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Abiotic Factors Relating to Squid Abundance as Determined from Groundfish Cruises 1970 - 1980

by

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This study is a repeat of Koeller (1980) which examined the factors affecting the distribution of squid as determined from data from the June groundfish survey cruises. For the last few years survey estimates of the distribution, biomass and length of squid on the Scotian Shelf have been reported (Koeller, 1980; Dufour, 1979; Scott, 1978).

METHODS

The data base and methods are essentially the same as reported in Koeller (1980). Our values vary slightly from those reported in Koeller (1980). This is because more restrictive criteria were used in this study to edit the data. If any of the values of temperatures or salinity were missing all the remaining variables associated with that set were dropped.

RESULTS AND DISCUSSION

From the means in Table 1 it is noted that 1976 had the highest catch rate and the highest surface and bottom temperatures. This year also had the lowest total catch which may reflect the abundance of predators. In the following analyses the data base is from 1970 to 1979 inclusive. As the 1980 data are preliminary they will not be included on the same basis as the earlier data. Multiple regression output and the correlation matrix for the first ten years of data are given in Tables 2 and 3.

The multiple regression is just significant at the 5% level. If one reduces the number of degrees of freedom in the numerator to just two variables, surface and bottom temperature, the regression is significant with an F-ratio of 12 ($F0.01, 2, 7 = 9.55$). The bottom temperature accounts for 68% of the observed variation.

Depth has been added to the correlation matrix but was not included in the regression. The mean depth of tow shows a negative correlation with all variables except total catch. Thus years when the average depth was large the squid catch was small. This is contrary to the usual belief that squid prefer deeper water. To look further into this relationship the individual tows for the years 1975 to 1979 were investigated. Using the same variables as above with the inclusion of the depth, the multiple regression was rerun. The results are summarized in Table 4.

The very low R2's indicate that for a given tow one cannot predict using a linear model the squid catch from the depth, surface temperature, bottom temperature, salinity and/or total catch. These observations are collaborated by lumping the catches by depth in intervals of 25 meters. The data shown in Table 5 have been accumulated for the years 1975 to 1979. The best catch rates are seen to be in the vicinity of 100 meter depths. The patterns for the individual years are quite similar to those presented for the 5 year total.

The influence of the time of day on the tow can also be evaluated looking at the data from the last five years. If the catch rates are grouped into 4 hour sets, Table 6 results. The time of day has a considerable affect on the catch rate with almost a factor of ten seen in the mean catch rates between the 0-4 and 8-12 catch groups. Although the standard deviations are quite large, the sample sizes give us some confidence in the magnitude of the diurnal nature of the catch rate. This factor should be incorporated into the biomass estimates, even though the distribution of the times of tows is fairly uniform. Factors were developed using the five year averages from Table 6 and normalizing so the 8-12 tows had a value of unity (see Table 7). When these factors are applied to the entire data base the resultant annual average become as shown in Table 8.

While the scaling for the diurnal effects has a large influence (a factor of 1.8) on the biomass estimates, its effect on the multiple regression was only slight. The R2 fell from .816 to .800. The reasons that only a small influence was noted are the uniformity of the tows in time and the relatively small number of large catch rates. The catch rates range from 0 to 5800 squid per half hour tow. However, in 1426 tows, 679 (48%) were zero and 570 (40%) were between 1 and 20. So, although the diurnal coefficients were large in about 90% of the cases they were multiplying small catch rates. The correlation matrix for the scaled data, Table 9, is as expected only slightly changed from the unscaled version.

As well as the influence of the time of day on catch rate, the importance of geographic location was investigated. Figure 1 is a map showing the positions of the hauls which had no squid and those which had a good catch. A good catch rate was defined for this instance to be above 100 squid. This represents 99 tows or 7% of the tows from 1970 to 1979. There were no good catches in the Bay of Fundy. However, there appears to be more than average along the edge of the Shelf and along the Laurentian Channel.

Recruitment

Recruitment of squid onto the Scotian Shelf is not well understood. The spawning population has not been found let alone estimated. Juveniles and larvae are found in the spring from Shelf waters out to the Gulf stream. The spatial and temporal extent of this recruitment phase have not been delineated. Figure 2 is a plot of subsequent years' catch rates. No pattern is evident and there are not enough data to explore a model of chaotic behavior as defined by May (1975) and other theoretical biologists. The catch rates from year to year (Figure 3) for the eleven year period do not appear to be cyclical or display any other obvious pattern.

The multiple regression coefficients are used with the means of the preliminary 1980 data for sea temperatures, salinity and total catch to predict the mean squid catch rate. Using the values from Tables 1 and 2 we find:

$$\begin{aligned} \text{Rate} &= 2236 + 120.2 \times 6.2 + 15.05 \times 13.1 \\ &\quad - .1105 \times 380 - 92.79 \times 33.45 \\ &= 32.6 \end{aligned}$$

which is twice the size of the observed rate. This poor agreement cannot be explained at present and it is not known to what degree 1980 is an anomolous year. (See Figure 3, 1975 points). A second consideration regarding the usefullness of this approach is the degree to which the independent variables in the above equation can be forecasted.

Discussion

The multivariate regressions imply that bottom temperature is the factor most closely related to squid abundance as determined by catch rates from the spring (July) groundfish survey data. The other factors considered, surface temperature, salinity, combined catch of all species and to a lesser extent depth, added only marginally to the ability to estimate the squid catch rate in a linear model. Although the time of day had a large effect on the catch rate, including this correction did not appreciably alter the multiple regression. The result of the diurnal effect on biomass estimates would be to increase them approximately two-fold.

On the basis of these data a recruitment relationship could not be determined and indeed it is doubtful that any of the established models of stock recruitment are applicable to this species.

REFERENCES

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May, R.W. 1975. Biological populations obeying difference equation: stable points, stable cycles and chaos. J. Theoret. Biol. 49: 511-524.

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Table 1. Mean annual statistics.

	CATCH #	SURFACE TEMP.	BOTTOM TEMP.	SALINITY %	TOTAL CATCH (KG)
1970	5.4	14.8	5.3	33.21	133
1971	23.6	13.4	5.7	33.13	217
1972	7.8	13.2	5.7	33.35	124
1973	8.4	15.0	5.7	33.41	143
1974	12.0	13.2	5.8	33.55	187
1975	35.7	14.7	5.4	33.34	126
1976	189.7	15.5	6.8	33.62	95
1977	51.3	14.3	6.4	33.66	184
1978	18.7	15.1	5.8	33.36	166
1979	72.5	13.9	6.5	33.47	493
1980*	16.3	13.1	6.2	33.45	380

*Preliminary

Table 2. Multiple Regression results.
r^2 = .82; constant term = 2236

VARIABLE	CO-EFFICIENT	S ERROR	T-VALUE	PROPORTION OF VARIATION
Bottom Temp.	120.2	38.0	3.16	.68
Surface Temp.	15.05	14.4	1.05	.09
Total Catch	-0.1105	0.116	-0.96	.02
Salinity	-92.79	102.0	-0.91	.03

Table 3. Correlation matrix.

VARIABLE	DEPTH	SURFACE TEMP.	BOTTOM TEMP.	SALI-NITY	TOTAL CATCH	SQUID CATCH #
Depth	1.000	-0.347	-0.124	-0.294	0.528	-0.310
Surface Temp.	-0.347	1.000	0.181	0.171	0.327	0.443
Bottom Temp.	-.124	0.181	1.000	0.757	0.318	0.823
Salinity	-0.294	0.171	0.757	1.000	0.053	0.552
Total Catch	0.528	-0.327	0.318	0.053	1.000	0.027
Squid Catch #	-0.310	0.443	0.823	0.552	0.027	1.000

Table 4. Summary of individual tow regressions.

YEAR	r2*	r (DEPTH-CATCH)	r (T BOTTOM-CATCH)
1975	.03	.01	.06
1976	.06	.14	.14
1977	.04	.09	.08
1978	.06	.11	.15
1979	.04	.01	-.07

*For all five independent variables.

Table 5. Squid catch rate as a function of depth.

DEPTH	# OF TOWS	MEAN CATCH/TOW	S.D.
0- 25	27	19	62
25- 50	242	8	20
50- 75	171	73	247
75- 100	103	241	676
100- 125	89	104	155
125- 150	45	57	147
150- 175	23	18	44
175- 200	17	11	26
200+	1	0	-

Table 6. Squid catch rate as a function of time of day.

TIME	# OF TOWS	MEAN CATCH/TOW	S.D.
0- 4	125	14	58
4- 8	112	78	266
8-12	115	130	578
12-16	120	104	300
16-20	130	79	240
20-24	117	36	149

Table 7. Diurnal factors for catch rate.

TIME	FACTOR
0 - 4	9.29
4 - 8	1.67
8 -12	1.
12 -16	1.25
16 -20	1.65
20 -24	3.61

Table 8. Corrected annual average catch rates.

YEAR	SQUID CATCH RATE	RATIO CORRECTED TO RAW
1970	9.6	1.8
1971	40.7	1.7
1972	14.4	1.8
1973	14.4	1.7
1974	25.1	2.1
1975	52.5	1.5
1976	337.9	1.8
1977	80.8	1.6
1978	30.9	1.7
1979	151.2	2.1
1980	26.6	1.6

Table 9. Correlation matrix for scaled catch rates.

VARIABLE		DEPTH	SURFACE TEMP.	BOTTOM TEMP.	SALI-NITY	TOTAL CATCH	SQUID CATCH #
Depth	10	1.000	-0.347	0.124	-0.294	0.528	-0.242
Temps.	11	-0.347	1.000	0.181	0.171	-0.327	0.412
Temp. B	12	-0.124	0.181	1.000	0.757	0.318	0.838
Saun.	13	-0.294	0.171	0.757	1.000	0.053	0.546
Total Catch	14	0.528	-0.327	0.318	0.053	1.000	0.099
Squid #	5	-0.242	0.412	0.838	0.546	-0.099	1.000

Table 10.

LENGTH DISTRIBUTION 2/ 6/81

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
4			1								
5	2	1	1			3					
6	2	3									
7	6	3				2	1				
8	11	2			1	4				1	
9	7	3	1		3	4			1	1	1
10	2	4	1		1	8	1		5	1	2
11	28	6	2		2	7			7	7	
12	61	15	11	2	3	1	1		18	29	3
13	75	25	24	5	8	4		3	18	44	3
14	72	63	62	20	27	27	7	17	24	46	23
15	117	174	128	33	68	50	7	31	40	45	71
16	136	260	230	64	140	157	35	74	109	66	114
17	124	305	285	89	222	427	204	226	270	230	221
18	55	322	223	174	366	439	744	545	603	550	288
19	30	192	129	200	397	274	1488	925	436	910	278
20	15	80	64	120	268	136	2158	831	213	838	161
21	3	19	24	59	148	49	1864	550	86	347	73
22		5		14	101	16	1243	346	32	175	21
23	2			5	66	8	601	149	11	68	11
24	1		1	2	29		219	70	6	14	3
25	1			1	6		67	32	1	9	1
26				1	7		30	16		3	1
27				1	1		2	8		1	1
28		1		3	1	1	2	2		1	1
29						1		4		2	3
30								3			
31							1				
MEAN	15.1	16.9	16.9	18.4	18.8	17.7	20.4	19.8	18.2	19.1	18.2

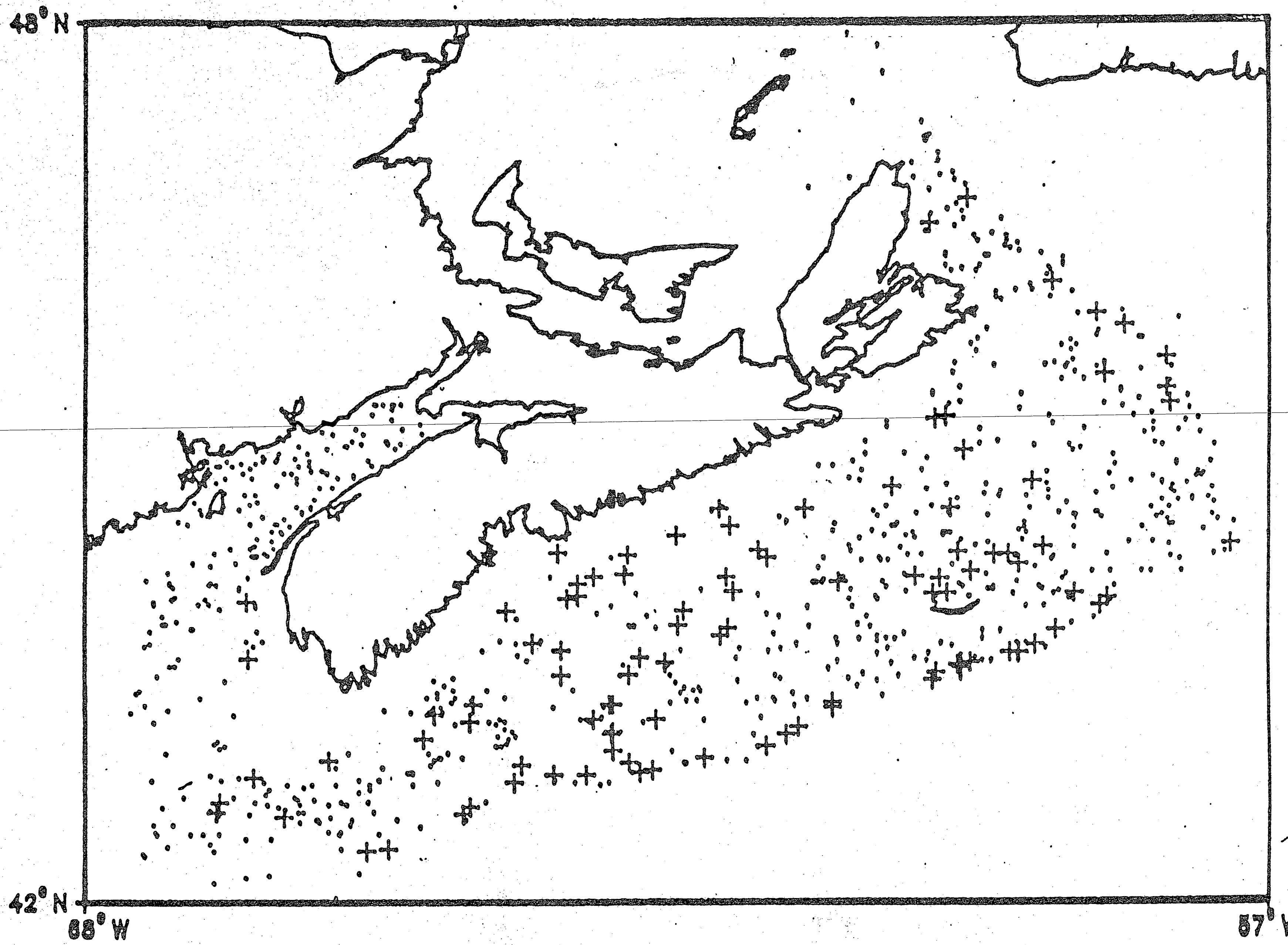

Figure 1. Squid catch rates of zero (.) and 100+ (+) from 1970 to 1979.

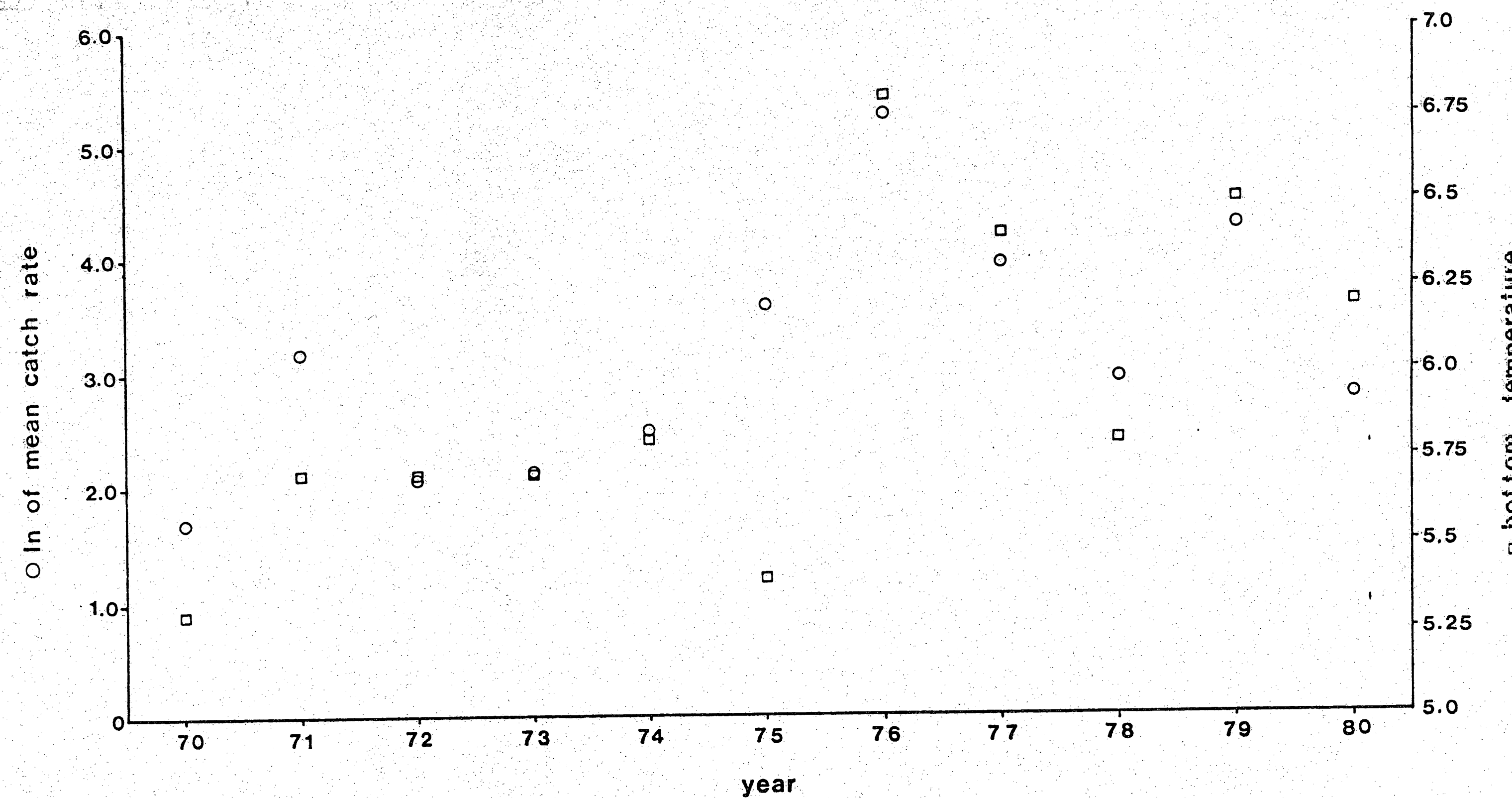

Figure 2. Successive year mean catch rates. (#/tow)

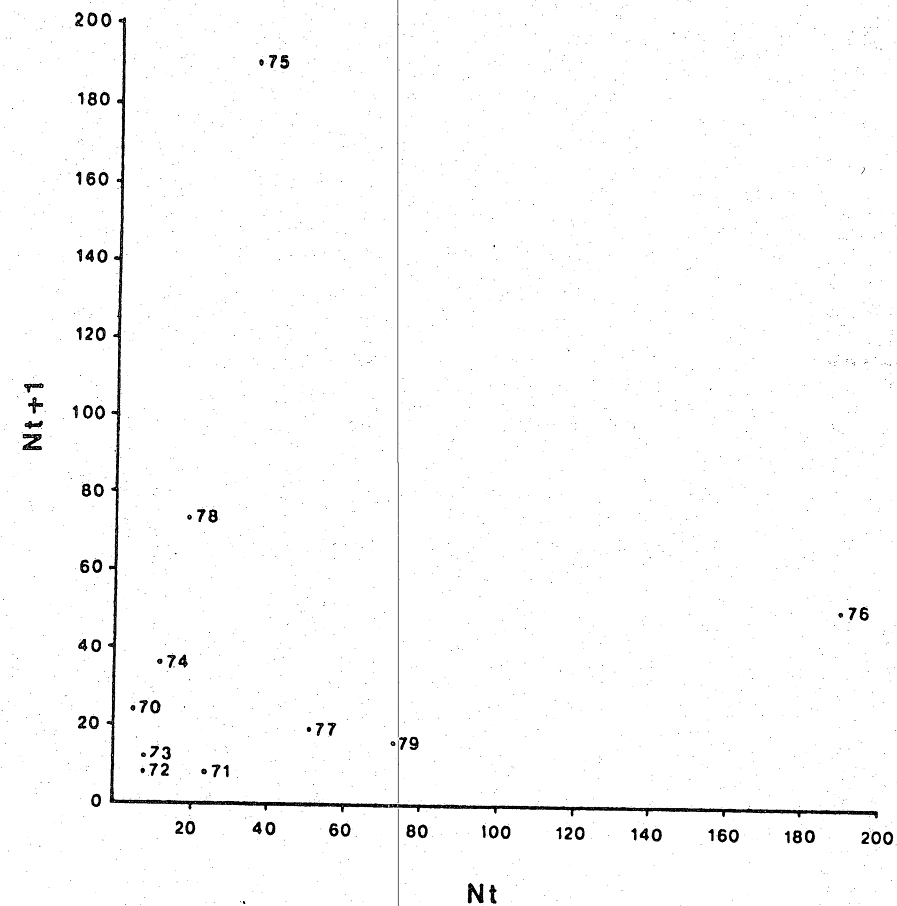

Figure 3. Natural log of mean catch rate and bottom temperature of research survey data.