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Investigations into the Relationship Between Shelf Bottom Temperature and the Silver Hake Catch Rate on the Scotian Shelf

by

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Introduction

On the Scotian Shelf, the silver hake (Merluccius bilinearis) represents an extremely important resource for foreign fleets fishing within Canada's 200 mile limit. In 1985 75,492 mt of silver hake was harvested by the USSR, Cuba, and Japan, more than any other groundfish species on the Scotian Shelf. Since 1977 fishing effort for silver hake by foreign vessels has been restricted to an area seaward of what is known as the Small Mesh Gear Line (SMGL; Figure 1), where gear with a codend mesh size as low as 60 mm could be employed.

Silver hake is a species which shows a preference for warmer water compared to most Scotian Shelf fish species. Scott (1982) lists the prefered temperature range for this species as approximately 7-10°C. The Scotian Shelf possesses a complex temperature structure, as cold, shallow shelf water is influenced by periodic invasion of warm slope water (Trites, 1982) particularly between 61° and 64°W latitude (Garcia, 1981). These intrusions vary from year to year, but in general are more intense during the summer months (Garcia, 1981). The temporal and spatial position of these water mass variations coincide almost exactly with the foreign silver hake fishery on the Scotian Shelf. During this period silver hake move into more shallow water to spawn (Garcia, 1981; Scott, 1982). In doing so this species may follow warm water inshore of the small mesh gear line, yet the commercial fleets are restricted to waters seaward of this line. Given this situation it might be expected that catches by the silver hake fishery would be affected by unusually high bottom temperatures on the Scotian Shelf. The objective of the present study was to investigate this phenomenon by comparing catch per unit effort (CPUE) by the silver hake fishery with bottom temperatures on the Scotian Shelf inshore of the small mesh gear line.

Methods

To investigate the relationship between water temperature on the Scotian Shelf and catch rates of silver hake seaward of the SMGL, the following hypothesis was tested. If warm slope water has intruded onto the Scotian Shelf, the silver hake will follow and the population will be less available to the fishery. This should result in a lower catch rate for the commercial fleet. Conversely, if temperatures on the Scotian Shelf remain low, silver hake will be confined to deeper waters and be more accessable to the foreign fleets. In this case, catch rates should be higher. The null hypothesis is that catch rates outside the SMGL are independent of bottom temperatures on the shelf. Testing this hypothesis requires temperature data for the area landward of the SMGL, and catch rates for the foreign fleet seaward of the SMGL, both broken down by season.

A vast quantity of oceanic temperature data is available through the MEDS database. Unfortunately, most of the measurements are surface temperature only. When near-bottom temperature data from this database for the area in question is broken down by year and season, the remaining data are not sufficient to provide a meaningful comparison. Despite the complex hydrodynamics of the Scotian Shelf, surface temperature data have been utilized by fleet captains in determining fishing locations for silver hake (Waldron, 1986 pers. comm.), suggesting a link between surface and bottom temperature. Temperature data collected on groundfish research surveys between 1970 and 1985 (unpublished) shows no significant correlation between surface temperature and bottom temperature ($r = 0.04$, $p > 0.05$). As a result, the MEDS database surface temperature data cannot be used to predict bottom temperature for this area.

Groundfish abundance on the Scotian Shelf has been routinely investigated by spring (March), summer (July), and fall (October) research surveys by Canada over the past 16 years (1970-1985, 4,182 sets). Station locations for these surveys were selected on a depth-stratified random design (Halliday and Kohler, MS 1971; Figure 2). Following each tow, bottom temperature was measured using reversing thermometers. The data set resulting from these surveys provides a relatively complete record of bottom temperatures on the Scotian Shelf to be compared to the silver hake catch rate of the commercial fleet.

For the purposes of the present study, critical areas of the Scotian Shelf immediately landward of the SMGL were defined (Figure 3). These were stratified by depth as follows; area I: less than 50 fathoms (strata 55, 56, 63, 64, and 73; Figure 2) and area II: 51-100 fathoms (strata 54, 62, 65, 72, and 77; Figure 2). Mean bottom temperature was calculated for each group, by season by year, for the period 1977-1985.

Catch data from the USSR silver hake fishery was selected for comparison with shelf bottom temperatures, as restricting the analysis to a single nation eliminates the need to correct for differences in fishing efficiency between countries. Catch and effort data were extracted from NAFO Statistical Bulletins (1977-1985). CPUE was calculated as metric tonnes/hour, broken down by season, with the following breakdown; spring: April-May; summer: July-August; fall: September. In addition, standardized catch rates for the USSR were calculated via a multiplicative model (Waldron et al., 1986). The estimated population biomass was calculated as follows: one VPA (terminal F of 0.25, M = 0.4) was run using partial recruitment from the 1985 assessment (Waldron and Fanning, 1985). A new partial recruitment was calculated from average F's at age for 1977-1983. Subsequently another VPA at terminal F of 0.25 and M = 0.4 was run, and the resultant population numbers were multiplied by the mean weights at age for each year.

Results and Discussion

Temperature data for the two critical areas for 1977-1985 are summarized in Tables 1a and b. Coverage was generally complete, with the exception of area I, spring, for which only 12 observations (3 empty cells) were available. Area I, on average, showed a warming trend from spring to fall, as temperature rose from 5.8°C to 9.7°C. Average temperatures for area II showed little seasonal change, ranging from 8.2 (spring and summer) to 8.0 (fall).

Catch statistics for the Soviet silver hake fishery (NAFO Statistical Bulletin) outside the small mesh gear line for 1977 to 1985 are presented in Table 2. A fall fishery by this country for silver hake occurred in only one instance (Sept., 1979), hence this season was not considered for further analysis.

CPUE for the fleets ranged from 0.75 (1980) to 2.36 (1982) for spring, and 0.75 (1980) and 1.91 (1982) for summer. Estimated 1+ biomass ranged from 140,707 mt in 1978 to 837,867 mt in 1985. These results are presented in Table 3. Standardized catch rates from the multiplicative model are also presented in Table 3.

Multiple regression techniques were employed to assess the effects of shelf bottom temperature on silver hake catch rates after accounting for effects of stock biomass. As the VPA for later years has not converged, the analysis was performed separately for three intervals: 1977-82, 1977-83, and 1977-85.

Initially, analysis was performed assessing the effects of temperature, by season, on the CPUE extracted from NAFO statistical bulletins. Results are presented in Table 4a and b.

In all cases, effect of shelf bottom temperature on catch rates is not significant ($p > 0.05$) after correction for biomass.

A second regression analysis was performed, comparing yearly standardized catch rates (from Waldron and Fanning, 1986) to shelf bottom temperature (July only). Results are summarized in Table 5. Again, bottom temperature was not found to significantly affect silver hake catch rates, except for one rise. In Area I, for the period 1977-82, a significant effect was found. However, examination of a scatterplot of the data (Figure 4) shows the regression to be driven by one influential point.

These data support the hypothesis that catch rates seaward of the small mesh gear line is independent of bottom temperatures landward of the line. However, it should be noted that these conclusions are based on a relatively small data set. Further research in this area is clearly indicated.

References

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Table 1a. Summary of Scotian Shelf research survey temperature data (mean, n, std. dev.) collected between 1977-1985.

Temperatures (°C) --- Area I

Year	Spring	Summer	Fall
1977	- mean 0 n - std. dev.	5.4 9 1.14	- 0 -
1978	6.8 2 0.57	5.8 12 1.54	7.6 5 1.88
1979	4.4 2 2.26	6.7 10 2.74	10.0 5 3.06
1980	4.9 3 2.64	6.2 3 1.13	7.6 7 1.75
1981	- 0 -	7.9 12 2.31	10.2 9 2.97
1982	- 0 -	4.7 10 2.24	10.6 8 4.39
1983	5.6 4 2.20	6.1 10 1.78	9.6 5 4.93
1984	9.9 1 -	8.9 15 1.84	10.9 11 1.67
1985	- 0 -	6.0 10 1.89	- 0 -
Total	5.8 12 2.32	6.6 91 2.33	9.7 50 3.12

Table 1b. Summary of Scotian Shelf research survey temperature data (mean, n, std. dev.) collected between 1977-1985.

Temperatures (°C) --- Area II

Year	Spring	Summer	Fall
1977	- mean 0 n - std. dev.	9.4 6 1.42	- 0 -
1978	7.0 4 1.23	7.7 13 1.13	7.0 6 1.56
1979	8.7 8 1.06	7.7 6 1.29	8.4 10 1.45
1980	9.6 6 0.59	8.6 9 1.02	8.5 7 3.50
1981	7.0 11 1.57	8.9 10 0.91	8.4 12 1.82
1982	7.8 6 0.59	6.2 12 1.84	4.7 3 2.32
1983	8.6 16 2.23	7.8 7 1.25	8.0 13 3.23
1984	9.0 9 1.23	9.5 11 2.45	8.3 5 2.80
1985	6.15 4 4.39	8.8 3 2.52	- 0 -
Total	8.2 64 1.98	8.2 77 1.84	8.0 56 2.53

Table 2. USSR silver hake catch statistics summary for the Scotian Shelf from 1977 to 1985, broken down by season (from NAFO Statistical Bulletin).

	CPUE (mt/hr)	
Year	Spring	Summer
1977	1.92	2.01
1978	1.36	1.68
1979	1.82	1.81
1980	1.17	1.18
1981	2.11	1.37
1982	4.39	3.55
1983	2.35	1.44
1984	4.15	2.49
1985	2.52	3.08

Table 3. Standardized catch rates (USSR) calculated via multiplicative model (from Waldron and Fanning, 1986) and estimated biomass (from VPA) for silver hake in the Scotian Shelf 1977-1985.

	Catch Rate		
Year	Mean	s.e.	Biomass (mt)
1977	1.95	0.154	181848
1978	1.60	0.105	140707
1979	1.76	0.126	177069
1980	1.67	0.198	178078
1981	1.42	0.158	187345
1982	4.20	0.700	302397
1983	2.25	0.432	327160
1984	3.04	0.507	482777
1985	3.26	0.413	837867

Table 4. Results of multiple regression analysis for CPUE (from NAFO statistical bulletin) for the USSR silver hake fishery vs estimated biomass (from VPA) and bottom temperature, for the Scotian Shelf.

i) 1977-1985

Season	Area	Variable	Significance (partial F)	r^2
Spring	I	biomass	0.013	0.91
		bottom temp.	0.466	0.93
	II	biomass	0.896	0.01
		bottom temp.	0.491	0.10
Summer	I	biomass	0.724	0.02
		bottom temp.	0.377	0.15
II	II	biomass	0.724	0.02
		bottom temp.	0.096	0.40

ii) 1977-1983

Season	Area	Variable	Significance (partial F)	r^2
Spring	I	biomass	0.208	0.63
		bottom temp.	0.840	0.65
	II	biomass	0.138	0.46
Summer	I	biomass	0.504	0.09
		bottom temp.	0.211	0.42
	II	biomass	0.504	0.09
		bottom temp.	0.110	0.56

iii) 1977-1982

Season	Area	Variable	Significance (partial F)	r^2
Spring	I	biomass	0.878	0.04
	II	biomass	0.026	0.85
		bottom temp.	0.848	0.85
Summer	I	biomass	0.051	0.66
		bottom temp.	0.334	0.76
	II	biomass	0.051	0.66
		bottom temp.	0.221	0.81

Table 5. Results of multiple regression analysis of standardized catch rate (USSR) vs estimated silver hake biomass (from VPA, Waldron, pers. comm.) and July bottom temperature, for the Scotian Shelf 1977-1985.

i) 1977-1985

Area	n	Variable	Significance (partial F)	r^2
I	9	biomass	0.078	0.38
		bottom temp.	0.357	0.47
II	9	biomass	0.078	0.38
		bottom temp.	0.080	0.64

ii) 1977-1983

Area	n	Variable	Significance (partial F)	r^2
I	7	biomass	0.072	0.51
		bottom temp.	0.132	0.74
II	7	biomass	0.072	0.51
		bottom temp.	0.161	0.72

iii) 1977-1982

Area	n	Variable	Significance (partial F)	r^2
I	6	biomass	0.004	0.89
		bottom temp.	0.040	0.98
II	6	biomass	0.004	0.89
		bottom temp.	0.256	0.94

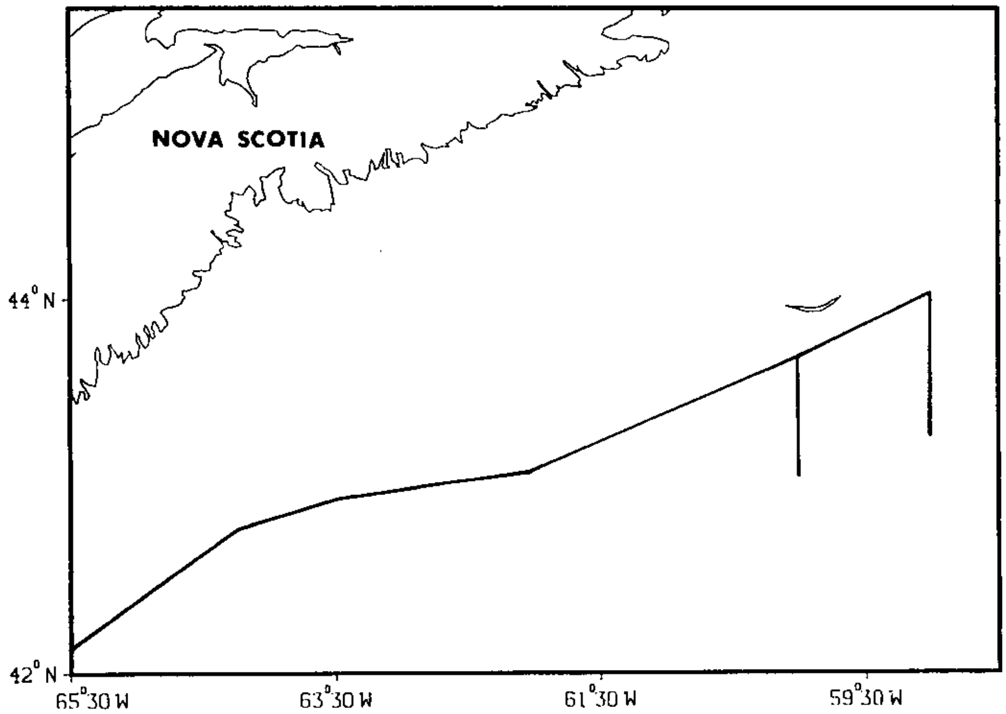

Figure 1. Map showing location of the small mesh gear line on the Scotian Shelf.

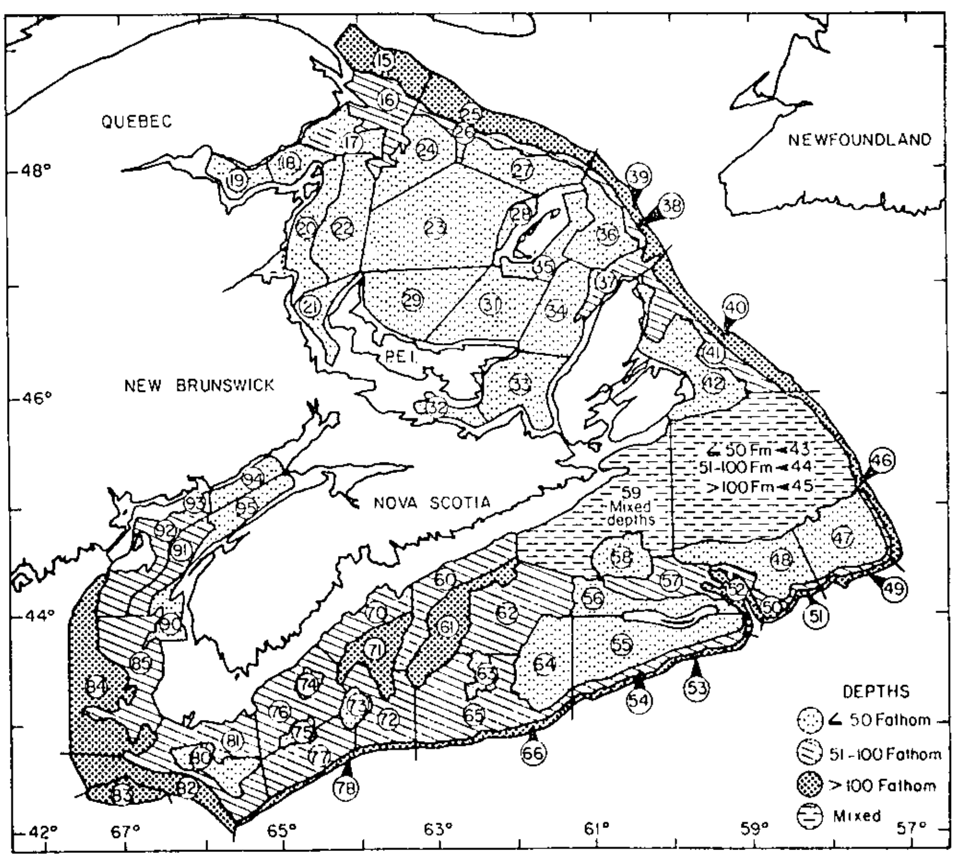

Figure 2. Map depicting depth stratification scheme with strata numbers for Fisheries Research Board groundfish cruises (from Doubleday, 1981).

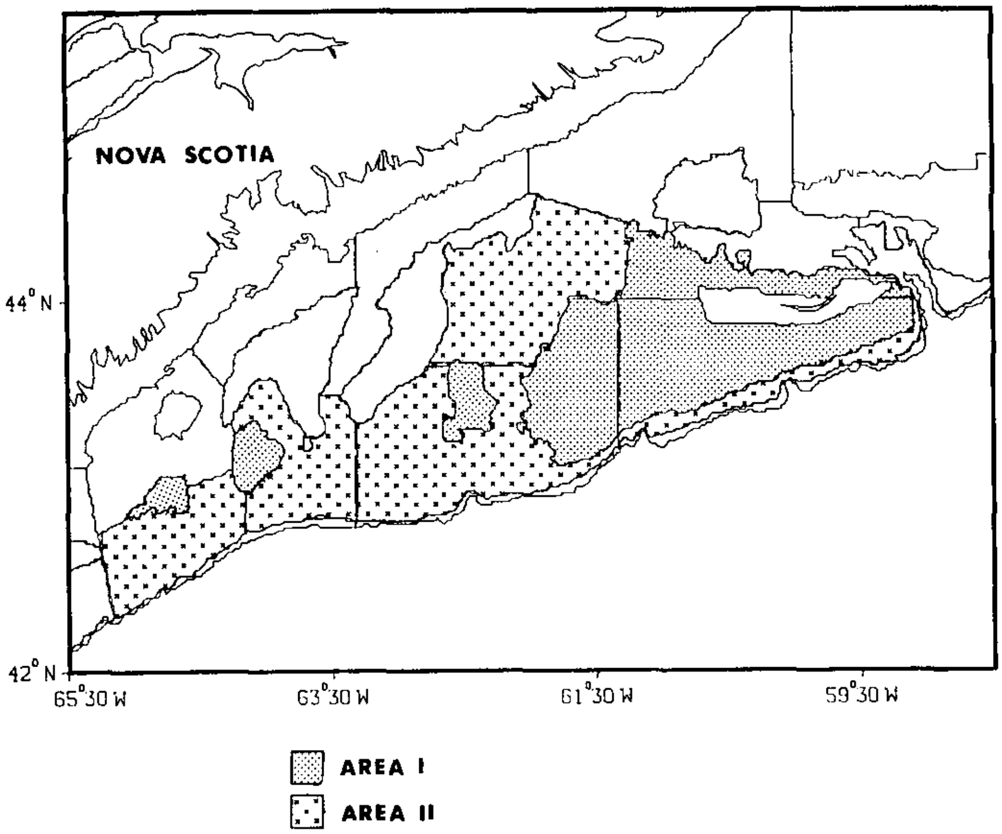

Figure 3. Map depicting the grouping of strata inside the small mesh gear line for comparison of average bottom temperatures.

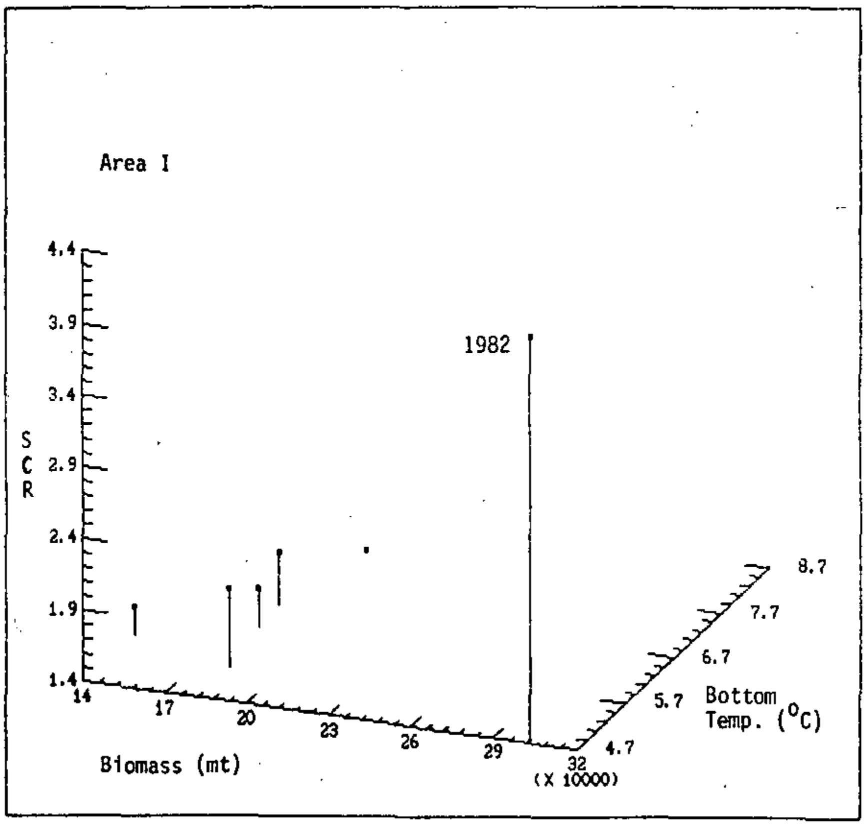

Figure 4. Scatterplot of standardized catch rate (SCR) vs biomass (mt x 10,000) and July bottom temperature (°C) for silver hake in the Scotian Shelf: Area I, 1977-1982.