An Analysis of the Catch Records of the Trawling Assisted by the Electronic Devices-II*.

The Length of Towing Time and the Amount of Catch per Haul of the Pacific Ocean Perch

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The popularization of the electronic supporting devices is one of the most remarkable and lately occurred advances of the fishing techniques. This accomplished the basic change in the details of the fishing work, consequently in the catch pattern and in the meaning of respective items of the catch records. It is a well-known fact that the groundfishes show a well defined bathymetric difference of the density. This is found through that of the catch per haul of the records of the traditional trawling. The application of the echo sounder saves the boats from shooting the gear in less profitable depth zones. This made it hard to find the bathymetric difference of the density of the groundfishes through the catch records of the trawling supported by the echo sounder.[1] The other reason of making the bathymetric difference of the density of the objective fish hardly observable in the catch records of the modern trawling is the adjustment of the length of towing time according to the density of the fishable population. This is realized with the assistance of the tension meter capable of recording the change of the load of the warp and the net recorder capable of recording the echo from the objects passing through the net mouth. There arises, accordingly, a possibility of the length of towing time applicable to the indicator of the density of the fishable population, in stead of the amount of catch per haul. The above-mentioned changes in the work pattern were found in the trawling rather regardless of the habit of the objective fish. It has been said that the trawl has been the fishing method of catching the fish on an even ground. The application of the echo sounder and the depth telemetric systems makes this method applicable to the schooling fish on rough grounds, too. The Pacific Ocean perch studied here is one of the representatives. To

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catch the fish like this, the boat steams round seeking the school. When the echo from the presumably profitable school is found out, the boat turns her course to the counter direction after a short steaming. She shoots her gear and steams very slowly hanging the net in the layer a little above the sea bed regulating the steaming speed and the length of warp with the assistance of the depth telemetric systems. And when she passes over the school again, the net is fallen down on the sea bed by stopping the engine and paying out the warp. When the boat yields a sufficient amount of fish, the net is hauled up on deck. Otherwise, the warp is wound up a little, and the boat steams again and repeats several consecutive attackings without hauling up the net. In the former case, the length of towing time indicates the fact quite different from that of the traditional trawling. In the latter case, the length of towing time may be applicable to the indicator of the density of the fishable population.

These changes in the fishing work necessitated the examination on the relation between the amount of catch per haul and the length of towing time, preceding the examinations on the change of the amount of catch per haul according to the conditions. The examination like this may provide us with many suggestions on how to evaluate the application of the electronic supporting devices. The other aim of the present series of reports was to examine whether the type of the echograms effectively used by the skipper as one of the field indicators for deciding the work pattern or not, although there remain many doubts, from the theoretical point of view, about the meaning of the echogram pattern observed. And one of the most useful factors for this purpose may be the difference of the work pattern — the length of the towing time and its relation to the amount of catch per haul — according to the echogram type.

The present report dealt, accordingly, with the relation between the length of towing time and the amount of catch per haul and its difference according to the type of the echogram observable in the same set of the records used in the preceding report.

Material and Methods

The present report used the same materials as those used in the preceding report.[1] They were the working records on the 1,837 hauls (among them, those on the 1,175 hauls had the description on the echogram) conducted by the three stern ramp trawlers (The trawler F, K, and I, abbreviated according to their initial) fishing mainly the Pacific Ocean perch during the season from April of 1968 to March of 1970 along the outer edge of the continental shelf from east of Kodiak Island to west of the Queen Charlotte Islands.

The time shooting the gear and that starting to wind up the warp were described in the original records. The intervals between them were timed and used in the present report. The towing time denotes this interval. The towing time varied from five minutes to 240 minutes, mainly 30 minutes to 150 minutes. In the present report, the towing times reckoned were used after the aggregation of them into the classes of

the nearest 30-minute intervals, because they inclined to take 30, 60, 90, 120, and 150 minutes, in spite of the fact that the times in the original records were described in five-minute intervals.

The amount of catch by a haul of the Trawler F and K was aggregated into the classes of five-ton intervals and used after the logarithmic transformation. And that by the Trawler I (z in tons) was aggregated into the classes of one-ton intervals and used after the $\log(z+2)$ transformation, because of the reason mentioned in the preceding report.

The echo-sounded depth just before shooting the gear ranged from 125 m to 475 m, mainly 200 m to 400 m. The recorded depths were used after the aggregation of them into the classes of the nearest 25-m intervals, like in the preceding report.

The echogram differs according to the performance of the echo sounder as well as the recording conditions. There is no doubt, however, that the echogram is one of the most powerful bases of making the skipper decide the work pattern. And the original records included the skipper's description on the echogram. The descriptions were classified into the 12 types shown in the note of Table 2, mainly according to the density and the relation to the bottom echo. The boats fished over very wide area. It is probable that the distribution pattern, including the density of the fishable population, differs according to the location. The records were stratified into the 29 groups according to the boat, the date, and the position shown in Fig. 1 of the preceding report. The words, "the group (of records)", indicate hereafter these strata. And the difference among the lengths of towing time and their relations to the amount of catch according to the echogram types observable in respective groups of the records were examined in the present report, through the same methods as those used in the preceding report.

Results and Consideration

1. The difference of the amount of catch per haul according to the length of towing time

In the trawling, the length of towing time was adjusted according to the density of the fishable population, for the purpose of the smooth handling the net and the smooth processing the catch. This was done in the traditional trawling, too. The echo sounder provides us with many informations on the distribution of the fish, and the depth telemetric systems and the tension meter supply us with the informations on the load on the warp and the objects passed through the net mouth. They assisted very much in the right adjustment of the length of towing time according to the density of the fish.

When the length of towing time is adequately adjusted according to the density of the fishable population, an equal amount of fish is yielded by a haul regardless of the length of towing time; in other words, the amount of catch by a haul does not show any significant regression on the length of towing time. When the length is insufficiently adjusted, a good catch is brought by the haul of short towing; in other words,

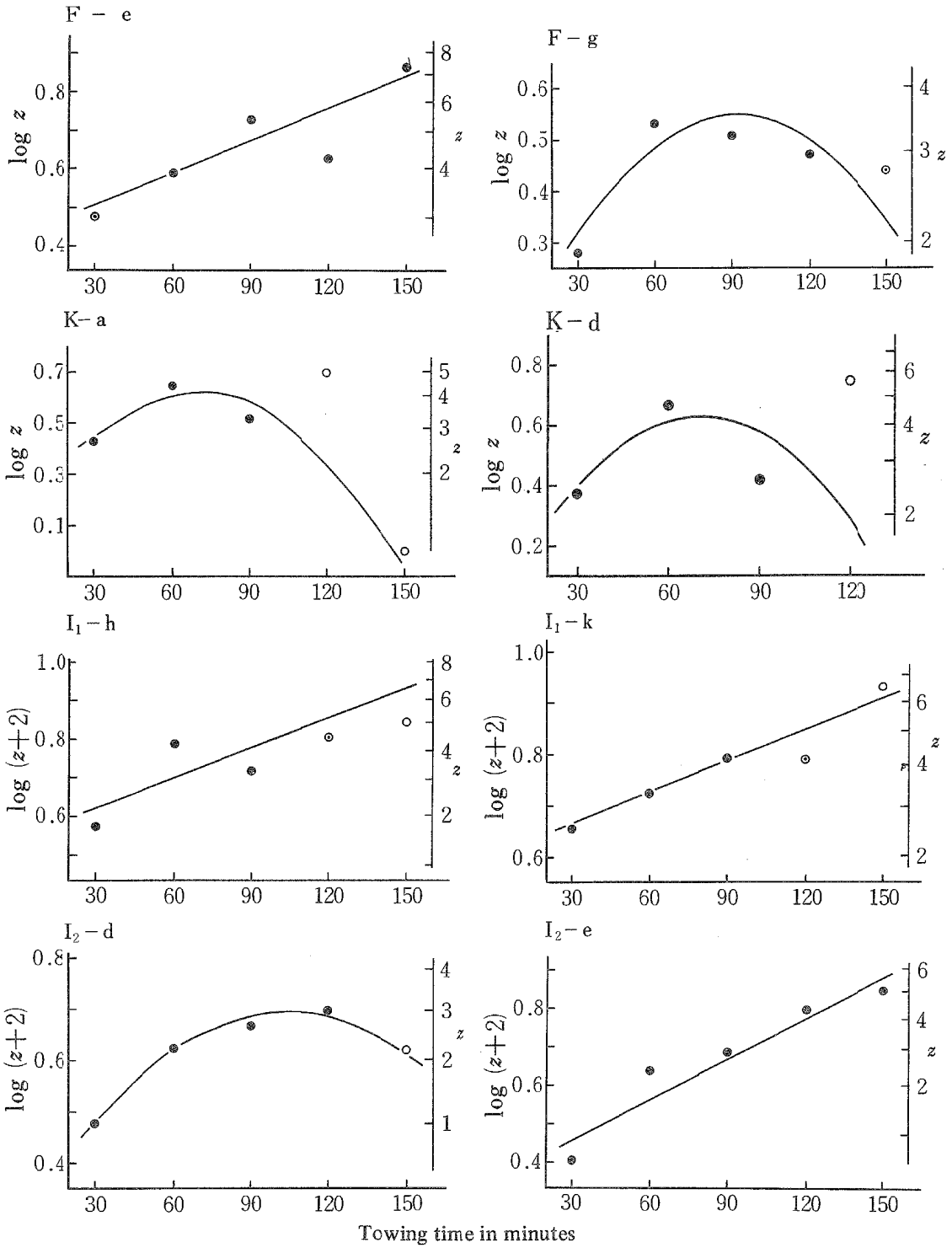
the amount of catch decreases in accordance with the length of towing time. When the length is over-adjusted, the catch increases in accordance with the length of towing time, but the rate of increase in the former is less than that of the latter. When the length of towing time is not adjusted at all, the catch increases in proportion to the

Table 1. The estimated quadratic regression equations and the linear ones of either log z or log (z + 2) on the towing time, and the results of the test on the significance of the rgeression coefficients.

Trawler-Fishing ground	a_0	a_1	a_2	$F_{2\cdot1}$	$F_{2\cdot2}$	b_0	b_1	$F_{1\cdot1}$	n
F — a						0.900	−0.496	1.63	5
b	0.462	−0.180	0.31	0.29	3.05	0.243	0.386	31.95**	234
c	0.658	−0.401	0.35	0.93	2.04	0.473	0.181	4.81*	15
d	0.924	−0.330	0.11	0.60	0.17	0.868	−0.161	2.49	43
e	0.461	0.192	0.04	0.11	0.02	0.422	0.283	8.97**	100
f	0.589	−0.108	0.17	0.05	0.16	0.514	0.138	1.15	23
g	0.044	1.104	−0.59	5.57	4.85*				144
K — a	0.066	1.585	−1.13	14.54	12.07**				173
b	0.068	2.445	−2.21	0.44	0.49	0.693	−0.113	0.04	5
c	−0.402	−2.315	1.93	0.18	0.22	0.477	0.217	0.09	11
d	−0.072	1.955	−1.37	9.13	6.79**				244
e						0.727	−0.286	0.71	9
I_1 — a						0.421	−0.201	0.17	6
b	−0.051	1.879	−1.42	3.82	2.70	0.318	−0.324	3.23	28
c						0.977	−0.625	1.06	5
d	0.426	0.282	−0.02	0.25	0.00	0.433	0.258	6.12*	55
e	0.540	1.719	−1.86	1.12	1.67	1.010	−0.355	2.33	41
f	0.087	1.363	−0.93	5.02	3.58	0.364	0.321	4.18*	51
g						0.145	0.519	4.13	9
h	0.371	0.865	−0.43	4.30	2.27	0.544	0.255	6.60*	77
i	0.114	1.992	−1.27	15.85	16.47**				60
j						0.762	−0.621	1.55	11
k	0.594	0.228	−0.02	0.59	0.01	0.601	0.204	7.39**	124
l	0.460	0.930	−0.88	2.04	2.42	0.689	−0.053	0.12	92
I_2 — c	0.181	1.437	−0.84	4.02	2.14	0.458	0.404	10.78**	23
d	0.284	0.772	−0.37	32.37	16.34*				211
e	0.229	0.709	−0.20	13.10	3.57	0.358	0.347	66.87**	88

Note: $\log z$ or $\log(z+2) = a_0 + a_1 x + a_2 x^2$
$\log z$ or $\log(z+2) = b_0 + b_1 x$
$\log z$ ..... For the trawlers F and K
$\log(z+2)$ ..... For the trawler I
F_{ij} ..... The Snedecor's F value with 1 and $n-(i+1)$ degrees of freedom for the j-th order regression coeffficient in the i-th order regression equation
n ..... Size of samples
x ..... Towing time (in 100 min.)
z ..... The amount of catch (in tons)
* ..... Significant at 0.05 level
** ..... Significant at 0.01 level

a) The time - catch relations with the observed frequency of the hauls



b) The comparison among those observed within the records by the same trawler during the same season

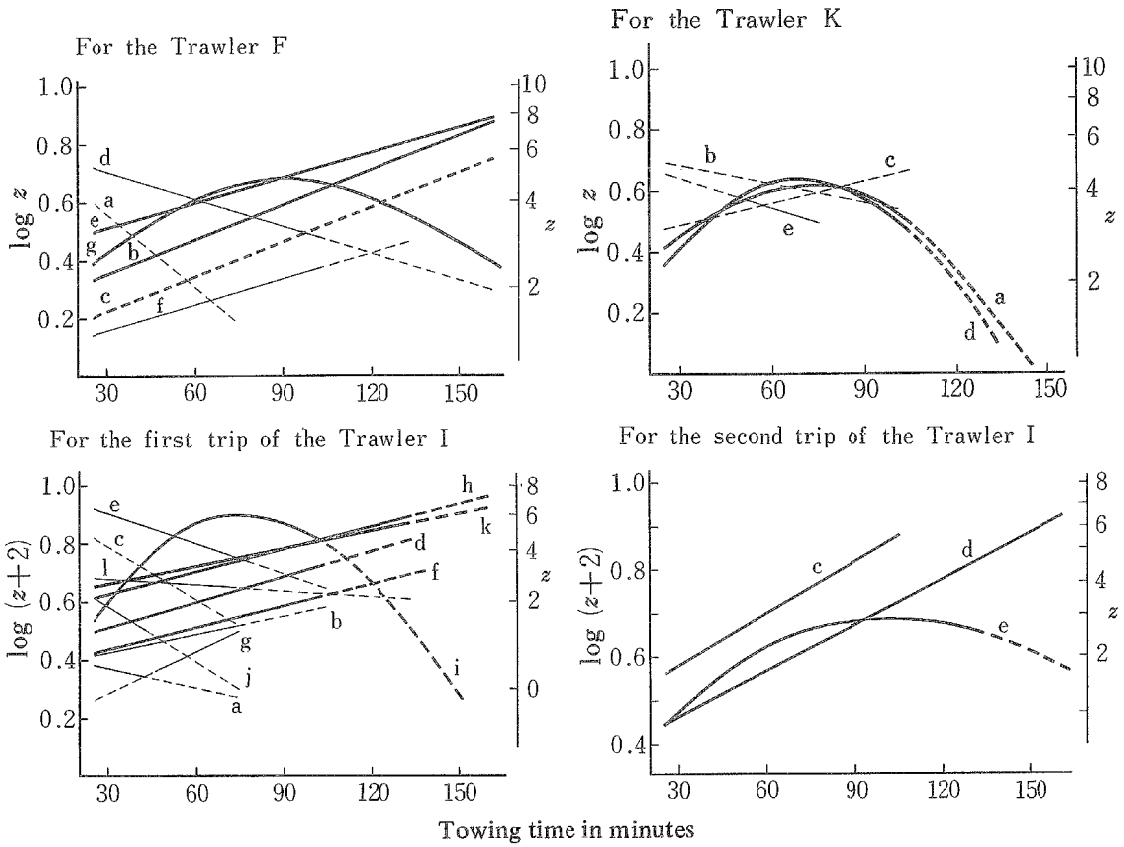


Fig. 1. The change of the amount of catch per haul in accordance with the length of towing time.

Note: The capital letter . . . . The abbreviation of the trawler
The small letter . . . . The location of the fishing ground

For a)
Sclid line . . . The regressive relation with significant coefficient
Solid circle . . . The amount of catch per haul in the classes of towing time with more than 11 records
Circle with center dot . . . That in the classes with five to ten records
Open circle . . . That in the classes with one to four records

For b)
Thick curve . . . The estimated relation with significant quadratic regression coefficient
Thick line . . . That with significant linear regression coefficient
Thin line . . . That with insignificant linear regression coefficient
The part of solid line. . . The range of the classes of towing time with the records of more than five hauls
The part of broken line . . . The classes of towing time with the records of less than five hauls

length of towing time. In the present case, the towing time was distributed over very wide range, from five minutes to 240 minutes. It is, accordingly, hard to neglect the possibility of the records being consisted of these three cases. And it is doubtful, on the other hand, whether the length of towing time is adjusted regardless of the condi-

tions or not. For example, it is probable that the boat tows the net over long hours at night, when the daily total of the landing is far less than the daily capacity of processing, for the purpose of the labor administrative reason over long stay of the boat in the fishing ground. All these possibilities suggested the complicated relation between the length of towing time and the amount of catch. This was examined through the significance test on the quadratic and linear regressions of the amount of catch per haul on the length of towing time.

As shown in Table 1 and Fig. 1, the amount of catch showed neither the significant quadratic regression nor the significant linear one in the 13 groups of records out of the 27 ones. In the five groups, the amount of catch showed a significant quadratic regression. In these groups, the maximum catch was found between 70 minutes and 100 minutes. The towing times of most of the records were shorter than this length. It may be, accordingly, said that the catch increased practically in accordance with the length of towing time. The significant linear increase of the amount of catch in accordance with the towing time was found in the nine groups of the records, although the increase of the catch was far less than that of the towing time. These facts meant that the length of towing time was adequately adjusted in a half of the groups and over-adjusted in the other half of them. The groups of the records by respective boats were distributed over the above-mentioned three types. Namely, whether the towing time was adequately adjusted or not was not due to the different work pattern according to the boat (or the different decision according to the skipper) but was due to some other reasons. One of the most probable factors making the boat over-adjust the length of towing time may be the distribution pattern of the objective fish. As shown in the preceding report, the boats attacked the schools of really very wide variation in the echogram type, i.e. in the distribution pattern. Some were suitable for the repeating attack of short towings (for example the echogram types T_c, T_f, and C_c), and the others were for long towing (for example, the thin or the spotted trace). The other factor probable to cause the seeming over-adjustment of the length of towing time was the different way of processing the catch according to the towing time. The compact school is suitable for a short towing, and the short towing has a possibility of catching the fish with less damage. This consists of, usually, the individuals of rather uniform size. These facts meant that the compact school is the good objective of the material fish for the frozen products either round or headed. In contrast with this, the scattering population is suitable for the long towing, the catch by the long towing shows a large size variation and is more seriously damaged than that by the short towing. The catch by the long towing is, accordingly, suitable for the materials of the fillet or fish block. The daily rhythmic change of the behavior pattern of the objective fish and that of the activity of the crew working in the processing plant for the purpose of the labor administrative reason over long stay were the other group of the factors probable to make it hard to adjust the length of towing time solely according to the density of the fishable population or the difficulty in yielding a good catch. Some examinations on these possibilities will be given in the succeeding report.

2. The difference of the length of towing time according to the type of the echogram

As stated above, the variety of the distribution pattern of the objective fish is one of the most probable factors making the boat unable to adjust adequately the length of towing time. There remain some theoretical uncertainties in the meaning of the type of echogram; but there is little doubt about such possibility that the type of the echogram has some relations to the distribution pattern of the objective fish and is one of the most powerful bases of making the skippers decide the work pattern.

Table 2. The homogeneity test of the echogram types in respect of the towing time.

a) The test in the trawler-ground strata (as examples)

F — b

Towing time (x min.)	Type of the echogram							
	i_c	t_c	s_c	i_f	t_f	T_f	s_f	n_r
30	5	10		1	1	1	2	
60	2	16	1	20	5		2	4
90	5	29	1	12	2		7	
120	4	17	1	8	2		1	
150		5		7	12		2	
Total frequency	16	77	3	48	22	1	14	4
$\bar{x}$	75.0	86.5	90.0	90.0	115.9	30.0	87.9	60.0
$\bar{z}$	10.8	3.8	7.9	4.8	5.9	10.0	2.4	1.5

$F_0=3.38^{**}$ $F^{7}_{150}(0.05)=2.07$ $F^{7}_{150}(0.01)=2.76$

F — e

x	t_c	s_c	i_f	t_f	s_f
30			2		
60	3		4	1	1
90	6		4	1	
120	2		2	1	
150	20	1	2	4	1
Total frequency	31	1	14	7	2
$\bar{x}$	127.5	150.0	85.7	124.3	105.0
$\bar{z}$	8.8	5.0	8.7	8.7	2.2

$F_0=3.71^{*}$ $F^{4}_{50}(0.05)=2.56$ $F^{4}_{50}(0.01)=3.72$

F — g

x	t_c	T_c	s_c	i_f	t_f
30	5	4		2	
60	27	3	5	5	3
90	12	1	1	1	
120	1	1		4	
150	2			2	
Total frequency	47	9	6	14	3
$\bar{x}$	69.6	56.7	65.0	87.9	60.0
$\bar{z}$	7.7	2.8	5.2	5.9	3.7

$F_0=1.94$ $F^{4}_{75}(0.05)=2.49$ $F^{4}_{75}(0.01)=3.58$

K — a

x	b_c	i_c	i_f	t_f	n_r
30	14	6	2	3	2
60	13	7	1	5	
90	3	1		2	
120	1				
150				1	
Total frepuency	31	14	3	11	2
$\bar{x}$	51.3	49.3	40.0	65.5	30.0
$\bar{z}$	9.2	4.7	4.0	3.6	1.0

$F_0=1.44$ $F^4_{55}(0.05)=2.54$ $F^4_{55}(0.01)=3.68$

K — d

x	b_c	i_c	t_c	s_c	i_f	t_f	T_f	s_f	n_r
30	12		1		30	16	19	3	5
60	5	4		2	20	18	23		5
90	1	1	3		9	14	5		
120						2	2		
Total frequency	18	5	4	2	59	50	49	3	10
$\bar{x}$	41.7	66.0	75.0	60.0	49.3	61.2	58.9	30.0	45.0
$\bar{z}$	5.3	5.2	6.6	15.0	2.0	1.9	6.8	3.7	0.0

$F_0=2.75^{**}$ $F^8_{150}(0.05)=2.00$ $F^8_{150}(0.01)=2.62$

I_1 — e

x	b_c	i_c	t_c	s_c	b_f	i_f	t_f	n_r
30	4	7	3	2	2	1		
60	2	2	1				1	
90			1			1	1	1
Total frequency	6	9	5	2	2	1	2	1
$\bar{x}$	40.0	36.7	48.0	30.0	30.0	30.0	75.0	90.0
$\bar{z}$	12.0	10.3	4.4	8.6	8.5	1.0	2.5	1.0

$F_0=2.71^{*}$ $F^7_{20}(0.05)=2.52$ $F^7_{20}(0.01)=3.71$

I_1 — h

x	b_c	i_c	t_c	T_c	s_c	b_f	i_f	t_f	n_r
30	9		12		3		3		2
60	4		8	2	2	2	2	2	1
90	2	1	6			1	1		2
120			2					1	1
150			1				1		
Total frequency	15	1	29	2	5	3	7	3	6
$\bar{x}$	46.0	90.0	61.0	60.0	42.0	70.0	64.3	80.0	70.0
$\bar{z}$	5.5	6.0	2.9	9.0	2.2	4.7	3.4	6.3	1.3

$F_0=0.98$ $F^8_{50}(0.05)=2.82$ $F^8_{60}(0.01)=2.10$

As shown in Table 2, the difference of the average lengths of the towing time for the schools showing the different types of echogram was significant in the seven groups of the records out of the 23 ones. All the groups showing the significant difference

I_1 — k

x	b_c	t_c	T_c	s_c	C_c	b_f	i_f	t_f	s_f	n_r
30	11	11	1	3	4	1	4	3		2
60	4	15	1	1	4	2	4	3		4
90	1	12				1	1	5		2
120		1					3	1	1	
150							2	1		
Total frequency	16	39	2	4	8	4	14	13	1	8
$\bar{x}$	41.3	62.3	45.5	37.5	45.0	60.0	79.3	79.6	120.0	60.0
$\bar{z}$	7.9	3.9	9.1	2.8	3.5	9.8	4.3	3.2	2.0	2.6

$F_0=2.71^{**}$ $F^{9}_{100}(0.05)=1.97$ $F^{9}_{100}(0.01)=2.59$

I_2 — e

x	t_c	s_c	t_f	s_f	n_r
30	6		1		6
60	7	1	2		4
90	11	2	1	1	14
120	6		2		3
150	6		2		8
Total frequency	36	3	8	1	35
$\bar{x}$	89.2	80.0	97.5	90.0	92.6
$\bar{z}$	4.0	3.0	4.3	0.0	2.8

$F_0=0.14$ $F^{4}_{80}(0.05)=2.48$ $F^{4}_{80}(0.01)=3.56$

I_2 — d

x	i_c	t_c	T_c	s_c	C_c	i_f	t_f	T_f	s_f	n_r
30	5	12	1	5	3	11	5	1		5
60		21		9	4	31	7		11	3
90		16		3		16	14		3	
120		1		5		2	3		1	
150		1				1	1			
Total frequency	5	51	1	22	7	61	30	1	15	8
$\bar{x}$	30.0	65.3	30.0	70.9	47.1	65.9	78.0	30.0	70.0	41.3
$\bar{z}$	1.8	2.8	2.0	3.1	1.6	2.2	1.8	3.0	1.9	1.3

$F_0=2.75^{**}$ $F^{9}_{200}(0.05)=2.00$ $F^{9}_{200}(0.01)=2.62$

of the length of towing time according to the echogram type, except one of them (the group I_1–e), showed the significant regression of the amount of catch on the length of towing time — either quadratic or linear. In these groups, the boats inclined to tow their net in a shorter time for either the thick trace or the trace attaching to the bottom echo than for the others. There were the eight groups showing the insignificant difference of the length of towing time according to the echogram type and showing the significant regression of the amount of catch on the length of towing time. The five groups of them (F–c, F–g, K–a, I_2–c, and I_2–e) consisted of the echograms of insufficient variety. It was hard to find the reason of making the difference insignificant in the three groups of the rest (I_1–f, h and i). In the other groups of records, the

b) The summarized results of the tests

Trawler-Fishing ground	F_0	$i-1$	$N-i$
F — b	3.38**	7	177
c	6.00	2	3
d	0.16	2	13
e	3.71*	4	50
f	1.39	4	2
g	1.94	4	74
K — a	1.44	4	56
b	1.50	2	1
c	2.42	4	4
d	2.75**	8	191

Trawler-Fishing ground	F_0	$i-1$	$N-i$
I_1 — b	0.61	5	12
c	0.60	1	3
d	3.72*	2	36
e	2.71*	7	20
f	1.80	6	28
g	0.28	2	4
h	0.98	8	62
i	1.75	8	48
k	2.71**	9	99
l	0.33	6	79
I_2 — c	2.42	3	19
d	3.52**	9	191
e	0.14	4	78

Note: The five of the strata were excluded from the test, because of either insufficient variety of echogram type observed or small sample size. The figures in respective columns in a) are the frequency of hauls.
i . . . The number of the echogram types observed
N . . . The total number of hauls conducted in the stratum
F_0 . . . The Snedecor's F value for the comparison among the average times, with (i-1) and (N-i) degrees of freedom

The following classification and the abbreviations 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
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

towing time showed the insignificant difference according to the echogram type, and the amount of catch did not show any significant regression on it. These facts and the large variation of the towing time within the same types of echogram suggested that the length of towing time should be adjusted according to the density of the fishable population, although it was hard to deny completely the presence of some other factors preventing the boats from adequately adjusting the length of towing time according to the difficulty in yielding a good catch.

3. The difference of the amount of catch per haul according to the length of towing time observable among the hauls for the schools showing the same types of echogram

The wide variety of the echogram types and the large variation of the length of towing time for the schools showing the same types of echogram necessitated the examination on the change of the amount of catch per haul in accordance with the length of towing time observable among the hauls for the same types of echogram, for the

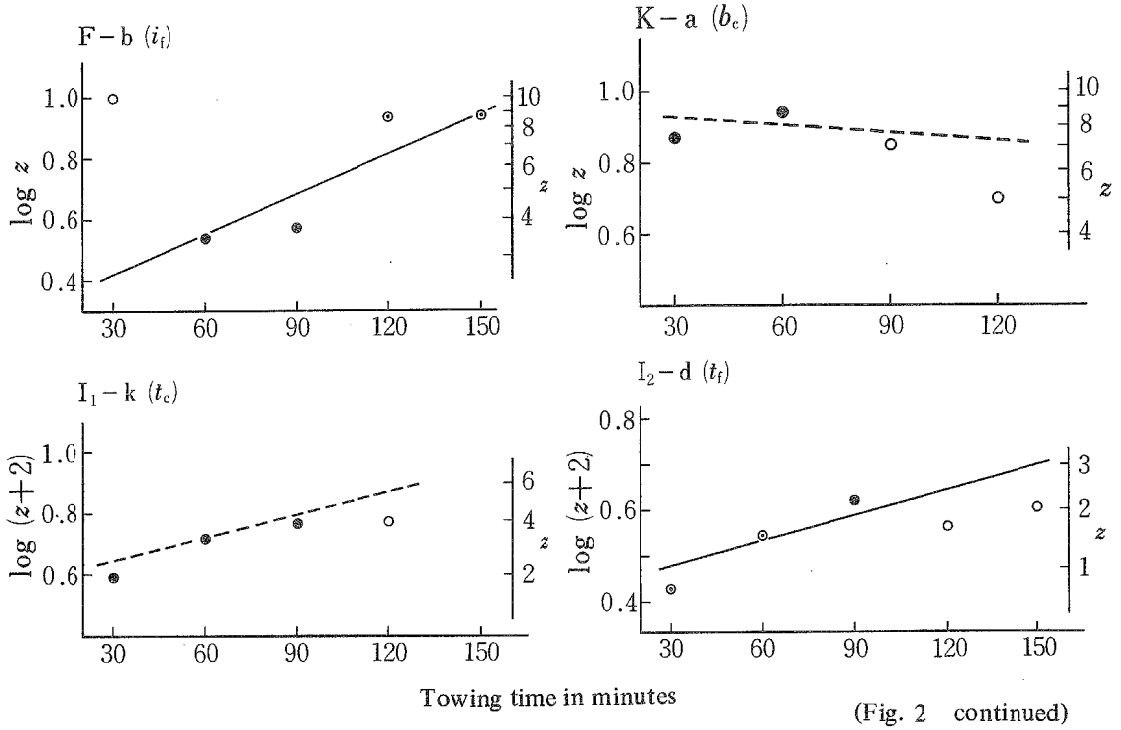
Table 3. The estimated quadratic regression equations and the linear ones of the amount of catch per haul on the towing time, by trawler, fishing ground, and the echogram type.

Trawler-Fishing ground	Echogram type	a_0	a_1	a_2	$F_{2\cdot1}$	$F_{2\cdot2}$	b_0	b_1	$F_{1\cdot1}$	n
F — b	i_c	0.970	−0.31	0.4	0.04	0.19	0.796	0.32	1.76	16
	t_c	0.487	−0.05	0.2	0.01	0.29	0.389	0.22	3.97*	77
	s_c						0.900	−0.00	0.00	3
	i_f	0.760	−0.65	0.5	0.41	1.18	0.289	0.44	8.38**	48
	t_f	−0.222	1.36	−0.4	1.20	0.40	0.102	0.58	15.13**	22
	s_f	−0.011	0.14	0.3	0.02	0.25	−0.212	0.66	7.18*	14
d	i_c	0.518	0.92	−0.7	0.64	0.86	0.975	−0.09	0.17	9
	t_c	0.925	0.50	−0.8	0.02	0.09	1.306	−0.66	1.01	6
e	t_c	−0.048	1.62	−0.6	1.38	1.01	0.642	0.24	3.63	31
	i_f	1.484	−1.17	0.5	1.67	1.14	1.131	−0.23	1.46	14
	t_f	1.863	−1.87	0.8	0.74	0.73	0.969	−0.02	0.01	7
g	t_c	0.591	0.43	−0.1	0.84	0.16	0.658	0.24	4.70*	47
	T_c	0.079	0.16	0.3	0.01	0.06	−0.052	0.64	3.04	9
	s_c						0.460	0.27	0.04	6
	i_f	0.022	1.70	−0.9	1.77	1.72	0.621	0.05	0.05	14
K — a	b_c	0.688	0.85	−0.7	0.87	1.02	0.918	−0.04	0.04	31
	i_c	0.999	−1.33	1.1	0.75	0.60	0.728	−0.16	0.32	14
	t_f	0.603	0.05	−0.4	0.00	0.28	0.811	−0.56	4.01	11
d	b_c	−0.948	7.59	−7.3	3.34	3.49	0.752	−0.06	0.01	18
	i_c						2.680	−2.98	11.47*	5
	t_c						0.619	0.27	0.25	4
	i_f	0.161	0.51	−0.4	0.14	0.11	0.263	0.08	0.13	59
	t_f	−0.428	2.31	−1.6	6.22	5.12*				50
	T_f	0.058	2.14	−1.1	3.54	1.64	0.440	0.72	7.14*	49
I₁ — d	t_c	0.872	−1.72	2.0	2.52	4.44*				23
	i_f	0.986	−1.13	0.9	1.22	1.45	0.645	0.08	0.19	15
e	b_c						0.861	0.64	1.08	6
	i_c						1.448	−1.14	2.49	9
	t_c	−0.297	4.30	−3.5	4.16	3.68	0.636	0.29	0.64	5
f	t_c	0.134	1.15	−0.8	1.67	1.42	0.391	0.11	0.44	18
	b_f						0.474	0.59	1.66	4
	t_f						0.806	−0.26	0.08	4
h	b_c	−0.453	5.17	−4.2	5.61	4.88*				15
	t_c	0.211	1.22	−0.7	5.99	4.41*				29
	s_c						0.482	0.28	0.23	5
	b_f						0.525	0.36	0.06	3
	i_f	0.208	1.19	−0.5	1.15	0.70	0.491	0.28	1.60	7
	t_f						0.523	0.46	2.47	3
	n_r	0.092	0.76	−0.2	1.02×10^3	170.16**				6
i	b_c	0.466	1.75	−1.4	2.23	2.16	0.925	0.07	0.07	31
	s_c	0.490	0.04	0.4	0.00	0.15	0.369	0.55	7.85*	12
	n_r	0.261	0.36	−0.1	0.28	0.07	0.335	0.19	2.45	5
k	b_c	1.094	−0.88	1.2	0.15	0.13	0.812	0.38	1.12	16
	t_c	0.332	1.09	−0.6	2.41	1.45	0.557	0.26	3.68	39
	s_c						0.031	1.54	4.02	4
	C_c						0.596	0.29	1.02	8
	b_f	1.970	−3.71	3.2	12.59	13.99	0.960	0.14	0.08	4
	i_f	0.527	0.18	0.1	0.06	0.04	0.481	0.32	6.25*	14
	t_f	0.142	1.14	−0.5	4.66	2.34	0.481	0.36	6.85*	13
	n_r	0.358	0.10	−0.0	0.01	0.00	0.358	0.10	0.19	8
l	b_c						0.674	0.35	1.62	38
	t_c	0.534	0.07	−0.2	0.01	0.02	0.571	−0.09	0.24	28
	b_f						0.381	1.06	8.61	3
	i_f						0.975	−0.96	1.35	9
	i_f						0.514	−0.21	0.13	4
I₂ — d	t_c	0.432	0.52	−0.2	4.11	1.56	0.527	0.21	9.83**	51
	s_c	0.378	0.77	−0.4	3.87	2.35	0.554	0.18	6.18*	22
	C_c						0.371	0.36	1.60	7
	i_f	0.200	0.97	−0.5	14.15	8.44**				61
	t_f	0.251	0.70	−0.3	6.50	3.88	0.428	0.18	6.28*	30
	s_f	−0.789	3.23	−1.7	2.75	2.25	0.347	0.32	2.53	15
	n_r						0.071	0.97	7.82*	8
e	t_c	0.306	0.61	−0.1	4.08	0.64	0.393	0.37	34.92**	36
	s_c						0.717	−0.03	0.01	3
	t_f	0.346	0.85	−0.4	1.35	0.88	0.600	0.17	1.92	8
	n_r	0.192	0.71	−0.2	8.24	2.50	0.336	0.33	36.15*	35

Note: The note is the same to that of Table 1.

purpose of clarifying the different ways of the adjustment of the length of towing time according to the type of echogram.

a) The time - catch relations with the observed frequency of the hauls



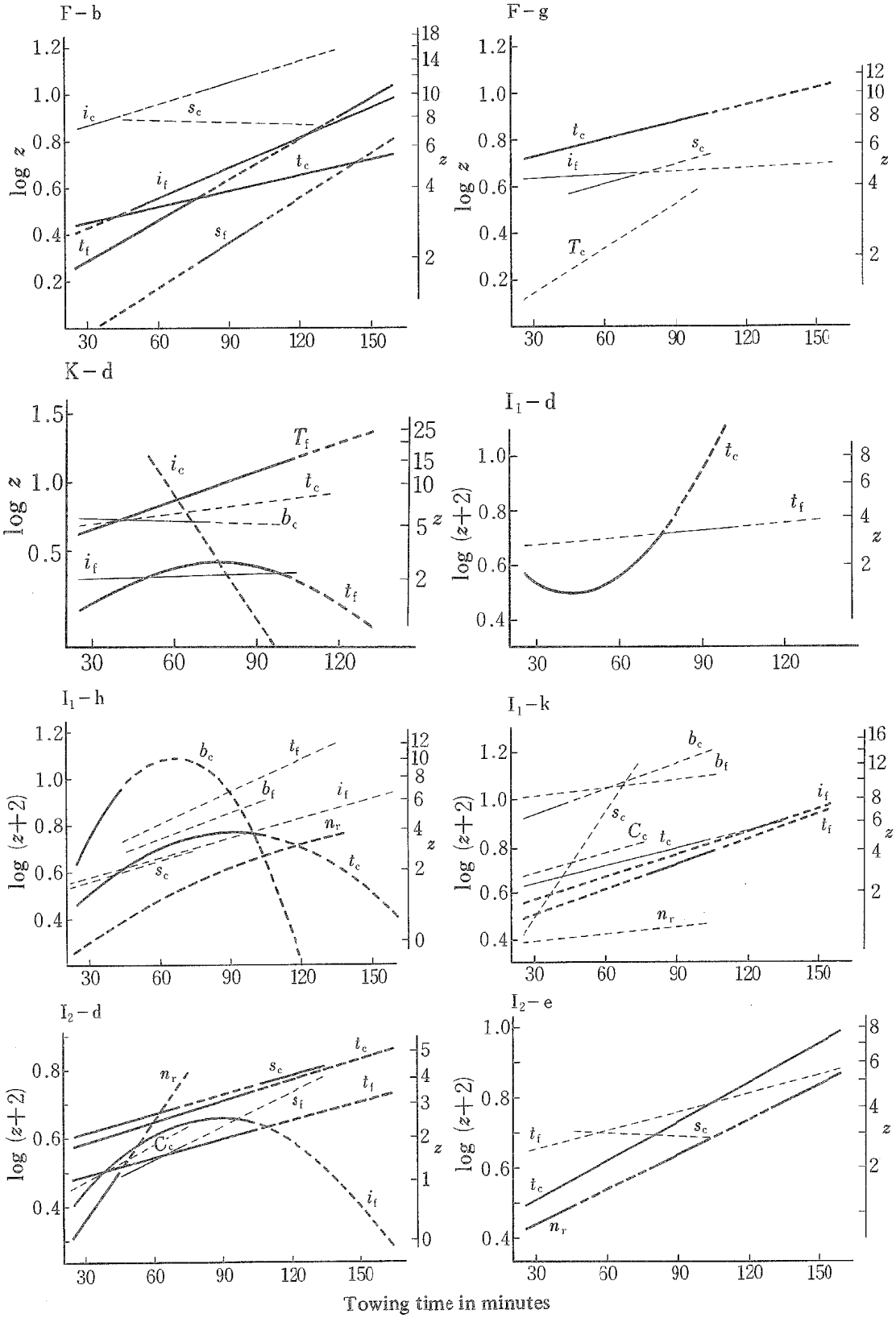
(Fig. 2 continued)

Fig. 2. The change of the amount of catch per haul in accordance with the length of towing time for schools showing respective types of echogram, by trawler and fishing ground.

Note: The note is the same to that of Fig. 1.
Solid line.....The regressive relation with significant coefficient
Broken line...The regressive relation with insignificant coefficient

The sufficient numbers of the records of the hauls for the schools showing the echogram of the types T_c, T_f, and C_c, were observed in the four groups of records. When the echogram of these types were detected, the boat passed over it and turned her course into the counter direction after a short steaming. Then, the boat shot her net and approached the school, hanging the net in a layer a little above the sea floor. As soon as the boat passed over the school again, the net was fallen down on the sea floor by stopping the engine and releasing the brake of the trawl winch. After a short towing using the way, the net was hauled up. And the fishing work like this was repeated. The towing time indicated the time interval between shooting the net and releasing the brake; in consequence, its meaning differed completely from the same words either for the traditional trawling or for the echoes of the different types. And whether a good catch was yielded or not depended on chance and was independently of the length of towing time. It is accordingly natural, as shown in the results, that the towing time for these schools was far shorter than that for the other types, and the amount of catch showed insignificant regression on it. In one of them (T_f in the group K–d),

b) The comparison among those observed within the records by the same trawler during the same season



the towing time was extended over a wide range, and the amount of catch showed a significant linear increase in accordance with the length of towing time. But the towing time for more than 85% of the hauls was within an hour. It is unreasonable to attack the school showing the echogram T_f with the long towing. And the long towing observed may be due to either of the following two possibilities: One was that the school was in the midlayer. The other was that the school showing the echogram of this type was found at the last part of long towing.

The thick echo, especially b_c was presumed to be the most profitable type. The regressive relation of the amount of catch on the length of towing time was examined in the 11 groups of records (the seven for b_c and the four for b_f). It is natural that the schools showing the echograms of these types were attacked with shorter towing than for the other types, and usually better catch than the other types was yielded. In the 10 groups, the amount of catch per haul did not show any significant regression on the length of towing time. Namely, the length of towing time was adequately adjusted so that an equal amount of catch might be yielded by a haul. In one of the groups (b_c in the group I_1–h), the significant quadratic regression with the maximum catch by a towing of an intermediate length was found out. But the towing time of most of the hauls was distributed in the range far shorter than the time of the maximum catch. And, it may be said, practically, that the amount of catch showed a very sharp increase in accordance with the length of towing time. Namely, it was hard to consider that the towing time was adjusted, but it was rather probable that the towing time was not adjusted at all.

The echogram type i_c is the presumably profitable form second to the thick trace. The amount of catch in one of the groups (K–d) showed a significant and sharp decrease in accordance with the length of towing time, but the decrease was very sharp and it was hard to regard it as the result of the insufficient adjustment. This group consisted of the records of the five hauls, and it was unreasonable to give much importance on this result. That in the other four groups showed neither the significant quadratic regression nor the significant linear one. It may be, accordingly, said that in general the length of towing time was adequately adjusted so that an equal amount of catch might be yielded by a haul.

The above-mentioned six types of echogram differed from the other five ones. The formers were thought to be the profitable types, and were attacked with rather shorter towing. And the significant regression of the amount of catch on the length of towing time was found in rather the exceptional cases. In contrast with this, the latters were thought to be the less profitable types, and were attacked with rather longer towing. And the amount of catch showed the significant regression on the length of towing time in about a half of the groups examined.

The echogram type t_c was the most profitable one among the latters. The amount of catch from the schools of this type showed a significant quadratic regression on the length of towing time in the two groups (I_1–d and I_1–h) out of the 13 groups. The relation in the former was concave to downward, and the time of the minimum catch

was near the shortest end. And the relation in the latter was concave to upward, and the time of the maximum catch was near the longest one. It may be, accordingly, said that the amount of catch increased practically in accordance with the length of towing time. The significant linear increase of the catch was found in the four groups; but the regression coefficient of them was smallest among the significant ones for the other types observed within the same groups of records. These facts meant that the length of towing time for this type was either adequately adjusted or slightly over-adjusted so that an equal amount of catch might be yielded by a haul.

For the schools showing the echogram of the type s_c, the amount of catch by a haul showed a significant linear increase in the two groups (I_1–i and I_2–d). In the former group, the records were concentrated into the classes of short towing, and whether it was reasonable to give much importance on this result or not was highly doubtful. In the latter group, the regression coefficient was smallest among the significant ones for the other types observable within the same group of records. The sample size of the other five groups showing the insignificant regression was extremely small. These results meant that it was hard to find any clear symptoms of over-adjustment.

The sufficient numbers of records for the echogram i_f were observed in the nine groups of records. In general, the towing time for this type was long and showed a large variation, and the catch was poor. The amount of catch in the group I_2–d showed a significant quadratic regression on the length of towing time with the maximum catch at an intermediate length. But most of the records were in the range of shorter towing than the maximum catch. And it may be practically said that the amount of catch showed a sharp increase in accordance with the length of towing time. The significant linear increase of catch in accordance with the length of towing time was found in the two groups. While, the amount of catch in the other six groups showed neither the significant quadratic regression nor the significant linear one on the length of towing time.

The towing time for t_f was longer and the amount of catch per haul was poorer than most of the other types. The amount of catch showed the significant quadratic regression in one of the groups (K–d) and the significant linear one in the three groups out of the 10 ones. The same fact to that mentioned in the other examples showing the significant quadratic regression may be said of the group K–d.

The amount of catch per haul for the echogram s_f showed the significant increase in accordance with the length of towing time in one of the groups out of the two groups.

These results of the examinations on the regressive relations of the amount of catch on the length of towing time were summarized, and the following trends were found out: In accordance with the presumable difficulty in yielding a good catch, (thick trace – $i_c - t_c - s_c - i_f$, t_f, and s_f), the possibility of the towing time being over-adjusted increased, the towing time elongated, and its variation became large, while the catch decreased. These difference in the ways of the adjustment according to the presumable profitability of the schools may be due to the following reasons: When the presumably profitable schools were found out, the towing time was adjusted so that an

equal amount of catch might be yielded by a haul, for the purpose of smooth work on deck and in the processing plant. Sometimes, the profitable schools were hardly found out and the boat was obliged to attack the presumably less profitable schools. In the case like this, the conditions were different. When some symptoms of entering a slightly better catch into the net were found out, the net was hauled up after rather shorter towing, with an intention of not making the processing plant waste long time for waiting for the material fish. When the density of the fishable population was very low and the symptoms like them were hardly found out, on the other hand, the net was towed over long hours, for the purpose of saving the hand in the processing plant from the work of very short time and making them take recess. The change of the skipper's mind according to the expectant amount of catch and the daily rhythmic difference of the difficulty in yielding a good catch may have a close relation to the difference of the way of the adjustment of the towing time.

The above-mentioned descriptions did not take the following fact into account: During the fishing in a ground, the skipper had to decide the work pattern according to the type of the echogram of the schools under the large haul-by-haul variation of echogram. The composition of the echogram types within a ground should, accordingly, have a close relation to the relative evaluation of the schools. And the present examination revealed the following outlines of the adjustment of the length of towing time in respective groups of records:

1) The significant quadratic regression of the amount of catch per haul on the length of towing time found out in the group K–a and the significant linear one found in the groups F–e and I_1–f, were due to the different adjustment of the length of towing time according to the echogram type. And it may be said that the length of towing time for the schools showing the same echogram type was adequately adjusted to equalize the amount of catch by a haul.

2) In the groups F–d, I_1–e, and I_1–l, the towing time was adequately adjusted to equalize the amount of catch by a haul, even when the difference in the echogram type was not taken into account. The present examination showed that the same was true of the hauls showing the same types of echorgam.

3) The trend of the over-adjustment (the significant increase of the catch in accordance with the towing time) in the groups K–d, I_1–i, and I_1–k, was mainly due to the same trend for the less profitable schools and the different way of the adjustment according to the echogram type.

4) The significant quadratic regression in the group F–g and the significant linear one in the group I_1–d were mainly due to the different range of the towing time and the different amount of catch according to the echogram type, and partly be due to the trend of the slight over-adjustment in t_c.

5) The trend of the over-adjustment in the group I_1–h was due to the same trend in the profitable schools.

6) The same trend in the groups F–b, I_2–d, and I_2–e, was due to the same trends

found in most of the types including both of the profitable ones and the less profitable ones. But the average length of the towing time differed according to the echogram type in the former two groupes.

Conclusion

As stated above, the towing time was adequately adjusted in the 44 examples out of the 66 ones. And the towing time and the amount of catch differed according to the echogram type even among the hauls conducted within the same ground by the same boat. The trend of the over-adjustment was found in the 20 ones. They were mainly the echogram of the less profitable types. These facts meant that the echogram type was used by the skipper as one of the most powerful field indicators for deciding the work pattern, in spite of many doubts about its meaning from the theoretical point of view. And the over-adjustment of the towing time for the less profitable schools may be due to the following reasons: The schools showing less profitable type of echogram was attacked only when the boat could not find out any profitable ones after long scouting or only when the skipper reached the conclusion from his long experience that the profitable school was hardly found out. The type of echogram observable within a ground showed a large variation and differed haul by haul. The different amount of catch according to the type was, accordingly, exaggeratedly impressed, especially that of the less profitable types. It was hard to neglect the influence of the skipper's intention of making the crew take recess in the case of the presumably poor catch for the purpose of the labor administration over long stay in the fishing ground.

The adjustment of the length of towing time and its difference according to the echogram type indicated the important role of the echo sounder and other electronic supporting devices in the modern trawling. Namely, the introduction of the modern electronic supporting devices, thus, changed completely the catch pattern — the relation of the amount of catch per haul to the conditions. And it may be said that the accurate interpretation or analysis on the catch records was hardly done without the full understanding on the difference of the work pattern caused by the introduction of these devices into the modern trawling.

Summary

The introduction of the echo sounder and other electronic supporting devices caused a basic change in the details of the fishing work. The representatives in the trawling were the selective attacking, the adjustment of the length of towing time, and the scooping for the schooling fish on the rough grounds. These changes in the pattern of fishing work induced a basic change in the meanings of respective items of the catch records. The present report dealt with the relation between the length of towing time

and the amount of catch and its difference according to the type of echogram observable among the records on the 1,887 hauls for the Pacific Ocean perch in the Bering Sea, for the purpose of clarifying the different ways of the adjustment of the length of towing time according to the echogram type and for the purpose of evaluating whether or not the echogram type was rightly interpreted by the skippers as the basis of deciding the work pattern (i.e. the adjustment of the length of towing time). And the results obtained are summarized as follows:

1. The length of towing time of a haul showed a large variation, being from five minutes to 240 minutes. The amount of catch showed neither the significant quadratic regression nor the significant linear one on it in the half of the groups of records, and showed the slight but significant increase in other half. Namely, the towing time was adequately adjusted in a half of the groups, and was over adjusted in the other half, when the difference of the echogram types was not taken into account.

2. When whether an equal amount of catch was yielded or not by a haul from the schools of the different type of echogram was left out of account, the length of towing time did not show any significant difference according to the echogram type in the 16 groups of records out of the 23 ones. In the seven groups, the towing time differed according to the echogram type, and that for the dense trace or the trace contacting with the bottom echo was shorter than that for the others.

3. When the different amount of catch according to the length of towing time and the echogram type was taken into account, the following trend was found out: The towing time for the echogram types T_c, T_f, b_c, and i_c was shorter and the catch from them was better than from the others. And the latter showed a significant regression on the former only in rather exceptional cases; namely, the towing time for the echoes of these types was adequately adjusted.

4. The adjustment differed according to the presumable profitability of the schools: 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 time) increased in accordance with the presumable difficulty in yielding a good catch (thick trace $-i_c - t_c - s_c - i_f$, t_f, and s_f).

Reference

1) NAKADA, Y., 1972: An Analysis of the Catch Records of the Trawling Assisted by the Electronic Devices – I. *This Jour.*, 20, 157–187.