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AN INVESTIGATION OF THE AVOIDANCE REACTIONS OF PACIFIC WHITING (*Merluccius productus*) TO DEMERSAL AND MIDWATER TRAWL GEAR

by

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Abstract

An experiment was conducted to demonstrate the avoidance behavior of Pacific whiting (*Merluccius productus*) when confronted by trawl gear. Echograms are presented to show their reaction during the day and night to demersal and midwater trawls and limited echo integrator data are presented which suggest that the fish also respond to vessel noise. Trawl hauls made during the day and at night cause significant disruption of depth layering and the fish consistently avoid trawl warps, doors and the mouth of the trawl by diving and by moving to the sides of the gear path. This behavior may result in trawl catch per unit effort (CPUE) rates and biological sample compositions that are quite different from what would be obtained from undisturbed fish layers. There are discussions of problems and sources of bias associated with assessment of the near bottom portion of pelagic fish abundance using demersal trawl and echo integration methods, the comparability of demersal trawl and acoustic survey data and the combination of concurrent survey results obtained by use of the two methods.

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Introduction

The avoidance reactions of Pacific whiting (Merluccius productus) and pollock (Theragra chalcogramma) in the Pacific ocean and several Atlantic gadoid species when confronted by a trawl are well known to commercial fishermen and scientific investigators; most will dive, even though that action may place them further within the scope of trawl gear (Saetersdahl, 1967; Wardle, 1984; Ona and Godo, 1990; personal observation). Also, the degree of reaction varies widely from species to species and is related to time of day, season, age and activity such as feeding, spawning etc. (Saetersdahl, 1967; Alverson, 1967; Mohr, 1967-A; Mohr, 1967-B; Ona and Godo, 1990; Olsen, 1990; personal observations). Some questions that come to mind when considering avoidance behavior include; how and to what degree is the biological composition of a trawl sample affected and; what are the effects of trawl avoidance on the results of quantitative trawl surveys ? Concurrent acoustic and demersal trawl survey results for Pacific whiting and pollock have routinely been summed to provide total biomass and population estimates (Bakkala and Alton, 1986; Karp and Traynor, 1988; Wespestad and Megrey, in press). Thus, it is important to determine whether sampling regions for the two survey methods overlap and to assess the significance of the effect with respect to synthesis of concurrent abundance estimates.

The Experiment

This experiment was designed to observe and describe the avoidance behavior displayed by Pacific whiting when disturbed by the approach of a trawl and to explore the implications of such behavior to resource assessments. The study was conducted in Port Susan, an inlet in Puget Sound near Everett, Washington, where a population of Pacific whiting is found during the winter months. Field operations were conducted during February 26-28, 1990. Two vessels were employed; an 11.3 m (37 ft.) utility boat containing hydroacoustic equipment and a 17.7 m (58 ft.) stern trawler. The trawler deployed two sets of gear; a Nor'Eastern bottom trawl and a Nor'Eastern rope trawl as described in Table 1. Two sets of hydroacoustic equipment were used simultaneously; a Biosonics 105 Khz echo sounder and echo integrator and a Simrad 38 Khz echosounder. The echo integrator was used to collect fish density data, while the 38 Khz echosounder was used to collect color echograms. Echo integration data were collected in 1 m depth strata for each 22 seconds of transecting (observation) time; about 23 m travel/output at a speed of 2 kn. Echograms were collected to show the depth region within about 40 m of the bottom. Observations of the movements of fish in relation to the trawls were made using two procedures. The first procedure consisted of running a series of transects (about 1/4 mile long) back and forth along a single line which was centered across the path of the trawler (Figure 2, detail A). The depth extent and relative abundance of fish within layers throughout the water column and the degree of layer disruption due to the reaction of the fish to the trawl gear is shown clearly on the echograms. Each echogram represents about 3-5 minutes of running time. After each pass across the path of the trawler was completed, a consecutive pass was started along a reciprocal heading. About 2 minutes were required for turning the boat and preparation of the data collection system for the next transect. Each series of observations was started well before the trawler had approached the transect line and was continued until the trawl had been pulled past the transect. Ten or more passes were made across the trawled path during each series, but only selected echograms are presented here. The trawl itself can be identified in some of the echograms but it is not possible to determine with certainty what portion of the trawl was being observed. The second data collection procedure consisted of positioning the acoustics vessel at a fixed location and pulling the trawl beneath its position (Figure 2, detail B). This procedure provided observations equivalent to a vertical slice of the water column through which the trawl was towed. Resulting echograms show the depth distribution of fish within layers and how the layers were disrupted due to reaction to the trawler and trawl gear.

Results

A single demersal trawl haul was made during the daytime on February 27 to determine the size and biological composition of the fish under study. Their size composition (Figure 1) indicates that they were mostly 2 and 3 years old; about half were mature. No species other than Pacific whiting were caught.

Demersal Trawl Observations While Transecting:

The daytime avoidance reaction of Pacific whiting when confronted by a demersal trawl is shown in Figure 3. Part A and B of the figure shows the depth distribution of fish during two selected transects across the path of the trawler. The first transect (Figure 3-A) was made before the trawler had approached and the fish were undisturbed. Note that they were in a well defined layer extending from about 15 m off bottom to the seabed and the higher densities were found from 4-8 m off bottom. Figure 3-B shows the depth distribution of fish in the vicinity of the trawl and the degree of disruption of the layer caused by its presence; the small "bump" (indicated by arrow) on the sea bed is a portion of the trawl. Note that large numbers of fish near the trawl dived onto or very near bottom and some apparently moved to the sides of the trawled path. Evidence discussed later indicates that fish react strongly to trawl warps and doors so the trawl was fishing on fish distributed very differently from that seen before they were disturbed. Another factor of importance is that the headrope of the trawl extended to 7-9 m above bottom, but the entire fish layer (about 15 m thick) was strongly affected. Very few fish remained in the water column above the trawl body. The echogram shown in Figure 4 was collected during two consecutive nighttime passes across the trawler's path; the turn around point is indicated by a vertical line. The highest fish densities in the layer were farther off bottom than during the day and the layer was more dispersed in the water column. In addition, more fish were close to bottom than during the day but there was no indication of a large proportion being very near bottom. Transects run across the path of the demersal trawl at night show that the reaction of fish was very similar to that seen during the daytime but was somewhat less severe. The trawl is shown on the sea bed and toward the center of first transect (Figure 4-A; arrow). Note that the fish were disturbed above the trawl to about 10 m above bottom, but remained relatively undisturbed above that point. Again, the fish appeared to move toward the bottom and to the sides of the trawled path. The echogram shown in part (B) of Figure 4 is from a transect completed shortly after the trawl had passed. The disturbance caused by the trawl is still evident as indicated by an area of very low fish density with somewhat heightened concentrations to either side (arrow).

Midwater Trawl Observations While Transecting:

Daytime and nighttime avoidance of the midwater trawl by Pacific whiting was similar to that observed during demersal trawl hauls; the fish consistently dived and some moved to the sides of the trawled path in the vicinity of the trawl. Figure 5 clearly shows the daytime reaction of Pacific whiting to the trawl. The location of the trawl is somewhat to the right of the center of the figure, at about mid fish layer depth (about 8-9 m off bottom; arrow). Note that the undisturbed part of the layer consists mostly of uniformly distributed fish from about 3 to 12 m off bottom. In the immediate vicinity of the trawl, the higher density portion of the layer was displaced as the fish dived toward bottom and away from the sides of the trawled path. A considerable number of fish dove to the sea bed. The nighttime reaction of Pacific whiting to the midwater trawl is shown in Figure 6. The location of the trawl is near mid-depth of the fish layer (Figure 6-A; arrow). The fish were more widely distributed in the water column, extending to nearly 30 m above the seabed, and were somewhat more closely associated with bottom than during the day, . The degree of avoidance of the trawl at night was similar to that observed during the day; most of the fish dived 10-15 m while some continued on to the sea bed. The disturbance of the layer was evident on the successive transect across the trawled path, after the trawl had passed, as a low density area extending from top to bottom of the echosign (Figure 6-B; arrow).

Demersal Trawl Observations from a Fixed location.

Data for this part of the experiment were collected by maintaining the acoustics boat at a relatively stationary position while the trawler pulled the demersal trawl through the observation zone (Figure 2, detail B). The acoustics boat was moved a few meters to a point close to the trawled path immediately after the trawler passed and was maintained at that position. Unfortunately, although the zone of observation was very near the trawled path, this adjustment did not position the boat sufficiently close to allow detection of the trawl as it passed. The echogram collected during the run (Figure 7) clearly shows the depth distribution of the fish before being disturbed, their reaction to a trawl warp and a door (Figure 7-B), within the vicinity very near the mouth of the trawl (Figure 7-C) and then the gradual recovery of their layering after the trawl had passed (Figure 7 (cont)). No change in the depth distribution of the fish is apparent on the echogram at the point where the trawler passed the position of the acoustics boat (Figure 7-A). However, a rapid change occurred with approach of the trawl warp and door. The door is located on bottom near the middle of the echogram (Figure 7-B, arrow). The fish started to dive about 30 seconds before arrival of the trawl door, apparently in response to the warp, and had sounded by as much as 8-10 m by the time the door had arrived (diving rate = 16-20 m/min). The mouth of the trawl passed close beneath the observation point about 1 minute after the door had passed, but was just outside the field of echo detection. Its vicinity was indicated by a somewhat higher fish density for a short period and the occurrence of fish higher in the water column than was observed prior to passage of the trawl mouth (Figure 7-C, bracket), perhaps indicating movement of fish to the side of the trawled path. Evidence of the trawled path through the fish layer, indicated by disruption of the layering pattern, persisted for at least 20 minutes (Figure 7 (cont)).

Analyses of echo integration data collected during the stationary observations revealed all of the factors that are readily visible on the echograms plus one feature that was not; a possible reaction of the fish to the presence of the trawler. The integration data were analyzed as a matrix of fish density values (depth X distance) that can be visualized as a longitudinal slice through the water column along the trawled path. A topographical plot of the matrix data, fish density/unit volume for 1 m depth intervals, is shown in Figure 8 and a plot of summed water column fish abundance by output, density/unit surface area for 22 sec. time intervals, is shown in Figure 9. Note in both figures (same data set) that a heightened density of fish is indicated during a short period as the trawler passed the acoustics boat (Figure 8-A, 9-A). The definition of the echogram is not sufficient to indicate this change. The higher apparent density in this region may reflect a change in the orientation of the fish, hence a change in acoustic reflectivity, in response to propeller or other ship noise. All of the avoidance reactions of the fish that were evident on the echograms are evident on the topographic plot and the plot of summed water column fish abundance (Figure 8, 9). The similarities between these data and echograms are obvious when they are compared. Note that the horizontal scales of the plots appear more compressed than the echograms shown in figure 8, since each plotted point represents 22 seconds of observation time. Disruption of the layering pattern due to trawl warps and doors is indicated in the plotted data by a drastic and rapid decrease in fish abundance between time interval 11 and 12 (Figure 8-B, 9-B). Passage of the mouth of the trawl adjacent to the field of observation is indicated at time interval 15 by a short duration of increased fish abundance, possibly due to fish moving to the side of the trawled path (Figure 8-C, 9-C). The remainder of both plots show the gradual return to the layering structure observed prior to passage of the trawl.

CONCLUSIONS AND DISCUSSION

The echograms presented in this report clearly show that midwater and demersal trawls significantly influence the behavior of Pacific whiting. A major and consistent behavioral trait observed during the study was their attempt to avoid demersal and midwater trawl gear by diving and to some degree by moving to the sides of the trawled path. Personal experience has indicated similar behavior by walleye pollock (*Theragra chalcogramma*) and rockfish (Sebastes sp.) in the Pacific ocean. Various European scientists have reported analogous behavior by Atlantic Gadoid species (Saetersdahl, 1967; Wardle, 1984; Ona and Godo, 1990).

The diving reactions of Pacific whiting to an oncoming trawl are demonstrated by a synthesis of the observations provided by several of the echograms presented in this report. Figure 7 shows that much of the diving reaction occurred before the fish were confronted by the mouth of the demersal trawl. Most apparently moved from a considerable distance above the headrope to within the physical scope of the trawl mouth, where they were more vulnerable to capture. This reaction appears to have been triggered by the trawl warp and door; the warp appears to have caused more disruption than the door. Disruption of fish layering from well above the headrope of the demersal trawl is also observed in Figure 3 and 4. Further evidence which suggests that fish will try to dive below a trawl; rather than move to the sides of its path is provided in the echograms showing the reaction of Pacific whiting to the midwater trawl (Figure 5, 6). These echograms show that most of the fish in the vicinity of the trawled path reacted by diving from well above the trawl to below its footrope depth. A similar reaction to a demersal trawl would place the fish in a position of high vulnerability. The diving behavior of fish as they are confronted by trawl gear can affect survey data in several ways. Some of the more obvious effects include biased estimates of population length or age compositions when they are based on trawl samples, erroneous or misinterpreted Catch Per Unit Effort (CPUE) values and overlapping sampling regions for concurrent demersal trawl and echo integration surveys.

Reduction of bias in length composition estimates of fish populations is of particular interest during analysis of echo integration data since acoustical reflectivity per unit biomass of fish is a function of their size composition. Non-representative length composition samples can result due to a variety of factors. These may include situations where a certain component of a population is more inaccessible than others, when several types of sampling gear having different catching characteristics are used or when fish actively avoid the trawls. Pacific whiting and walleye pollock are often found in separate depth strata as juveniles and adults; the younger fish are often more vigorous in their avoidance of a trawl. The result is that representative samples from all parts of the populations may be difficult to obtain and may not be equally accessible to demersal and midwater trawls.

The diving of Pacific whiting in response to trawl gear may result in CPUE values that are not representative of fish densities in the near bottom component of the population. The echograms presented in Figure 3, 4 and 7 indicate that the demersal trawl used in this study may have an effective vertical fishing distance that extends to well above its headrope height. Catch per unit effort values computed using the area swept by the trawl can represent the true abundance of pelagic fish in the water column if most dive into its path, but the value may also be highly variable due to changes in the depths occupied by the target species or changes in their behavior. The major implications of these factors are; 1) the effective sampling volume, the volume from which fish are effectively caught, may be highly variable when a demersal trawl is used to assess the abundance of pelagic and semi-pelagic fish and; 2) care must be exercised when interpreting or combining the results of area swept and echo integration survey results in order to avoid the effect of double counting and overestimation of the resource.

The response behavior of fish to ship generated noise is of concern during assessment of their abundance using echo integration. Small changes in average tilt angle can have a significant effect on acoustic reflectivity and will result in biased estimates of biomass. Olsen (1990) has observed a decrease in echo intensity from fish that have been disturbed by a vessel and interprets the effect as being due to the fish diving as the vessel approaches. Conversely, this study detected an apparent increase in echo intensity (fish density) in response to vessel noise (Figure 8-A, 9-A). Various authors have shown that fish have some ability to sense the direction and distance to a sound source (Parker, 1904; Harris and van Bergeijk, 1962; Enger, 1967; Schuijf, 1975) and thus may be able to orient on its location. Orientation on ship noise could result in the fish tending to align themselves perpendicular to the sound path, corresponding to a more nearly horizontal aspect than when undisturbed, as a ship passes directly overhead. The result would be that the distribution of fish tilt angles would tend more toward horizontal and increased numbers would be viewed in near dorsal aspect by an echosounder located on, or very near, the vessel. Acoustic reflectivity (backscattering strength) of fish is near maximum at dorsal aspect (Nakken and Olsen, 1977; Foot and Nakken, 1978; Fedotova and Shabata, 1983). The result on echo integration would be upwardly biased values since a larger proportion of the fish would contribute increased reflected acoustical energy. This effect could account for the apparently heightened echo integration values observed during the experiment as the trawler passed very close to the location of the stationary acoustics boat. The disagreement between the observations reported by Olsen (1990) and those of this study may be due to differences in species behavior or to the manner in which this study was conducted. Further investigation of the effects of fish reaction to vessel noise on echo integration and of the avoidance behavior of fish to trawl gear are planned.

Acknowledgements

The efforts and cooperation of Messrs. Norm Lemberg, George Kautsky and Steve Burton of the Washington State Department of Fisheries and Mr. Egil Ona of the Institute of Marine Research, Bergen, Norway, contributed substantially to the planning, conduct and interpretation of this research. In addition, the Wash. St. Dept. of Fisheries supplied the acoustics vessel and most of the data collection equipment. The trawl vessel Chasina was owned and operated by Mr. Kurt Dobzynsky. The contributions of all parties are gratefully acknowledged.

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Table 1. Descriptions of the demersal and midwater trawl gear used during the Port Susan trawl avoidance study.

Demersal Trawl

TYPE:Nor'eastern Bottom Trawl

Headrope;27.5 m
Footrope;32.0 m
Bridles;55 m (3/side)
Doors;3.25 sq m (5x7 ft)
Headrope height;7-9 m (measured while fishing)
Effective spread;13-14 m (measured while fishing)

Midwater Trawl

TYPE:Nor'eastern Rope Trawl (rectangular)

Horiz. opening;18.3 m (measured while fishing)
Vert. opening;12.2 m (measured while fishing)
Bridles;37 m (2/side)
Doors;1.5 sq m, high lift

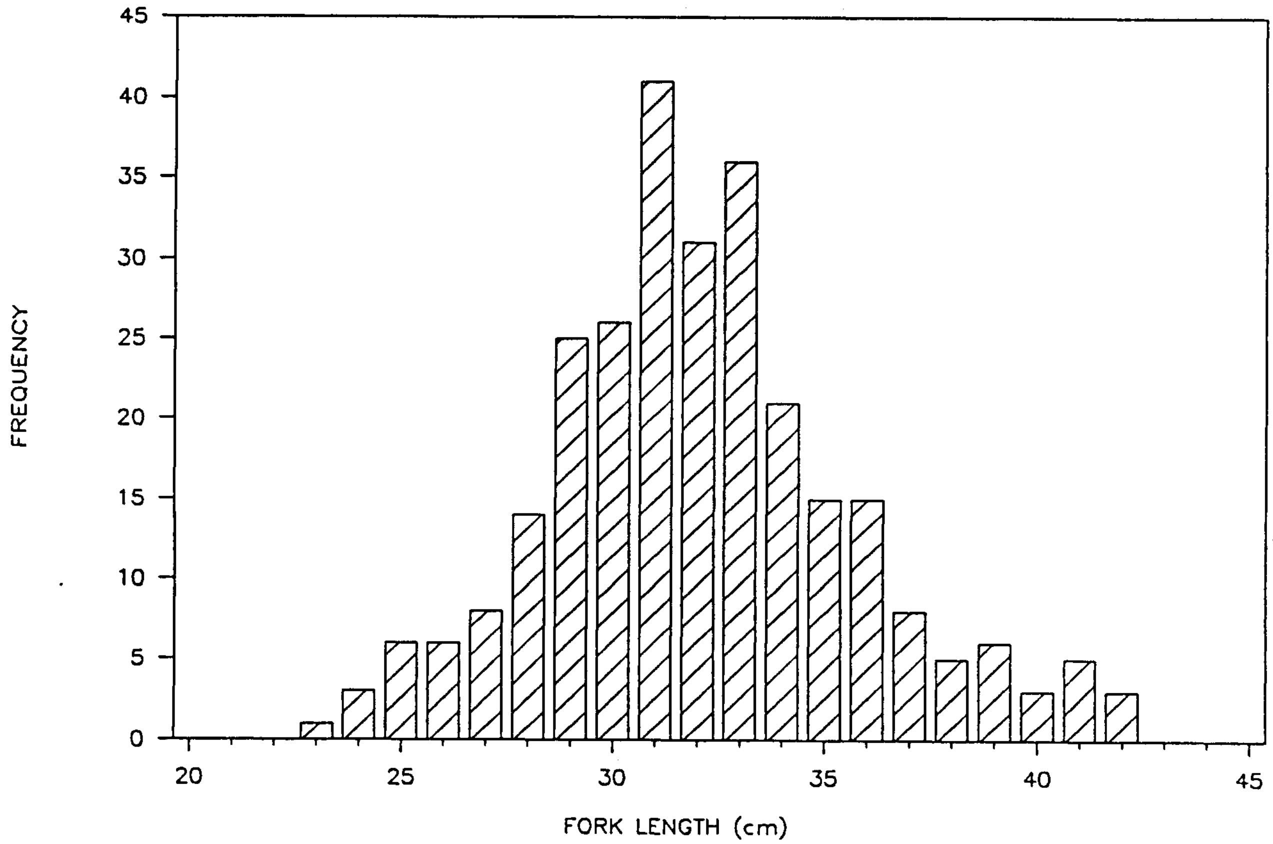

Figure 1. The size composition of Pacific whiting (Merluccius productus) during the trawl avoidance experiment conducted in Port Susan, February 26-28, 1990.

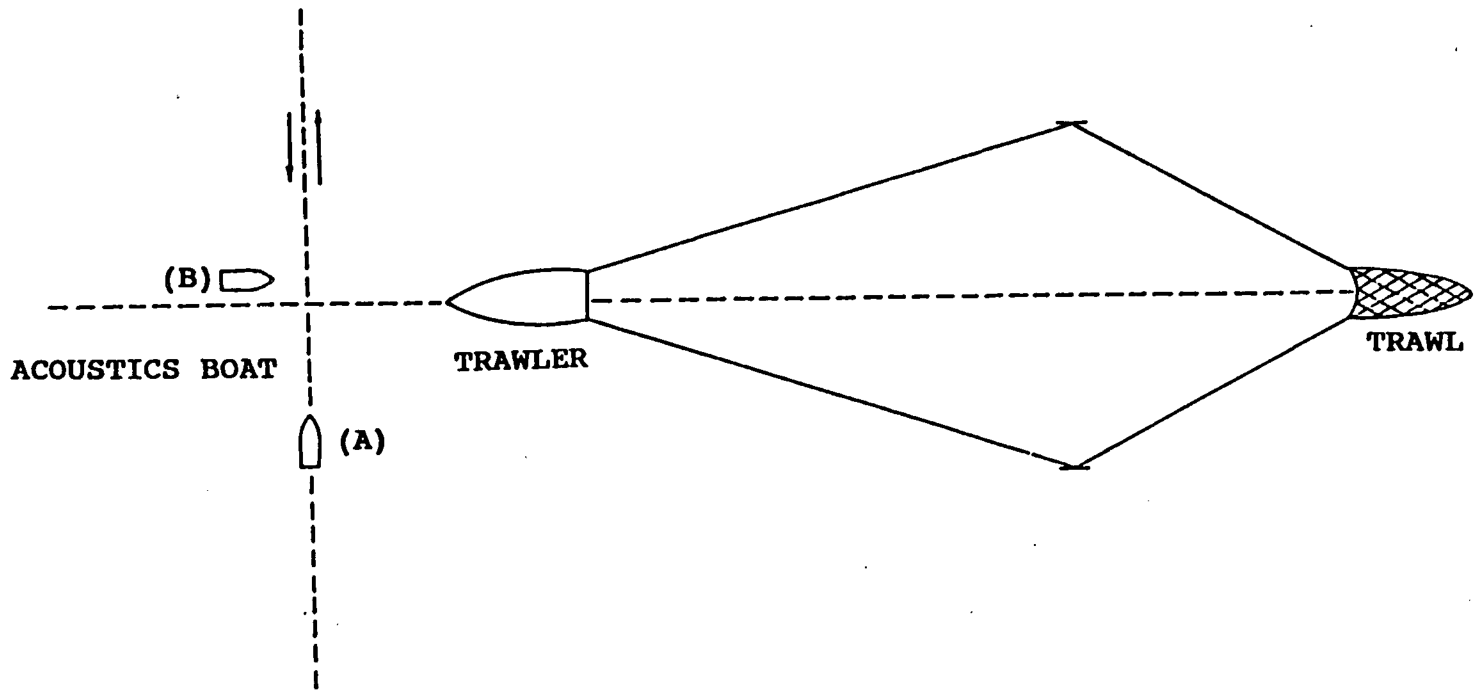

Figure 2. Diagram showing echogram and acoustic data collection procedures used during the Port Susan trawl avoidance experiment; "A" transects were run continuously back and forth across the path of the trawler until the trawl had been pulled well past the transect line. "B" indicates the position occupied by the acoustics boat while the trawler pulled the trawl beneath its position.

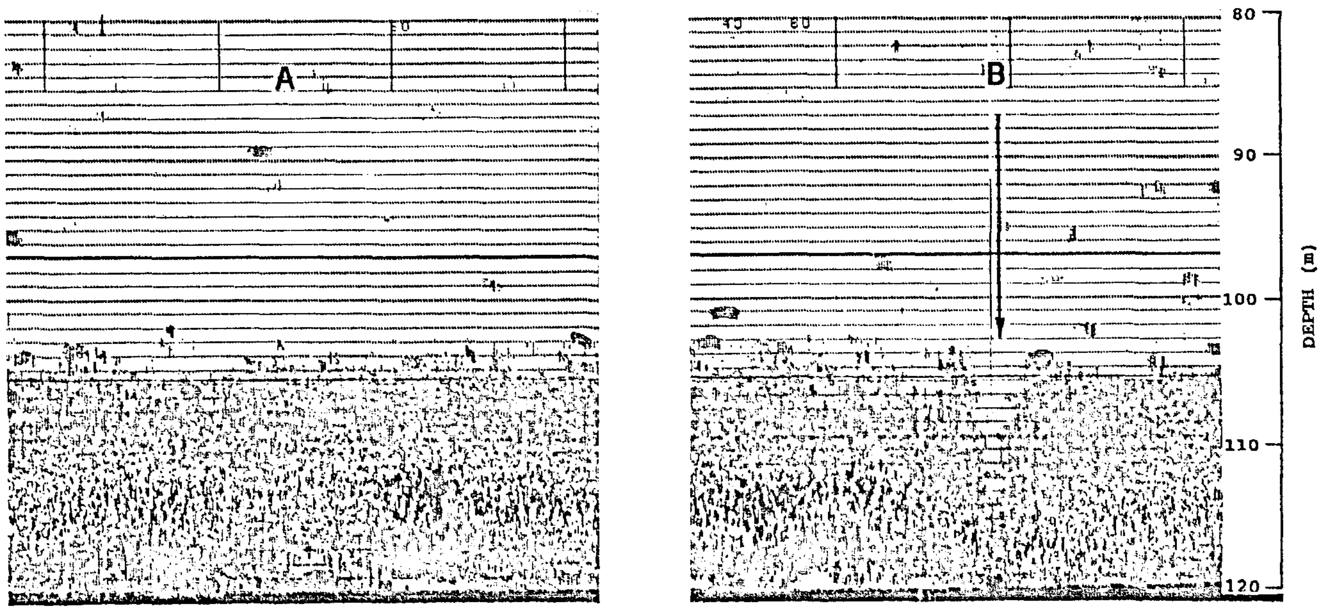

Figure 3. Echograms showing the daytime depth distribution of Pacific whiting in Port Susan; "A" before they had been disturbed by the demersal trawl and; "B" as they were confronted by the trawl. Location of the trawl is indicated by "bump" on bottom in echogram "B". Transects were run across trawled path.

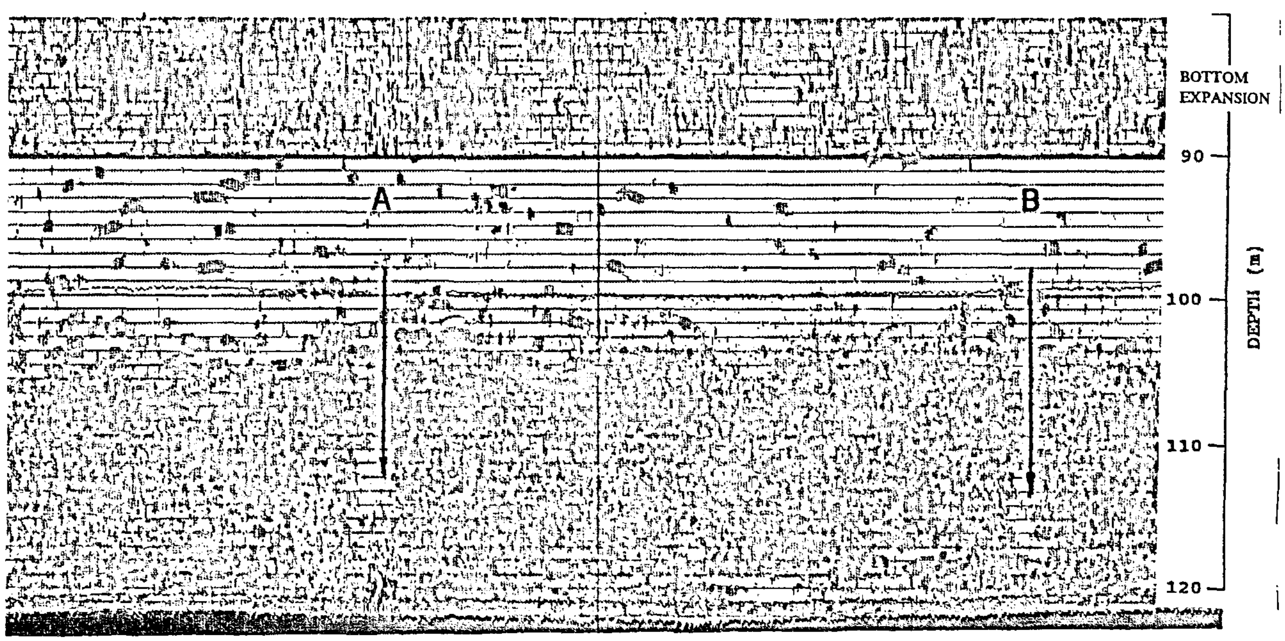

Figure 4. Echogram showing the nighttime depth distribution of Pacific whiting in Port Susan as they were confronted by a demersal trawl(A), and the trawl path through the fish layer about 5 minutes after the trawl had passed (B). Transects were run across the trawled path.

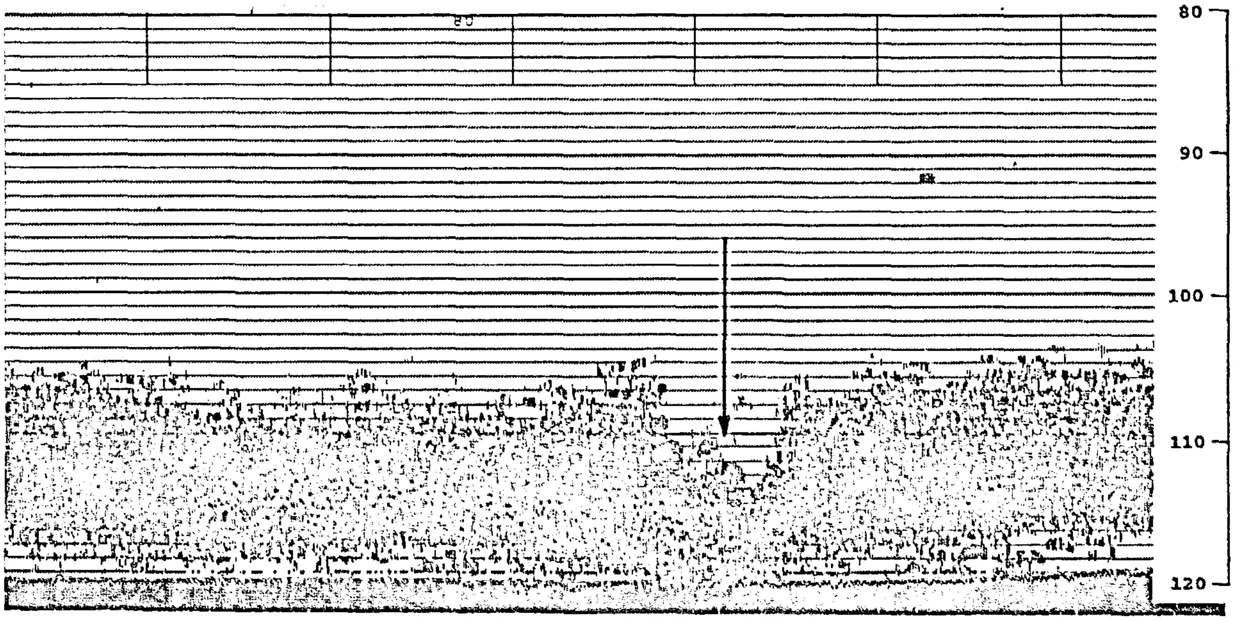

Figure 5. Echogram showing the daytime depth distribution of Pacific whiting in Port Susan as they were confronted by a midwater trawl (arrow). Transect was run across the trawled path.

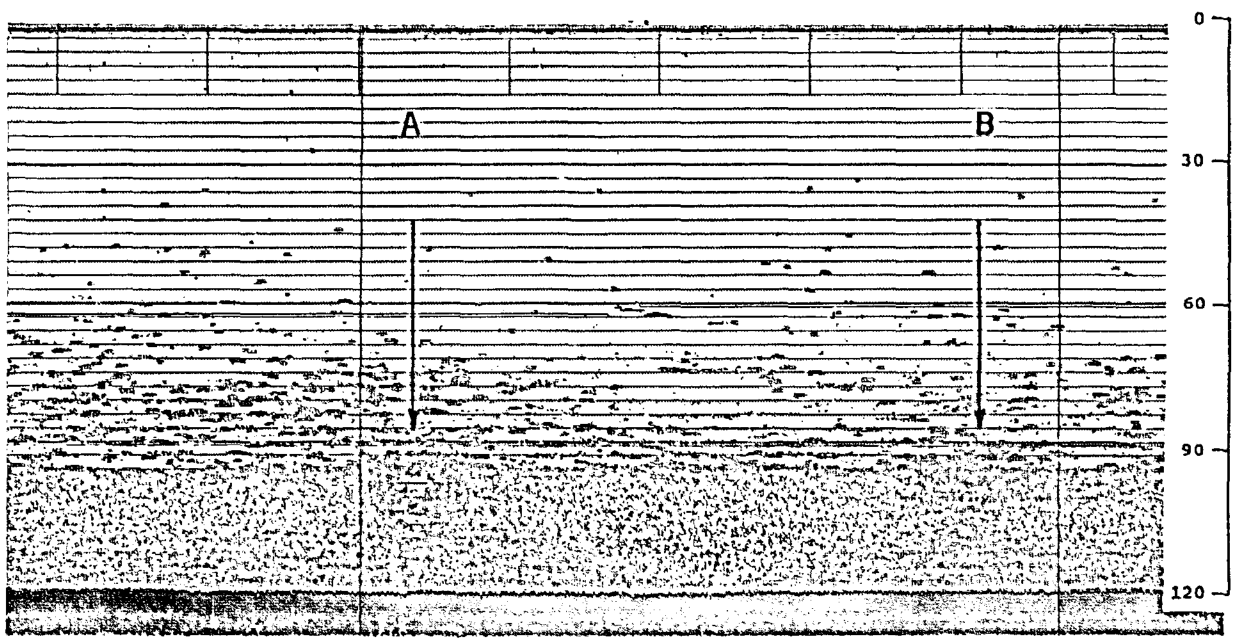

Figure 6. Echogram showing the nighttime depth distribution of Pacific whiting in Port Susan as they were confronted by a midwater trawl (A) and the trawled path about 5 minutes after passage of the gear (B). Transects were run across the trawled path.

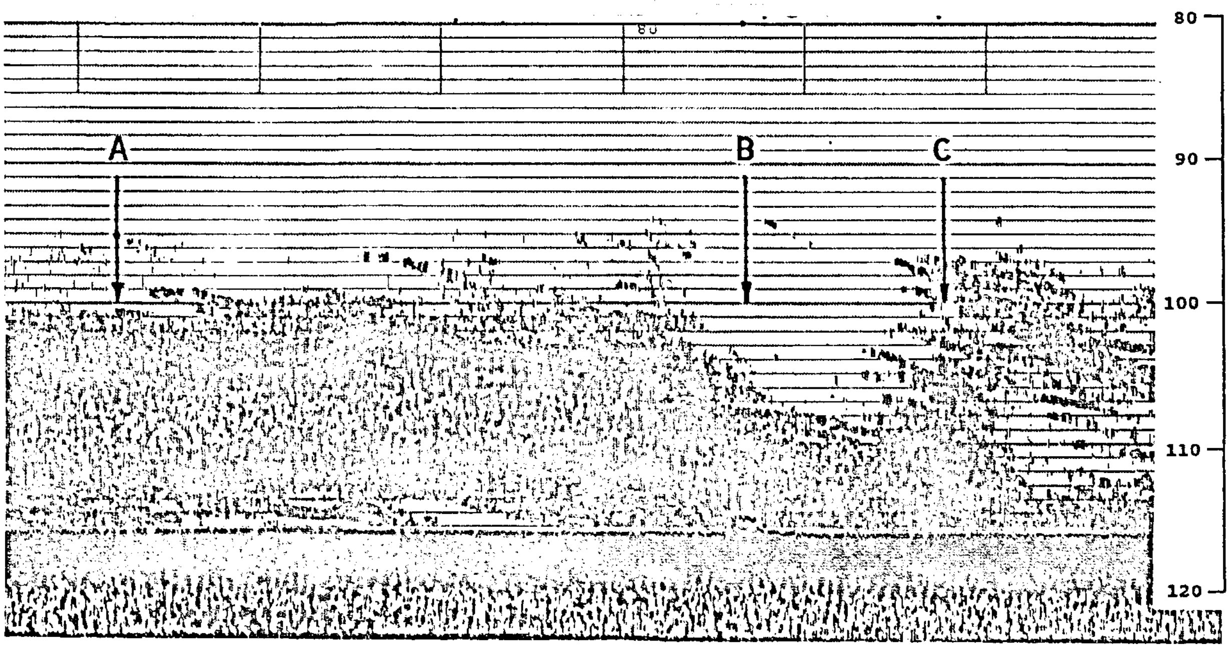

Figure 7. Echogram showing the effect of the demersal trawl on the depth distribution of fish as it was pulled under the acoustics boat. Note: (A), the point where the trawler passed the acoustics boat; (B), detection of a trawl door ("bump on bottom"), and (C), the region where the trawl mouth passed adjacent to the acoustics boat. Acoustics boat was stationary.

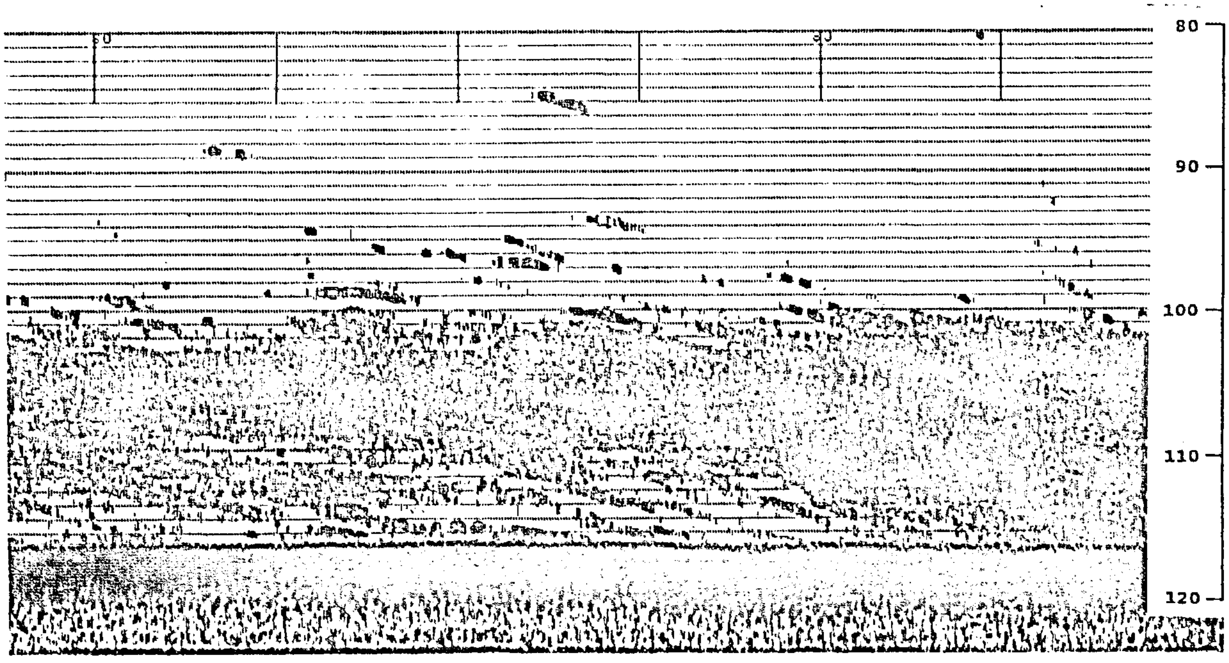

Figure 7 (continued). Echogram showing the daytime depth distribution of fish from about 14 to 20 minutes after passage of the demersal trawl. Acoustics boat was stationary.

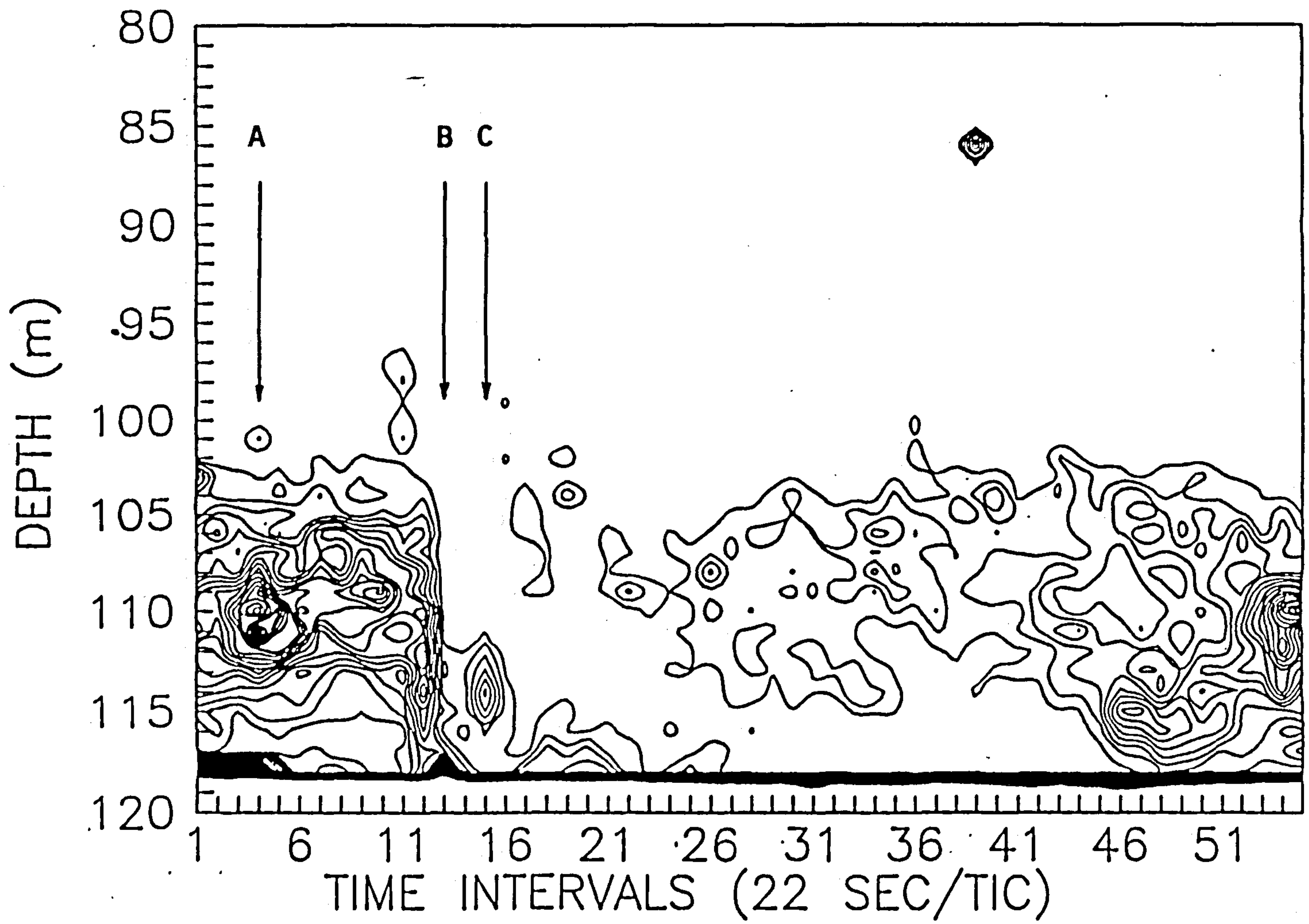

Figure 8. Topographic plot showing relative fish density at depth along a transverse section of a demersal trawl path. Note; "A", the apparently high density of fish adjacent to the trawler; "B", The on bottom "bump" indicating the position of a trawl door and; "C", the region where the trawl mouth passed adjacent to the acoustics boat.

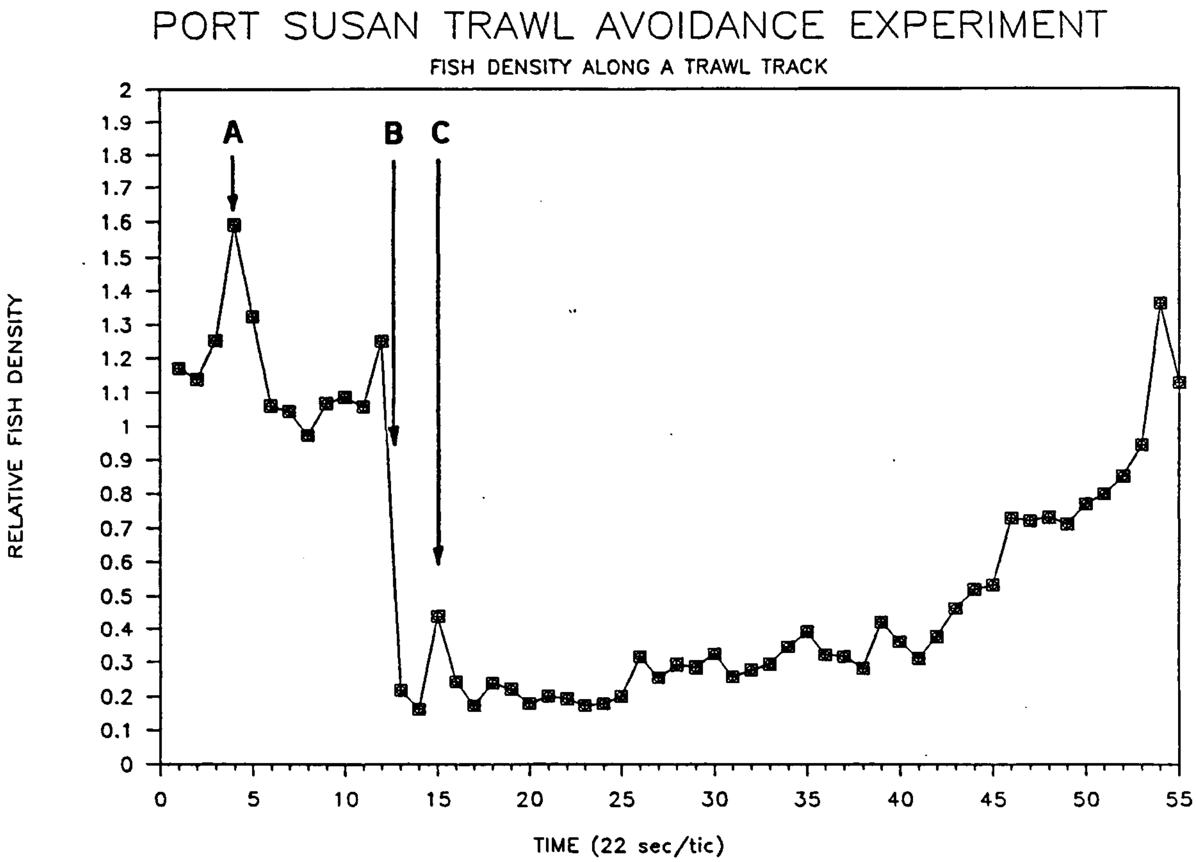

Figure 9. Summed water column biomass (80 m to bottom) as the demersal trawl was pulled below the position of the acoustics boat. Note; "A", the increased values as the trawler passed the acoustics vessel; "B", the large decrease as a trawl warp and door passed the observation point and; "C" the region where the trawl mouth passed adjacent to the acoustics boat.