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Feeding Cycles of Greenland Halibut (*Reinhardtius hippoglossoides*) in the Flemish Pass Area in Relation to Catch Rates (1991-92)

by

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ABSTRACT.

The seasonal cycle in feeding activity of Greenland halibut shows a maximum in autumn in depths between 700 - 900 m. In deeper waters no seasonality appears at all. A 24-hour cycle in feeding activity is observed which is length related, with a day-time (6-12 hour interval) maximum in smaller fish (<60 cm) and at both sunset and night (18-24 hour and 0-6 hour intervals) in the largest fish (<80 cm). The intermediate length class (60-80 cm) shows a minimum in feeding activity in the afternoon (12-18 h) and in general a maximum in the interval 6-12 h, but in this group significant feeding activity occurs also at night.

Catch rates decrease in autumn and reach a maximum in winter. In winter, increased catchs occurs mainly at night (0-6 h interval) and are based mainly in the smallest length class (<60 cm), which feeds least during this time interval. An inverse relationship between feeding intensity and catch rates is been observed.

INTRODUCTION.

Greenland halibut is the target species of the deep-water Spanish trawler fleet in the Flemish Pass area (NAFO Div. 3LM and northern 3N). This fishery has been monitored since it began in 1990 by observers on board each trawler throughout the fishing season. This yields important information on fishing effort and catch rates as well as a continuous and exhaustive biological sampling of this species, and provides an exceptional opportunity to analyse variations in biological traits of the fish which may affect their catchability over long time periods.

The diet and morphology of Greenland halibut indicate a more pelagic way of life than other flatfishes (SMIDT 1969, HAUG and GULLIKSEN 1982). It is supposed to spend considerable time in the upper water layers which must certainly be linked with feeding behaviour.

The objective of this paper is to examine the annual and 24-hour cycles in feeding intensity, and to compare them with the catch rates obtained by the fishing fleet on the same basis, using data provided by observers on board the commercial fishing fleet. Two assumptions are made: (a) the extent of the vertical migrations is related with feeding activity, and (b) the withdrawal of fish from the bottom should result in a decrease in fishing efficiency as the gear used is a bottom-trawl.

MATERIAL AND METHODS.

From July 1991 to July 1992, 114835 stomachs of fish from 30 to 105 cm were examined (Table 1) in the area shown in Fig.1. For data processing the length range has been divided into three categories: <= 60 cm, 60-80 cm and >=80 cm. Fishing activity is restricted to depths greater than 700 m and three depth strata are defined: 700-900 m, 900-1100 m and 1100-1500 m. For each month, data from 5 observers were selected at random to cover the whole daily cycle and the entire depth range (only 4 are available for January and April).

Trawls last an average of five hours, and the position, time, depth and catch are recorded for each one. In the trawls sampled, the length, sex and maturity stage for each fish is recorded. The degree of stomach fulness is visually determined according to a 4-point scale: 1 = empty; 2 = 1/2 full; 3 = full; 4 = evaginated or with signs of regurgitation.

The percentage of empty stomachs (PES) is used as a measure of feeding intensity. It has been selected as the simplest and least ambiguous of the degrees of fulness, to avoid bias due to differing criteria between observers. The PES properly describes trends in feeding activity as regurgitation in this species has been found to be negligible, in agreement with what has been observed in other flatfish (BOWMAN 1986). The changes in feeding activity in a 24- hour cycle are analysed by grouping the samples into six-hour intervals, according to the time at the middle of the trawl they came from. The PES is calculated independently for every observer to evaluate the dispersion of the results. Only large samples (more than 50 individuals examined by trawl) are taken into account for the calculations. The monthly feeding intensity is analysed through the means of the PES obtained in the 24-hour intervals. Both annual and 24-hour cycles of the PES are calculated by depth strata and length intervals.

The catch rates (Kg/hour) by month in the same trawls used to obtain the PES are computed for the time intervals defined above. They are made with only two vessels to avoid the variability of the values (one from July to December 1991 and another from January to July 1992). To make comparable the trends in the yield of these two trawlers, a coefficient is applied to balance the differences in fishing power, obtained with the multiplicative model of VAZQUEZ (1981). Catch rates in hourly intervals are distributed amongst the length categories, using the length distributions of the corresponding month and hour interval, to obtain the fraction in weight of those length categories in the total catch. As the length distribution of this species in the catch is closely related with depth (JUNQUERA et al. 1982), a narrow range of depth is selected (900-1100 m). In this way the differences in yield by length can be safely compared with the hour. If a larger depth range would were involved, the increase in abundance of the larger fish with depth would hide any variation due to the time of day. Catch rates by length categories and hour intervals have been calculated for the periods July-August, October-November, January-February and April-May.

The differences in PES among observers in relation to the variability in the monthly and daily means of PES are evaluated through a two-factor ANOVA (SOCKAL and ROLHF 1969).

RESULTS.

* 24-Hour cycle.

When data are grouped by depth strata, the mean PES among observers for the hour intervals showed no detectable trend during the day. The two-factor ANOVA applied on data grouped in this way indicated that neither the factor 'observer' nor the factor 'hour of day' have a significant influence on the variance of the results (5 % significance level) in any month.

However, if data are grouped by length categories (Table 2) clear pattern appears of daily variation in feeding intensity. For the smaller fish (length <= 60 cm), peak feeding activity (minimum values of the) is in day-time, most of the year in the 6-12 h interval, although it shifts to the 12-18 h interval in the autumn. In January the differences in the means of PES by hour are not significant, but a slight decrease in the 6-12 h interval can still be observed. On the contrary, in the largest fish (length >= 80 cm) peak the feeding activity is at the sunset and night, most of the year in the 18-24 h interval. Another minimum in PES also occurs in the second half of the night (0-6h). There is no obvious seasonal trend in this feature. In the intermediate category (length 60-80 cm) the pattern is not so clear. The minimum in PES is observed every month in the 6-12 h interval and the maximum in the 12-18 h interval. However, the PES decreases again at sunset and at night, indicating that significant feeding activity occurs also at night in this group. These daily patterns in feeding activity remain invariant throughout the year and differences between observers in the PES estimated are not significant in relation to this daily variation (5 % significant level).

* Annual cycle.

Fig.2 shows the monthly means in PES obtained from the means in the 24-hour cycle by depth strata. Maximum feeding activity (minimum values of PES) is observed in the shallowest depth stratum (700 - 900 m) in October-November, but no seasonality is evident at greater depths. However, average PES decreases with depth, indicating an increase in feeding activity.

The same lack of seasonality is evident in monthly means of PES obtained from the 24-hour cycle based on length categories (Fig. 3), . The only differences with the monthly means by depth strata are that the PES now are in general lower, and the standard deviations more homogeneous. This is because the length classes taken into account here have a marked daily pattern of variation, which is masked when we look at depth strata alone.

* Trends in catch rates.

Fig. 4 shows the monthly catch rates (Kg/hour) for the period July 1991 to June 1992 in the depth range 900-1100 m. Catch rates decrease continously during summer and autumn, with a pronounced minimum in November, and increase again in winter, when maximum values are attained, and decrease again in spring. Catch rates by hour intervals show a similar pattern of seasonal variation. However it is remarkable that in the winter period, the increase in catch rates is most pronounced at night (0-6 h and 18-24 h intervals) while it is much less important in day-time (6-12 h interval).

The different length classes show a daily pattern in feeding activity of opposite sense in the smallest and the largest fish. So to study the influence on catch rates of daily feeding activity, catch rates by length class are compared with the corresponding 24-hour cycle observed in each length class and month. The results (Fig. 5) indicate that, for the smallest fish (<=60 cm), lower catch rates coincide with the hours of feeding activity (lower PES), that is in the day-time, quite clearly in summer and winter, less clearly. For the largest fish (>= 80 cm), peak catch rates occur in day time, and coincide with the lowest feeding activity in summer and autumn, although in the latter, a peak in catch rate is also found at night, together with low PES. In winter, fish >= 80 cm disappear from the depth range analysed here. In the intermediate length category (60-80 cm), the correspondence between hours of low PES and high catch rates is not very clear, as it does not appear at all during autumn and winter and is only weakly apparent in spring and summer. The seasonal cycle of catch rates for each length class at the reference depth stratum (900 - 1100 m) shows that small (< 60 cm) and medium (60 - 80 cm) fish are equally represented in summer and autumn catches, although the largest fish (> 80 cm) still contribute significantly. But the medium sized fish contribute little to the catches in winter and spring, and the largest fish nothing. This indicates a seasonal shift of medium and large fish into deeper waters.

DISCUSSION.

These results indicate an increase in feeding activity in autumn at the shallowest depths (700 - 900 m), in agreement with CHUMAKOV and PODRAZHANSKAYA (1986), but who also found high feeding activity in summer in contrast with the present results. In deeper strata no seasonal trend is observed. A lack of seasonality in Greenland halibut feeding intensity has also been reported by BOWERING and LILLY (1992) and PEDERSEN and RIGET (1992), but their results refer to shallower depths than those dealt with here.

Feeding activity increases with depth, as already shown by CHUMAKOV and PODRAZHANSKAYA (1986). As fish length increases with depth (JUNQUERA et al. 1992) this result is congruent with higher feeding activity of larger fish, which has also been observed.

There is a clear size dependent 24-hour cycle in feeding activity. The smallest (< 60 cm) and the largest fish (> 80 cm) show opposite daily cycles. While the former feed mainly by day, the latter feed at sunset and during the nigth. This pattern does not vary during the year, and must be due to differences in diet. It is well known in this species that diet varies with size (SMIDT 1969; CHUMAKOV and PODRAZHANSKAYA 1986; BOWERING and LILLY 1992). Differences between length groups in the peak hours of feeding may be due to rhythms in the availability of their respective prey, as already indicated in other flatfish (ZAMARRO 1992).

Daily variations in feeding activity in the intermediate sized fishes (60 - 80 cm) are not as clear as in the other groups. The most prominent feature is a minimum in feeding activity in the afternoon (12 - 18 h interval) throughout the year. Feeding is usually maximal by day, but some feeding also occurs by night, and is occasionally quite significant. BOWERING and LILLY (1992) reported an abrupt change in diet and geographic distribution at lengths of about 64-69 cm. So the length interval used here (60-80 cm) may be rather artificial and include fish with different habits, which may account for the heterogeneity in the results in this length category.

The decrease in monthly catch rates in autumn and their increase in winter is a regular trend in this fishery and has already been already described (JUNQUERA et al. 1992; JUNQUERA and ZAMARRO 1992). The reduction in catch rates in autumn coincides with the decline of PES in the 700 - 900 m depth stratum, which means a period of high feeding activity. Also, the winter catch rates are higher at night (0 - 6 h interval). As this increase is mostly based on smaller fish (< 60 cm), and it is during that time interval that this length group feeds leasts, it is evident that their feeding behaviour affects catch rates, that is, they are more easily caught when their feeding activity is lowest. This perhaps due to the fact that Greenland halibut feeds mostly in the pelagic or batipelagic layers (SMIDT 1969; CHUMAKOV and PODRAZHANSKAYA 1986), and not on the bottom. The coincidence between high catch rates and low feeding activity, and the reverse is quite clear in the largest fish (>80 cm) in summer and spring, but this should not affect catch rates very much since their contribution by weight to the catch is low. Some of the discrepancies between the 24-hour cycle in feeding activity and catch rate by length class may be due to the fact that the former is obtained from 5 vessels, while the latter is derived from only one vessel in summer and autumn, and one other in winter and spring.

The results obtained support the assumptions made at first. Agreement between observers is reasonable, since the variance from this source does not have a significant influence on the trends observed. It is concluded that in this fishery, part of the variability in catch rates is due to the feeding activity of fish.

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TABLE 1.- Sampling description.

Sampling period	Number of observers	Number of stomachs	Number of sets
Jul. 1991	5	12292	125
Aug. "	5	13747	147
Sept. "	5	9455	105
Oct. "	5	10208	128
Nov. "	5	11430	135
Dec. "	5	6271	69
Jan. 1992	4	5580	61
Feb. "	5	7602	82
Mar. "	5	8003	90
Apr. "	4	6905	75
May "	5	10289	112
Jun. "	5	13053	142
TOTAL...................		114835......	1271

TABLE 2.- Monthly percentage of empty stomachs (PES) by hour interval and length classes, number of stomachs examined and standard deviations.

		Length <= 60 cm			Length 60-80 cm			Length >= 80 cm		
		PES	Num.	SD	PES	Num.	SD	PES	Num.	SD
JUL. 1991	(0 - 6 h.):	77	1085	14	41	1383	16	46	98	17
	(6 - 12 h.):	49	686	16	29	150	13	79	1863	17
	(12 - 18 h.):	59	215	16	72	2483	13	48	614	15
	(18 - 24 h.):	75	2088	17	36	1140	11	28	158	11
AUG. "	(0 - 6 h.):	83	1414	17	47	1041	16	23	131	6
	(6 - 12 h.):	59	1746	17	35	255	16	79	1723	10
	(12 - 18 h.):	61	1032	13	66	2967	20	42	630	9
	(18 - 24 h.):	68	1770	15	47	904	7	29	137	12
SEP. "	(0 - 6 h.):	84	680	7	53	539	11	43	149	18
	(6 - 12 h.):	64	734	13	29	127	10	80	1767	13
	(12 - 18 h.):	28	143	6	73	456	11	60	793	8
	(18 - 24 h.):	83	863	8	46	1113	16	28	99	13
OCT. "	(0 - 6 h.):	83	564	7	53	397	20	26	91	13
	(6 - 12 h.):	45	736	20	30	122	14	71	2312	11
	(12 - 18 h.):	24	410	2	76	2228	9	50	1333	13
	(18 - 24 h.):	72	616	14	53	1307	14	29	654	18
NOV. "	(0 - 6 h.):	91	263	7	60	1104	15	31	223	13
	(6 - 12 h.):	53	593	19	37	241	9	72	1382	14
	(12 - 18 h.):	50	544	9	73	2934	14	47	704	19
	(18 - 24 h.):	81	1455	9	49	1893	12	36	94	15
DIC. "	(0 - 6 h.):	81	322	12	63	508	16	49	225	14
	(6 - 12 h.):	59	342	17	54	204	13	75	402	19
	(12 - 18 h.):	66	411	20	76	1608	15	55	217	14
	(18 - 24 h.):	74	916	12	63	823	19	38	146	13
JAN. 1992	(0 - 6 h.):	84	400	5	40	205	9	45	91	11
	(6 - 12 h.):	74	209	13	37	97	9	80	1001	6
	(12 - 18 h.):	80	430	3	79	1409	20	61	271	12
	(18 - 24 h.):	80	744	5	64	618	14	30	83	9
FEB. "	(0 - 6 h.):	78	756	7	45	305	5	33	121	15
	(6 - 12 h.):	47	617	14	43	102	10	80	975	20
	(12 - 18 h.):	80	524	11	81	2350	20	43	172	9
	(18 - 24 h.):	79	899	5	48	660	11	15	106	6
MAR. "	(0 - 6 h.):	84	503	3	51	517	12	37	122	13
	(6 - 12 h.):	57	238	11	35	109	10	77	1127	6
	(12 - 18 h.):	75	189	19	81	2328	7	51	234	8
	(18 - 24 h.):	79	1308	6	53	887	12	41	145	14
APR. "	(0 - 6 h.):	82	762	7	48	465	11	53	124	12
	(6 - 12 h.):	60	728	13	44	148	13	77	205	6
	(12 - 18 h.):	75	196	9	83	2092	4	49	76	7
	(18 - 24 h.):	81	1129	7	55	883	8	25	97	6
MAY "	(0 - 6 h.):	86	602	5	47	507	12	37	123	16
	(6 - 12 h.):	63	845	20	28	125	11	85	1805	3
	(12 - 18 h.):	68	1046	17	81	3516	18	57	571	8
	(18 - 24 h.):	80	2129	9	51	982	8	15	154	10
JUN. "	(0 - 6 h.):	82	642	13	49	559	13	35	75	12
	(6 - 12 h.):	65	2033	20	41	255	10	84	2143	13
	(12 - 18 h.):	75	1260	15	81	2501	8	54	903	8
	(18 - 24 h.):	82	1987	6	56	714	12	28	101	7

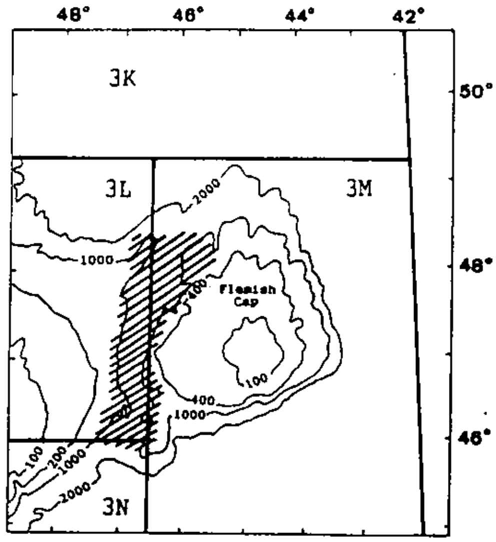

FIG. 1 - Sampling area in 1991-92. (Depth in meters).

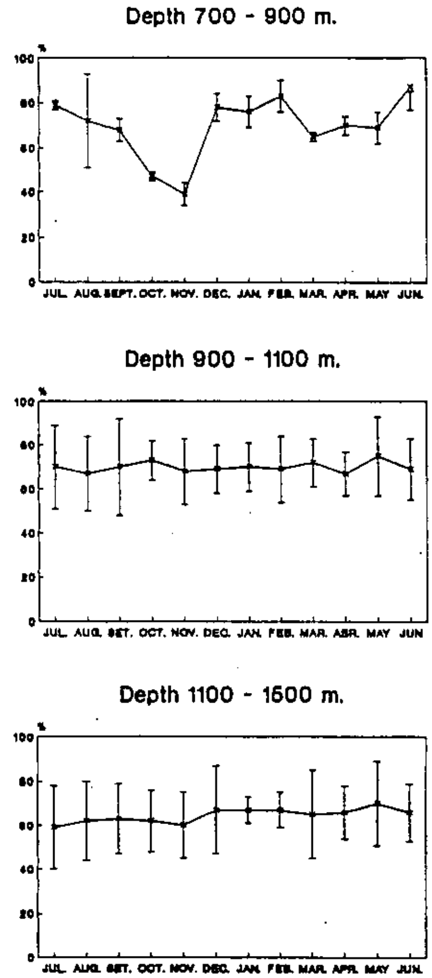

FIG. 2 - Monthly means and standard deviations in the percentage of empty stomachs (PES) by depth strata.

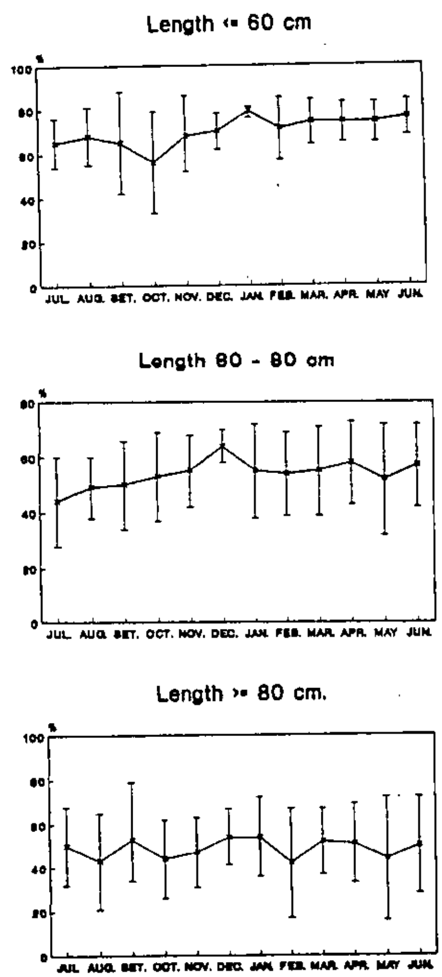

FIG. 3 - Monthly means and standard deviations in the percentage of empty stomachs (PES) by length categories.

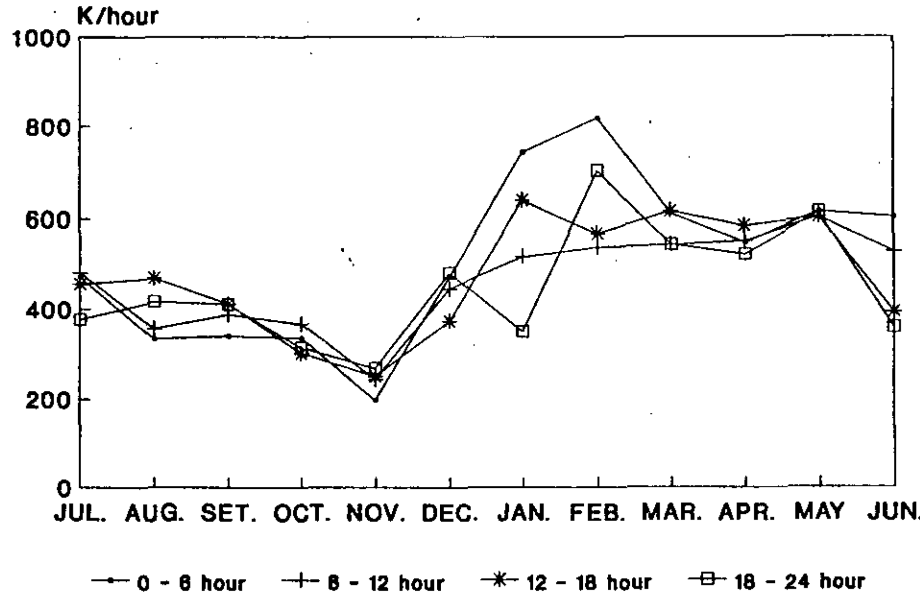

FIG. 4 - Monthly catch rates (Kg/hour) by hour intervals and depth range of 900 - 1100 m.

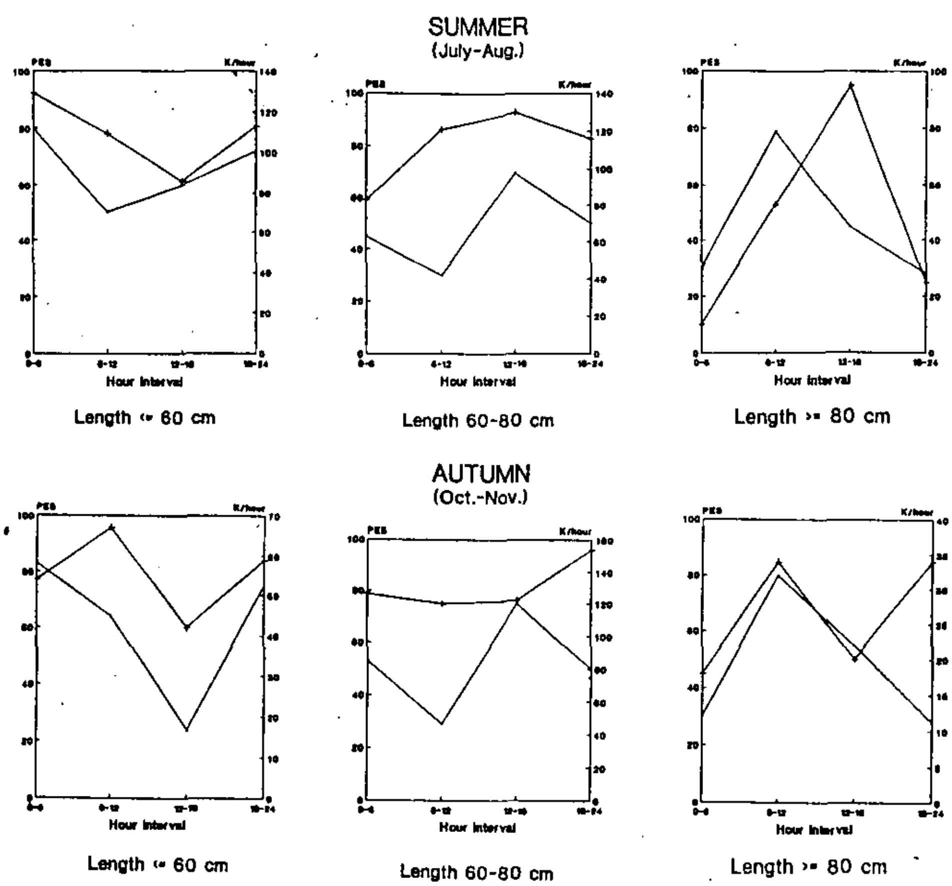

FIG. 5a - Catch rates (Kg/hour) by length categories and hour intervals in summer (July - August) and autumn (October - November).

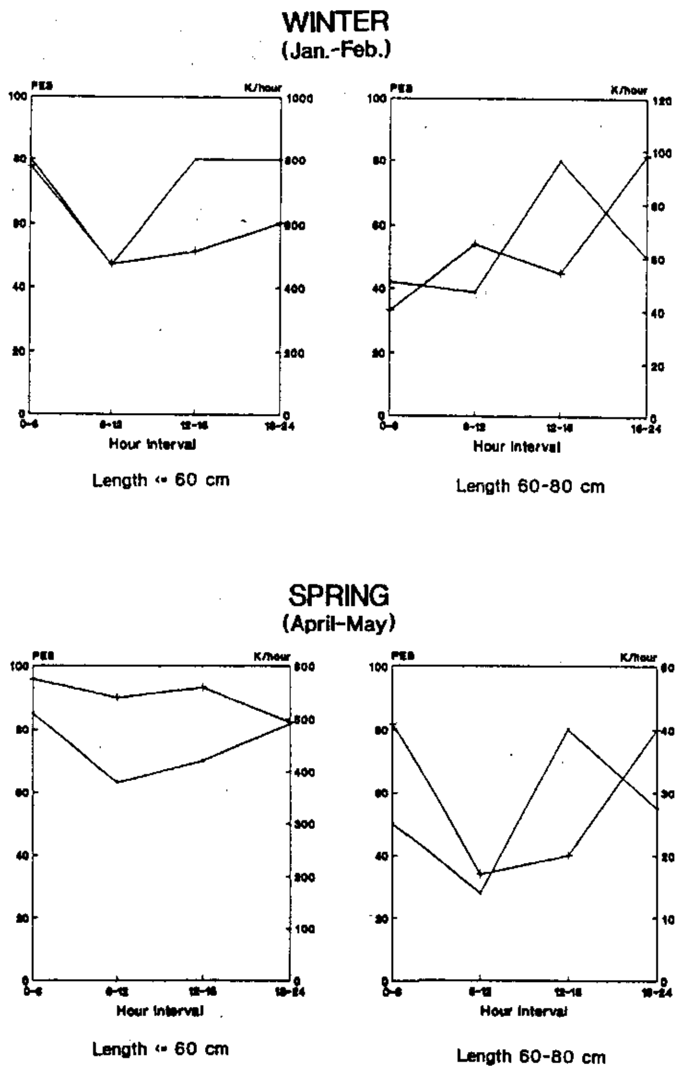

FIG. 5b - Catch rates (Kg/hour) by length categories and hour intervals in winter (January - February) and spring (April - May).