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FREEZING FISH AT SEA--NEW ENGLAND

Part 9 - Improvements in the Brine - Freezing Mechanism on the Trawler Delaware

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ABSTRACT

The original experimental freezer that was used on the U. S. Fish and Wildlife Service's research trawler Delaware demonstrated the feasibility of freezing fish in brine on a fishing vessel and provided data and experience that proved valuable in designing a new freezer that is more practical for use in the New England trawl fishery.

This new freezer consists essentially of a deep rectangular tank in which the fish are carried through refrigerated brine in large cylindrical baskets mounted on an endless-chain conveyor. The freezer is rugged, yet simple in design and easy to repair; and it permits loading and unloading on deck. Because the fish that are unloaded from the freezer can be dropped into the frozen-storage hold through hatches located on deck adjacent to the freezer, the fishermen need spend only a minimum of time in the hold when storing the fish.

The design of the new freezer is described in detail.

INTRODUCTION

Freezing fish at sea holds promise of certain economic and technological advantages over the time-honored icing method for preserving the catch aboard fishing vessels. Principal among these potential advantages are the following:

Fig. 1 - View showing location of fish charging and discharging portion of the brine-freezer tank.

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(a) Catching fish on more distant grounds.

(b) Landing fish of high and uniform quality.

(c) Landing capacity loads.

(d) Leveling out supplies of raw material for the processing plant through frozen storage.

Freezing at sea is not new, having been practiced successfully, for example, by the West Coast tuna fishery for many years. However, introducing the practice to another fishery--in this case the New England fishery--requires the development of new equipment and procedures to suit the particular conditions encountered.

One of the principal objectives of the freezing-fish-at-sea project at the Boston Technological Laboratory of the U. S. Fish and Wildlife Service is to develop equipment for handling, freezing, and storing fish which can be readily installed on existing New England trawlers. This approach to the problem has been taken in order that heavy capital expenditures for extensive alterations or new vessel construction may be avoided and that the average annual payloads of the existing vessels may be increased.

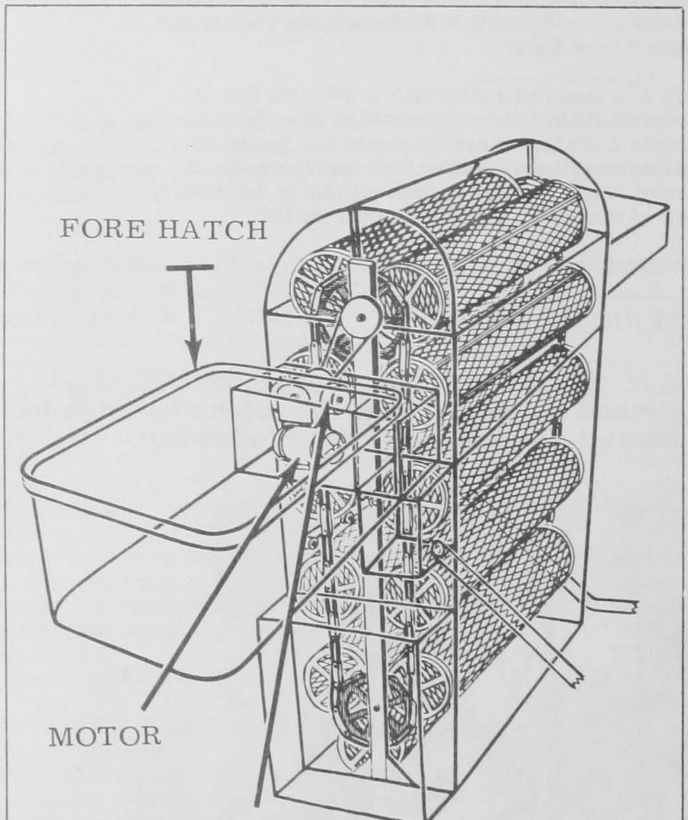

Fig. 2 - Arrangement of perforated containers of freezing mechanism.

Since the processing of raw material into a finished product aboard ship is not involved, the freezer-equipped trawler should not be classed as a factoryship. Rather, fitted with freezing and storage facilities, the trawler would be enabled to land full loads of uniformly high-quality raw material for processing (thawing, filleting, and refreezing of the fillets) in shore plants.

The purpose of this report is to outline briefly the earlier work on the project, and then to describe in more detail the recent progress in the development of equipment aboard the Service's experimental freezing trawler Delaware.

PRELIMINARY INVESTIGATION

Experiments conducted in 1948 (Hartshorne and Puncochar 1952) indicated that frozen fillets of good quality can be produced from haddock frozen in-the-round at sea. The refreezing of these fillets was found not to be deleterious, as is traditionally believed, provided the fish were frozen when fresh-caught and that normally good commercial practices were followed when the frozen fish were thawed and filleted and the fillets were refrozen.

These results led to further experiments (Magnusson, Pottinger, and Hartshorne 1952) designed to explore, on a pilot-plant scale, methods of freezing fish at sea and of thawing, filleting, and refreezing the fillets ashore. In these studies, technological, economic, and engineering aspects of the problems were all considered in order that the outcome might form a basis for commercial scale experimental development and eventually lead to successful commercial operations.

Of the freezing methods studied, immersing the fish in refrigerated brine appeared the most promising and was therefore chosen for the commercial-scale experiments. The chief favorable features of brine freezing are that it is fast and that the equipment is compact, simple, and rugged.

Of several thawing methods investigated, immersing the frozen fish in circulating fresh water appeared best, and this method was developed through the pilot-plant stage (Magnusson and Hartshorne 1952).

THE TRAWLER DELAWARE

Data obtained in the pilot-plant experiments with a small-scale brine freezer were used as a basis for the design of a commercial-scale freezer for a fishing vessel. The next step was the acquisition, reconditioning, and equipping, in early 1951, of the trawler Delaware. The 148-foot steel trawler, which had been in commercial operation for several years, was among the larger vessels of the New England fishing fleet. Alterations to the hold and the installation of the refrigeration machinery and an experimental freezer have been described fully in this series of reports (Butler, Puncochar, and Knake 1952; Oldershaw 1953). Briefly, this consisted of installing a 25-ton absorption refrigeration machine in the aftermost pen section of the original fish hold, installing a brine freezer, and dividing the hold into two refrigerated rooms (for 0° F. storage of frozen fish) and one insulated pen section for the storage of iced-gutted fish. This hold arrangement facilitates the comparison of brine-frozen fish with iced-gutted fish from the same catches and also provides several storage areas for separating experimental lots of frozen fish.

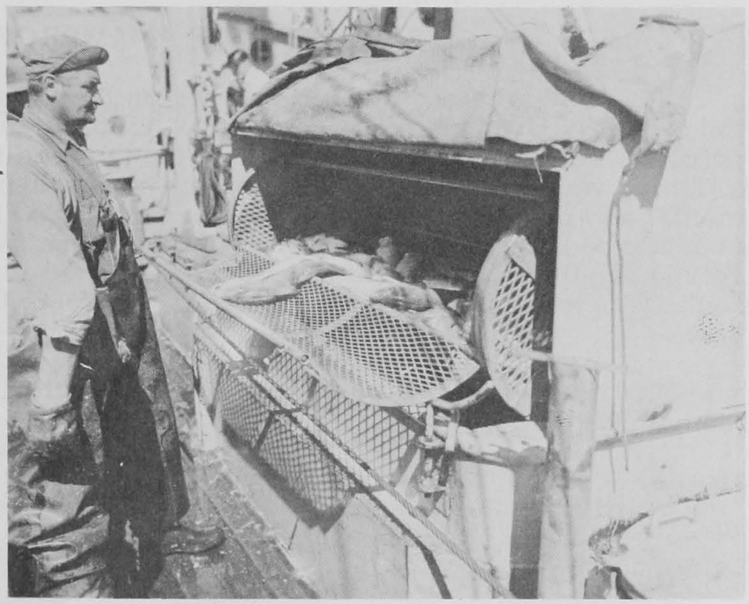

Fig. 3 - Panel of basket is swung open for loading or unloading fish.

REFRIGERATED HOLDS: The two 0° F. cold-storage holds are refrigerated by a secondary refrigerant (a solution of ethanol), chilled by a 5-ton shell-and-tube flooded-type cooler. This solution is circulated through a total of 3,900 linear feet of $1\frac{1}{4}$-inch iron pipe coils mounted on deckheads, bulkheads, and sides of the holds. The original hold insulation of 4 inches of cork, lined with $1\frac{1}{2}$-inch tongue-and-groove sheathing, was considered adequate for the experimental purposes of the Delaware.

FIRST EXPERIMENTAL FREEZER: The first experimental freezer on the Delaware was located amidships in the after-refrigerated hold. It consisted of a rectangular steel tank that contained the refrigerated brine. Mounted on a horizontal drive shaft in the tank was an expanded metal drum divided into 12 equal segments fitted with hinged covers. Each segment had a capacity of about 250 pounds of fish. The brine was pumped through a shell-and-tube cooler, circulated through the freezer, and then returned through a strainer to the cooler. Except during experiments in which other freezing solutions were being tested, the brine was 22-percent by weight sodium-chloride solution. The freezer was designed to operate at a temperature between 2° and 5° F.

REFRIGERATION MACHINE: The 25-ton ammonia-absorption refrigeration machine was installed to handle both the freezing and the cold-storage loads. To supply steam to the refrigeration machine as well as to heat the vessel, the original 5-hp. boiler located in the engineroom was replaced with a 30-hp. boiler, with no appreciable loss of usable engineroom space. Since the boiler is fired with Diesel oil and the vessel has more than adequate fuel capacity for normal trips, no additional fuel tanks were required.

As a safety measure, the refrigeration machinery, including the 20-ton brine cooler and the 5-ton ethanol-solution cooler, was confined in a watertight compartment equipped with spray nozzles, a sump, and an overboard discharge pump. In case of a serious ammonia leak, the compartment can thus be flooded and then pumped out.

DEVELOPMENT OF AN IMPROVED FREEZER

The original experimental freezer on the Delaware was used extensively during the operating seasons of 1951 and 1952. During that time the machine fulfilled its principal requirements of demonstrating the feasibility of freezing fish in brine on a fishing vessel, supplying the samples of round-frozen fish for laboratory experiments, and providing data and experience upon which the design of an improved freezer could be based. Its chief shortcomings were its inconvenient location within the refrigerated hold and the difficulty encountered in handling the fish from the deck to the freezer and then in discharging them from the freezer into the cold-storage pens.

The following were considered necessary features to be incorporated into the design of a new freezer:

(a) Permit loading and unloading from either side of the deck. (Fish unloaded from the freezer could then be dropped into the cold-storage hold through adjacent hatches.)

(b) Have capacity to handle anticipated normal catches, plus an appreciable overload.

(c) Occupy the least possible deck space and in no way interfere with normal operation of deck gear.

(d) Agitate the fish sufficiently to prevent their sticking together and to promote rapid freezing.

(e) Provide for draining excess brine from the fish before they are discharged into the hold.

(f) Be simple in design, rugged, and easy to repair.

(g) Provide for continuous straining of the brine, with easy access to the strainer for cleaning on deck.

Of several proposed freezers considered, the one judged to be the most satisfactory consisted of a deep rectangular brine tank, extending above deck, in which the fish would be carried through the brine in large cylindrical baskets mounted on an endless chain conveyor.

In the development of this new freezer, it was decided to proceed directly to the full-scale installation on the vessel rather than to undertake small-scale studies in the shore pilot plant. Since the practicability of brine freezing at sea has already been established, the new freezer was regarded as a step in the development of equipment rather than a new development in itself. Furthermore, the machine could undergo realistic tests only at sea under actual operating conditions. The following is a description of the new freezer, which was installed on the Delaware just prior to the 1953 summer operating season.

BRINE TANK: The rectangular brine-freezer tank, approximately 8 feet long by 5 feet wide by 14 feet deep, is situated lengthwise on the centerline of the vessel between the aft and mid-fish hatches (fig. 1). It extends upward from the bottom of the frozen-storage hold to a height of about 30 inches above deck. The tank was constructed by removing the top from the original brine tank and extending the sides upward through a 5- by 8-foot opening cut in the deck. Fabricated of half-inch steel plate reinforced by vertical 7-inch by 4-inch by $\frac{7}{16}$-inch angles on approximately 2-foot centers, the tank is welded to the deck plate and adjacent hold stanchions.

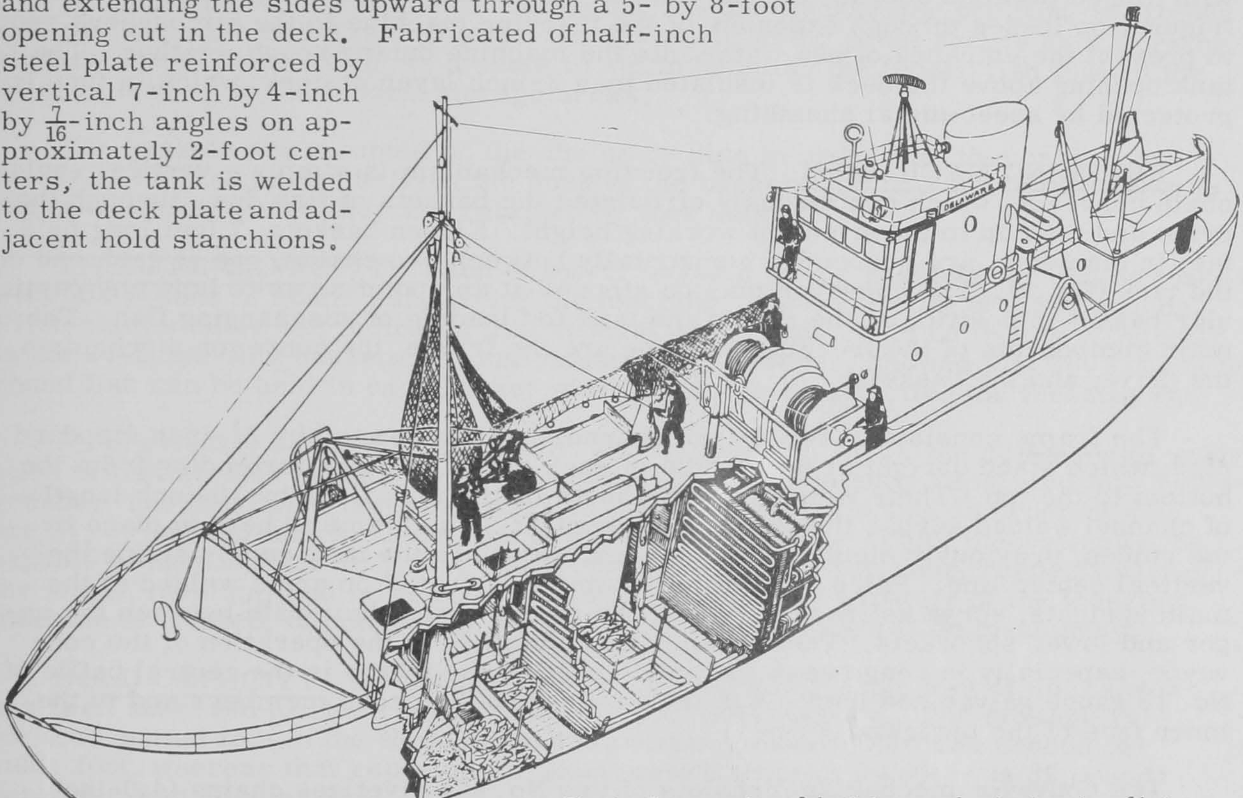

Fig. 4 - Cutaway view of the Delaware showing location of brine-freezing tank and both iced and frozen fish storage bins.

It is thus a watertight integral part of the ship's structure. Filled to a depth of about 10 feet, the tank has a capacity of about 35,000 pounds of sodium-chloride brine.

Four 2-inch inlet ports, located on the starboard side of the tank about one foot below the deck, feed the refrigerated brine at 120 gallons per minute from a 3-inch header. The brine is forced to flow downward on the starboard side and upward on the port side by a vertical baffle attached to the conveyor frame in the center of the tank.

An overflow chamber, approximately 18 inches square, extending from 2 feet above deck to $3\frac{1}{2}$ feet below it, is welded to the forward end of the tank near the port side. The chamber contains a removable strainer basket 12 inches in diameter by 16 inches deep, which is made accessible from the deck through a hinged cover atop the chamber. The brine flows into the chamber through a 18- by 8-inch opening cut in the tank wall and, after passing through the strainer, returns to the brine-circulating pump through a 4-inch return line. This centrifugal pump, driven by a 2-hp. motor, is located in the refrigeration machinery compartment at an elevation of approximately 5 feet below the liquid level in the brine tank. It pumps the brine first through the shell-and-tube brine cooler, which is also located in the refrigeration machinery compartment, then out to the freezing tank, to complete the brine circuit.

The tank may be pumped out by opening the valve in a 3-inch line running from the bottom of the tank to the brine return line. The brine is then discharged overboard through a line connecting with the refrigeration plant cooling-water system.

Other tank accessories include a 22- by 16-inch removable inspection plate on the lower aft end, a 2-inch drain plug, two sets of $1\frac{1}{2}$- by $1\frac{1}{2}$-inch angle guides to receive the conveyor frame, and a removable hoodlike cover. The cover, shown in figure 1, has $\frac{1}{4}$-inch steel plate semi-circular ends to which is welded a No. 14 gauge, sheet-steel hood. The hood envelopes only the upper portion, leaving a full length, 24-inch-wide opening on each side for the loading and the discharging of the fish. The openings, formerly protected by drop curtains of heavy canvas, are now fitted with hinged plywood doors. The purpose of the cover is to prevent excessive refrigeration losses through exposure of the freezing machine to the atmosphere and to prevent the entrance of sea water into the machine during rough weather. The tank opening above the deck is insulated by a 3-inch layer of cork, which in turn is protected by sheet-metal sheathing.

FREEZING MECHANISM: The freezing mechanism is simply a vertical endless-chain conveyor, which continuously circulates the baskets of fish down through the brine and then up to a convenient working height. Eleven baskets, 7 feet long by 2 feet in diameter, are suspended horizontally between two chains, one at each end of the tank (fig. 2). The conveyor may be stopped at any point so as to hold any particular basket in position at the rim of the tank for loading or discharging fish. The main components of the freezing machine are the frame, the conveyor mechanism, the drive, and the baskets.

The frame consists of two 6-inch channels, cross-braced by $2\frac{1}{2}$-inch standard pipe, which stand upright at the middle of each end of the tank, extending from the bottom to the top. Their weight is distributed on the tank floor by 18-inch lengths of channel welded across the foot of each upright. The frame is held in place by the guides, previously mentioned, which are welded to the tank ends, astride the vertical center line. Pairs of parallel channels, mounted on arms welded to the main uprights, serve as tracks to guide the chains along their path between the upper and lower sprockets. These guides lend stability to the operation of the conveyor, especially in rough seas. Also attached to the frame is the central baffle of No. 16 gauge galvanized iron. It is tack-welded to the cross members and to the inner face of the uprights.

The conveyor mechanism consists of two No. 458 rivetless chains (4.0-inch pitch) running on pairs of sprockets 30.65 inches in diameter. The upper drive shaft, $2\frac{7}{16}$ inches in diameter, rides in split babbitted pillow blocks bolted to the top of the frame; the lower $1\frac{1}{2}$-inch idler shaft rides in rubber bearings mounted on spring-loaded takeup assemblies, which move in slots cut in the web of the 6-inch channels.

The drive is housed in a $\frac{1}{4}$-inch steel enclosure at the forward end of the tank, adjacent to the overflow chamber, above deck. A 2-hp., 115V, DC motor drives the conveyor at $3\frac{3}{4}$ r.p.m. through a worm-gear reducer and chain drive. The $3\frac{3}{4}$ r.p.m. of the sprockets imparts a linear speed of 30 f.p.m. to the chains; thus the $29\frac{1}{3}$-foot chains, carrying 11 equally-spaced baskets, make a complete cycle in about 1 minute. The motor is controlled by a reversing switch, accessible from either side of the tank at the forward end. The normal direction of travel, looking forward, is counterclockwise in order that the baskets will be carried downward on the port side and upward on the starboard, against the direction of the circulating brine. The drive is controlled by a reversing switch for convenience in positioning the baskets for loading and discharging.

The cylindrical baskets, 2 feet in diameter by 7 feet long, were fabricated of No. 9 gauge flattened $\frac{3}{4}$-inch expanded metal, preformed into cylinders by rolling, then welded to rigid frames. The ends of the frames were constructed of $1\frac{1}{4}$- x $1\frac{1}{4}$- x $\frac{3}{16}$-inch angle rolled to a diameter of 2 feet and strengthened by four $\frac{1}{4}$- x 2-inch flat steel spokes. The ends were then joined by 7-foot lengths of $\frac{3}{4}$-inch pipe spaced around the perimeter. For loading and discharging, each basket is fitted with a full-length, 20-inch-wide panel of expanded metal, rolled to form a section of the basket wall. In order that these panels could be swung outward and downward when the baskets were positioned on either the port or the starboard side of the tank, it was necessary to attach them to the basket frames by a combination hinge and latch. These fittings, which are similar to a common door bolt, were incorporated into the $\frac{3}{4}$-inch pipe frames of the panels. When extended the bolts act as hinge pins; when retracted they disengage the panel on one side, permitting it to swing out.

When the panel of a basket is swung open in the discharging position, it extends out over the edge of the tank (fig. 3). In this position the panel serves as a working surface and to some extent as a chute to aid in handling the frozen fish toward the hatches leading to the frozen-storage areas.

The baskets are mounted on the chains by pins in order that they may rotate freely. The pins protrude from the hubs of the baskets and fit loosely into holes in the chain links, where they are retained by lock nuts.

FREEZER CAPACITY: Each of the 11 baskets on the new freezer can be loaded with 500 pounds of round fish, giving the machine a total capacity of 5,500 pounds. Pilot-plant studies had indicated that at least 400 pounds could be frozen efficiently in the 20-cubic-foot baskets. Actual experience, however, showed that 500 pounds of round fish can be held in each basket without materially affecting the freezing rate.

As previously reported (Magnusson and Hartshorne 1952), the commercial varieties of fish studied in the current project may be conveniently separated into 3 size-groups. The maximum freezing times in the refrigerated brine, in order of size, are $1\frac{1}{2}$, 3, and 4-5 hours. Thus, the new freezing machine would, theoretically, be capable of handling 3,660, 1,830, and 1,100-1,370 pounds per hour, respectively, of the small, medium, and large fish. The actual sustained capacity of the freezing machine is limited, of course, by the capacity of the refrigeration machinery.

HOLD CAPACITY: A stowage rate of 33 pounds per cubic foot of hold space has been observed for the round-frozen fish on the Delaware. The stowage rate for iced-gutted fish in the New England trawlers is usually 45 to 50 pounds per cubic foot, whereas that reported for Northwest European trawlers is 32 pounds per cubic foot (Eddie 1953).

As now fitted for experimental freezing at sea, the Delaware has a cold-storage capacity of about 125,000 pounds of round-frozen fish. In addition, about 15,000 pounds of iced-gutted fish can be carried in the forward compartment (fig. 4).

Were the Delaware to be fitted for commercial rather than experimental operation, consideration could be given to relocating the refrigeration machinery in the main engine room in order to make more hold space available for refrigerated storage. By the employment of all of the original seven pen sections of the hold for refrigerated storage, the capacity would rise to an estimated 200,000 pounds of round-frozen fish. If 15 percent is deducted to compensate for the weight of the viscera in the frozen fish, this capacity would be equivalent to 170,000 pounds of iced-gutted fish. A survey shows that in 1953, for example, 5 New England trawlers, similar in gross tonnage to the Delaware, landed an average of 115,000 pounds per trip. Their landings exceeded 170,000 pounds in somewhat less than 10 percent of the trips and, in these instances, averaged about 200,000 pounds.

Owing to the peculiarities of the Delaware's hull design, its hold is considered proportionately smaller than are the holds of other similarly-sized trawlers. Were a more typical 148-foot trawler to be equipped to freeze fish at sea, the capacity to store frozen fish would likely be greater than the 200,000 pounds estimated for the Delaware.

ACKNOWLEDGMENT

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WHEN WAS THE TRAWL NET INVENTED?

In common with other methods of fishing, no specific date can be assigned to when the method of fishing called trawling was first invented or used. A sketch of a net similar in many respects to a modern trawl was found on the back of an official document of about the sixteenth century, in Europe. No other information is available on this net. Trawling in the modern sense started at about 1880 in Europe with the introduction of steam propulsion for fishing vessels. The gear used today is basically similar to the gear used at the end of the last century, although many refinements have been added. Trawling is now one of the most important methods of commercial fishing. This method, involving the use of a flattened conical net dragged over sea floor and in the middle waters, should not be confused with trolling, in which a hook and line is dragged behind a moving boat. Unfortunately, the term line trawling is also used for the method of fishing which uses a series of baited hooks, which either lie on the bottom or are suspended in midwater. This method is more properly called long-line fishing.

--Sea Secrets, May 31, 1955
The Marine Laboratory, University of Miami,
Coral Gables, Fla.