An Analysis of the Catch Records of the Alaska Pollack Trawling – III*

The Daily Rhythmic Change of the Catch Pattern

By

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The preceding report[1] dealt with the bathymetric change of the relation between the catch and the length of towing time, and the clearest findings were 1) a large variation of the length of towing time, 2) a sharp decrease of the catch per minute of towing in accordance with the length of towing time (The catch by long towing was poorer than that by short towing or similar to it), and 3) the segregation of the depth zones in respect of the catch-time relation. The density of the fishable population varies according to time and space. The modern factory trawler is equipped with the fish detecting device of excellent performance. And it is possible to avoid the inefficient towings when the variation of the density is relating to the space. However, it is hard to do so when the variation is relating to the daily rhythmic change of the behavior pattern of the objective fish. And the evaluation of the long towing yielding a poor catch differs according as the variations of the amount of catch and the length of towing time are relating to time or space. In the case of the density variation relating to the daily rhythmic change, the lowering of the efficiency during the hour of low density is inevitable; while, in the case of the variation not relating to the hour, it may be said that the boat spends many efforts uselessly over many hours. To discern which of these possibilities the fact is, the daily rhythmic change of the catch pattern was examined in the present report.

Material and Method

The same materials as those used in the preceding reports[1,2] were used in the present report. They were the catch records of the 2,736 towings (after removal of the records on the 54 accidental towings and on the 342 towings with more than 10% of catch occupied by the other species than the Alaska pollack) by a minced fish factory trawler during the

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season from December 23 in 1968 to May 2 in 1970 along the outer edge of the continental shelf of the Eastern Bering Sea.

The records were stratified according to the month and the location of the fishing ground shown in Fig. 1 of the first report of this series. The amounts of catch were aggregated into the classes of 10-ton intervals, the echo-sounded depths were into the classes of 25-m intervals, and the lengths of towing time were into the classes of 5-minute intervals, because the distribution and the accuracy of measurement were taken into account. The hours of shooting the gear were aggregated into the classes of 2-hour intervals. And the quadratic regressions of the former three factors on the last one were examined.

Results

1. The amount of catch by a towing

There are many types of the daily rhythmic change of the amount of catch. Among

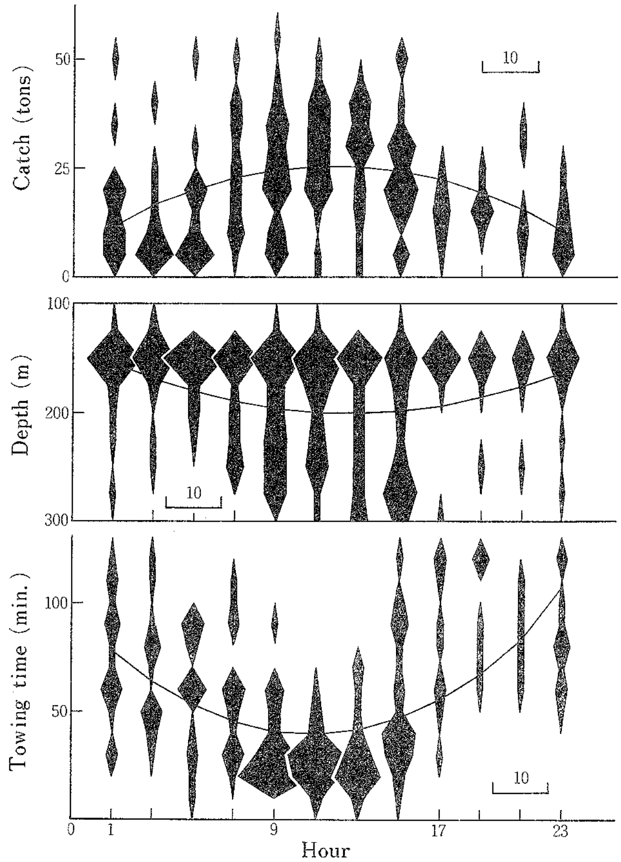

Fig. 1. The bi-hourly change of the frequency distributions of the amount of catch by a towing (upper), the trawled depth (middle), and the length of towing time (lower) (on Jan. '69).

them, the most probable types are as follows: 1) two peaks a day, around the dawn and the dusk, 2) a peak around the dawn, 3) a peak around the dusk, 4) a peak around the noon, and 5) a peak around midnight. According to one peak or two peaks, the amount of catch shows either a quadratic regression on the hour or a fourth order one. To find which of the types the Alaska pollack is, the bi-hourly changes of the frequency

Table 1. The quadratic regression equations of the amount of catch by a towing (y in tons) on the hour (x).

Month	a_0	a_1	a_2	$F_{2\text{-}1}$	$F_{2\text{-}2}$	n
Dec. '68	16.6	0.80	−0.035	0.36	0.43	36
Jan. '69	8.8	2.80	−0.119	32.23**	33.11**	195
Feb.	10.6	2.58	−0.115	23.06**	25.90**	164
March	24.7	0.66	−0.031	3.30	4.13*	212
April (A)	24.7	0.20	−0.011	0.06	0.08	78
April (B)	22.0	−0.50	0.016	0.94	0.56	116
May (B)	19.4	1.13	−0.058	1.83	3.01	53
May (A)	15.3	1.67	−0.079	5.29*	7.17**	86
June (C)	10.0	0.70	−0.038	0.29	0.50	27
July	16.9	1.50	−0.059	13.54**	13.40**	219
Aug.	14.9	1.80	−0.080	25.60**	30.30**	230
Sept.	18.2	1.19	−0.060	8.55**	12.71**	235
Oct.	16.2	0.62	−0.023	2.97	2.59	209
Nov.	21.4	−0.14	−0.004	0.07	0.03	135
Dec.	0.9	2.61	−0.108	0.67	0.85	20
Jan. '70	12.0	1.59	−0.067	9.39**	10.44**	158
Feb.	20.5	0.56	−0.024	1.50	1.66	161
March	23.3	1.29	−0.060	10.03**	13.12**	202
April	8.5	2.97	−0.141	38.44**	53.94**	200

Notes $y=a_0 + a_1x + a_2x^2$

F_{2i} ...The Snedecor's F value of the i-th order regression coefficient in the quadratic equation, with 1 and $(n - 3)$ degrees of freedom

n ....Size of samples

*significant at 0.05 level **significant at 0.01 level

The letter in parenthesis is the abbreviation of the area shown in Fig. 1 of the first report of this series.

distribution of these three factors chosen in the present report are shown in Fig. 1. This figure suggested that the most probable type for the Alaska pollack should be the Type 4, i.e. a peak around the noon. Accordingly, the quadratic regression equation of the amount of catch by a towing on the hour was estimated, and the significance of its quadratic coefficient was tested.

As shown in Table 1, the quadratic coefficient in the 18 month-ground groups of the records was negative and the linear one in the 17 groups each out of the 19 groups was positive; and the former was significant in the 10 groups. And as shown in Table 2 and

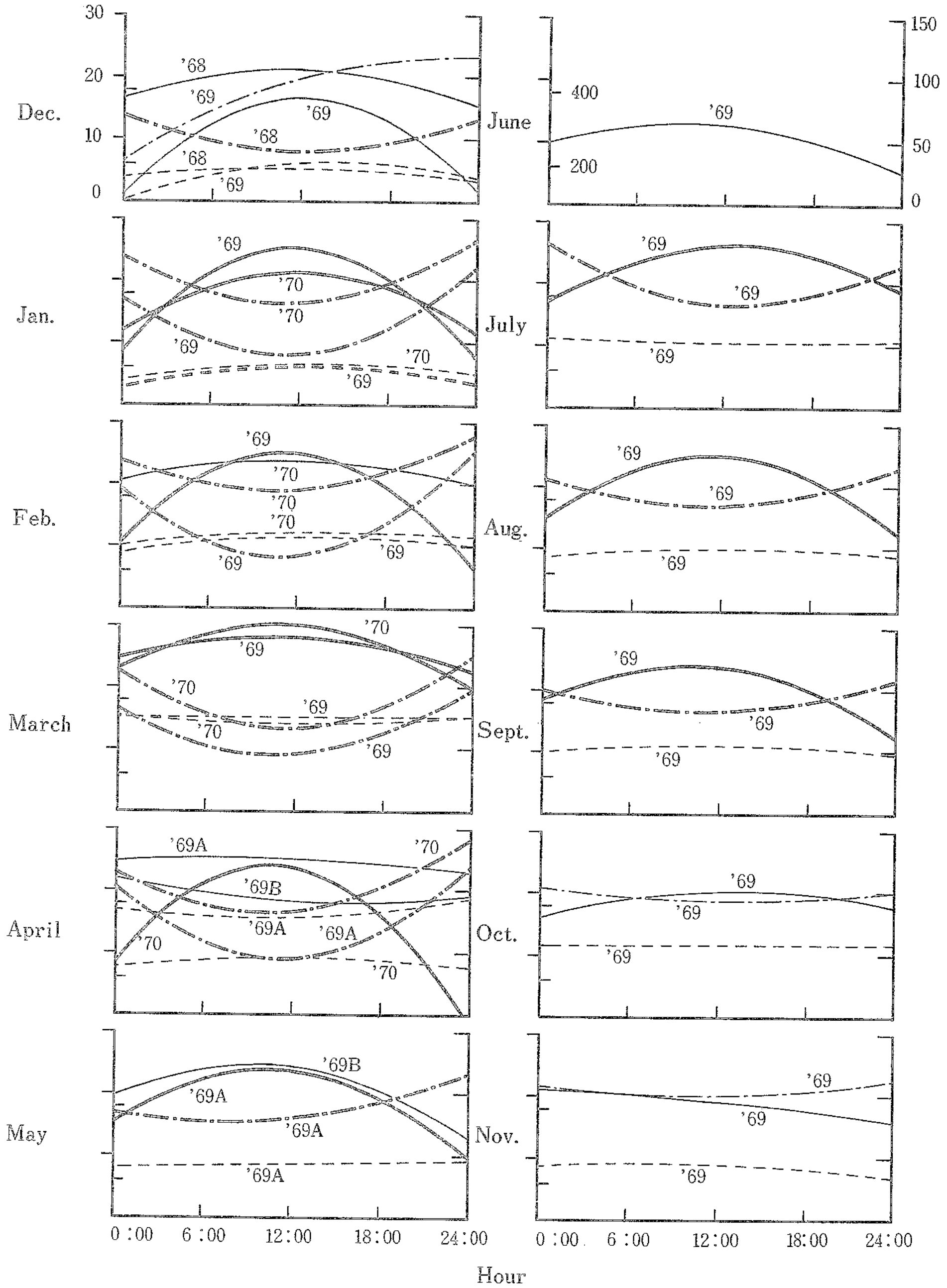

Fig. 2. The daily rhythmic change of the catch pattern.

Note: The amount of catch by a towing....Solid curve, the outer scale on the left or ordinate (in tons)
The trawled depth.........Broken curve, the inner scale on the left ordinate axis (in meters)
The length of towing time.......Chain curve, the inner scale on the right ordinate axis (in minutes)
The curve...........The regression curve with significant quadratic coefficient
The curve...........That with insignificant one

Table 2. The maximum and the minimum values of the catch, the trawled depth, and the towing time, estimated through their quadratic regression equations on the hour.

	Catch (tons)				Depth (m)				Towing time (min.)			
	Max. (Min.)		0：00	24：00	Max. (Min.)		0：00	24：00	Max. (Min.)		0：00	24：00
	Hour	Amount			Hour	Depth			Hour	Length		
Dec. '68	11：26	21.2	16.6	15.6	10：23	182	168	158	(12：15)	(40)	70	68
Jan. '69	**11：46**	**25.3**	8.8	7.5	12：39	**200**	146	157	(10：37)	(40)	86	113
Feb.	**11：13**	**25.1**	10.6	6.3	13：57	287	250	268	(10：44)	(42)	97	126
March	**10：39**	**28.2**	24.7	22.7	17：30	357	351	356	(10：48)	(45)	81	99
April (A)	9：06	25.6	24.7	23.2	(9：10)	(362)	382	415	(11：10)	(44)	103	122
April (B)	(15：38)	(18.1)	22.0	19.2								
May (B)	9：44	24.9	19.4	13.1								
May (A)	**10：34**	**24.1**	15.3	9.9	45：00	255	235	251	(7：09)	(77)	84	117
June (C)	9：13	13.2	10.0	4.9								
July	**12：43**	**26.4**	16.9	17.9	(15：00)	(273)	284	277	(13：17)	(82)	133	115
Aug.	**11：15**	**25.0**	14.9	12.0	12：44	262	244	248	(11：23)	(84)	107	112
Sept.	**9：55**	**24.1**	18.2	12.2	11：15	274	264	261	(11：26)	(82)	100	104
Oct.	13：29	20.4	16.2	17.8	15：00	298	293	296	(13：20)	(94)	105	101
Nov.	(−17：30)	(22.6)	21.4	15.7	7：16	250	244	219	(9：10)	(102)	107	115
Dec.	12：05	16.7	0.9	1.3	14：53	202	100	164	21：46	115	34	114
Jan. '70	**11：52**	**21.4**	12.0	11.6	13：37	201	168	182	(11：08)	(82)	120	133
Feb.	11：40	23.8	20.5	20.1	18：20	299	269	296	(10：00)	(96)	120	143
March	**10：45**	**30.2**	23.3	19.7	(13：20)	(338)	359	351	(11：21)	(67)	115	127
April	**10：32**	**24.1**	8.5	−1.4	11：46	252	228	226	(10：00)	(84)	115	145

Note: The values estimated through the equations with the significant quadratic coefficient are printed in Gothic. The letter in the parenthesis is the abbreviation of the area shown in Fig. 1 of the first report of this series.

Fig. 2, the estimated maxima of catch in most of the groups were found around the noon, when the length of towing time was taken into account. Namely, the trend of a good catch in the daytime and a poor catch at night was found out in most of the groups, and this trend was significant in about a half of the groups.

2. The trawled depth

The preceding section hinted the daily rhythmic change of the behavior pattern of the objective fish. The trawled depths were scattering over wide range. These facts suggested that the objective fish should show a daily rhythmic change of the swimming depth. There are the two probable types of the change in the swimming depth. One is that the fish swims near the sea bed in the daytime and floats up at night, because the Alaska pollack is a roundfish living loosely depending on the sea bed. The other is that the fish shifts along the sea bed and lives on the deep ground in the daytime and on the shallow ground at night, because the good fishing ground is near the steep sloap. The trawled depth in the former case hardly shows any significant regression on the hour, while that in the latter case shows the clear regression on it. The bi-hourly change of the bathymetric distribution of the towings in Fig. 1 hints that the regression may be quadratic, if any. Accordingly, the quadratic regression equation of the trawled depth on the hour was estimated, and the significance of its quadratic coefficient was tested, for the purpose of finding out whether the behavior pattern was the former type or the latter one.

Table 3. The quadratic regression equations of the trawled depth (y in meters) on the hour (x).

Month	a_0	a_1	a_2	$F_{2\cdot1}$	$F_{2\cdot2}$	n
Dec. '68	168	2.7	−0.13	0.36	0.54	36
Jan. '69	146	8.6	−0.34	19.05**	16.57**	195
Feb.	250	5.3	−0.19	5.00*	3.65	164
March	351	0.7	−0.02	0.22	0.10	212
April (A)	382	−4.4	0.24	1.34	2.01	78
May (A)	235	0.9	−0.01	0.10	0.01	86
July	284	−1.5	0.05	0.93	0.65	219
Aug.	244	2.8	−0.11	2.68	2.82	230
Sept.	264	1.8	−0.08	1.50	1.83	235
Oct.	293	0.6	−0.02	0.14	0.16	209
Nov.	244	1.6	−0.11	0.51	1.35	135
Dec.	100	13.7	−0.46	3.10	2.68	20
Jan. '70	168	4.9	−0.18	3.35	2.90	158
Feb.	269	3.3	−0.09	0.99	0.41	161
March	359	−3.2	0.12	2.91	2.57	202
April	228	4.0	−0.17	1.22	1.43	200

Notes are the same as those shown in Table 1.

As shown in Table 3 and Fig. 2, the trend of deepening in the daytime and shallowing at night was found in the 13 month-ground groups out of the 16 ones, although the quadratic coefficient was significant only in one of the groups. This fact meant that the trawled depth showed a rough trend of a slight deepening in the daytime.

3. The length of towing time

If the boat fished on the ground of the uniform density, the amount of catch by a towing increases nearly in proportion to the length of towing time. And even when the lowering of the efficiency of the net due to the over-packing of catch in net is taken into account, the catch may increase along a loose convex curve with the maximum far out of the class of the longest towing. But the fact contrary to this was found in the preceding reports[1),2)]. This fact hinted that the density of the fishable population was not uniform. And it is probable, as above-mentioned, that the density varied not relating to the space but relating to the hour. The amount of catch depends not only on the density but also on the length of towing time. Accordingly, it is necessary to examine the daily rhythmic change of the length of towing time, for the purpose of finding out not only the evidence supporting that the occurrence of the long and inefficient towings has a close relation to the hour but also the evidence supporting that the daily rhythmic change of the amount of catch by a towing was not due to the long towing in the daytime and the short towing at night. And the quadratic regression equation of the length of towing time on the hour was estimated, and the significance of its quadratic coefficient was tested, because the bi-hourly change of the frequency distribution of the length of towing time suggested the quadratic relation between them.

Table 4. The quadratic regression equations of the length of towing time (y in minutes) on the hour (x).

Month	a_0	a_1	a_2	$F_{2\cdot1}$	$F_{2\cdot2}$	n
Dec. '68	70	−4.9	0.20	4.85*	4.90*	36
Jan. '69	86	−8.7	0.41	66.07**	81.79**	195
Feb.	97	−10.3	0.48	65.34**	80.70**	164
March	81	−6.7	0.31	33.63**	41.30**	212
April (A)	103	−10.5	0.47	25.51**	24.77**	78
May (A)	84	−2.0	0.14	1.58	4.76*	86
July	133	−7.7	0.29	32.48**	29.76**	219
Aug.	107	−4.1	0.18	16.98**	21.07**	230
Sept.	100	−3.2	0.14	13.33**	16.46**	235
Oct.	105	−1.6	0.06	4.38*	3.85	209
Nov.	107	−1.1	0.06	0.86	1.33	135
Dec.	34	7.4	−0.17	1.98	0.74	20
Jan. '70	120	−6.9	0.31	34.29**	43.26**	158
Feb.	120	−4.8	0.24	15.06**	22.09**	161
March	115	−8.4	0.37	45.06**	53.06**	202
April	115	−6.2	0.31	25.37**	38.49**	200

Notes are the same as those shown in Table 1.

As shown in Table 4 and Fig. 2, the length of towing time showed a concave relation to the hour; and the quadratic regression coefficient was significant in the 13 groups out of the 16 ones. Namely, the boat repeated the towings of the short hours in the daytime and conducted the long towings at night.

Discussion

The quadratic regression coefficient of the amount of catch by a towing on the hour was significant in the 10 month-ground groups of the records out of the 19 ones. And the good catch was found mainly in the daytime. Among the nine groups of the records with the insignificant quadratic regression coefficient, the two groups [June(C) and December in 1969] showed the same trend as those of the significant one, but the quadratic coefficient was insignificant because of a small sample size. The five groups [December in 1968, April (A), May (B), and October in 1969, and February in 1970] showed the similar trend; but the quadratic coefficient was insignificant because the catch at night did not show any clear decline. The two groups showed the trend contrary to the others. However, their coefficients were small, and it was hard to regard that the catch in these groups showed a concave relation to the hour, but it may be said that the similar amount of catch was yielded by a towing regardless of hour. The fishing ground is in the water of high latitude. And the length of daytime shows a large seasonal change. The groups showing the insignificant regression were found in the limited seasons (April to May and October to December). However, it was hard to find any clear relation between their distribution and the length of daytime. The present records comprized those of the three trips. The first trip ended on May 23 in 1969; the second ended on Nov. 26 in 1969; and the third ended on May 2 in 1970. These facts hinted that the groups showing the insignificant regression were in the latter half of the trips. However, it was hard to tell whether this trend was anything serious or nothing but a coincidence. As above-mentioned, the difference of the groups with the insignificant coefficient from those with the significant one was the obscure decline of the catch at night. The amount of catch by a towing depends on the density and the length of towing time. Accordingly, if the daily rhythmic difference of the length of towing time in the former groups was severer than the latter groups, the probable decline of catch at night might be diminished into the insignificant difference. It was, however, hard to find any fact in support of this possibility, but the fact contradictory to this was found out.

The trawled depth was the factor showing the faintest daily rhythmic change among the three factors examined in the present report. A significant trend of deepening in the daytime and shallowing at night was found only in one of the groups. The difference due to the daily rhythmic change was small. However, it was hard to say that the trawled depth did not show the daily rhythmic change, because the similar trend was found in the other 12 groups, although they were insignificant. As shown in Fig. 1, most of the towings were concentrated into one or two depth zones regardless of hour. The estimated depth at night showed this depth zone. And the deepening in the daytime was due to the tailing of the frequency distribution of the towings into the deep zone. Namely, the boat fished mainly in the same depth zones throughout day and night, and fished in the deep zones more frequently in the daytime than at night. The preceding report[1] showed that the variation of the catch by a towing in the deep zones was smaller than that in the shallow zones, and this resulted in the segregation of the depth zones in respect of the catch-time relation. The present results revealed that this may be due to the fact that the boat fished in the deep zone only in the limited hours, while in the shallow zones throughout day and night. And this may be due to the technical reasons shown in the preceding report. Namely, during the hours of high possibility of finding out dense schools, the boat sought the schools over wide depth range and attacked them; while in the hour of low possibility of finding out dense schools, she inclined to fish in the zone of the highest possibility of encountering dense schools.

In regard to the daily rhythmic change of the swimming depth of the objective fish, the most important problem is to find whether the change is the floating up–and–settled down type or the shift along the sea floor, because the boat used the method capable of catching only the fish living closely to the sea bed. The amount of catch and the length of towing time showed a clear daily rhythmic change in the density of the fishable population—dense in the daytime and less dense at night; the trawled depth showed a slight change. These facts suggested that the daily rhythmic change of the swimming depth of the Alaska pollack should be the floating up–and–settled down type. And the inefficient work at night should be due to the floating up of the objective fish at night, i.e. inevitable so far as the boat employed the bottom trawling; accordingly, the introduction of the midwater trawling may be one of the most effective ways of increasing the daily total of catch by overcoming the lowering of the efficiency of the bottom trawling at night.

The length of towing time was the factor showing the clearest daily rhythmic change—short towing in the daytime and long towing at night. And the significant quadratic regression on the hour was found in the 13 groups of the records out of the 16 ones. Among these 13 groups, the catch showed the clear daily rhythmic change in the 10 groups. In the three groups [December in 1968, April (A) in 1969, and February in 1970], the catch showed an increasing trend in the daytime, but this was insignificant. The towing time in these groups showed the shortening in the daytime. Accordingly, it may be said that the catch per minute of towing, i.e. the density of the fishable population, showed the daily rhythmic change in these groups, too. From October to December, all the three factors chosen here did not show any significant regression on the hour. Namely, the catch pattern in these months did not show the daily rhythmic change. It was hard to find any clear relation of these three months either to the length of towing time or to the trawled depth.

One of the clearest findings in the first report[2] was the elongation of the towing time in accordance with the passing of season. In the early season, as shown in Fig. 1, the towing times in the daytime were concentrated into the classes of the short towings, and those at night were distributed over many time-classes. And the elongation of the towing time was mainly due to the shift of the frequencies of the towings into the classes of the long towings in all the hours and scattering of those in the daytime over many time-classes.

The principal aim of the present series of work is to clarify the relation between the catch and the other factors. It is natural that the catch depends on the length of towing time; but the preceding report[1] revealed that the long towing yielded a poorer catch than the short towing or similar amount of catch to it. The present report revealed that both the amount of catch and the length of towing time showed the daily rhythmic change—a good catch and a short towing in the daytime. Accordingly, the trend found in the preceding report may be due to the fact that the records in the same depth zones were distributed over the different hour classes. And it is necessary to examine again the same problems after stratification of the records into the hour classes.

Conclusion

To summarize, it may be said that the daily rhythmic change is one of the most influential factors on the amount of catch. And the influence of this factor should be taken into account; otherwise it is hard to clarify the catch pattern exactly. Among the three factors chosen in the present report, the clearest daily rhythmic change was found in the length of towing time, which is the factor decided by the human's will. The second clearest one was found in the amount of catch by a towing, which is the factor as the result of the interaction of the density (not controllable by human's will) and the length of towing time. And the faintest one was in the trawled depth, which is the factor primarily depending on the distribution of the objective fish and out of our control. The objective fish, the Alaska pollack, showed the daily rhythmic change of the behavior pattern of the floating up–and–settled down type. And the inefficient work at night should be due to this reason. The trend of the change in the first factor was to diminish the variation of the catch by a towing due to the different density of the fishable population; however, the presumable daily rhythmic change of the density may be very large, and this remained still in the daily rhythmic change in the amount of catch by a towing.

Summary

The preceding report showed that the minced fish factory trawler sometimes conducted the long towings and yielded a poor catch. For the purpose of finding out the convincible reason of the occurrence of these inefficient work, the daily rhythmic change in the catch pattern observable in the catch records of an Alaska pollack factory trawler during the season from December in 1968 to May in 1970 along the outer edge of the continental shelf of the Eastern Bering Sea was examined, and the following results were obtained:
1. The amount of catch by a towing showed a daily rhythmic change, and the boat yielded a good catch in the daytime and a poor catch at night.
2. The length of towing time showed the clearest daily rhythmic change; and the boat repeated the towings of short hours in the daytime and towed her net over many hours at night.
3. The trawled depth showed the faintest change.
4. These facts meant that the seemingly inefficient work pattern found in the preceding report (a good catch by a short towing and a poor catch by a long towing) was due to the settling down of the fish in the daytime and floating up of it at night.

References

1. MAÉDA, H., 1974: *This Jour.*, **22**, 147 – 165.
2. MAÉDA, H., 1972: *ibid.*, **21**, 1–20.