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Vertical distribution and optimum sampling strategy for 0-group silver hake (*Merluccius bilinearis*) surveys on the Scotian Shelf

by

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Introduction

The problem of recruitment prediction is particularly pressing for management of the silver hake fishery on the Scotian Shelf. Conventional summer groundfish surveys have failed to provide useful recruitment indices for this species partly because the time between recruitment to the survey and to the fishery is too short. This is probably compounded by changes in availability, both diel and longer term, to the survey gear. 0-group surveys could provide an earlier estimate of year-class strength for predictive purposes, but increased variability associated with major ecological changes during this phase could make abundance estimates difficult to implement. The principle unknowns here are juvenile mortality, or the time at which the size of a year-class is established, and vertical migration. This report deals only with the latter.

Methods

The data available comes from 3 stratified random trawling surveys conducted jointly by Canada and the USSR in October of 1978, 1979 and 1980. In 1978, strata 47 to 81, inclusive, (Figure 1) were covered with 100 randomly chosen stations. A small meshed midwater trawl was towed near bottom, depth being determined only approximately by the amount of warp out and warp angle. In 1979 the same 100 stations were repeated but a headline transducer was now used to determine depth and to keep the trawl within 1- 2 meters of the bottom at all times. In 1980 a new set of random stations was selected and sampling restricted to strata 60-78, the area of greatest 0-group hake abundance during the previous two years. A headline transducer

was again used. For all surveys, sets were 30 minutes in duration, timed from when depth was reached to beginning of haulback.

All silver hake fry, or a known subsample, were measured to the nearest centimeter in 1978 and 1979, and to the millimeter above in 1980.

During the 1980 survey, five stations were selected for vertical distribution studies at which more than 100 silver hake fry had been caught in the regular survey set (Figure 2.). At each of these stations at least one vertical profile was completed which consisted of 1 set in each of the following depth intervals: near bottom as in regular survey; 6-20 m; 20-40 m; 40-60 m; 60-100 m and 100-150 m off bottom. Each profile was restricted to night (at least one hour after sunset to at least one hour before sunrise) or day (at least one hour after sunrise to at least one hour before sunset). Each set consisted of a 3-step oblique tow with ten minutes each at the bottom, mid-point and top of the depth interval, beginning at the bottom. The upper limit of the shallowest depth interval was determined by the depth of the water column and the shallowest depth that the trawl could be fished (20 m below the surface). At three of the five stations, control hauls were made in order to determine the number of fish that might be caught above the experimental depth interval during shooting and hauling. Controls consisted of shooting the net to the top of the experimental depth interval for which the control was intended, and retrieving immediately. They were done either immediately after the experimental tow, or on the following night at the time that the experimental tow had begun.

A number of 3-step oblique tows were also done in 1980. These covered the entire water column, with ten minutes each near bottom, midwater and surface, always beginning near bottom.

Results and Discussion

During October most 0-group silver hake caught by the trawl are approximately 2-4 centimeters long and range about 1 to 8 centimeters (Table 1). The distribution of catches within strata from the three surveys reveals some general information about their depth preferences at this time (Table 2). In 1978 the largest catches consistently occurred in the 51-100 fathom (92-183 m) strata, in the central part of the Scotian Shelf. No pattern was evident in 1979 and 1980, probably because catches were very small during these years. All three years however showed consistently low

catches in the shallowest (≤50 fath) strata. On the Scotian Shelf sivler hake spawn mainly in August and September on the shallows (≤50 fath) west of Sable Island (Noskov et al. 1979). It appears that by October the young fry may have already moved into deeper water.

Superimposed on longer term horizontal and vertical migrations is the pattern of diel vertical migration. Figure 3 shows diel changes in catch rates from the regular survey tows. During October the mean times of sunrise and sunset are 06:40 and 17:40, respectively. A clear pattern is seen in 1979 and 1980 where catches increase dramatically before sunrise, drop off to very low numbers during the day, increase again greatly after sunset and then drop off again during the night. This pattern was not as evident in 1978. Catches did increase to a maximum after sunset but large catches were sustained for a longer time into the night and also occurred during daylight. Assuming that silver hake exhibit the usual diurnal migration pattern of being higher in the water column at night, then the most plausible explanation for Figure 3 is that they were mainly below the net during the day and above it at night, becoming available to the gear only as they moved past it before sunrise and after sunset. The somewhat different pattern seen in 1978 is probably due to the different deployment of the gear. It is unlikely that the theoretical 1-2 m off bottom was achieved during this survey and estimates of depth were probably conservative to avoid trawl damage, resulting in an actual depth consistently further off bottom. This would explain the sustained high catches during the night. Inaccuracy in determining gear depth would also result in the occasional on-bottom set resulting in some large catches during the day. The large catch rates at 4, 8 and 11 o'clock in 1978 are in fact due to one exceptionally large catch during each of those hours. The somewhat larger catch rate at noon in 1979 is also due to one set and can be considered anomalous.

Vertical distribution studies conducted during the 1980 survey confirmed that silver hake juveniles are found high in the water column at night (Table 3). Three night profiles (V_3, V_4 & V_5) had maximum catches in the shallowest depth interval and all but one (V_1) had maximum catches above the near-bottom interval. Relatively large numbers were however caught at all depths, suggesting a fairly even distribution throughout the water column at night. Control hauls showed that considerable numbers of fry

could be caught during the shooting and hauling procedure and are needed to interpret results from experimental hauls. The distribution of fry, corrected for contamination, at the three stations where control tows were made (Figure 4) confirms that large numbers are found in lesser depths at night, either within or above the thermocline. The bimodal distribution of catches at V_5 and V_6 may be due to avoidance of the temperature minimum at these stations. In fact, five of the seven profiles showed bimodality, with a sixth showing three modes. Another explanation for this pattern is that concentrations caught at one depth were caught again at a different depth later. Figure 3 shows that changes in distribution are occurring during much of the night. Despite the precaution of waiting at least one hour after sunset, it is doubtful that a profile, which takes about 8 hours to complete, could be conducted completely during a time of no movement.

Three profiles were completed by day (Table 3). All produced negligible numbers of fry relative to the large catches made at the same stations at night. At two stations (V_1 and V_4) the trawl was fished directly on the bottom during the day (2 sets) with only 1 fish caught. At V_3, fishing within a midwater scattering layer by day also had negative results. After three profiles produced few silver hake by day, no further day profiles were attempted, but the low daytime catchability was confirmed at subsequent vertical distribution stations with a 3-step, near-bottom, midwater and surface tow. It is unlikely that silver hake undergo reverse migration and are found in the unfished part above a depth of 20 m during the day since relatively large numbers would have been caught as contaminants. Bowman and Bowman (1980) showed that the low daytime catchability of silver hake ($\geq$20 cm) by pelagic trawls, off-bottom trawls, and even bottom trawls with roller gear is probably due to their daytime habit of remaining undisturbed within depressions on the bottom as gear passes closely over them. Our results suggest that 0-group silver hake have already adopted this behaviour at the time of the juvenile surveys in October.

Five stations (P_1-P_5, Figure 2) were fished in the vicinity of V_4 during daylight on October 8 to see if the concentration of hake seen the previous night might have moved out of the study area. No concentrations were encountered during the day but when these stations were repeated on the night of October 8-9, all sets produced large numbers (Table

4). It is unlikely that a patch of fry at least 10 miles across had moved completely out of the area within 4 hours on the morning of October 8 and returned again after dark. All sets were of the 3-step, near-bottom, midwater and surface type except the night tow at P_5 which was a near-bottom tow only.

Toward the end of the 1980 survey, 13 regular fishing stations in strata 62, 64 and 65 which had been occupied previously during daylight with a near-bottom tow were repeated at night using the 3-step, near-bottom, midwater and surface method. All but one station produced higher numbers at night (Table 5). Significant concentrations of silver hake fry had not been detected by the near-bottom day tow.

During the course of the survey in 1980 no major change in ontogenetic vertical distribution was detected such as a shift from a pelagic to a demersal phase. 0-group silver hake are apparently found near the surface at night throughout October. The expected pattern of ontogenetic movement is that as the fish grows its migrations towards the surface at night cover progressively shorter vertical distances until it remains relatively close to the bottom at all times. Such a pattern would appear as an increase in mean size with depth in the vertical distribution studies. This was not evident (Figure 5) in October indicating that the shift to a more demersal habit had not yet begun. Some evidence of differential vertical distribution of sizes was seen in the regular survey data. Changes in mean size with time of day (Figure 6) indicate that smaller fish were caught during the day. This is seen more clearly from the length frequencies of the day and night catches (Figure 7). (The decrease in mean size at 3 o'clock in Figure 6 is due to one large catch of postlarvae in stratum 66. This set is excluded in Figure 7). The probable explanation for the difference in sizes between night and day is that smaller fish (about 20 mm) have not yet developed the on-bottom day distribution and are still off-bottom and available to the trawl by day.

Conclusions

The above evidence indicates that fishing during the day with a midwater trawl is not warranted and will greatly increase the variance of abundance estimates. Near-bottom tows at night are also not indicated since most of the population is above the net. With the present gear the best

survey design in October is a night survey using a 3-step, near-bottom, midwater and surface tow. The lack of more precise information on changes in vertical distribution with time (and other factors) as well as the probability that these changes occur throughout the night makes it impracticle to define a narrower vertical range for a routine night survey tow.

It is possible that silver hake fry could be caught on the bottom during the day with special gear. Bowman and Bowman (1980) found that bottom trawls with chain disc or cable sweeps catch more silver hake during daylight than bottom trawls with rollers, probably because the former "scare up" the fish. Similar gear may prove effective for juveniles. It is unlikely that day and night tows with different gear (or a different type of set with the same gear) could be used interchangeably for abundance estimates because of their vastly different catchability coefficients, which would not be easily intercalibrated. A more rational survey design would fish a standard pelagic set at night and then repeat the same stations by day, fishing on bottom with specialized gear. Such a survey would take advantage of the 24-hour working capability of most research trawlers as well as produce a replicate abundance estimate.

Acknowledgements

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References

Bowman, R. W., and E. W. Bowman. 1980. Diurnal variation in the feeding intensity and catchability of silver hake (Merluccius bilinearis). Can. J. fish. Aquat. Sci. 37: 1565-1572.

Noskov, A. S., A. I. Sherstiukov, and A. N. Romanchenko. 1979. Distribution and abundance of silver hake eggs, larvae, and juveniles, and environmental conditions off the Nova Scotia Shelf in August-October 1978. ICNAF Res. Doc. 79/VI/100.

Table 1. Length frequencies of silver hake (1-35 cm) given in total fish caught per centimeter in the 1978, 1979 and 1980 "fry" surveys on the Scotian Shelf.

Length (cm)	1978	1979	1980
1	184	774	22
2	4602	7762	600
3	2877	1014	989
4	1181	388	961
5	192	108	110
6	35	53	13
7	16	9	0
8	32	6	0
9	22	9	0
10	5	15	0
11		13	0
12		17	1
13	1	30	0
14	1	37	2
15		56	5
16	3	72	6
17	4	130	3
18	7	163	18
19	11	229	32
20	15	306	47
21	38	301	51
22	33	279	64
23	36	246	65
24	12	191	49
25	3	184	68
26	5	176	104
27	5	183	145
28	8	184	145
29	3	242	106
30	8	252	100
31	8	294	95
32	7	215	77
33	9	117	84
34	8	84	26
35	5	48	8

Table 2. Mean number of silver hake fry caught per stratum.

Strata	Depth	1978	1979	1980
47	≤50	0	0	
48	≤50	0	0	
50	51-100	3	0	
51	>100	0	0	
52	>100	0	0	
53	>100	0	0.8	
54	51-100	0	5.7	
55	≤50	0.4	0.6	
56	≤50	17.3	15.3	
57	51-100	0.3	3.0	
58	≤50	0	0	
59	≤50->100	1.0	0	
60	51-100	386.0	8.0	6.0
61	>100	74.8	21.5	28.3
62	51-100	283.0	5.6	53.5
63	≤50	30.5	0	1.0
64	≤50	13.5	15.3	23.0
65	51-100	640.0	6.6	33.5
66	>100	0.5	2166.3	82.5
70	51-100	185.0	1.0	12.8
71	>100	90.7	93	16.5
72	51-100	176.5	15	25.1
73	≤50	59	1.5	0
74	≤50	0	2.5	3.0
75	≤50	1.0	6.5	0
76	51-100	19.7	19.5	26.0
77	51-100	274.5	123.5	14.9
78	>100	20.0	34.0	26.8
80	≤50	6.0	6.3	
81	51-100	1.2	14.2	

Table 3. Results of silver hake vertical distribution studies conducted in 1980.

	Interval	V_1 Time	#	V_2 time	#	V_3 time	#	V_4 time	#	V_5 time	#	V_6 time	#	V_7 time	#
	F							04:27	333	21:27	349	22:13	126		
	E	03:00	22			04:25	541	03:00	250	23:13	294	00:13	43	21:07	211
	D	01:46	129			01:55	222	01:38	229	00:52	67	01:35	42	22:28	320
Night	C	00:08	178			00:00	269	00:21	276	02.18	298	03.12	69	00:00	149
	B	22:40	65			22:17	305	22:53	108	03.44	176	06:27	235	01:33	120
	A	21:14	226	02:50	322	20:09	256	21:15	195	05:24	110	08:30	19	04:15	111
	E	14:44	0	14:58	23	16:08	2								
Day	D	13:08	0	13:28	1	14:42	8	+		+		+			
	C	11:32	0	11:46	0	13:13	3	08:12	0	09:07	1	08:45	0		
	B	09:57	0	10:10	5	11:28	0								
	A	08:27	28	08:23	14	08:03	0								
	E									23:22	139	00:12	70		
Control	D									01:00	14	01:26	39	23:23	57
	C									02:26	22	02:56	19	00:51	22
	B									04:00	99	06:30	32	03:25	57
	A									05:30	93	05:14	28	05:22	96
Depth (m)		125		230		110		155		150		155		105	
Dates		3-4/10		5/10		6-7/10		7-8/10		10-12/10		14-16/10		19-20/10	
Position		43°01'N 62°22'W		43°10'N 61°21'W		43°44'N 62°13'W		43°53'N 62°28'W		43°08'N 63°28'W		Same as V_4		Same as V_3	

+ Near bottom, midwater and near surface tow

A=near bottom; B=6-20m, C=20-40m, D=40-60m, C=60-100m, D=100-150m except at V_2 where C=20-60m, D=60-100m and E=100-200m.

Table 4. Results of the "patch" study conducted in 1980.

Station	Night		Day	
	Time	#	Time	#
P_1	21:40	336	08:12	0
P_2	00:10	339	09:45	8
P_3	01:56	203	11:47	2
P_4	03:38	223	13:52	1
P_5	06:10	100	15:52	0
$\bar{X}$		240		2

Table 5. Catches of silver hake fry at regular survey stations during day (near-bottom tow) and night (oblique tow).

Night			Day		
Date	Time	#	Date	Time	#
24-10	22:55	137	5-10	17:50	7
25-10	04:44	18	2-10	09:00	20
25-10	19:50	277	3-10	10:41	0
25-10	22:05	26	3-10	12:08	3
26-10	00:34	424	3-10	13:47	24
27-10	23:17	262	28- 9	14:07	4
28-10	00:50	488	29- 9	10:05	0
28-10	04:32	28	3-10	16:37	10
28-10	20:10	299	29- 9	13:53	2
28-10	23:06	240	29- 9	16:20	5
29-10	04:18	63	30- 9	07:48	0
29-10	23:40	58	8-10	15:52	0
30-10	04:30	58	9-10	08:16	0
	$\bar{X}$	183			6

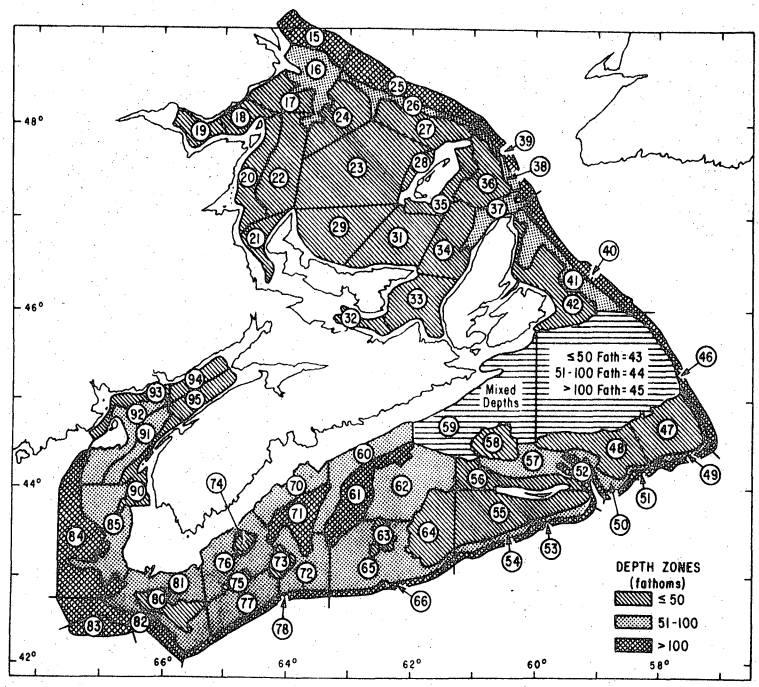

Figure 1. Stratification scheme used for the juvenile silver hake surveys 1978-80.

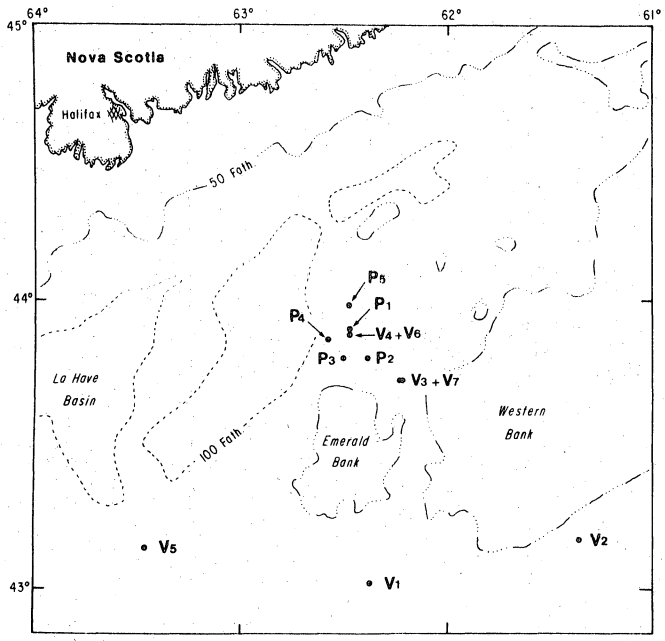

Figure 2. Location of stations at which vertical distribution studies were conducted (V_1-V_7) in 1980, and of "patch study" stations occupied on October 8-9, 1980.

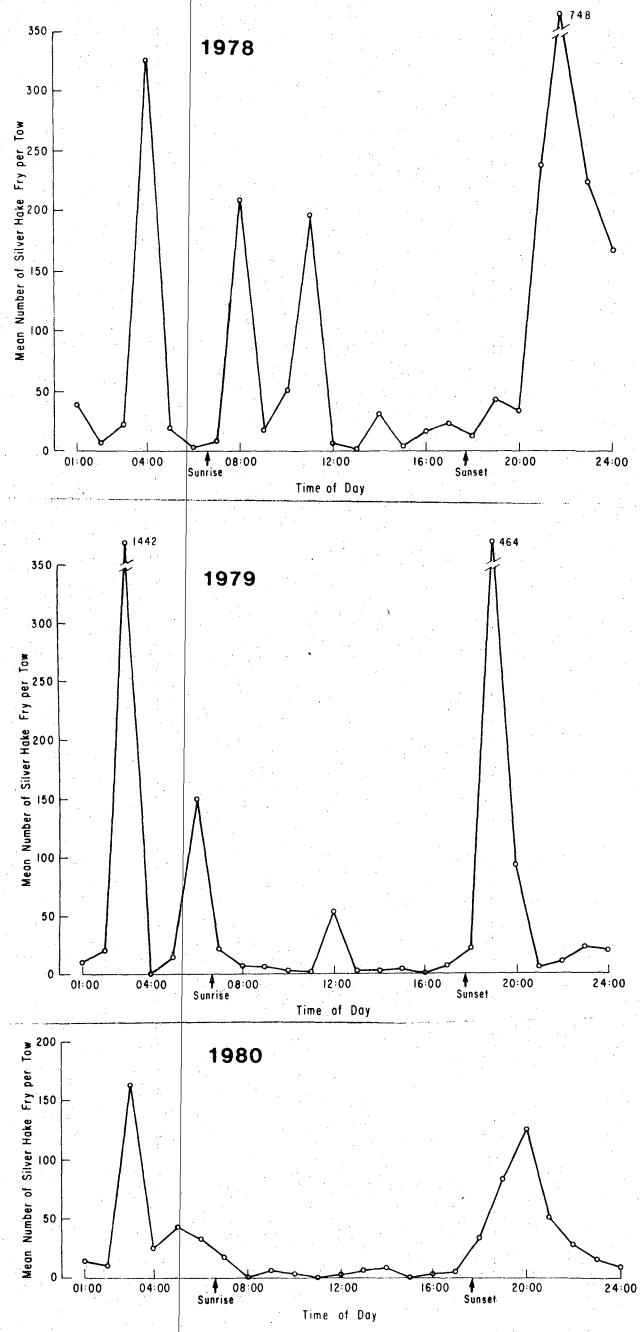

Figure 3. Changes in catch rates with time of day during the silver hake juvenile surveys, 1978-80.

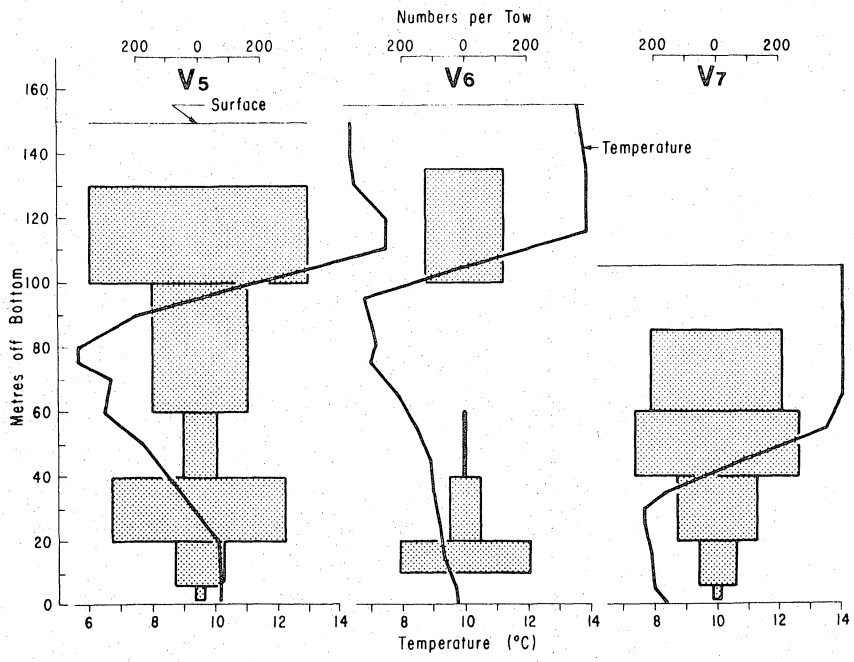

Figure 4. Night vertical distribution of silver hake juveniles, corrected for contamination, at three locations, 1980.

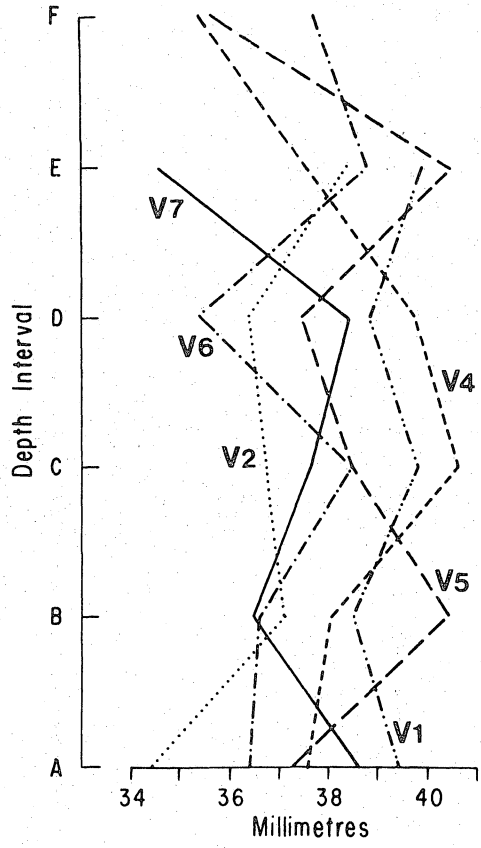

Figure 5. Mean total length of silver hake caught in various depth intervals at the vertical distribution stations occupied in 1980.

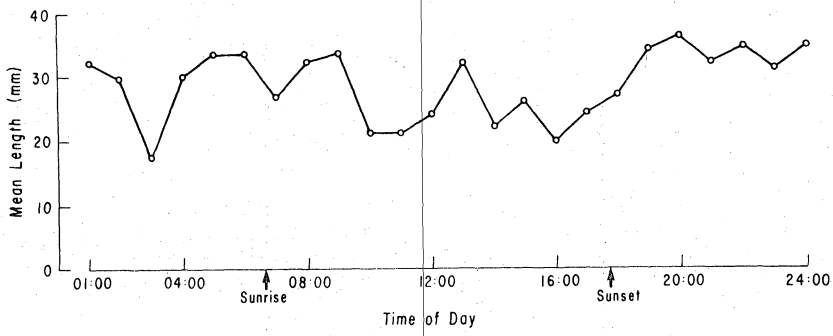

Figure 6. Change in mean total length of silver hake with time of day in regular survey sets, 1980.

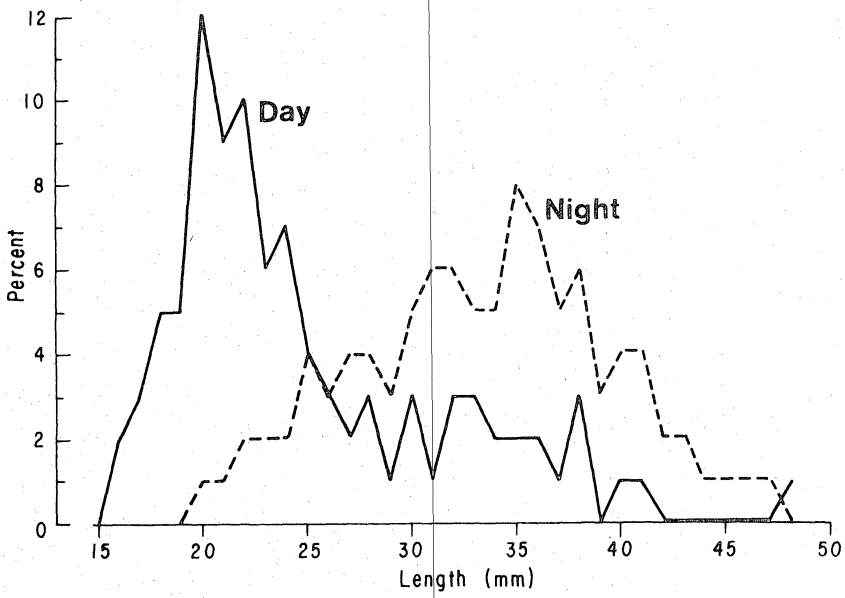

Figure 7. Length frequencies of silver hake caught during day (0700-1800) and night (1800-0700) in the regular survey sets of the 1980 survey.