An Analysis of the Catch Records of the Trawling Assisted by the Electronic Devices— III.*

Daily Rhythmic Change Observable in the Catch Records of the Pacific Ocean Perch

By

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The seasonal change of the bathymetric distribution of the amount of catch per haul of the Pacific Ocean perch and that of the number of the hauls were examined in the first report of this series[1], for the purpose of clarifying the difference of the meanings of the descriptions in the catch records of the modern trawling induced by the full application of the modern electronic supporting devices. In spite of a well-known bathymetric difference of the density of the objective fish, however, it was hard to find it in the catch per haul of the modern trawling, but some facts suggestive of it were found in the number of hauls, probably because of the selective attacking the profitable echoes and the adjustment of the length of towing time, both of which were realized by the good assistance of the electronic devices.

In order to give the further consideration, these relations were examined after the stratification of the records according to the echogram type. The length of towing time showed a large variation even for the schools showing the same echogram type in the same depth zone of the same ground in the same season. To clarify the details of the adjustment of the length of towing time for equalizing the amount of catch by a haul and to find the change of the amount of catch after the elimination of the influence of the different length of towing time, the relations between the amount of catch and the towing time—either before or after the stratification of the records according to the type of echogram were examined in the second report[2]. And it was found out that the adjustment differed according to the presumable profitability of the schools. Namely, the possibility of the towing time being over-adjusted (the rate of the examples showing a significant increase of the amount of catch in accordance with the length of towing

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time) increased in accordance with the presumable difficulty in yielding a good catch.

The boats attacked the schools showing the echograms of very rich variety, including those hardly thought to be a good object of the trawling, such as the thin or spotted trace not contacting with the bottom echo. They towed sometimes their nets over many hours. And it was hard to find the reason of conducting the work of extremely low efficiency like this. These facts suggested the presence of some other factors deeply influential in the fishing pattern and hardly to be made up by the fishermen's effort. The Pacific Ocean perch is a round-fish capable of living loosely depending on the sea floor. This fish feeds mainly on the large planktonic animals and the small fish. These prey show a wide daily rhythmic vertical movement. And it is probable that the Pacific Ocean perch shows it too, pursuing the prey. The different relation between the echo of the school and that of the bottom according to the hauls is one of the facts in support of the above-mentioned suggestion. These facts suggested that the daily rhythmic change of the behavior of the objective fish should be one of the factors having a decisive influence on the fishing pattern, because the trawl is the fishing method capable of catching only the fish living very closely to the sea floor. And the daily rhythimc change of the catch pattern observable in the same records used in the preceding reports was examined in the present reoprt, although it was hard to find any clear relation between the results and the change of the behavior of the objective fish because any of the direct method of clarifying the change of the behavior pattern was hardly applicable.

Material and Method

The present report used the same materials as those in the preceding two reports of this series[1,2]. They were the working records on the 1,887 hauls conducted by the three stern ramp trawlers (the two 3,000 ton ones, abbreviated to F and K, according to their initials; and a 500 ton one, abbreviated to I) fished mainly the Pacific Ocean perch along the outer edge of the continental shelf from east of Kodiak Island to west of the Queen Charlotte Islands during the season from April of 1968 to March of 1970.

These records were stratified into the 29 groups according to the trawler and season, as shown in Fig. 1 of the first report[1]. The word, the group, used in the present report indicated this classification of the records. The 12 groups consisted of the records of less than 20 hauls. And they were excluded from the examination; in consequence, the records in the 17 groups were used in the present report. For the purpose of clarifying whether the catch pattern shows a daily rhythmic change or not, the quadratic regression equations of either the amount of catch per haul or the depth fished or the length of towing time were estimated—either before or after the stratification of the records according to the type of echogram, and the significance of the quadratic regression coefficient was tested. In the estimation of the regression equations, the amounts of catch by a haul of the trawler F and K were aggregated into the classes of the nearest

5-ton intervals and used after the logarithmic transformation, and those by the trawler I (z tons) were into the classes of the nearest 1-ton intervals and used after the log $(z+2)$ transformation, because of the reasons shown in the first report[1]. The echo-sounded depths described in meters were used after the aggregation of them into the classes of the nearest 25-m intervals, because the distribution and accuracy of sounding were taken into account. The towing times were described in 5-minute intervals, but they were used after the aggregation of them into the classes of the nearest 30-minute intervals.

The echogram differs according to not only the distribution pattern of the objective fish but also the performance of the echo-sounder and the recording conditions. There is no doubt, however, that the echogram was used as one of the most powerful bases of making the skipper decide the work pattern. The descriptions on the echograms were classified into the 12 types shown in the note of Table 2, mainly according to the density of the echo and the relation to the bottom echo.

The time starting to tow the gear (in the local mean time) and that of the finish of towing were described in the original records. The records were aggregated into the 12 hour-classes of two-hour intervals according to the time started to tow the gear.

Results and Consideration

1. The amount of catch per haul

As shown in Table 1 and Fig. 1, the regression equation of the amount of catch per haul took the negative quadratic coefficient and the positive linear one in the 16 groups out of the 17 ones, although the quadratic coefficient was not significant (0.05 level) in the seven groups. And most of the equations showed the maximum catch per haul at 11:00 to 13:00 and the minimum catch at midnight. This fact may be due to the following relation between the mechanism of trawl for catching the fish and the behavior pattern of the objective fish. It is a well-known fact that the main prey—the planktonic animals—shows a well defined daily rhythmic vertical movement, floating up at night and sinking down in the daytime. And the trawl is the fishing method capable of catching exclusively the fish living very closely to the sea floor. If the objective fish shows a daily rhythmic vertical movement pursuing the prey, the catch by the trawl shows the pattern found out here. There aroused doubts as to the amount of catch per haul depending exclusively on the behavior pattern of the objective fish. Somewhat large within-group variation of the depth trawled threw a doubt as to the daily rhythmic vertical movement of the Pacific Ocean perch being the floating up-and-sinking down pattern or the movement along the sea floor. The large variation of the length of towing time suggested that the daily rhythmic difference of the amount of catch per haul should be leveled by adjusting the length of towing time.

2. The depth trawled

If the Pacific Ocean perch shows the movement along the sea floor, the boat attacks the schools on the shallow grounds at night and those on the deep grounds in the daytime. If the fish shows the vertical movement of the floating up-and-sinking down pattern, in contrast with this, the depth trawled does not show any clear daily rhythmic change. To find either of these possibilities, the quadratic regression of the depth trawled on the hour was examined. As shown in Table 1 and Fig. 1, there were no groups of records showing the significantly negative quadratic regression on the hour, which was the expected pattern under the former supposition. There were the 12 groups showing insignificant quadratic regression, which was the expected pattern under the latter supposition. And the pattern contrary to the former supposition was found in the other five groups. These results denied the former supposition, and supported the latter one. And the large within-group variation of the depth trawled may not be due to the daily rhythmic movement of the objective fish.

3. The length of towing time

Among the 17 groups of the records, the four groups showed the significant quadratic regression of the length of towing time on the hour, showing the minimum about at noon. All of them were the groups showing the significant quadratic regression of the amount of catch per haul. The same trend was found in the other six groups, although the quadratic coefficient was insignificant. Among them, the two groups were those showing the significant quadratic regression of the amount of catch. The trend contrary to them was found in the other seven groups; the quadratic coefficient was, however, significant in none of them. And that of the amount of catch per haul in the five groups of them was also insignificant.

The results in these three sections meant that the increasing trend of the catch per haul in the daytime and the decreasing one at night were found in most of the groups, although these trends were insignificant in a half of the groups; while in a quarter of the groups, the same trends of the density of the trawlable population were far clearer than those found in the daily rhythmic change of the amount of catch per haul because of the significant daily rhythmic difference of the length of towing time.

4. The composition of the towings in respect of the echogram type

The above-mentioned results suggested that the Pacific Ocean perch should show a daily rhythmic movement in the floating up-and-sinking down pattern. The original records comprised the descriptions on the echograms of the schools attacked. There is a doubt as to the echogram type applicable to the examination on the daily rhythmic change of the distribution pattern of the objective fish, because the echogram type depends not exclusively on it. The homogeneity test of hour classes in respect of the composition of the echogram type revealed the change of the composition in the records of the three trips out of the four ones. The test after the stratification of the records according to the fishing ground showed that the significant difference of the composition

Table 1. The estimated quadratic hour regression equation.

a) The amount of catch per haul, after either logarithmic or log $(z+2)$ transformation

$\log z$ or $\log (z+2) = a_{1\cdot0} + a_{1\cdot1}x + a_{1\cdot2}x^2$

Trawler-Fishing ground	$a_{1\cdot0}$	$a_{1\cdot1}$	$a_{1\cdot2}$	$F_{1\cdot1}$	$F_{1\cdot2}$	n
F — b	0.333	0.056	−0.002	12.15	12.35**	234
d	0.730	0.017	−0.001	0.32	0.80	43
e	0.207	0.125	−0.005	33.60	36.21**	100
f	0.558	0.018	−0.001	0.43	0.59	23
g	0.191	0.081	−0.004	13.11	18.55**	145
K — a	0.327	0.057	−0.003	8.90	12.65**	173
d	0.048	0.098	−0.004	31.57	34.48**	244
I_1 — d	0.563	0.009	−0.001	0.23	0.37	55
e	0.283	0.131	−0.006	24.28	22.67**	41
f	0.427	0.016	−0.001	0.83	1.09	50
h	0.547	0.033	−0.001	2.36	2.87	78
i	1.139	−0.033	0.000	0.89	0.00	60
k	0.584	0.036	−0.002	6.04	7.77**	124
l	0.167	0.089	−0.003	16.00	15.72**	92
I_2 — c	0.614	0.013	−0.000	0.52	0.20	23
d	0.565	0.011	−0.001	2.86	4.28**	211
e	0.457	0.046	−0.002	12.24	12.18**	88

b) The depth trawled $y = a_{2\cdot0} + a_{2\cdot1}x + a_{2\cdot2}x^2$

Trawler-Fishing ground	$a_{2\cdot0}$	$a_{2\cdot1}$	$a_{2\cdot2}$	$F_{2\cdot1}$	$F_{2\cdot2}$	n
F — b	2.428	0.007	−0.000	0.31	0.04	234
d	1.802	0.134	−0.004	3.22	2.34	43
e	3.015	0.002	−0.000	0.01	0.04	100
f	2.193	0.054	−0.002	1.88	1.88	23
g	3.068	−0.030	0.002	0.66	2.79	145
K — a	3.359	−0.014	0.000	0.46	0.11	173
d	2.978	−0.056	0.002	36.25	44.28**	244
I_1 — d	2.451	−0.016	0.001	0.44	0.91	55
e	2.706	−0.083	0.003	5.69	4.22*	41
f	2.333	−0.017	0.001	0.08	0.30	50
h	3.204	−0.164	0.006	24.20	22.05**	78
i	2.952	−0.148	0.008	3.91	6.89*	60
k	2.667	−0.027	0.002	0.97	2.04	124
l	2.694	−0.072	0.003	4.66	4.20*	92
I_2 — c	2.505	−0.015	0.001	0.08	0.27	23
d	2.252	−0.016	0.001	1.53	2.73	211
e	2.987	0.013	−0.001	0.63	0.85	88

c) The length of towing time $t = a_{3\cdot0} + a_{3\cdot1}x + a_{3\cdot2}x^2$

Trawler-Fishing ground	$a_{3\cdot0}$	$a_{3\cdot1}$	$a_{3\cdot2}$	$F_{3\cdot1}$	$F_{3\cdot2}$	n
F — b	7.247	0.252	−0.007	3.04	1.40	234
d	8.785	−0.357	0.017	0.56	0.88	43
e	10.286	0.158	−0.003	0.43	0.09	100
f	10.042	−0.766	0.036	3.55	3.72	23
g	9.566	−0.659	0.032	13.80	21.27**	145
K — a	5.418	−0.030	0.002	0.06	0.13	173
d	5.688	0.028	−0.003	0.09	0.73	244
I_1 — d	5.224	0.227	−0.010	0.82	0.87	55
e	6.091	−0.435	0.020	4.00	4.45*	41
f	6.270	−0.211	0.007	0.98	0.59	50
h	6.260	−0.250	0.010	1.11	2.66	78
i	5.030	0.150	−0.004	0.16	0.08	60
k	8.036	−0.467	0.020	7.89	9.46**	124
l	5.799	−0.344	0.016	4.56	7.11**	92
I_2 — c	4.493	0.241	−0.005	0.83	0.25	23
d	7.603	−0.097	0.002	0.59	0.16	211
e	6.986	0.364	−0.012	1.97	1.40	88

Note: z .... The amount of catch per haul in tons

y .... The depth in 100m

t .... The length of towing time in 10 minutes

F_{ij} .. The Snedecor's F value for a_{ij} with 1 and n-4 degrees of freedom

n ... Number of haul (i. e. the sample size)

The abbreviation of the fishing ground was shown in Fig. 1 of the first report.

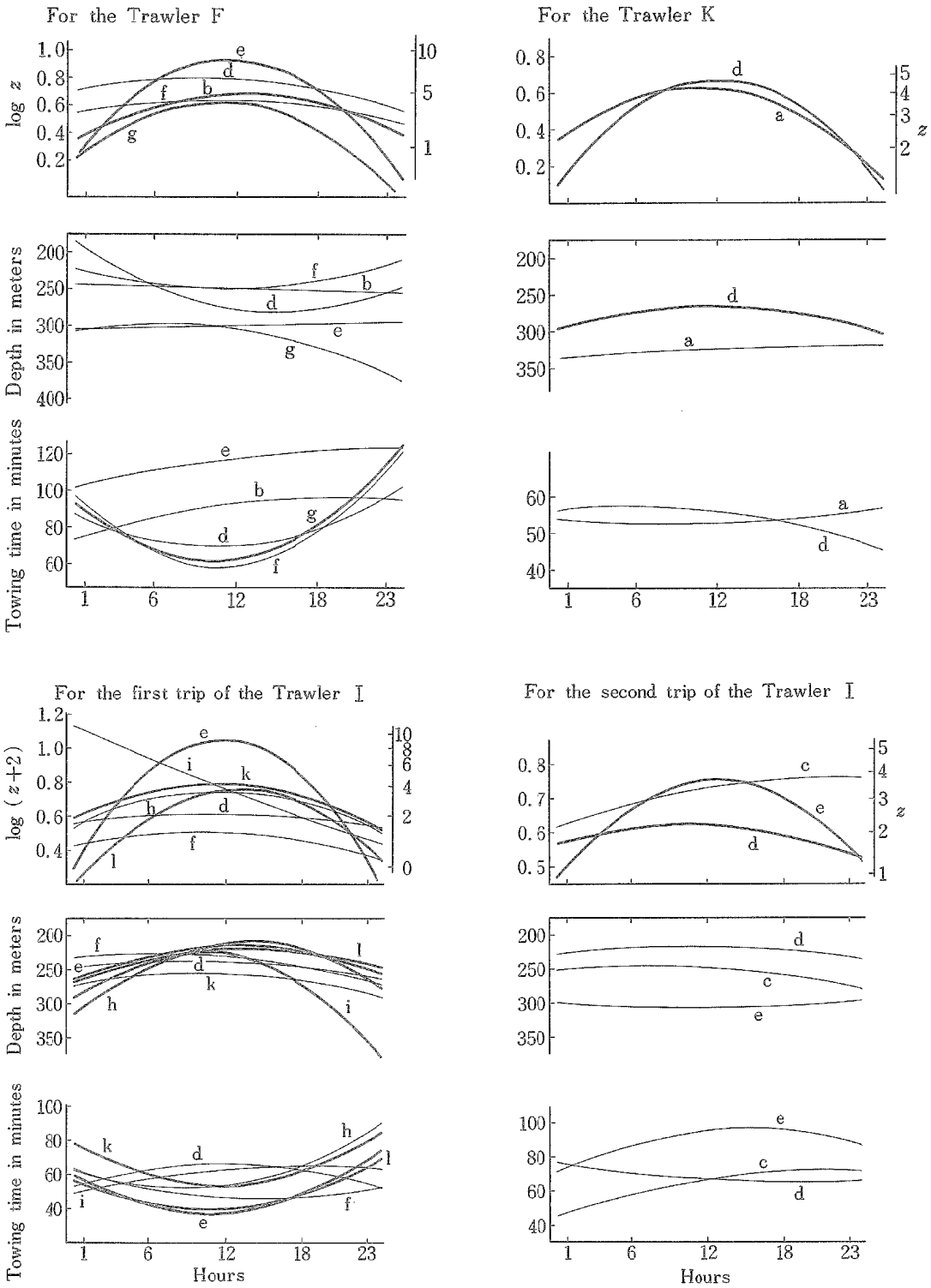

Fig. 1. The daily rhythmic change of either the amount of catch per haul (upper), or the depth trawled (middle), or the length of towing time (lower).

Note: The relation showing the significant quadratic regression on the hour is illustrated by the thick curve, and that showing insignificant one is by the thin curve. The letter attached to the curve is the abbreviation of the fishing ground.

Table 2. The homogeneity test of the hour classes in respect of the composition of the echogram types.

a) Before the stratification according to the echogram type (hour class . . . 2 hour intervals)

Trawler	Type of the echogram	m	n	χ_0^2	Prob.
F	i_c t_c i_f t_f s_f s_c T_c	12	7	99.30**	0.01—0.005
K	b_c i_c t_c i_f t_f T_f n_r	12	7	122.75**	<0.005
I_1	b_c i_c t_c b_f i_f t_f s_c	12	7	183.02**	<0.005
I_2	t_c i_f t_f s_c s_f	12	5	22.05	>0.995

b) After the stratification according to the echogram type (hour class. . . 4 hour intervals)

Trawler-Fishing ground	Type of the echogram	m	n	χ_0^2	Prob.
F — b	i_c t_c i_f t_f s_f	6	5	46.57**	<0.005
e	t_c i_f t_f	6	3	5.12	0.90—0.75
g	t_c i_f s_c T_c	6	4	35.74**	<0.005
K — a	b_c i_c t_f	6	3	9.70	0.50—0.25
d	b_c i_f t_f T_f	6	4	90.03**	<0.005
I_1 — e	b_c i_c t_c	5	3	17.05**	0.05—0.025
f	b_c t_c b_f t_f	6	4	18.54	0.25—0.10
h	b_c t_c i_f s_c	6	4	23.09	0.10—0.05
i	b_c s_c	6	2	11.29*	0.05—0.025
k	b_c t_c i_f t_f	6	4	50.42**	<0.005
l	b_c i_c i_f t_f	6	4	38.09**	<0.005
I_2 — d	t_c i_f t_f s_c s_f	6	5	15.59	0.75—0.50
e	t_c t_f s_c	6	3	12.14	0.50—0.25

Note: m . . . The number of the hour classes
n . . . The number of the echogram types

The following classification and the abbreviation of the echogram types were used in the present report.

Abbreviation	Echogram type
b_c	The black trace rising from the bottom echo
i_c	The trace of intermediate density contacting with the bottom echo
t_c	The thin trace contacting with the bottom echo
T_c	The tower trace rising from the bottom echo
s_c	The spotted trace contacting with the bottom echo
C_c	The trace contacting with the echo from the edge of a cliff
b_f	The black trace not contacting with (floating up from) the bottom echo
i_f	The trace of intermediate density not contacting with the bottom echo
t_f	The thin trace not contacting with the bottom echo
T_f	The tower trace not contacting with the bottom echo
s_f	The spotted trace not contacting with the bottom echo
n_r	No reflection

was observable in the seven groups out of the 17 ones.

These results suggested that the change of the number of schools showing the echogram of respective types should be applicable to finding the clue to conjecture the daily rhythmic change of the distribution pattern of the objective fish.

5. The frequency of towings for the schools showing the echogram of respective types (Before the stratification of the records according to the fishing ground)

The records by the trawler F consisted of the towings for the echograms of the seven types. The quadratic regression of the frequency of towing on the hour was significant in the two of them. They were the types of the intermediate density (i_c and i_f), and showed the maximum of frequency about at 9:00 or 13:00. The frequency of towing for the other types did not show any significant quadratic regression on the hour.

The trawler K attacked mainly the schools showing the echogram of the nine types. The significant quadratic regression with the maximum frequency at noon was found in the towings for the types b_c and T_f, which were probably the most profitable types. The frequency of towing for the type t_c showed a significant quadratic regression with the maximum at about 4:00. And that for the type s_f showed the significant one with the maximum at about 20:00. The significant quadratic regression with the minimum at noon was found in the frequency of towing for the least profitable type (t_f). The frequency of towing for the other types did not show any significant quadratic regression on the hour.

Among the 10 major types in the records by the trawler I during her first trip, the significant quadratic regression on the hour was found in the frequencies of towing for the five types. The frequency for the most profitable type—b_c—showed a clear daily rhythmic change with the maximum at noon. That for the types s_c and i_c showed the maximum at noon, but the daily rhythmic difference was far smaller than that of the type b_c. The towing for the type T_f was found within limited hours, showing the maximum at about 15:00. The frequency for the type i_f showed the significant daily rhythmic change with the minimum at noon, although the daily rhythmic difference was far smaller than that for b_c.

The schools attacked during her second trip were mainly the eight types. Among them, the frequencies for the three types—t_c, s_c, and s_f—showed significant quadratic hour regression with the maximum at noon, although the daily rhythmic difference of the frequencies for the latter two types was far smaller than that for the first type. The frequency of towing for the type n_r showed a significant quadratic hour regression with the minimum at noon.

These results were summarized, and it may be said that the frequency of the towings for the trace contacting with the bottom echo except the thin one inclined to show the maximum at noon and that for the trace not contacting with the bottom echo inclined to show the minimum at noon. These facts suggested the following daily rhythmic change of the behavior pattern of the objective fish: The Pacific Ocean perch should stay closely to the sea floor in the daytime and float up at night. Before concluding so, attention should be paid to the following points: The original records were obtained during the commercial work and not during the echo survey. Namely, these results were found in the frequency of towings and not in the number of echoes observed. The influence of the daily rhythmic difference of the length of towing time and the time expended on the scouting work should be taken into account. During

Table 3. The estimated quadratic hour regression of the frequency of towings for the schools showing the echogram of respective types.

a) The records of all the fishing grounds being pooled

Trawler	Echogram type	$a_{4\cdot0}$	$a_{4\cdot1}$	$a_{4\cdot2}$	$F_{4\cdot1}$	$F_{4\cdot2}$	n
F	i_c	− 0.472	0.977	−0.051	76.82	89.52**	10
	t_c	10.681	0.893	−0.038	1.49	1.67	12
	i_f	− 1.550	1.832	−0.073	11.97	11.56**	12
	t_f	2.343	0.091	−0.002	0.10	0.02	12
	s_c	− 1.589	1.714	−0.125	5.32	5.88	7
	s_f	1.545	0.000	0.001	0.00	0.01	11
	T_c	− 7.821	1.548	−0.060	7.02	7.14	7
K	b_c	1.248	0.869	−0.038	11.11	12.95**	12
	i_c	1.976	0.104	−0.008	0.52	1.94	12
	t_c	− 9.634	1.929	−0.080	79.82	81.00**	6
	i_f	8.405	−0.810	0.034	3.48	3.82	12
	t_f	8.480	−0.673	0.028	11.38	12.37**	12
	s_c	−35.763	5.300	−0.188	5.08	5.00	4
	s_f	−30.329	3.000	−0.076	39.87	40.00*	5
	T_f	−26.781	6.077	−0.243	11.37	10.73**	12
	n_r	0.401	0.104	−0.002	0.52	0.13	12
I_1	b_c	−15.911	6.926	−0.325	23.98	26.58**	9
	i_c	− 2.332	0.893	−0.043	35.76	34.75**	8
	t_c	11.585	0.878	−0.048	1.60	2.94	12
	b_f	− 1.849	0.603	−0.020	1.87	1.52	11
	i_f	6.791	−0.718	0.037	3.74	5.93*	12
	t_f	3.655	−0.288	0.012	0.45	0.48	12
	s_c	− 1.954	1.083	−0.046	7.39	5.78*	10
	C_c	−23.993	3.386	−0.107	3.05	3.16	6
	T_f	−22.450	3.214	−0.107	22.36	22.50*	5
	n_r	2.077	−0.228	0.014	1.20	2.71	12
I_2	i_c	− 7.875	1.048	−0.030	3.32	3.13	7
	t_c	2.132	1.847	−0.080	18.46	21.36**	12
	i_f	2.429	0.310	−0.006	0.99	0.20	12
	t_f	2.678	0.212	−0.011	0.64	1.01	12
	s_c	0.080	0.513	−0.021	20.43	21.46**	12
	s_f	0.381	0.213	−0.009	5.48	5.74*	12
	C_c	−19.787	2.729	−0.085	1.52	1.51	6
	n_r	6.901	−0.900	0.040	8.95	10.79**	12

b) After the stratification of the record according to the fishing grounds

Trawler-Fishing ground	Echogram type	$a_{5\cdot0}$	$a_{5\cdot1}$	$a_{5\cdot2}$	$F_{5\cdot1}$	$F_{5\cdot2}$	n
F — b	i_c	— 0.329	0.813	−0.048	7.91	9.66*	9
	t_c	8.863	−0.975	0.048	5.97	8.97*	12
	i_f	— 0.063	0.859	−0.033	7.24	6.39*	12
	t_f	3.324	−0.302	0.011	4.51	3.75	12
	s_f	— 7.327	1.142	−0.034	14.87	15.58**	9
— g	t_c	— 0.720	1.648	−0.082	16.95	18.03**	10
	i_f	— 3.852	0.907	−0.033	3.68	4.48	9
	t_f	−59.963	6.800	−0.188	5.06	5.00	4
	s_c	— 5.950	3.200	−0.250	1.32	1.63	5
	T_c	— 7.821	1.548	−0.060	7.02	7.14	7
K — a	b_c	0.280	0.724	−0.033	27.18	35.27**	12
	i_c	1.982	−0.114	0.003	0.50	0.21	11
	i_f	— 0.746	0.361	−0.015	13.35	14.18**	10
— d	b_c	0.984	0.252	−0.005	0.75	0.20	12
	i_c	— 4.545	1.236	−0.063	13.79	14.41*	6
	t_c	— 5.241	1.071	−0.045	24.64	25.00*	6
	i_f	8.847	−0.955	0.039	5.11	5.30*	12
	t_f	7.936	−0.849	0.034	10.97	10.47*	12
	T_f	−26.781	6.077	−0.243	11.37	10.73*	8
	n_r	— 0.534	0.019	0.000	0.01	0.00	12
I_1 — k	b_c	— 3.267	1.229	−0.057	12.50	13.75**	9
	t_c	1.401	0.708	−0.035	3.75	5.52*	12
	i_f	3.045	−0.524	0.023	21.77	25.72**	12
	t_f	2.165	−0.342	0.016	7.63	9.96*	12
	s_c	— 4.898	1.043	−0.045	1.60	1.71	6
	C_c	−19.330	2.700	−0.085	5.02	5.11	6
	n_r	0.903	−0.135	0.007	2.13	3.73	12
— l	b_c	— 7.516	2.602	−0.115	18.94	18.50**	9
	t_c	1.208	0.366	−0.017	27.03	3.58	12
	b_f	−58.163	6.700	−0.189	4.91	5.00	4
	i_f	— 0.614	0.714	−0.071	37.88	40.00*	5
	T_f	−14.900	2.143	−0.071	39.75	40.00*	5
I_2 — d	i_c	— 7.411	1.012	−0.030	19.79	20.00*	7
	t_c	2.673	0.577	−0.028	38.58	55.33**	12
	i_f	2.429	0.310	−0.006	0.99	0.19	12
	t_f	3.213	−0.059	0.000	0.00	0.04	12
	s_c	— 0.089	0.461	−0.018	12.21	11.94**	12
	s_f	0.381	0.213	−0.009	5.48	5.74*	12
	C_c	−19.787	2.729	−0.085	1.52	1.51	6
— e	t_c	— 4.777	1.772	−0.069	9.40	11.59*	10
	t_f	— 0.963	0.342	−0.013	6.00	5.41	10
	n_r	6.745	−0.964	0.040	14.53	15.64**	12

Note: a) $f_\cdot = a_{4\cdot0}+a_{4\cdot1}x+a_{4\cdot2}x^2$
b) $f_i = a_{5\cdot0}+a_{5\cdot1}x+a_{5\cdot2}x^2$
where $f_\cdot$ is the frequency of towings in all the grounds being pooled, and f_i that in the ground i in an hour-class.

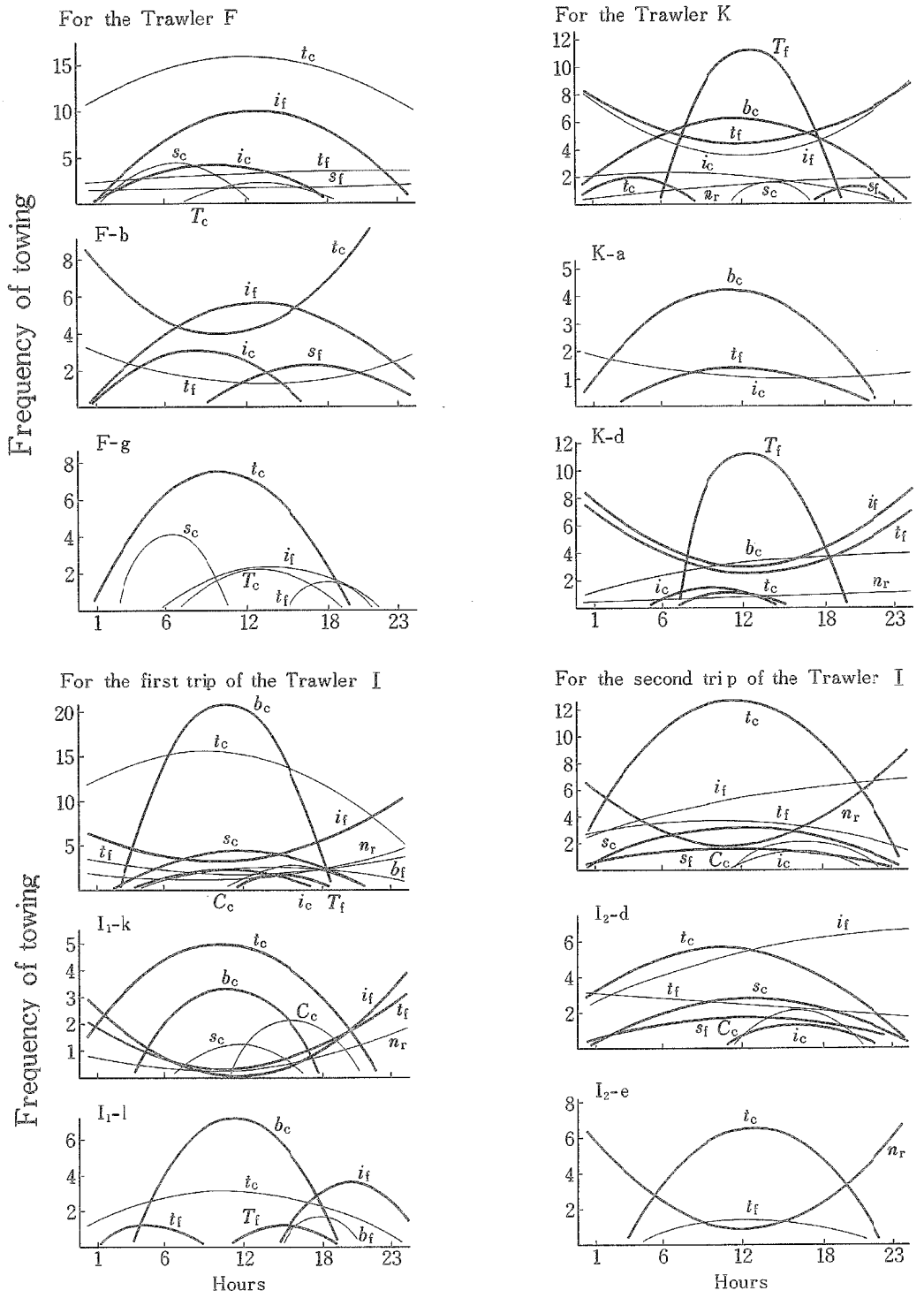

Fig. 2. Daily rhythmic change of the frequency of towings for the schools showing respective types of echograms.
Upper: The records in all the fishing grounds being pooled

Note: The relation showing the significant quadratic regression on the hour is illustrated by the thick curve, and that showing insignificant one is by the thin curve. The letter attached to the curve is the abbreviation of the echogram type.

the commercial work, the boat steams round seeking echoes from the profitable schools. When she finds them within a short hour of scouting, she attacks them. And only when she can not find them easily or when the skipper reaches the conclusion that it is hard to find the profitable schools basing on his long experience and on the results of the scouting, the schools showing the echograms of less profitable type are attacked. When the echo of the profitable type is found during the last part of the towing and a good catch is yielded, the skipper describes the type as the profitable one. Namely, the boat picks up only the profitable schools, looking over many traces of the less profitable types. The other fact making the results complicated was the different relative evaluation of a type according to the composition of the echograms in the fishing ground. In consequence, it is probable that the relative frequency of the occurrence of the echograms of the profitable types in the hour classes of high frequency of towing for them is far higher than that of the towing for them, and the relative frequency of occurrence of them in the hour classes of low frequency of towing for them does not show any large difference from that of towings. And it is hard to tell that the less frequent towing for schools showing the echoes of not contacting with the bottom echo in the daytime is due to the daily rhythmic change of the difficulty in finding out the profitable type or due to the daily rhythmic movement of the objective fish.

6. The frequency of towings for the schools showing the echograms of respective types (After the stratification of the records according to the fishing ground)

These possibilities suggested that the examination after the stratification of the records according to the fishing ground should provide us with some clues to solve the modification due to the above-mentioned reasons inevitable in the records of the commercial fishing, because of the following reasons: A trip extended over three to six months, and covered very wide area as shown in Fig. 1 of the first report. And it was hard to consider that the density and the distribution pattern of the Pacific Ocean perch were the same throughout a trip. The composition of the echogram types differs according to the fishing grounds. And the skipper was obliged to choose the objective school under successive findings of the schools of very rich variety of the echogram type. In consequence, the relative evaluation of the echogram of the same type differs according to the different composition of the echograms among the different fishing grounds. Namely, the relative evaluation of the echogram of an intermediate profitability should be high when the profitable schools were hardly found out, while that should be low when the profitable ones were easily found out. Whether the daily rhythmic change of the frequency of towings for the echograms of a type differs according to the difficulty in finding out the echograms of more profitable type than that or not may provide us with some suggestions to tell whether the modification due to the commercial reason was influential or negligible.

The records in the two groups a trip were chosen, and stratified according to the the echogram type. And the quadratic regression of the frequency on the hour was examined. The results showed the following facts: The frequency of towing for the

profitable types (b_c, T_c, and T_f) inclined to show the significant quadratic regression with the maximum in the daytime, suggesting the dense schooling in the daytime. The towings for i_c were found mainly in limited hours in the daytime, suggesting the same trend. In contrast with the trends of towings for these profitable schools, the trends of towings for the types t_c, i_f, and t_f, differed according to the frequency of towings for more profitable schools. This finding may be one of the best examples suggesting the necessity of paying full attention to the modification due to the commercial reason observable in the estimation of the biological problems through the records of commercial fishings.

The results of these two sections were summarized, and it may be said that the Pacific Ocean perch inclined to form schools contacting with the sea bed in the daytime, but it was hard to tell whether the number of the schools of the intermediate or low profitability showed the decreasing trend in the daytime or not.

Conclusion

All the results were summarized, and it may be concluded that the work pattern and the catch were deeply affected by the daily rhythmic change of the behavior pattern of the objective fish: The Pacific Ocean perch inclined to form dense schools on the sea floor in the daytime, and a good catch was yielded by the towing of short time in the daytime; but it was hard to tell whether the frequent attacks by long towings for the echoes of less profitable types at night were due to the different difficulty in finding out the profitable schools or due to the floating up or scattering of the schools. The large within-group variation of the depth trawled may be due to some other reasons than the daily rhythmic movement of the objective fish.

Summary

In the preceding reports, the catch records of the trawling for the Pacific Ocean perch along the outer edge of the continental shelf from east of Kodiak Island to west of the Queen Charlotte Islands during the season from April of 1968 to March of 1970 were examined, for the purpose of showing the difference in the catch pattern of the modern trawling induced by the full application of the electronic supporting devices. The large haul-by-haul variations of the amount of catch, the depth trawled, the length of towing time, and the type of echogram suggested the presence of some other factors deeply influential in the fishing pattern and hardly to be made up by the fishermen's effort. One of the most probable factors may be the daily rhythmic change of the behavior pattern of the objective fish. And the examinations through the quadratic regression on the hour revealed the following facts:

1. The 16 examples (the groups of the records during the same season by the same boat)

out of the 17 ones showed the maximum of catch per haul at 11:00 to 13:00, although the quadratic hour-regression was not significant in the seven examples.
2. The large within-group variation of the depth trawled was not due to the daily rhythmic movement of the objective fish along the sea floor.
3. In the quarter of the examples, the towing time showed a significant quadratic hour-regression, being shortest at noon. Namely, the density of the trawlable population showed the daily rhythmic change far clearer than that found in the amount of catch per haul (highest at noon and lowest at midnight).
4. The hour classes were dishomogeneous in respect of the composition of the echogram type, in the seven groups of records out of the 17 ones.
5. The frequency of towings for the profitable echoes (b_c, T_c, and T_f) inclined to show the significant quadratic hour-regression with the most frequent towings in the daytime. In contrast with this, the trend of the daily rhythmic change of the frequency of towings for the less profitable echoes—t_c, i_f, and t_f—differed according to the frequency of the towings for the profitable ones, showing the frequent towings in the daytime when there were few towings for the echoes of the profitable one, while showing the less frequent towings in the daytime when there were many towings for the profitable schools.
6. It may be said that the Pacific Ocean perch inclined to form schools on the sea floor in the daytime, but it was hard to tell whether the number of the schools of the intermediate or low profitability showed the decreasing trend in the daytime or not, because of the modification of the results inebitable in the catch records during the commercial work.

References

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