OBSERVATIONS ON TRAWL-DOOR SPREAD AND A DISCUSSION OF INFLUENCING FACTORS

By Fredrick Wathne*

SUMMARY

During the spring and summer of 1958, biologists of the Bureau of Commercial Fisheries conducted a population survey of the king crab, Paralithodes camtschatica (Tilesius), in the Southeastern Bering Sea, using an otter trawl. In the course of the investigation, measurements of the trawl-door spread were obtained. These measurements were examined to determine the effect of water depth, vessel speed, and total catch on door spread.

It was found, when using a warp-scope ratio of 3:1, that the spread of the doors was greater in deep water than in shallow water. Door spread in shallow water appeared to decrease with increased vessel speed. There was also some indication that larger catches reduced door spread; however, the relationship was not strong.

Fig. 1 - 75-foot schooner-type vessel Tordenskjold chartered for the king crab survey.

The work of DeBoer (1957) who used especially designed instruments, demonstrated that door spread is largely determined by the degree of contact between the doors and the bottom. The present paper proposes that, when using a small scope

---

*Fishery Methods and Equipment Specialist, Branch of Exploratory Fishing and Gear Research, Division of Industrial Research and Services, U. S. Bureau of Commercial Fisheries, Seattle, Wash.

ratio in shallow water, the pull by the warp at the door is upward. This results in the tilting of the door outward and forward as observed by DeBoer. Because contact between the door and the bottom in this case is poor, the spread is small. In deeper water the door theoretically loses its tilt and operates squarely, resulting in good bottom contact and increased spread. In still greater depths the door may tilt back and in. Although the contact would seem to be reduced, the spread increases further. This effect is here interpreted as the probable result of the downward pull by the warp at the door, which forces it into the bottom resulting in better contact and increased spread.

BACKGROUND

During the spring and summer of 1958, biologists of the U. S. Bureau of Commercial Fisheries conducted a population survey of the king crab, Paralithodes camtschatica (Tilesius), in the Southeastern Bering Sea. In the course of the trawling operations, records of distance traveled, cable scope, and catch were kept, and measurements of trawl-door spread were obtained. Data collected were made available to the Bureau's Branch of Exploratory Fishing and Gear Research for evaluation of the effects of these variables on the spread of the trawl during fishing. The measurements of door spread were taken to assist in a population study and were not specifically designed to accrue information for gear evaluation. Controlled experiments covering various depth ranges and speeds were not conducted. The observed relationships, therefore, should be considered as qualitative rather than quantitative.

GEAR AND METHODS

A 75-foot schooner-type vessel, the M/V Tordenskjold, was chartered for the survey (fig. 1). The vessel, powered by a 180 hp. engine, has a mean draft of 9 feet and a beam of 18 feet. The trawling gear, typical of Pacific coast trawlers, was towed from davits on each side of the stern and hauled over the starboard side. A 400-mesh eastern otter trawl, with a 71-foot headrope and a 94-foot groundrope, was fished using 3 by 6-foot doors weighing approximately 550 pounds each. Seven-fathom extensions were added forward of each wing and the extended wings were secured directly to the doors.

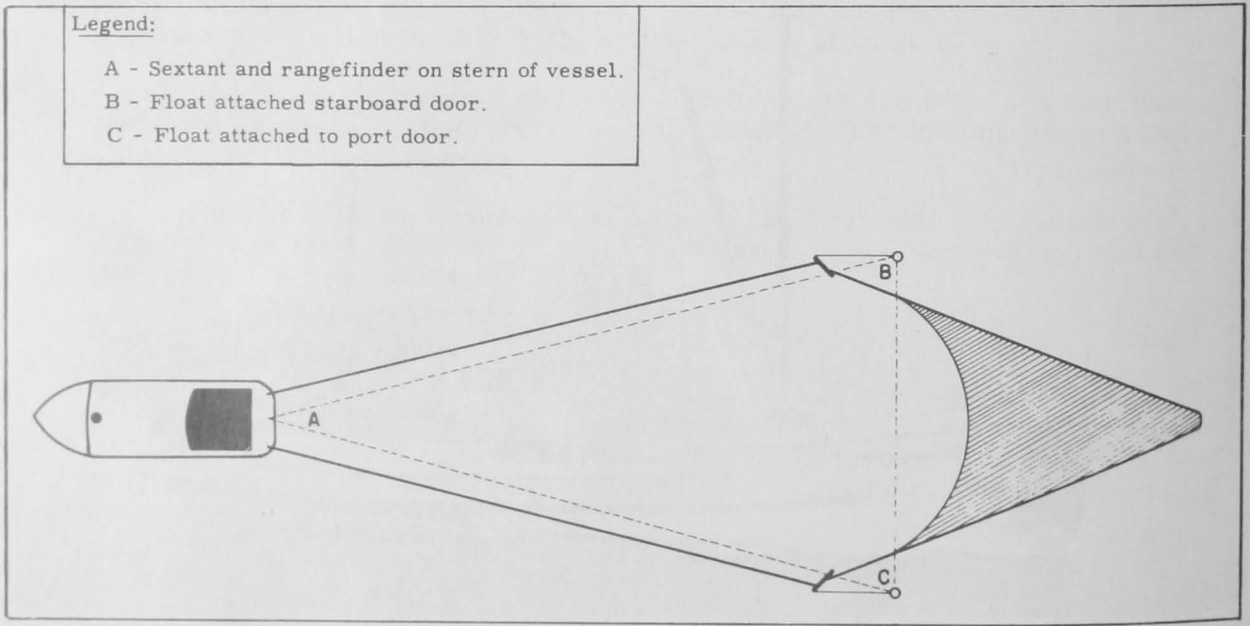

Fig. 2 - Angles and distances measured to determine door spread.

The spread of the doors, while trawling, was determined as follows: Spherical floats, 18 inches to 20 inches in diameter, were secured to the doors with 100 fathoms of $\frac{1}{16}$-inch stainless-steel cable. Since all fishing was conducted in waters shallower than 80 fathoms, this amount of cable insured that the floats would reach the surface while the gear was being towed. The angle between the floats, from a point on the stern of the vessel, was measured with a sextant, and the distance from this point to the floats was measured with a U. S. Navy range finder. The distance between the doors was obtained by solving the triangle formed by the vessel and the floats (fig. 2). This method is similar to that used by Carlson (1952).

Fig. 3 - The "lawn roller" meter used to measure the distance traveled by the trawl on the bottom--developed by the Fisheries Instrumentation Laboratory, U. S. Fish and Wildlife Service, Seattle, Wash.

The distance traveled by the trawl on the bottom was measured by a meter attached to the cod end (fig. 3). The meter was equipped with two counters that made independent readings. This served as a check and insured a measurement in the event that one counter malfunctioned. The speed of the vessel was calculated by relating the measured distance to the dragging time.

RESULTS

During the survey a total of 120 drags was made, of which 91 were used in this analysis. These drags were made at depths ranging from 20 to 62 fathoms and at vessel speeds from 2.0 to 3.0 knots. The total catch per drag ranged between 350 and 5,000 pounds.

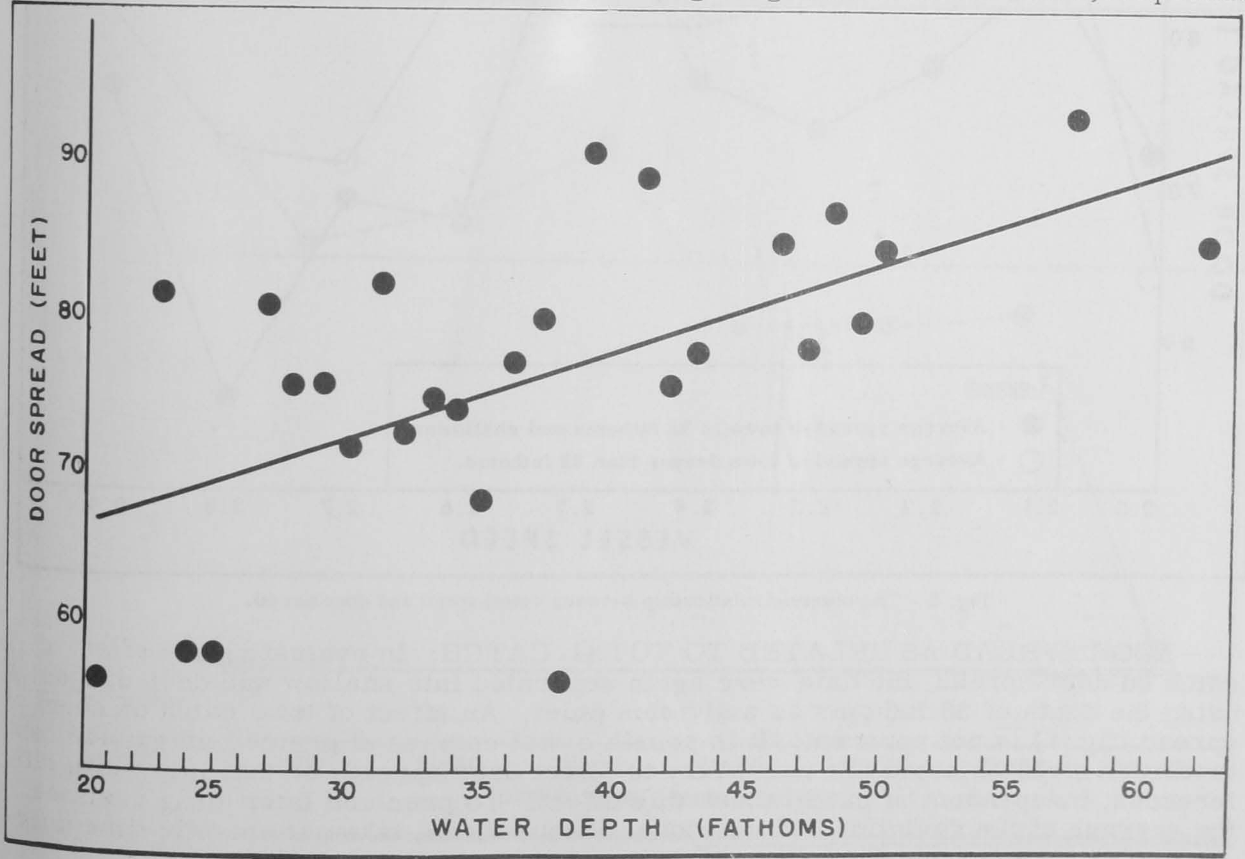

Fig. 4 - The relationship between water depth and door spread.

DEPTH AS RELATED TO DOOR SPREAD: The average door spread per drag, using a constant scope ratio[1] (2.9-3.1 to 1), as related to water depth is shown in figure 4. The results demonstrate a greater spread as the water depth increases. This suggests that a scope ratio of 3:1 was not adequate for obtaining the maximum spread of this trawling gear in shallow water. The need for greater scope ratios in shallow water is in agreement with the observations of numerous investigators, including Miyamoto (1957). Saito (1957) and Bullis (1951) report that fishermen use scope ratios greater than 3:1 in shallow waters. DeBoer (1957), using various scope ratios in a constant water depth ($8\frac{1}{2}$ fathoms), demonstrated a progressive increase of door spread with scope ratios varying from 3.4:1 to 8.1:1.

DOOR SPREAD AS RELATED TO VESSEL SPEED: To minimize bias due to the effect of increasing door spread with increasing depth, the data have been separated into two groups: drags at 38 fathoms and shallower, and drags deeper than 38 fathoms. The relation of vessel speed to door spread is shown in figure 5. In shallow water there is a tendency for the door spread to decrease with greater speeds, but in deeper water this trend is not apparent. A decrease in door spread in shallow water, following increased vessel speed, is consistent with the results obtained by Ketchen (1951).

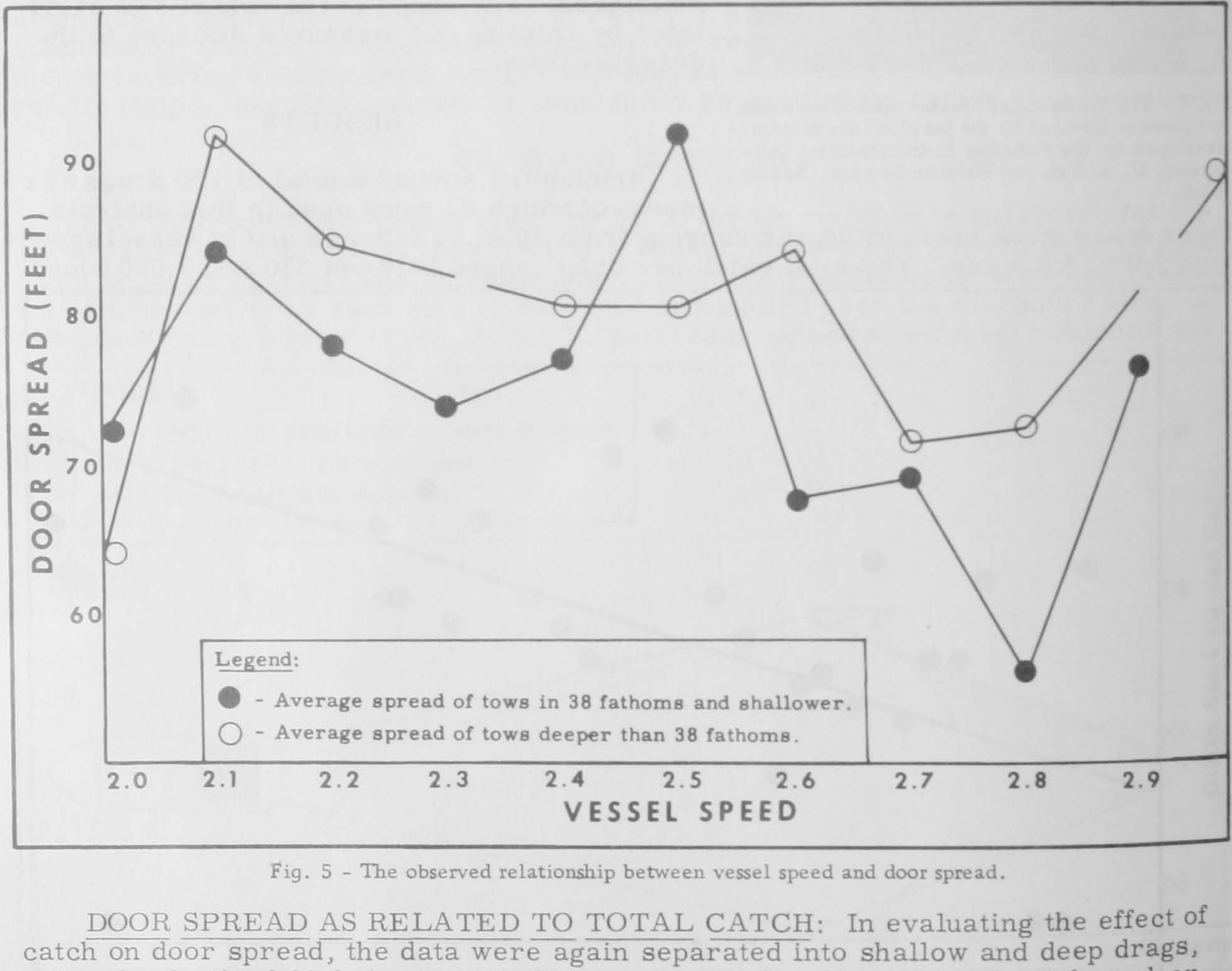

Fig. 5 - The observed relationship between vessel speed and door spread.

DOOR SPREAD AS RELATED TO TOTAL CATCH: In evaluating the effect of catch on door spread, the data were again separated into shallow and deep drags, using the depth of 38 fathoms as a division point. An effect of total catch on door spread (fig. 6) is not apparent. It is possible that catches of greater magnitude than those that were obtained are necessary to affect door spread, or that inter-drag differences, independent of catch, mask this effect. To preclude inter-drag variance, the average of the deviations of individual observations, taken at specific time inter-

---

[1] Ratio of towing cable out to water depth.

vals, from the average within drag spread were calculated and the resulting points were plotted (fig. 7). Using this technique, a trend of decreasing spread with increased dragging time is indicated. The spread of the doors apparently decreases as the dragging time progresses, presumably because of increased catch. The relationship, however, is not strong; and as previously noted, the size of the catches may have been insufficient to markedly affect door spread.

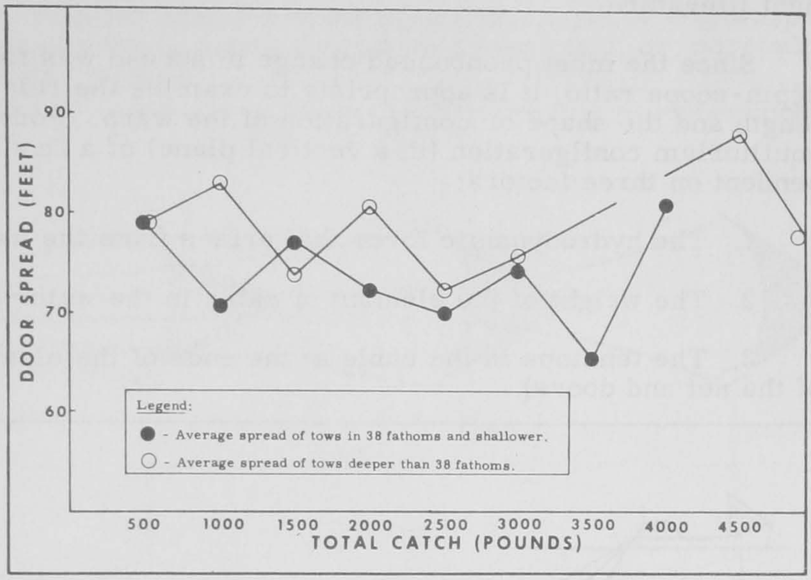

Fig. 6 - The observed relationship between total catch and door spread.

FACTORS AFFECTING DOOR SPREAD

The foregoing observations between scope ratio, speed, and door spread are in agreement with experiments and observations of other research workers directed at the evaluation of these factors. The confirmation of those previous studies, however, is primarily of academic interest in that it offers little more quantitative knowledge than is already available. The variation in spread between drags, observed in this study, demonstrates the wide variability in behavior of the trawl in

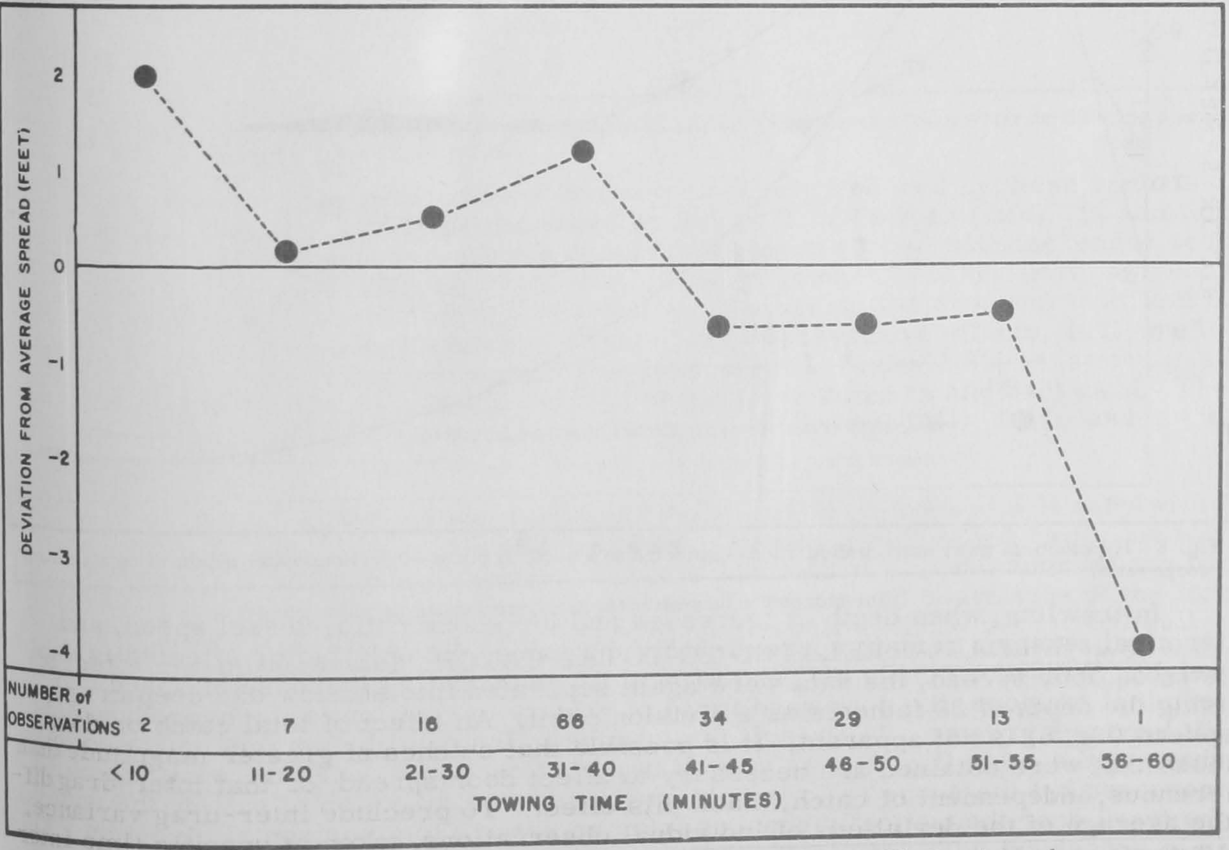

Fig. 7 - The average of deviations from the average within-tow spread at specific time intervals.

operation and illustrates the value of a more complete understanding of the factors which determine the spread of the trawl doors. The following discussion is based largely on observations and a synthesis of ideas resulting from a survey of pertinent literature.

Since the most pronounced change in spread was found to be associated with the depth-scope ratio, it is appropriate to examine the relationship between the warp length and the shape or configuration of the warp. Pode (1951) points out that the equilibrium configuration (in a vertical plane) of a flexible cable in a stream is dependent on three factors:

1. The hydrodynamic force that arises from the water flow (vessel speed).

2. The weight of the element of cable in the water (length of cable out).

3. The tensions in the cable at the ends of the element (pull of vessel and drag of the net and doors).

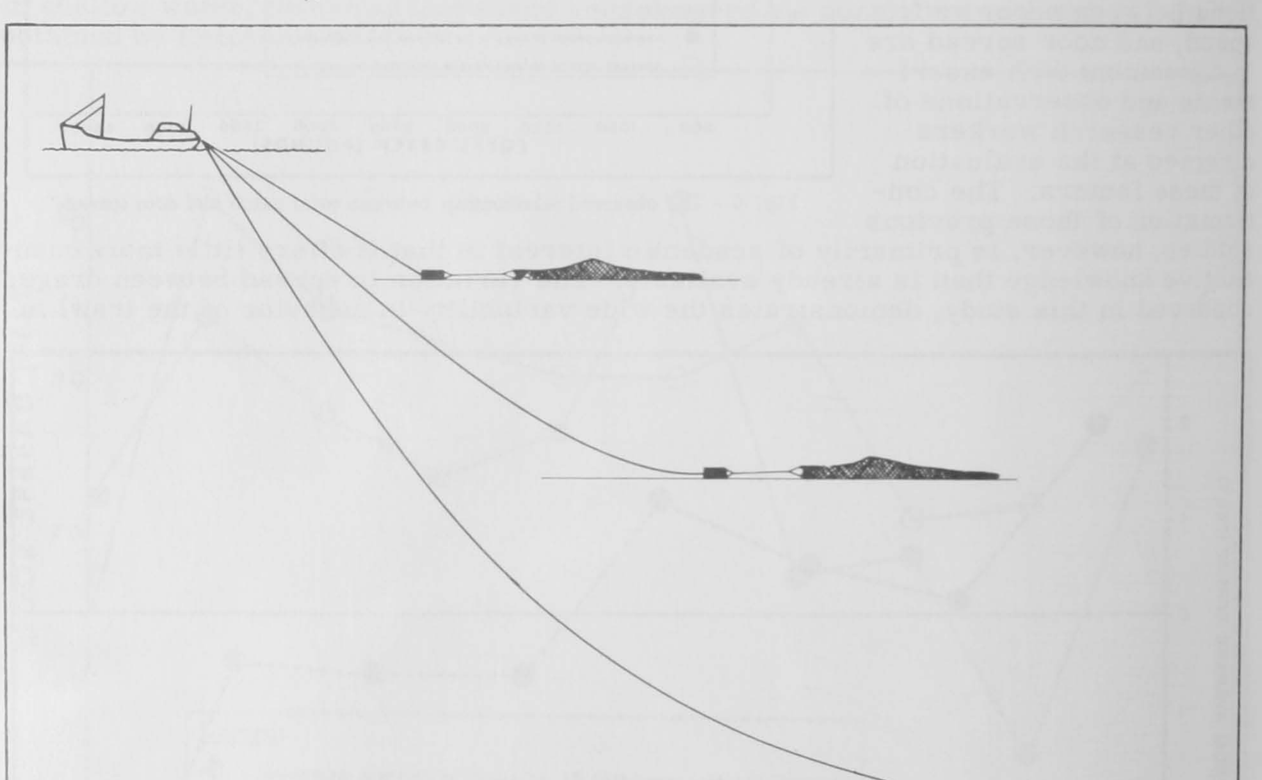

Fig. 8 - Hypothetical trawl warp configuration--projected to a vertical plane--in various water depths using a constant scope ratio.

In trawling, when depth is increased and the scope ratio, vessel speed, and terminal tensions remain approximately the same, the only factor affected is cable weight. With more cable out, and without a compensating increase of speed and terminal tensions, the downward force of gravity in relation to the hydrodynamic lift becomes greater. The result is a change in the equilibrium configuration or shape of the cable (fig. 8). As viewed in a vertical plane, when the water depth is increased but the scope ratio is held unchanged, the direction of pull by the cable at the trawl door theoretically changes from an upward to a horizontal direction. This is in agreement with results of studies of trawl warp configuration by Kullinberg

(1951) and Kobayashi and Takashashi (1951 a and b). The theoretical change in the lateral configuration of the warp with increased depth (scope ratio unchanged) is shown in figure 9. The direction of pull on the door by the warp in shallow water is apparently forward, and with increasing depth, tends to become progressively inward, toward the mid-line. Similar changes of configuration or shape of a warp may be obtained by either increasing depth, using a constant scope ratio, or increasing scope ratio in a constant water depth.

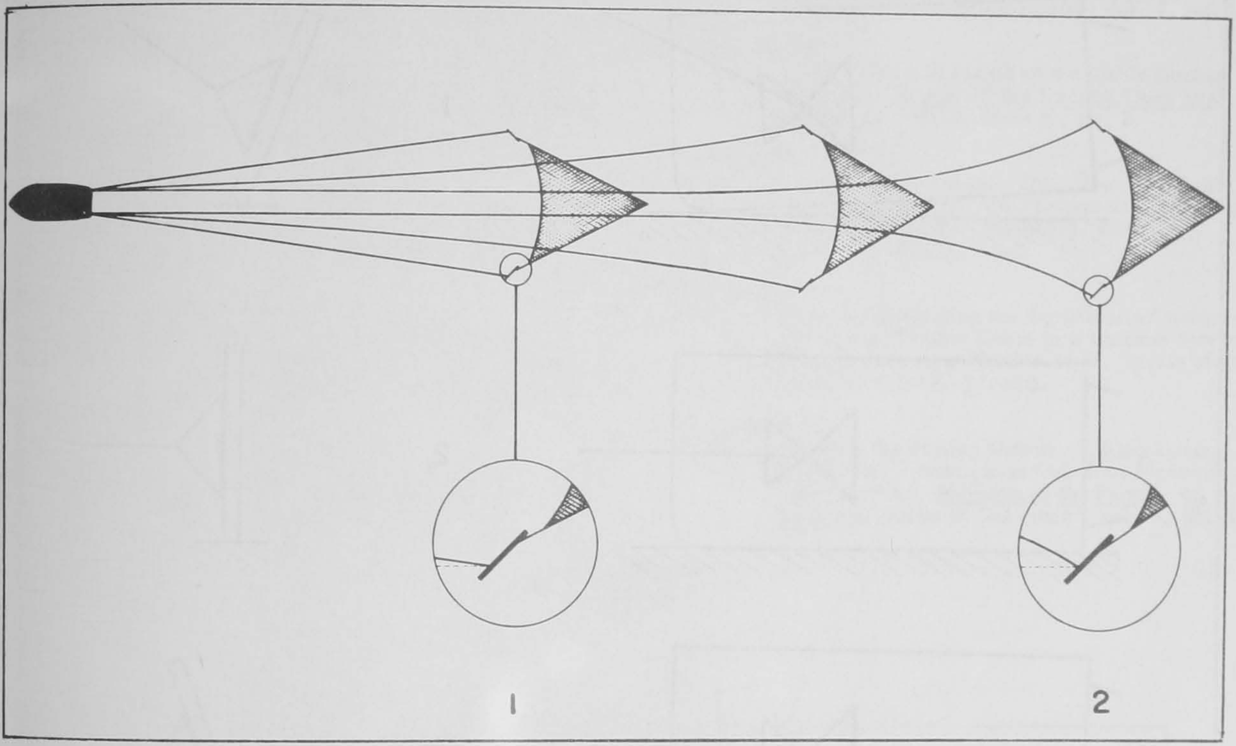

Fig. 9 - Hypothetical trawl warp configuration--projected to a horizontal plane--in various water depths using a constant scope ratio in (1) shallow water, (2) deep water.

The effect on the performance of the trawl door produced by these various directions of pull of the warp is indicated by the work of DeBoer (ibid). In addition to observing instrumental evidence of increased door spread with increased scope ratio (in a constant depth), he found that the longitudinal tilt of the door, as recorded by his instruments, was from forward to aft; the lateral tilt, from out to in; and the angle of attack, from large to small. Figure 10 shows the above effects. In figure 10(1) the door is tilted out and foreward. The door shown in figure 10(2) is laterally and longitudinally square, and in figure 10(3) the door is tilted in and backward. The warp is pulling upward, forward, and downward in figures 10(1), 10(2), and 10(3), respectively.

The resultant effect of the mentioned factors on door spread will vary with water depth and towing speed. In shallow water, using a small scope ratio, the warp is apparently pulling up and forward. This would tend to pull the door off the bottom resulting (because of its construction and the direction and magnitude of the forces affecting it) in a tilting of the door outward and forward. Since the lateral pull is probably minimal in this situation, the angle of attack will be large. The forward tilt, however, reduces the contact with the bottom and, therefore, the shearing effect, resulting in reduced spread. Using the same scope ratio in deeper water, the warp apparently pulls forward and in, resulting in a minimum tilt in both directions and a smaller angle of attack. Since contact with the bottom is better, the shearing effect is increased. Although in this instance the angle of attack is smaller, the spread is greater. DeBoer (ibid) found that with a greater increase in scope ratio (analagous to a further increase in depth using the same scope ratio) the door tilt became slightly aft (tilt 0.5°) and in; and although the angle of attack decreased further, the spread of the doors continued to increase. This is probably because the warp was pulling down (in a vertical plane) since it was on or near the bottom ahead of the door, and tended to force the door into the bottom. Although slightly tilted, the contact of the door with the bottom would be better than in the previous instances, and therefore, the shearing effect and the spread would be greater.

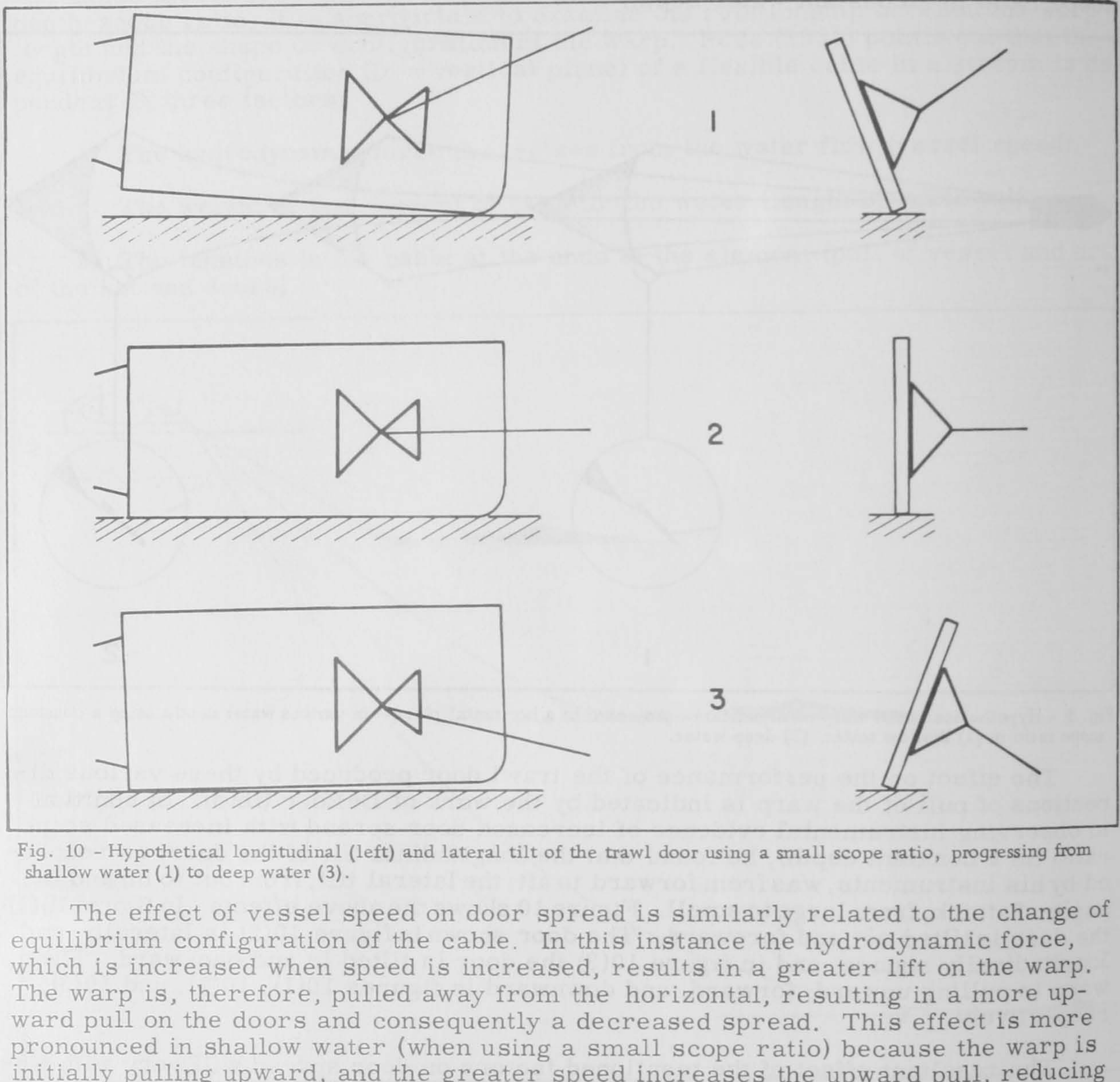

Fig. 10 - Hypothetical longitudinal (left) and lateral tilt of the trawl door using a small scope ratio, progressing from shallow water (1) to deep water (3).

The effect of vessel speed on door spread is similarly related to the change of equilibrium configuration of the cable. In this instance the hydrodynamic force, which is increased when speed is increased, results in a greater lift on the warp. The warp is, therefore, pulled away from the horizontal, resulting in a more upward pull on the doors and consequently a decreased spread. This effect is more pronounced in shallow water (when using a small scope ratio) because the warp is initially pulling upward, and the greater speed increases the upward pull, reducing the bottom contact and, consequently, the spread. In deeper water, with the same scope ratio, an equivalent speed increase will also alter the shape of the cable. The effect on the warp at the trawl door, however, is much less and it lies within a range that will not produce significant changes in the position of the door.

The foregoing observations and considerations indicate that the spread of a trawl is determined principally by the degree of contact between the doors and the bottom. Considering the number and variability of the factors which influence door spread, it is apparent that obtaining consistent optimum spread is extremely complex. Development of doors that will produce optimum contact with the bottom within a wide range of scope ratios and speeds, or that will produce maximum spread independent of bottom contact, could be rewarding.

LITERATURE CITED

BULLIS, H. R.
1951. Gulf of Mexico Shrimp Trawl Designs. U. S. Fish and Wildlife Service, Fishery Leaflet 394 (September), 16 pp.

CARLSON, CARL B.
1952. Increasing the Spread of Shrimp Trawls. Commercial Fisheries Review, vol. 14, no. 7, July 1952. (Also Separate No. 316.)

DE BOER, P. A.
1957. Trawl Gear Measurements Obtained by Underwater Instruments. FAO International Fishing Gear Congress 1957, Hamburg, Germany, Paper, No. 25 (b), 21 pp.

FISH AND WILDLIFE SERVICE, U. S.
1957. Fisheries Instrumentation Laboratory Newsletter, U. S. Fish and Wildlife Service, vol. 1, no. 1 (November).

KETCHEN, K. S.
1951. Preliminary Experiments to Determine the Working Gape of Trawling Gear. Fisheries Research Board of Canada, Progress Reports of the Pacific Coast Stations, No. 88 (October).

KOBAYASHI, K., and TAKAHASHI, H.
1951a. A Study on Fishing Trawl Operated in Any Depth of Sea Water. Bulletin of the Faculty of Fisheries, Hokkaido University, vol. 1, nos. 3 and 4.

1951b. A Study on Fishing Trawl Operated in Any Depth of Sea Water (cont.). On the Relations Between the Length of Warp and the Frontage of Otter Board. Bulletin of the Faculty of Fisheries, Hokkaido University, vol. 2, no. 1.

KULLINBERG, B.
1951. On the Shape and Length of the Cable During Trawling. Report of the Swedish Deep Sea Expedition, vol. 2, Zoology, no. 2.

MIYAMOTO, H.
1957. On the Relation Between Otter Trawling Gear and Towing Power. FAO International Fishing Gear Congress 1957, Hamburg, Germany, Paper No. 105 (b), 7 pp.

PODE, LEONARD
1951. Tables for Computing the Equilibrium Configuration of a Flexible Cable in a Uniform Stream, Navy Department, The David W. Taylor Model Basin, Report 687 (March).

SAITO, ICHIRO
1957. Studies on the Fishing Ground, Fishing Gears, and Fishing Technique in One-Boat Medium Trawl Fishery. Memoirs of the Faculty of Fisheries, Hokkaido University, vol. 5, no. 1.

◆

WHAT ATTRACTS FISH?

The sense of smell plays a fairly important part in the lives of all fish, but it is not the only sense upon which they rely to obtain food. They rely also upon the organs of sight and hearing; however, if these should fail, they could probably locate food by smell alone.

In some fish the sense of smell is extremely acute. The smell of blood or of decaying fish, for instance, attracts sharks from great distances. The extent to which the sense of smell is employed for locating food varies not only with the species of fish but also with circumstances.

The U. S. Bureau of Commercial Fisheries has conducted some research on the effects of sound on fish and from that work it is felt that except for the initial "start" when sound is first perceived, there is little effect either as an attracting force or as a repelling one.

In summary, it appears from research done on stimuli which attract fish that the sense of sight is probably the most important sense to the fish in terms of recognizing danger, food, etc. Consequently, it would seem that attractants designed to stimulate the sense of sight would be the most effective. This applies to fish in both fresh-water and the marine environments.