the 65-foot commercial shrimp trawler 'Washington,' which operated off the northern coast of Oregon. The first tow was made with a standard, 57-foot, semiballoon trawl which took 1,400 pounds of shrimp and 4,900 pounds of fish and trash. In 8 succeeding tows with the BCF shrimp-sorting trawl, catches ranged from 1,000 to 2,000 pounds of shrimp. Four percent trash occurred in one evening tow; 1 percent or less trash was captured in the other 7 daytime tows (Fig. 7). All catches included many small, gray, cragonid shrimp. Tows in the same general area and of similar duration made by the 'Trask' and 'Western Maid' using conventional shrimp trawls took more shrimp than the BCF shrimp-sorting trawl, but their catches also included up to 5,000 pounds of trash per tow. On the following trip, the Washington using the wing trawl also made smaller catches of shrimp than did vessels using the conventional shrimp trawl. Furthermore, it was noticed that the Washington often traveled only 60 percent of the distance covered by vessels using standard shrimp trawls.

Use of the trawl by the Washington on the 2 trips indicated a need for further gear modifications to (1) increase average size of pink shrimp captured by using web with larger meshes in the inner and outer panels, (2)

Fig. 8 - This 1,500-pound catch of shrimp could be dumped into the vessel's hold after washing without time-consuming hand sorting.

reduce incidental catch of unwanted cragonid shrimp, (3) improve handling alongside the vessel by lengthening the shrimp bag, and (4) increase the catch of pink shrimp.

A second wing trawl was then constructed and tested aboard the Washington. It also had a 100-foot headrope and 106-foot footrope. The wings as observed by scuba divers opened about 5 feet vertically. The inner panel wings were of 2-inch No. 12 knotted nylon. Outer panel wings of $\frac{7}{8}$-inch knotless nylon were attached to $1\frac{1}{16}$-inch No. 18 knotted nylon in the body and shrimp bag sections.

Fishing trials with the modified sorting trawl continued to demonstrate the potential of this design. Catches, although still smaller than those of nearby trawlers, were of commercial size. Almost no trash was captured with the sorting trawl, and the shrimp could be placed directly into the hold for icing without sorting (Fig. 8). On the first day, the catch rates were 1,460 pounds per hour by the Washington with the sorting trawl, 1,380 pounds per hour by Trask (conventional trawl), and 1,285 pounds per hour by Western Maid (conventional trawl). The following day the Washington made 2 tows and took 805 pounds per hour, while the Trask took 2,380 pounds per hour, and the Western Maid 2,100 pounds per hour.

The BCF shrimp-sorting trawl still retained some small shrimp because of its $1\frac{1}{16}$-inch retainer web as compared to $1\frac{1}{2}$-inch web of commercial trawls. Table shows age

Age Composition of Shrimp Taken October 8-9, 1968, in A 57-Foot Semiballoon Trawl and A BCF Shrimp-Sorting Trawl (Unpublished Data, Oregon Fish Commission)

Age	Carpace Length	57-Foot Semiballoon Trawl with $1\frac{1}{2}$-Inch Web	BCF Shrimp-Sorting Trawl with $1\frac{1}{16}$-Inch Web
	mm.	%	%
1	15.5-17.5	3.5	7.0
2	18.0-21.5	61.3	62.2
3 & older	22.0-25.0	35.1	30.8

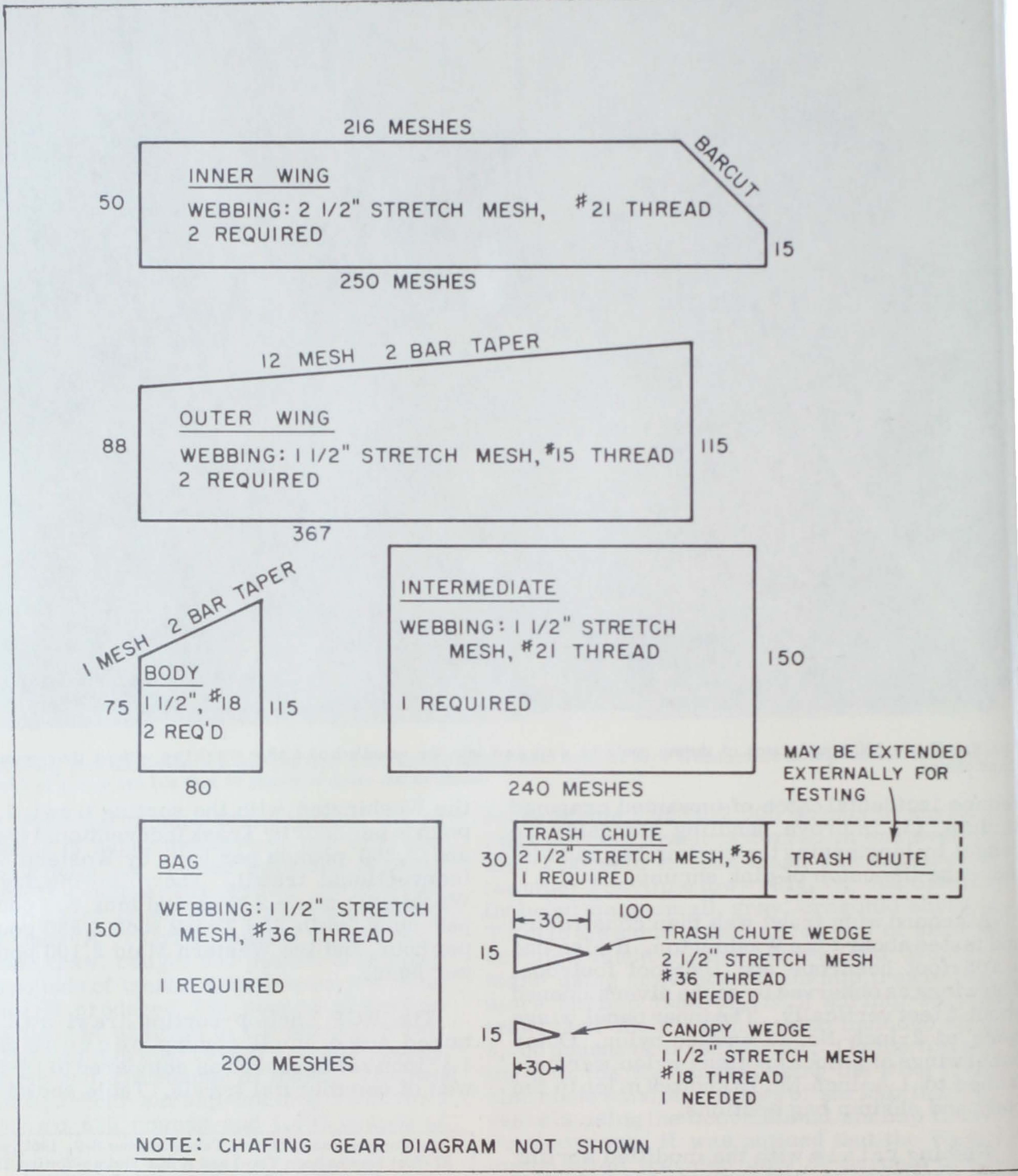

Fig. 9 - Sample cutting diagram for BCF shrimp sorting trawl.

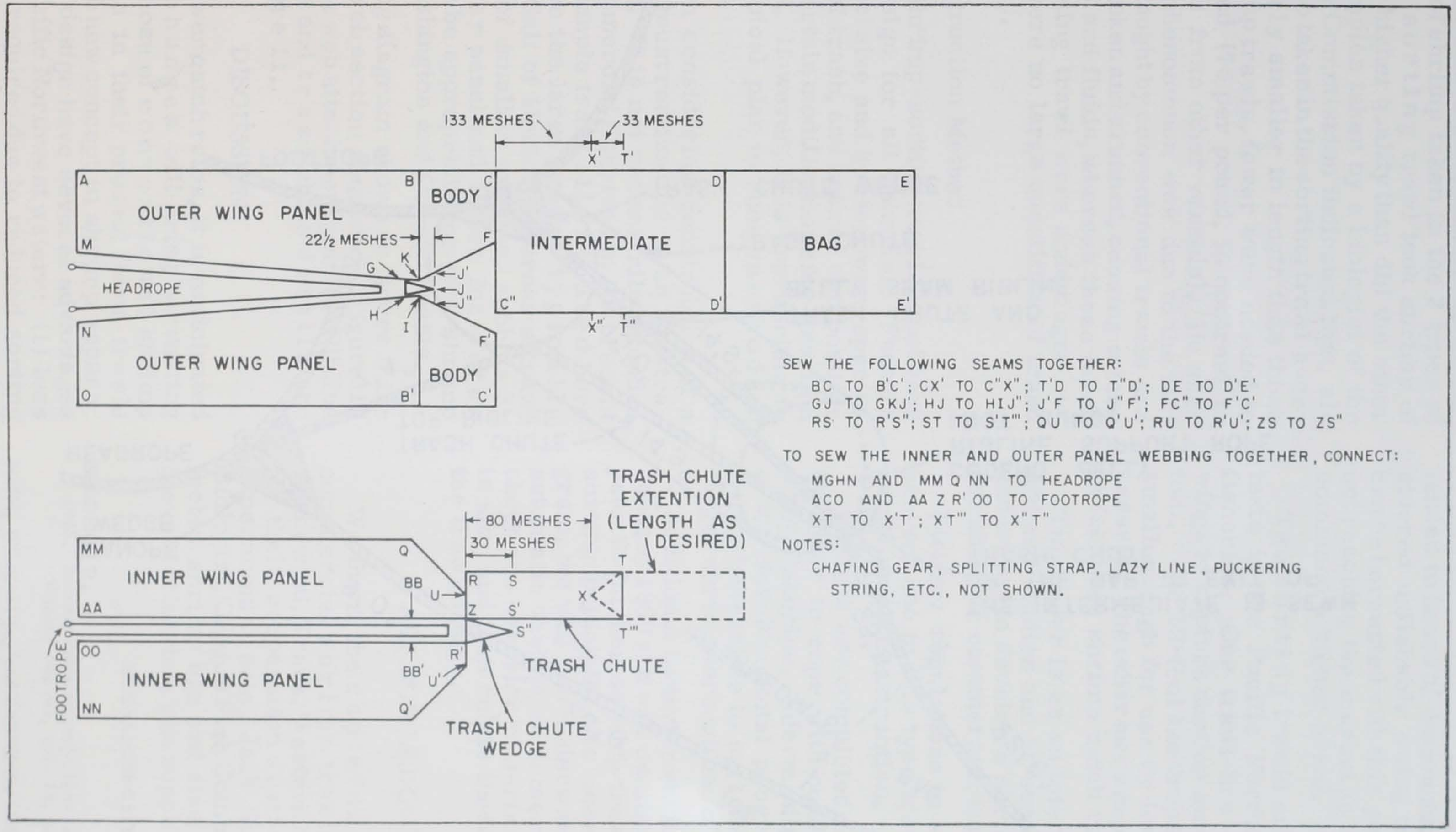

Fig. 10 - Sample construction plans for BCF shrimp sorting trawl.

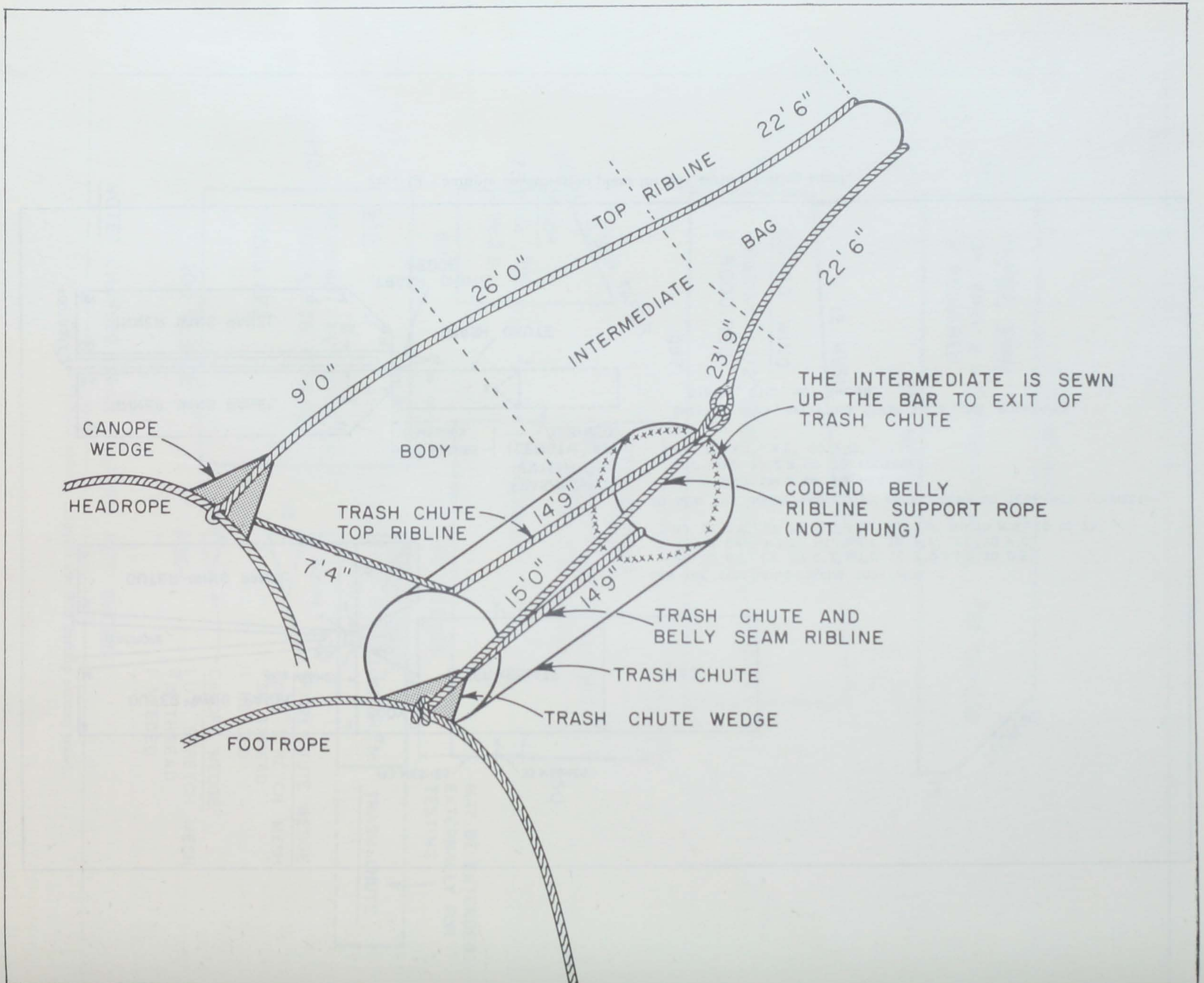

Fig. 11 - Details of ribline and trash chute for the BCF shrimp sorting trawl.

composition of shrimp taken in the 2 types of trawls. The sorting trawl took shrimp of considerably higher quality than did the other vessels. Samples taken by a biologist of the Oregon Fish Commission indicated that, although shrimp taken in the sorting trawl averaged slightly smaller in length than those taken in shrimp trawls, fewer were needed to weigh a pound (75 per pound, in contrast to 81 per pound from other vessels). He suggested this phenomenon was due to the fact that shrimp caught by conventional trawls are frequently broken and crushed, causing a loss of body parts and fluids, whereas those taken with the sorting trawl were undamaged because there were no large quantities of trash in the cod end.

Sample Construction Method

The BCF shrimp-sorting trawl cannot have the same design for all fisheries. Factors such as vessel size and horsepower, species fished, type of trash, and bottom composition will dictate certain modifications for greatest efficiency. However, it is appropriate to present a typical plan to show methods of construction.

Fishermen considering construction of a sorting trawl must realize this is an illustrative design. It is not necessarily intended for use in commercial fisheries in its present form. The sample trawl illustrated here might apply to the large prawns typically found in the Gulf of Mexico, whereas a trawl constructed of smaller meshes, such as 2-inch for inner panel and 1-inch for outer panel, would be appropriate for pink shrimp along the Washington and Oregon coasts.

The cutting diagram shown in figure 9 includes each web section required. Figure 10 illustrates the web attachment points. Ribline configuration and trash chute details are shown in figure 11.

DISCUSSION

Despite lower catch rates, it is anticipated that design changes will bring harvesting rates up to those of conventional shrimp trawls. Even in their present form, trawls employing the new concept in shrimp separation in their design have several advantages for use in Pacific Northwest waters: (1) less manpower is required due to reduced sorting time, (2) fishing time is not lost to sorting shrimp from trash, and fishing may be extended to hours of darkness, (3) grounds considered unfishable owing to excessive trash can be harvested with this gear, and (4) product reaching the market is superior and may command a higher price.

Two sorting trawls are now undergoing tests in the Pacific Northwest pink-shrimp fisheries. One trawl has somewhat higher wings to capture shrimp several feet off bottom. The 50-foot headrope makes the trawl small enough for use by low-horsepower vessels. The other has a modified trash chute to increase shrimp catch rates.

This paper is as an interim report. Additional studies and at-sea fishing trials are underway to develop a shrimp-sorting trawl suitable for commercial fishing.

Fishery regulations in some regions now prevent use of this type trawl because of the small-mesh construction.

Designs are completed for sorting trawls modified to cope with conditions existing in other fisheries. Information gained thus far in the developmental program suggests that it may be feasible to sort small shrimp from larger shrimp through use of multiple sieving.

Additional behavior studies were begun in January 1969 and will continue throughout the year to further develop trawls using the new sorting principle. To accelerate this program, we will use underwater television and automatic deepwater cameras to learn more about the behavior of shrimp to fishing gear in situ, and then relate these observations to the trawl design.

ACKNOWLEDGMENTS

We thank the captains and crews of the commercial shrimp trawlers, Washington, Tradewind, Trask, Western Maid, and Jaka-B for their cooperation during field trials of experimental nets; Jack Robinson, Fishery Biologist, Oregon Fish Commission, who collected shrimp age and size information; and Steve Marinovich, who supplied model trawls.

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