Effects of Environmental Factors on Trawl Survey Operations and Catches as Evidenced by a Doppler Speed Log

by

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Laboratory Reference No. 78-08

INTRODUCTION

Bottom trawl surveys have been used routinely for many years to sample demersal and other fish species, and as a consequence have become a standard procedure in freshwater and marine fisheries research. In such surveys an attempt is made to standardize the sampling gear, towing speed, towing time, sampling season, etc., in order to make the data comparable for use in a variety of fisheries analyses.

The methods used in the semiannual bottom trawl surveys conducted by the National Marine Fisheries Service's (NMFS) Northeast Fisheries Center (NEFC) in Woods Hole, Massachusetts, are described by Grosslein (1969). The research vessel ALBATROSS IV, a 57-m stern trawler, has been routinely used by the NEFC to conduct the standardized surveys since 1963. Since that time the speed of the ALBATROSS IV during each survey tow has been monitored by an electromagnetic (EM) log, an instrument which measures the ship's velocity through the water. However, a variety of dynamic environmental factors such as wind, wave action, and tidal currents affect the velocity and distance that a vessel will travel over the seabed during any given time period. A standard trawling speed of 3.5 knots was recorded for each tow without taking into consideration those factors operating on the ship which tend to distort the relationship between its water speed and its seabed speed.

A Raytheon[1] Doppler Speed Log (DSL-200), an instrument which provides an instantaneous record of vessel velocity and a cumulative readout of distance traveled over the bottom, was installed on the ALBATROSS IV in 1976 (Raytheon Corp. 1975). With this instrument it was possible during the 1976 spring and autumn surveys to evaluate the true velocity and distance traveled over the bottom by the ALBATROSS IV during timed survey tows. The DSL-200 operates on the principle of the Doppler effect wherein a transmitted hydroacoustical signal is reflected off the seabed and back to a receiver located on the ship's hull. The change in the frequency of the signal between transmission and reception is measured to determine the velocity and distance traveled by the vessel. This report describes how environmental factors affected standard 30-min trawl tows (measured from the time the trawl warps were fully set to the beginning of the haulback) and how variable towing distances affect catches for three ALBATROSS IV surveys in 1975 and 1976.

METHODS

During the 1976 spring and autumn surveys, the distance traveled over the bottom during each timed tow, as determined by the Doppler Log, was recorded on standard bottom trawl survey catch-reporting logs. These records were used in a variety of analyses to determine whether environmental factors influenced the distance that the trawl traveled during a tow. Two environmental factors, tidal and wind-driven currents, were calculated for the 1976

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

spring survey by using the Tidal Current Tables Atlantic Coast of North America[2] and the rotary-tide indicators from National Ocean Survey charts. These calculated currents were then correlated both individually and in combination with vessel velocity over the seabed by means of linear regression to determine possible relationships (Edwards 1976). To account for the fact that currents could potentially either retard or reinforce the vessel's velocity, depending upon whether the vessel was heading into or away from the currents, the data were stratified into three groups based on the differences between the compass directions of trawling activities and of prevailing currents ($0\text{-}45^{o}$, $46\text{-}135^{o}$, $136\text{-}180^{o}$).

Results from a 1975 trawl mensuration cruise, where operational efforts were confined to a relatively small area (259 km^2) with similar bottom characteristics and depths, were examined for possible catch/speed relationships. Since no Doppler distances were available from this cruise, it was necessary to calculate the velocity by summation of EM log speed vectors and tidal current vectors. A simple linear regression equation was fitted for the two sets of 1976 spring data to determine whether Doppler velocity and velocity calculated from vector summation could be used interchangeably. The observed (Doppler) and calculated (vector sum) values were used in a Student's t-test to test for the significance of the slope of the line (Mendenhall 1972). Results from the 1976 spring and authmn bottom trawl surveys and the 1975 trawl mensuration cruise were also examined for a possible relationship

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[2]USDOC. NOAA. 1977. Tidal Current Tables Atlantic Coast of North America, 215 pp.

between distance traveled during a tow and the catch (in weight and number) by means of the Spearman rank correlation coefficient test (Mendenhall 1972).

RESULTS

A plot of the data collected during the 1976 spring survey (Figure 1) indicated Doppler distances ranging from 0.5 to 2.3 nautical miles with a mode at 1.6 nautical miles (for a vessel velocity of 3.2 knots). A similar plot for the 1976 autumn survey (Figure 2) indicated a range of 0.4-2.5 nautical miles with a mode at 1.6 nautical miles (for a vessel velocity of 3.2 knots). Velocities for the 1975 trawl mensuration cruise were calculated from starting and ending Loran positions for 30-min tows. Calculated velocities ranged between 2.3 and 4.8 knots with no apparent mode (Figure 3).

The regression of all available values for wind-driven, tidal, and combined wind-driven and tidal currents on vessel velocity for the 1976 spring survey indicated a positive relationship when tows were made with the current and a negative relationship when made against the current (Figure 4). There was no apparent relationship between wind-driven currents and ship velocity (Figure 5), but a positive relationship was evident between tidal currents and ship velocity when the vessel moved with the current and a negative relationship was noted when it moved against the current (Figure 6).

Thirteen demersal or semi-demersal species of fishes taken during the 1976 spring survey were used in Spearman rank correlation coefficient tests which compared weight or number of fish per tow and the distance traveled over the bottom. This test provided a nonparametric measure of the association between the two variables. Weight and number information from five species of fish obtained during the 1976 autumn survey was also used in the Spearman test. The Spearman test did not demonstrate any simple relationship between the distance traveled over the bottom and the catch (both in weight and number) for the 1976 spring and autumn surveys (Tables 1 and 2).

Doppler (independent variable) and calculated (dependent variable) speeds from the 1976 spring survey were regressed to yield a prediction equation of $f(x) = 0.59x + 0.91$, with $r = 0.65$. A t-test for the slope of this line showed a significant relationship at $p<0.005$ (Figure 7). Since it appeared that vessel velocity could be obtained from vector summation values using the above prediction equation, velocities for the 1975 trawl mensuration cruise were calculated and used in weight/number versus vessel speed comparisons. However, a relationship between vessel velocity and catch was not demonstrated using the Spearman test (Table 3).

DISCUSSION

Based on distances traveled during 30-min survey tows, the ALBATROSS IV seldom averaged 3.5 knots (the mode is 3.2 knots) and showed wide variation in velocity (Figures 1-3). Although variability in the accuracy of velocity measurements by shipboard instruments is possible, environmental influences such as tidal currents, wind-driven currents, and wind are likely responsible for much of this variation. Results indicate that tidal currents are the most influential of those factors. During past surveys the trawl cables (warps) have actually been observed going slack when heading into a strong tidal current, indicating little or no forward movement of the trawl (Jensen, personal communication)[3].

[3] H. Jensen, Woods Hole Laboratory, NEFC, NMFS, NOAA, Woods Hole, Massachusetts.

Figure 5 shows that total current velocity does, indeed, influence the velocity of the vessel. When total current velocity is separated into its component parts, wind-driven and tidal, it is apparent that the wind-driven current has little effect on the vessel (Figure 4). Tidal current appears to be the main influence affecting ship velocity, with the speed more than 1 knot greater when trawling with the current than against it (Figure 4). However, when the tidal-current data were used in a Spearman rank correlation coefficient test for association between the velocity of the current and the distance traveled during the tow, there was no significant (α=0.05) association. There are possibly several reasons for this. A triple stratification scheme (0-45°, 46-13°, and 136-180°) was arbitrarily chosen to dramatize the effect of trawling with and into the current. A decided paucity of tidal and wind-driven current data restricted our choice of smaller angles which might have shown such a relationship.

Another important aspect which was examined was the difference between the actual direction the ship moved and the recorded compass direction. Figure 8 shows that when the ship was trawling across the current (46-135°), there were large (up to 80°) differences between the compass trawl direction that was recorded and the actual ground trawl direction as interpolated from Loran bearings. However, due to insufficient data points, statistical tests were not able to give definite insight into real trends. Figure 8 does raise a question, though, on the physical condition of the net at those times when the vessel was trawling across the current. Frequently, the trawl cables (warps) have been observed at 45° angles to the apparent ship direction instead of directly astern.

Analysis of the relationship between vessel speeds and trawl catches may be used in determining an optimum vessel speed which would maximize the probability of catching most species of fish. Results, however, did not suggest a definite relationship. Since the bottom trawl surveys are based on a random selection of stations which are not necessarily located on fish concentrations, a large amount of variation is expected. Any number of factors such as water depth, season, water temperature, time of day, orientation of fish to any currents, and fish behavior could cause much of this variation.

Results of this study suggest the need for the NEFC bottom trawl survey to incorporate finer control of the distance and velocity over the bottom during trawl tows. Sampling methods have, in the past, used duration of tow as a convenient parameter for standardization. Time is probably of much lesser consequence than the actual distance traveled over the bottom. This report clearly demonstrates that the duration of the tow does not provide the necessary standardization to insure a constant distance traveled during the tow. To improve the standardization of the ALBATROSS IV bottom trawl surveys, the Doppler system (DSL-200) should be used instead of the EM log to determine distance and velocity.

The instantaneous velocity of the vessel, as indicated by the Doppler system, should be maintained at 3.5 knots for 30 min to insure a tow of 1.75 nautical miles. Time, velocity, and distance over the bottom could be standardized by this procedure which could result in a decrease in the present high variance about the mean of the trawl catches.

Literature Cited

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Edwards, A.L. 1976. An Introduction to Linear Regression and Correlation. Univ. of Washington. W.H. Freeman and Co., 213 pp.

Grosslein, M.D 1969. Groundfish Survey Methods. National Marine Fisheries Service, Northeast Fisheries Center. Laboratory Ref. No. 69-2 34 pp.

Mendenhall, W., and L. Ott. 1972. Understanding Statistics. Duxbury Press, 310 pp.

Table 1. Spearman rank correlation coefficient (Z) tests for relationships between the distance the trawl was towed and the catch in the trawl for the 1976 spring survey.

Species	Z value	Significance level (∝0.05)
Yellowtail flounder	1.06 (weight)	NS[1]
	1.16 (number)	NS
Winter flounder	1.58 (weight)	NS
	0.03 (number)	NS
Sand lance	1.39 (weight)	NS
	0.76 (number)	NS
Atlantic wolffish	1.56 (weight)	NS
	1.35 (number)	NS
Atlantic cod	0.20 (weight)	NS
	0.13 (number)	NS
Pollock	2.26 (weight)	$P<0.05$
	1.33 (number)	NS
Haddock	-0.98 (weight)	NS
	-1.11 (number)	NS
Redfish	0.78 (weight)	NS
	1.05 (number)	NS
Windowpane	0.39 (weight)	NS
	0.75 (number)	NS
Witch flounder	1.46 (weight)	NS
	1.14 (number)	NS
American plaice	0.03 (weight)	NS
	0.93 (number)	NS
Red hake	0.08 (weight)	NS
	0.51 (number)	NS
White hake	0.90 (weight)	NS
	0.77 (number)	NS

[1]NS = not significant.

Table 2. Spearman rank correlation coefficient (Z) tests for the relationships between the distance the trawl was towed and the catch in the trawl for the 1976 autumn bottom trawl.

Species	Z value (weight)	Significance level (∝=0.05)	Z value (number)	Significance level (∝=0.05)
Red hake	0.46	NS[1]	0.76	NS
Windowpane	0.26	NS	0.00	NS
Yellowtail flounder	0.74	NS	0.69	NS
Silver hake	0.42	NS	-0.17	NS
Atlantic cod	-1.09	NS	0.92	NS

[1]NS = not significant

Table 3. Spearman rank correlation coefficient (Z) tests for the relationships between the distance the trawl was towed and the catch in the trawl for the 1975 trawl mensuration cruise.

Species	Z value (weight)	Significance level (∝0.05)	Z value (number)	Significance level (∝=0.05)
Red hake	-0.05	NS[1]	-0.15	NS
Windowpane	-0.54	NS	-1.72	NS
Yellowtail flounder	-0.31	NS	0.08	NS
Silver hake	-0.70	NS	-0.93	NS
Haddock YOY[2]	-0.44	NS	-1.26	NS

[1]NS = not significant.
[2]YOY = young of the year.

Figure 1. Doppler distances for the 1976 spring bottom trawl survey of the ALBATROSS IV.

Figure 2. Doppler distances for the 1976 autumn bottom trawl survey of the ALBATROSS IV.

Figure 3. Calculated velocities of the ALBATROSS IV during the 1975 summer trawl mensuration cruise.

Figure 4. Simple linear regression of Doppler velocity on total current velocity for the 1976 spring bottom trawl survey.

Figure 5. Simple linear regression of Doppler velocity on wind driven current velocity for the 1976 spring bottom trawl survey.

Figure 6. Simple linear regression of Doppler velocity on the tidal current velocity for the 1976 spring bottom trawl survey.

Figure 7. Simple linear regression of Doppler velocity on calibrated velocity for the 1975 trawl mensuration cruise.

Figure 8. Simple linear regression of difference between the compass bearing during trawling and Loran-interpolated direction and the tidal current velocity for the 1975 trawl mensuration cruise.

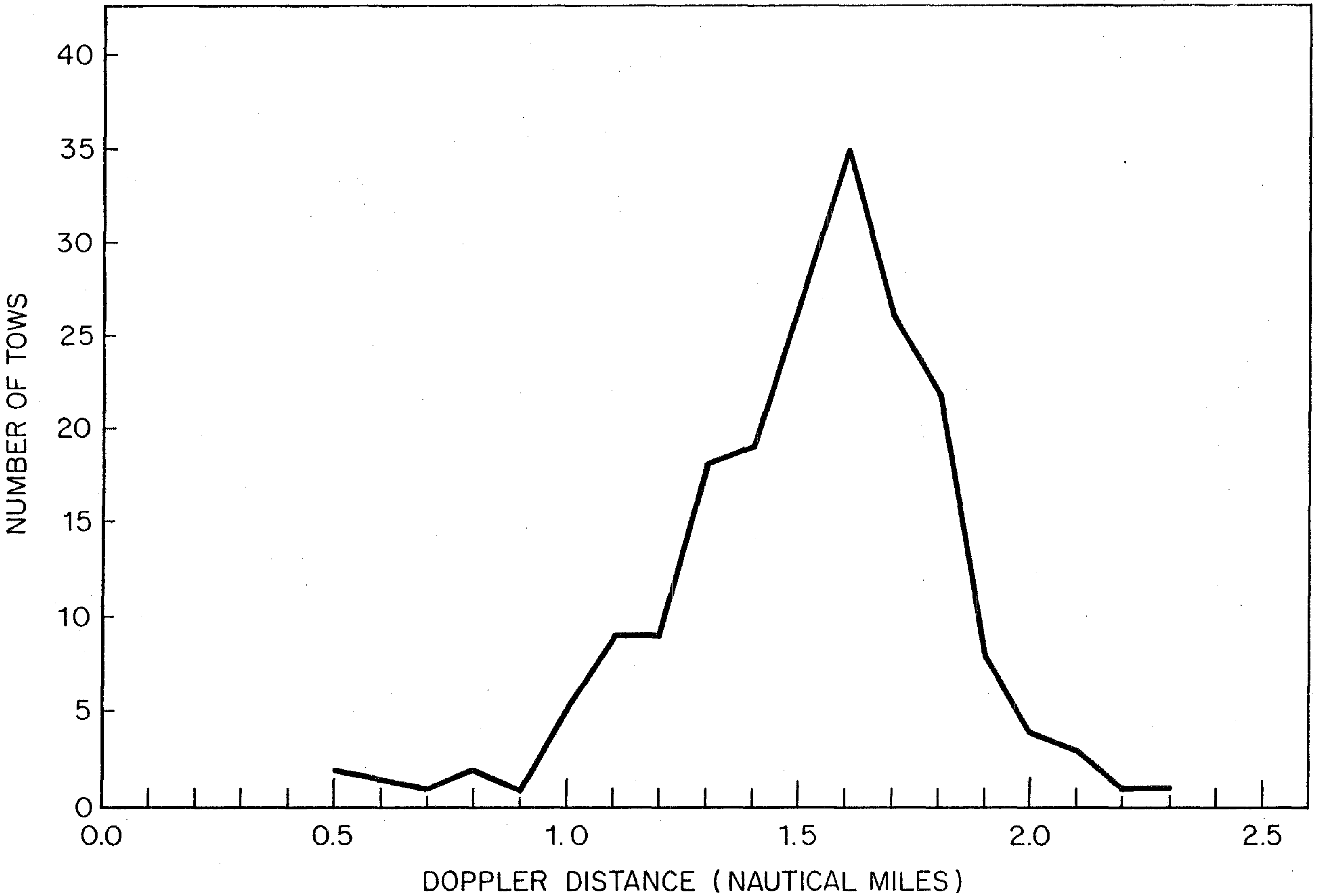


Figure 1. Doppler distances for the 1976 spring bottom trawl survey of the ALBATROSS IV.

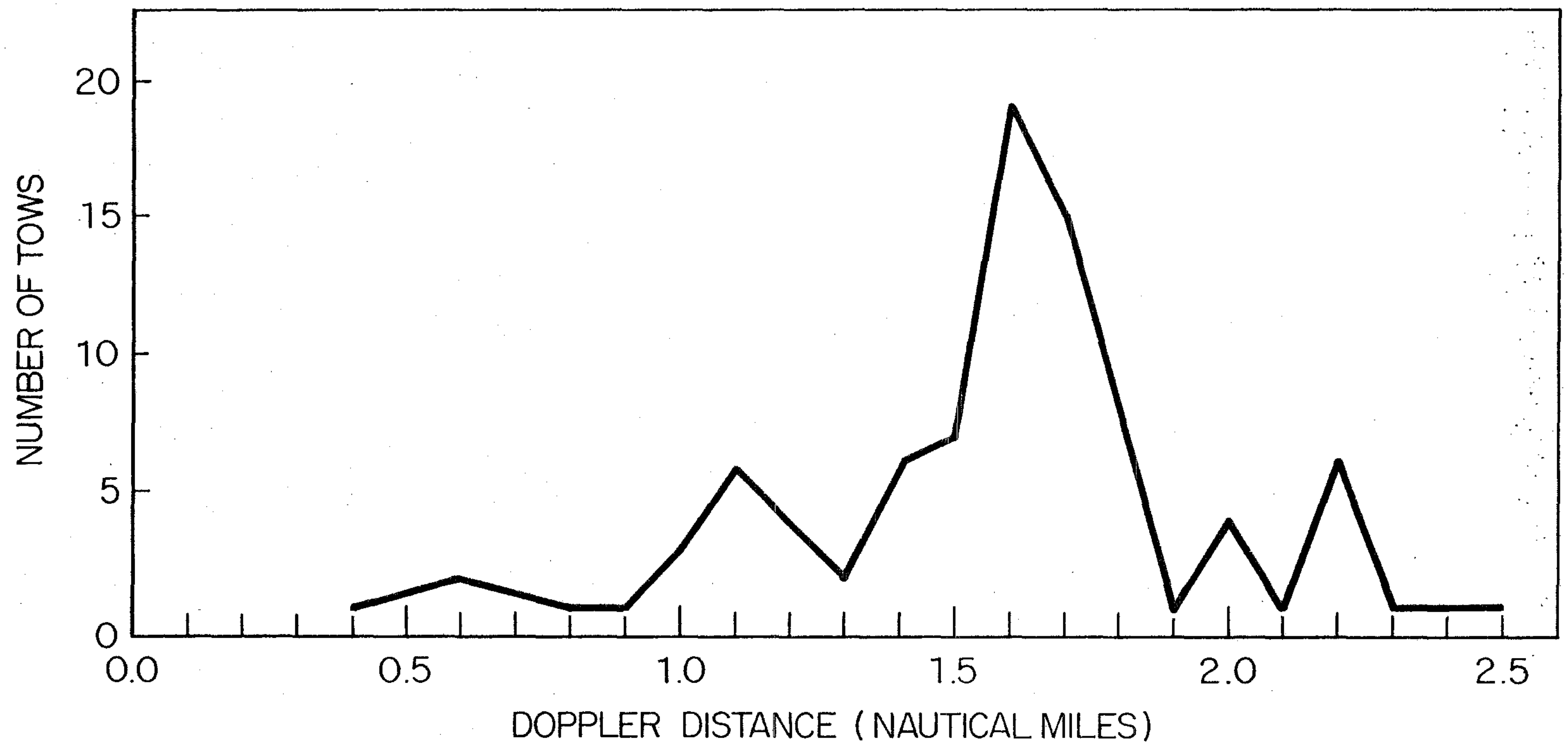


Figure 2. Doppler distances for the 1976 autumn bottom trawl survey of the ALBATROSS IV.

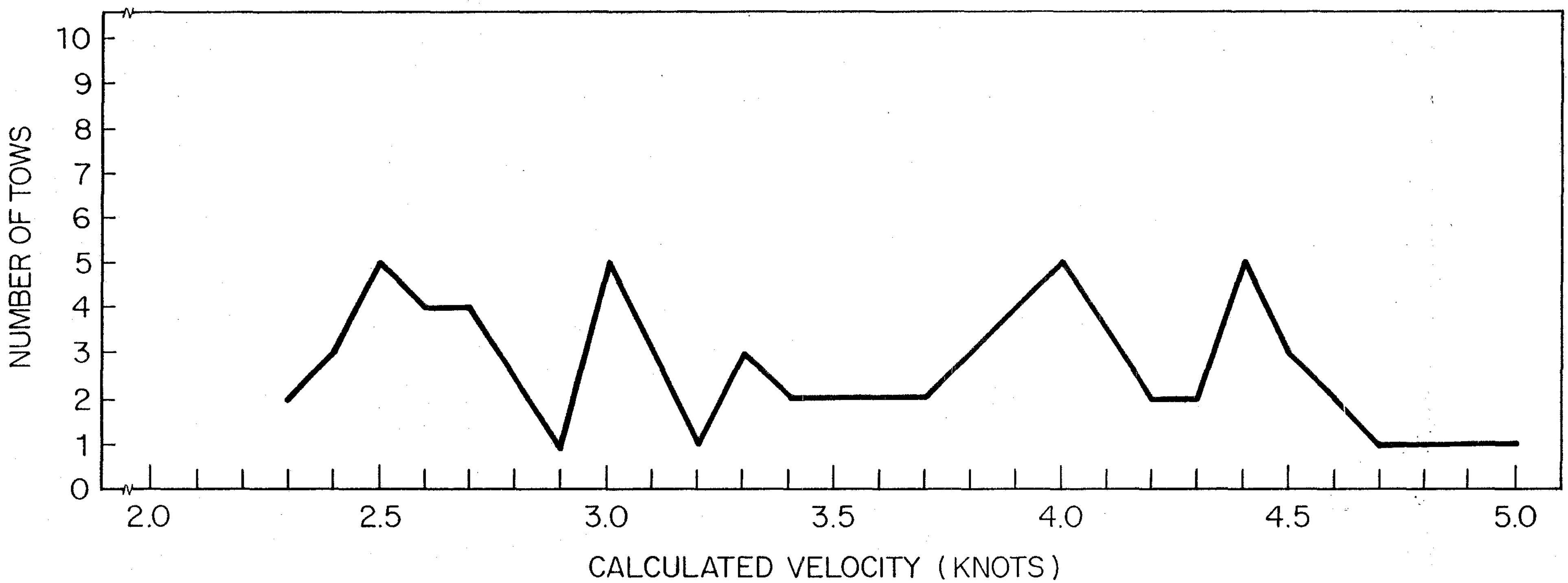
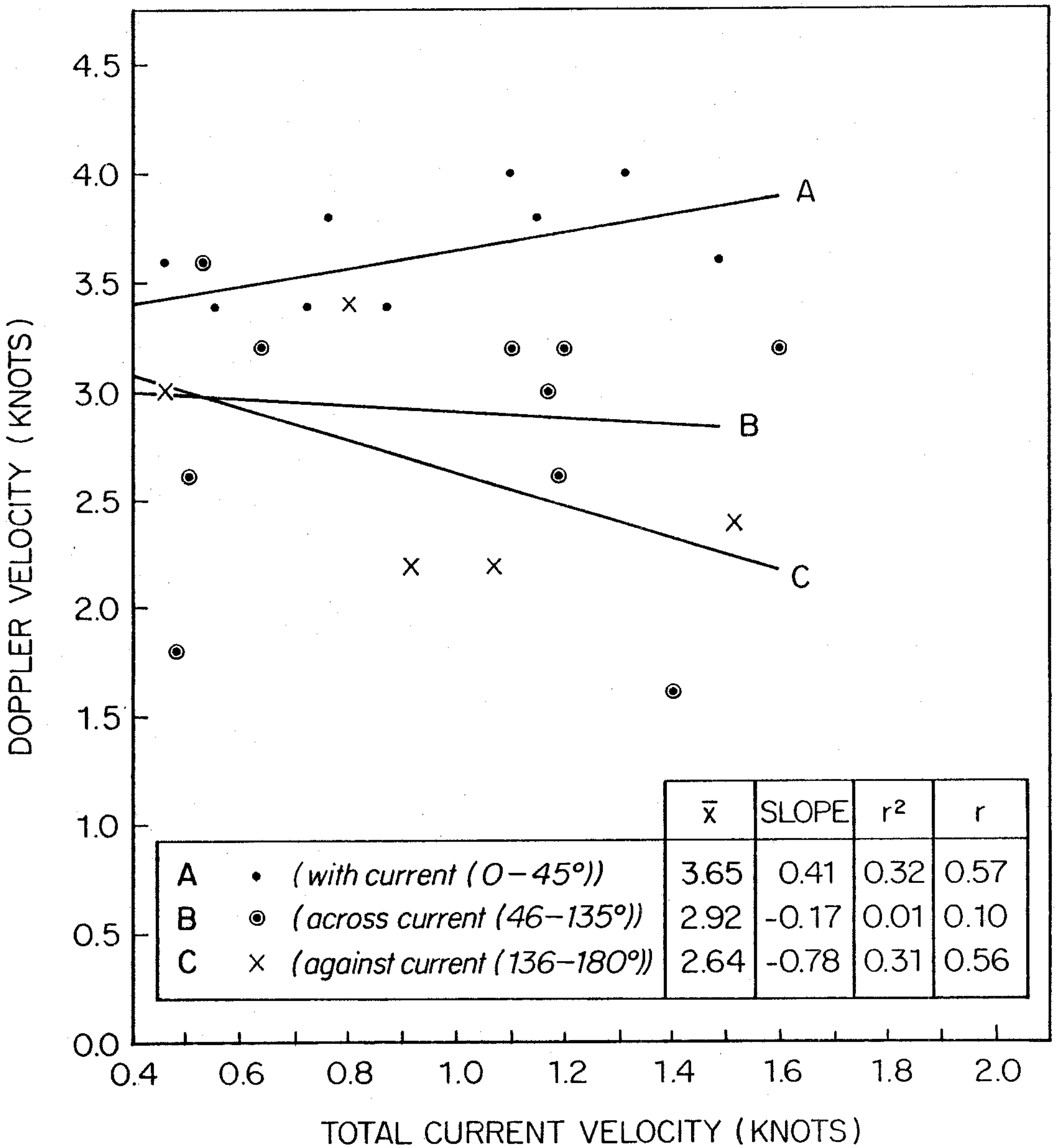


Figure 3. Calculated velocities of the ALBATROSS IV during the 1975 summer trawl mensuration cruise.



		x̄	SLOPE	r^2	r
A	• (with current (0–45°))	3.65	0.41	0.32	0.57
B	⊙ (across current (46–135°))	2.92	-0.17	0.01	0.10
C	× (against current (136–180°))	2.64	-0.78	0.31	0.56

Figure 4. Simple linear regression of Doppler velocity on total current velocity for the 1976 spring bottom trawl survey.

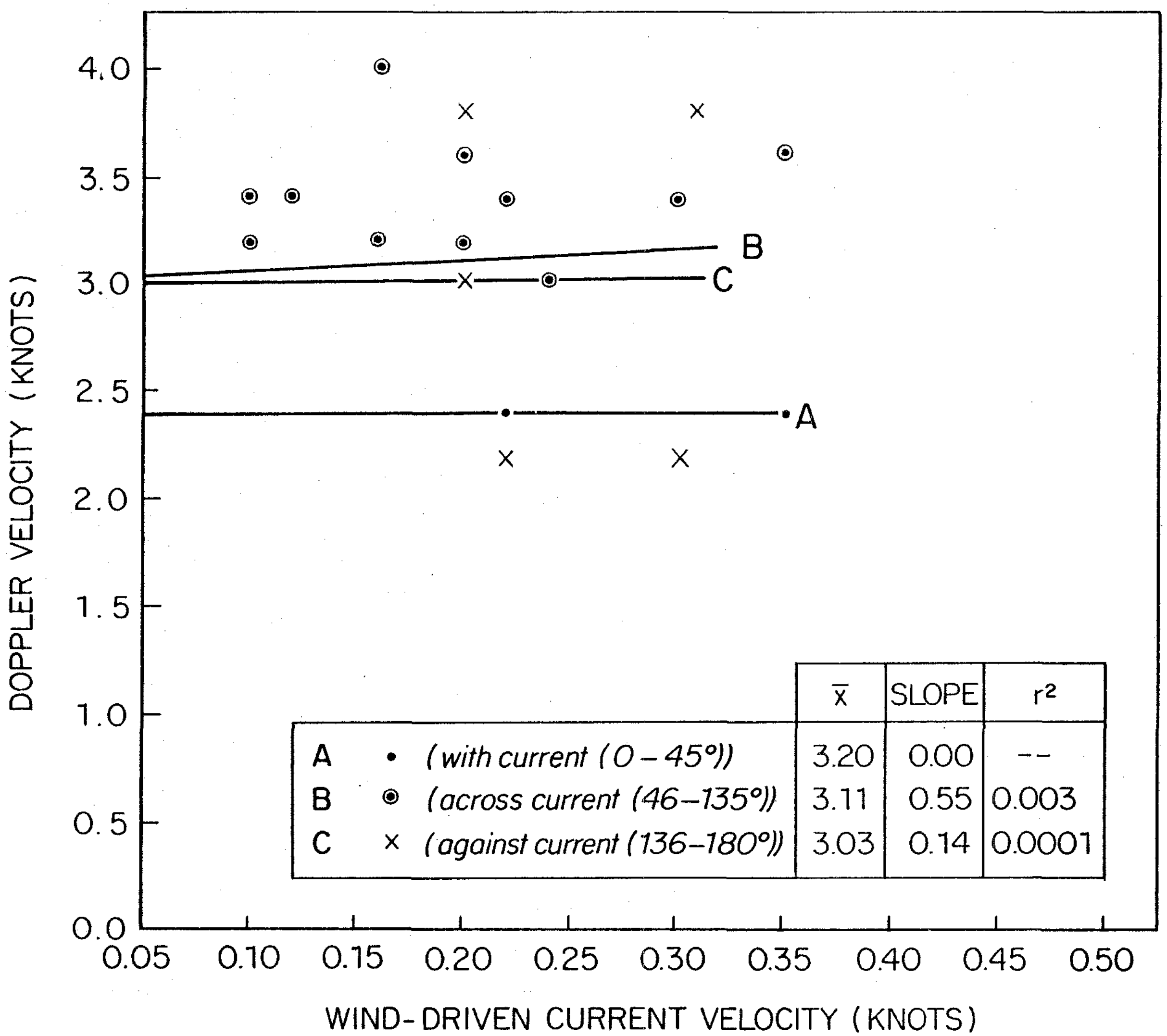


Figure 5. Simple linear regression of Doppler velocity on wind driven current velocity for the 1976 spring bottom trawl survey.

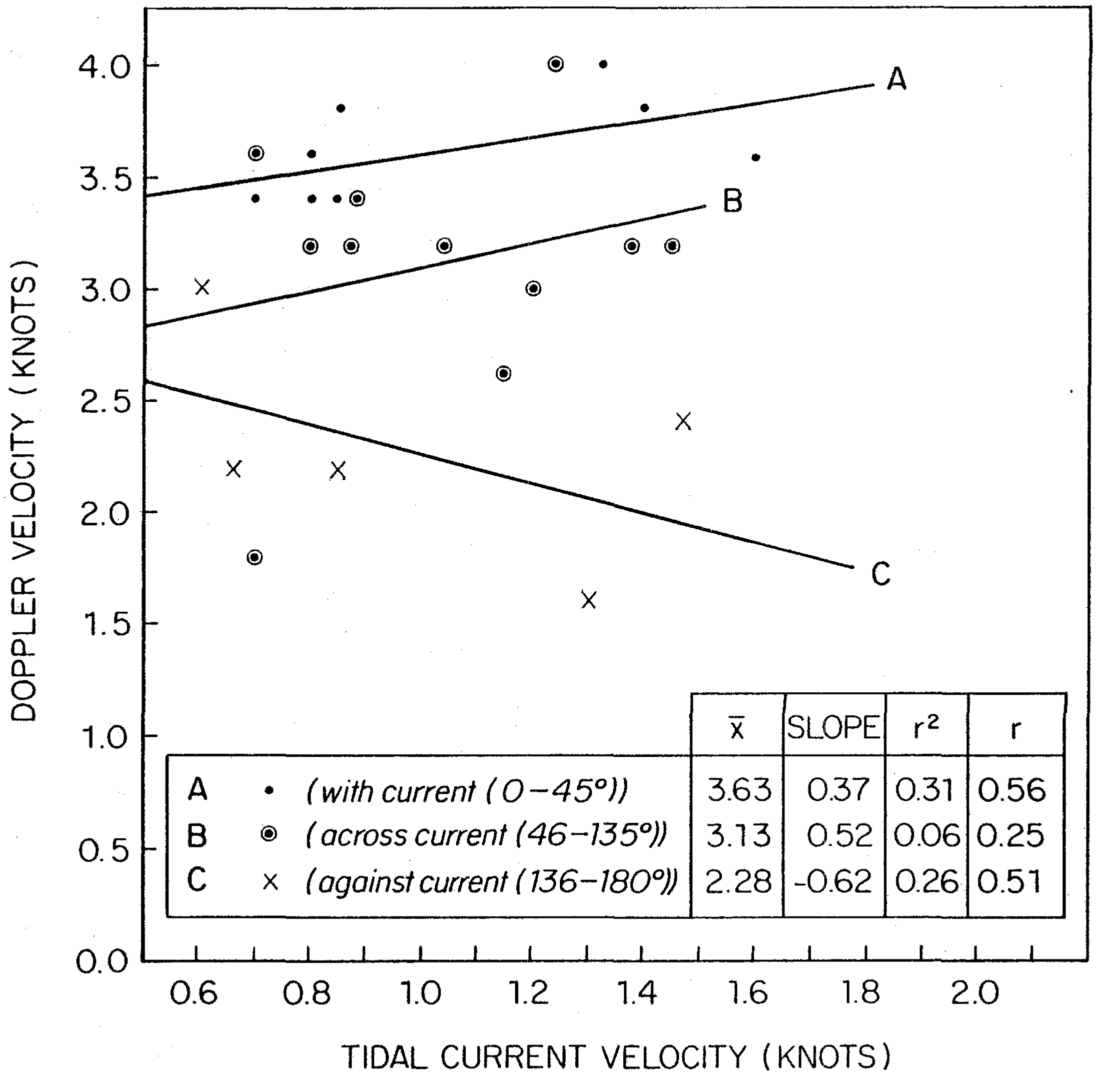


Figure 6. Simple linear regression of Doppler velocity on the tidal current velocity for the 1976 spring bottom trawl survey.

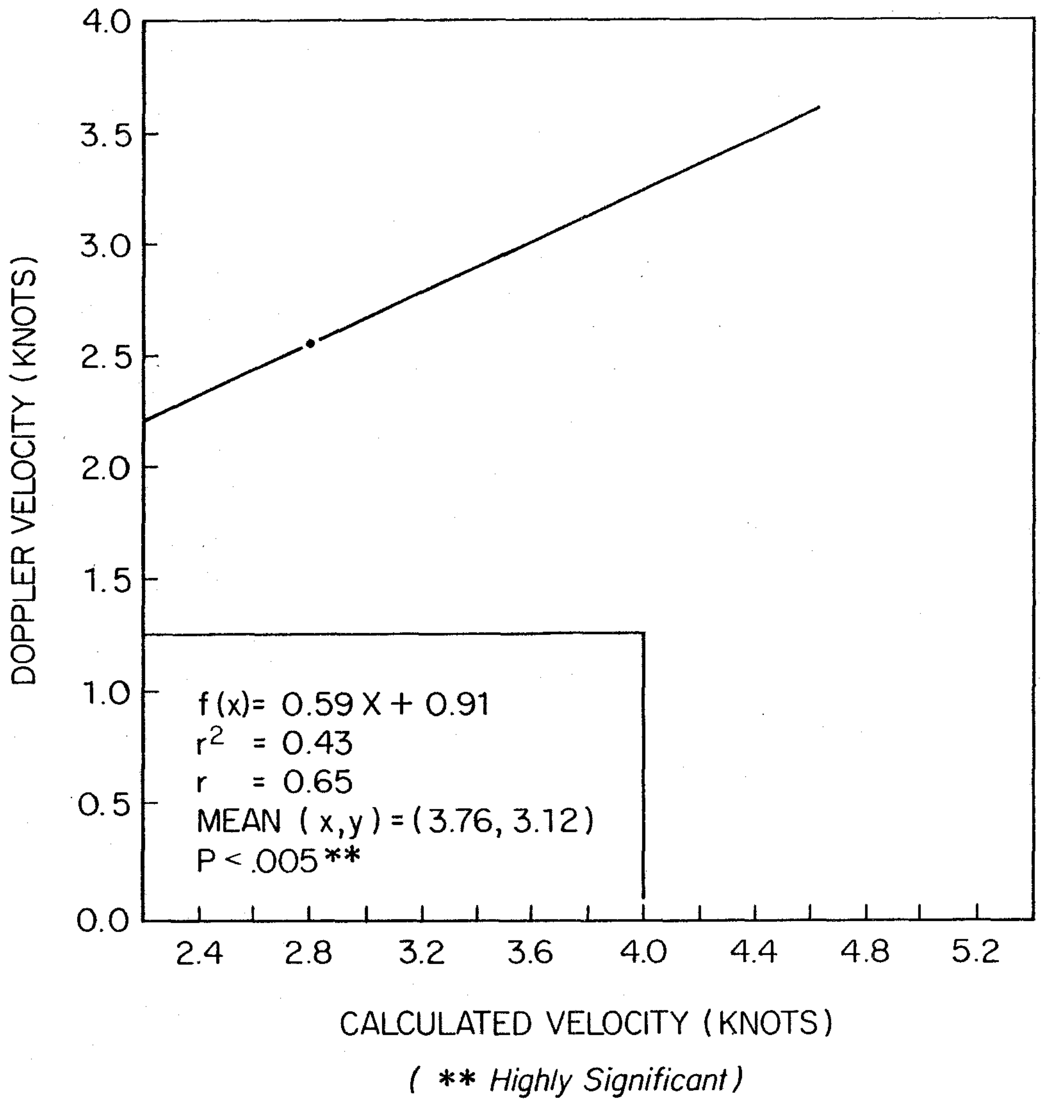
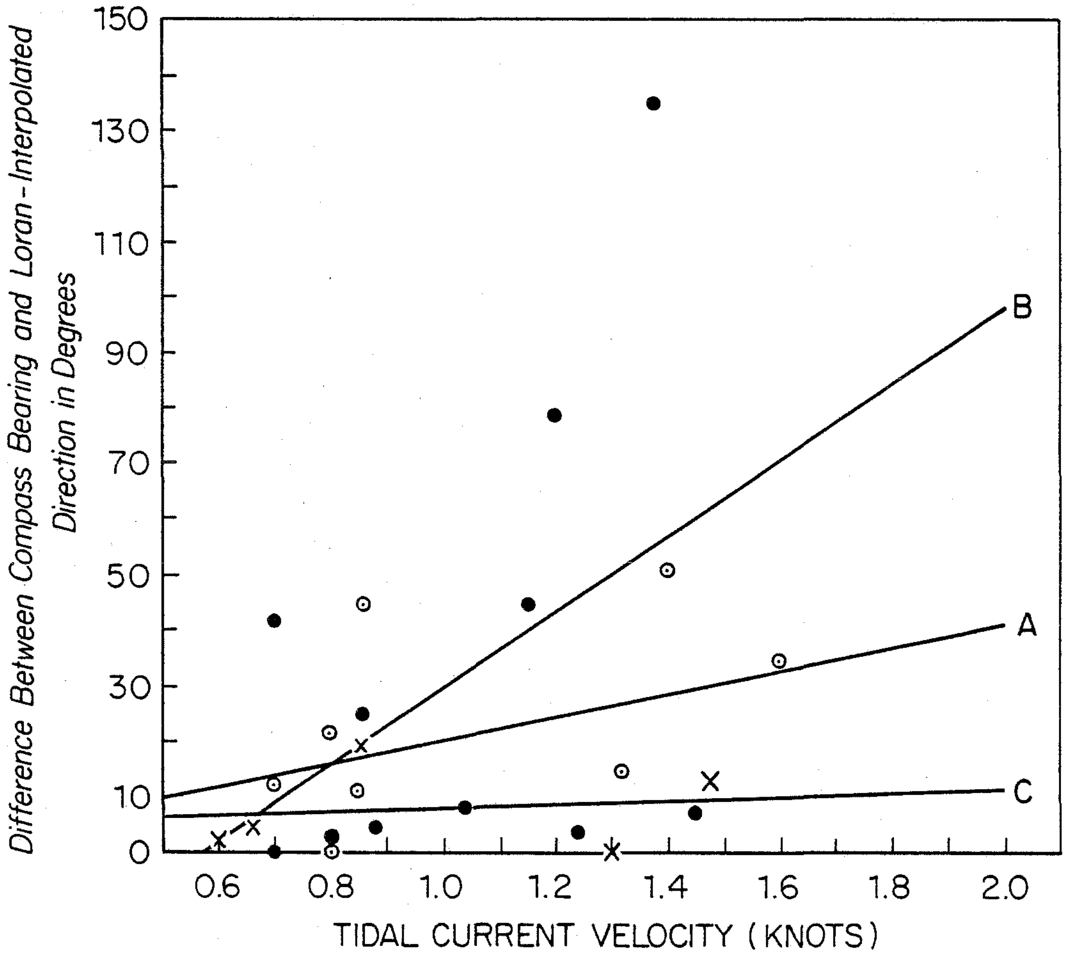


Figure 7. Simple linear regression of Doppler velocity on calibrated velocity for the 1975 trawl mensuration cruise.



			r^2
A	•	*(with current (0–45°))*	0.51
B	⊙	*(across current (46–135°))*	0.43
C	×	*(against current (136–180°))*	0.16

Figure 8. Simple linear regression of difference between the compass bearing during trawling and Loran-interpolated direction and the tidal current velocity for the 1975 trawl mensuration cruise.