An Analysis of the Catch Records of the Trawling Assisted by the Electronic Devices – I.*

Bathymetric Change of the Amount of Catch per Haul of the Pacific Ocean Perch and its Relation to the Echogram Type

By

Yutaka NAKADA

The recent rapid advances in science and technology evolved a revolutional change in all the industries. The fishing techniques could not be one of the very rare examples unaffected by them. And the details of the fishing methods have been revised completely in these days, although it was hard to find any basically new methods invented out as the results of the recent technical revolution. This is true in all the fishing methods including such traditional ones as the hand angling and small net fishing. The trawling is one of the representatives of the methods affected profoundly by the technical improvement, because this is the fishing method exposed to the severest conditions. Namely, a few decades ago, the trawling–including the bull trawling and the Danish seining--was the method applicable only to the smooth grounds with few obstraction; but this has been improved into the method applicable to all the fishing grounds regardless of the depth and the bottom character as the results of the application of the echo sounder of excellent performance with an assistance of the depth telemetric devices, the powerful hydraulic hauling devices, and the resistive synthetic netting materials. In company with the expansion of the explorable grounds, the fishing ability and the details of the gear construction and gear handling had been changed completely, compared to something like the different fishing method. And the catch records of the trawling fully supported by the electronic devices should be examined through the different method of analysis taking the influence of the change of the gear handling into consideration. In the present series of the reports, the catch records of the Pacific Ocean perch by the three stern ramp trawlers were analyzed, with an intention to show an outline of the difference in the catch records brought by the

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full application of the electronic devices. Among the results obtained, those on the seasonal bathymetric change of the catch by a haul, number of hauls, and their relation to the skipper's description on the echogram as the basis of his decision to choose the objective school were shown in the present report.

Material and Method

The materials used in the present series of reports were the working reports of the three stern ramp trawlers fishing chiefly the Pacific Ocean perch (*Sebastodes alutus*; but probably some associated deep water rockfish species are included) during the period from April of 1968 to March of 1970 along the outer edge of the continental shelf from east of Kodiak Island in the Gulf of Alaska to west of the Queen Charlotte Islands. The trawlers were, for convenience' sake of representation, abbreviated according to their initials as follows: The trawler F (a freezer trawler of the 4,000 ton class), the trawler K (that of the 3,500 ton class), and the trawler I (a 500 ton class trawler working as a scout for the former two large trawlers; she made two trips during the above-mentioned season and the suffix represented the trip number; the trip with suffix 1 was from April to August of 1968 and that with the suffix 2 was from May to July of 1969).

Usually the principal objectives of the freezer trawlers are chosen depending on many factors, the representatives being not only such biological factors as the relative abundance, the availability, and the bathymetric distribution of the fish, but also such economic or administrative factors as the market price, the market capacity, the daily capacity of the boat for processing, and the capacity of the fish hold to be filled. The above-mentioned fact makes complicated the analysis on the catch records. But there are some exceptions. The large stern ramp factory trawler exclusively aims at a single species, the Alaska Pollack, throughout the seasons because of the construction of her processing plant. For the purpose of saving the work of sorting the catch according to the market classification and simplifying the work pattern of processing, our freezer trawler fishing in the Bering Sea and the Gulf of Alaska, sometimes, exclusively aims at a single sort of fish, although the objective fish varies according to the season and the fishing grounds. The records during these works are thought to be rather free from the influence of the economic or administrative factors, although the objective fish is chosen chiefly according to these factors. The working reports during the work of catching the Pacific Ocean perch were used, accordingly, in the present series of reports. Even during this kind of work, there were some hauls yielding the noticeable amount of the other salable fish than this. The records on these hauls should be excluded from the examination because some of the hauls may be due to misinterpretation of the fish echo and the others may be done purposively. The records on the hauls with more than 10% of the catch occupied by the other fish than the Pacific Ocean perch were, accordingly, excluded from the present examination. And the records on the 1,887 hauls were available to the present work. Among them, the records on the 1,175 hauls had the description on the echogram. In the working reports used here, the data on the following items were included: the date, the position fished, the shooting and hauling hour, the towing course and speed, the depth fished, the warp length, the angle between the warps, the height of net mouth, the revolution of main engine during towing, the amount of total catch by a haul, the catch composition, some oceanographic and meteorological conditions, the time spent in finding out the fish echo, and the type of echogram attacked. And the bathymetric changes of the amount of catch per haul and the number of hauls in relation to the types of the skipper's descriptions on the echogram were examined in the present report.

With assistances of the informations from the fellow boats, the trawlers shifted their fishing grounds pursuing the presumable migration of the fish school. The shift of the fishing grounds and the dates fished therein are shown in Fig. 1. In the present report, the records were examined after the stratification into the 29 groups (the seven groups for the trawler F, the five groups for the trawler K, the 12 and five groups for the first and the second trips of the trawler I) denoted by the alphabet in this figure.

The amount of catch by a haul was, usually, recorded in tons. But, on the trawler I, this was recorded in tenth's tons when the catch was poorer than five tons. While, on the

a) For the Trawler F

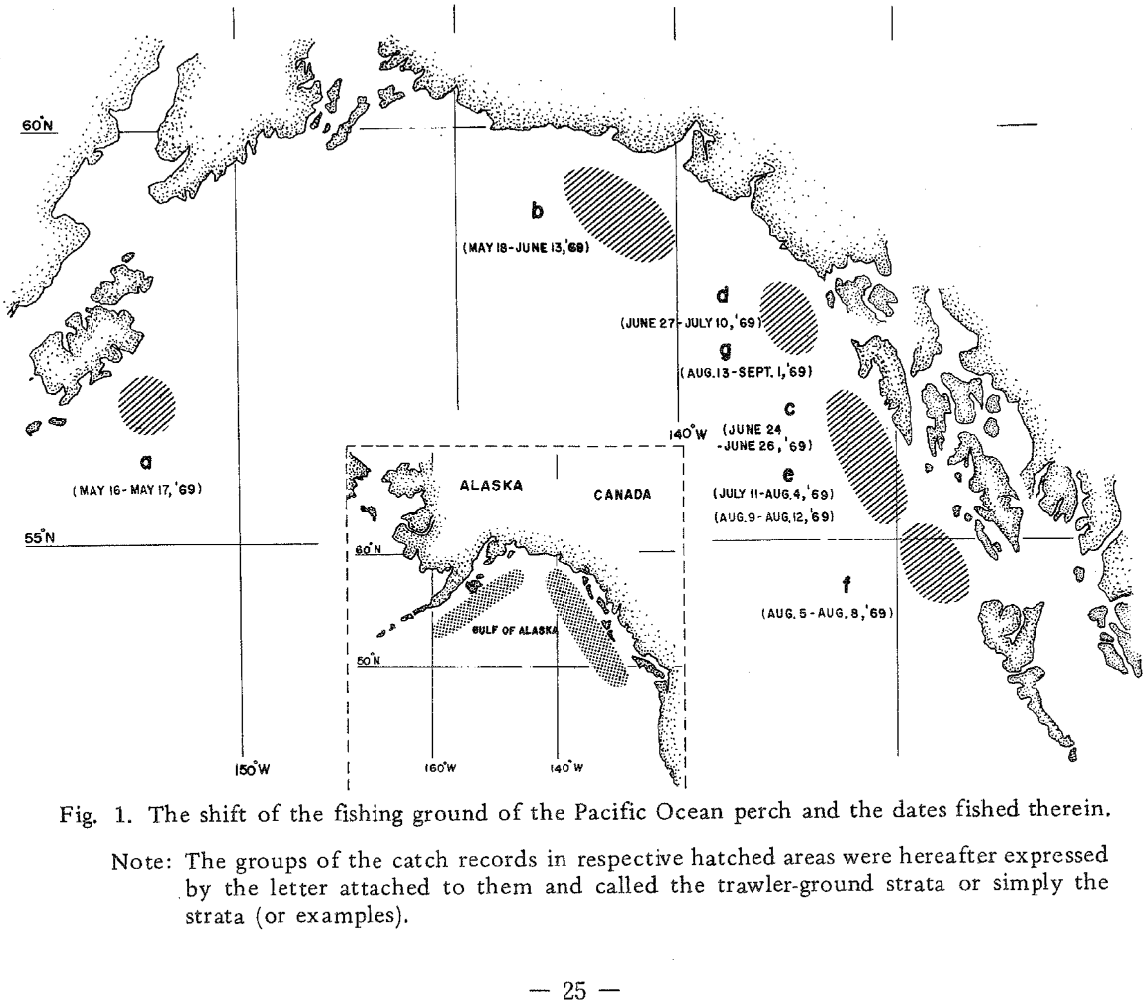


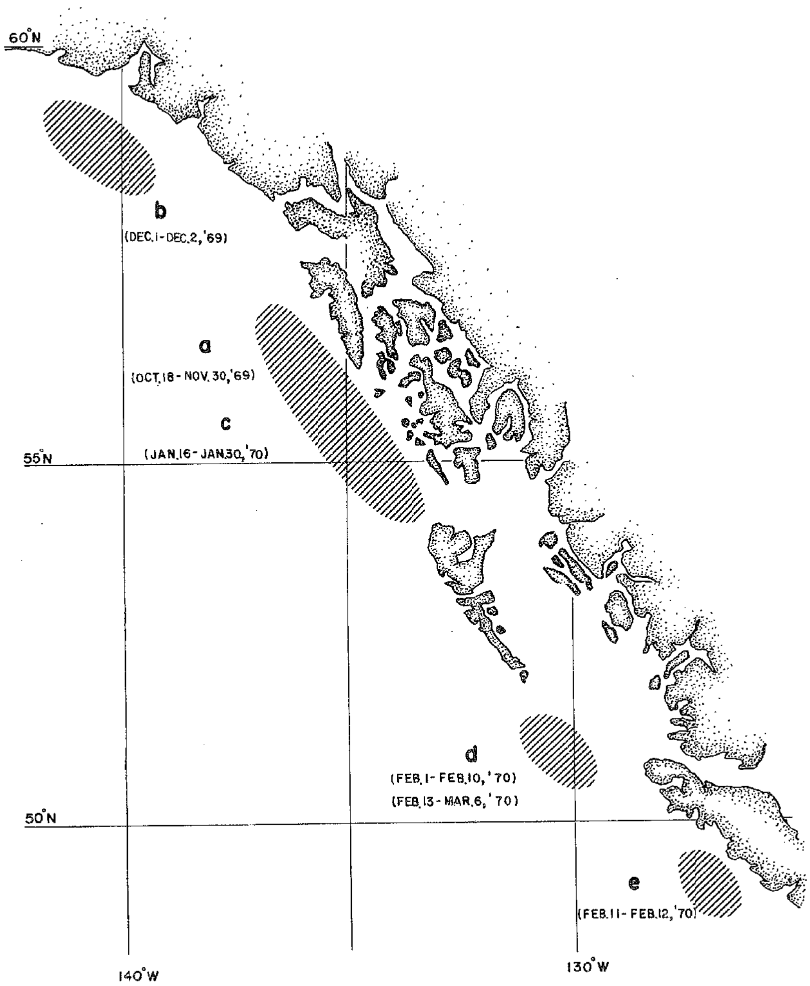
Fig. 1. The shift of the fishing ground of the Pacific Ocean perch and the dates fished therein.

Note: The groups of the catch records in respective hatched areas were hereafter expressed by the letter attached to them and called the trawler-ground strata or simply the strata (or examples).

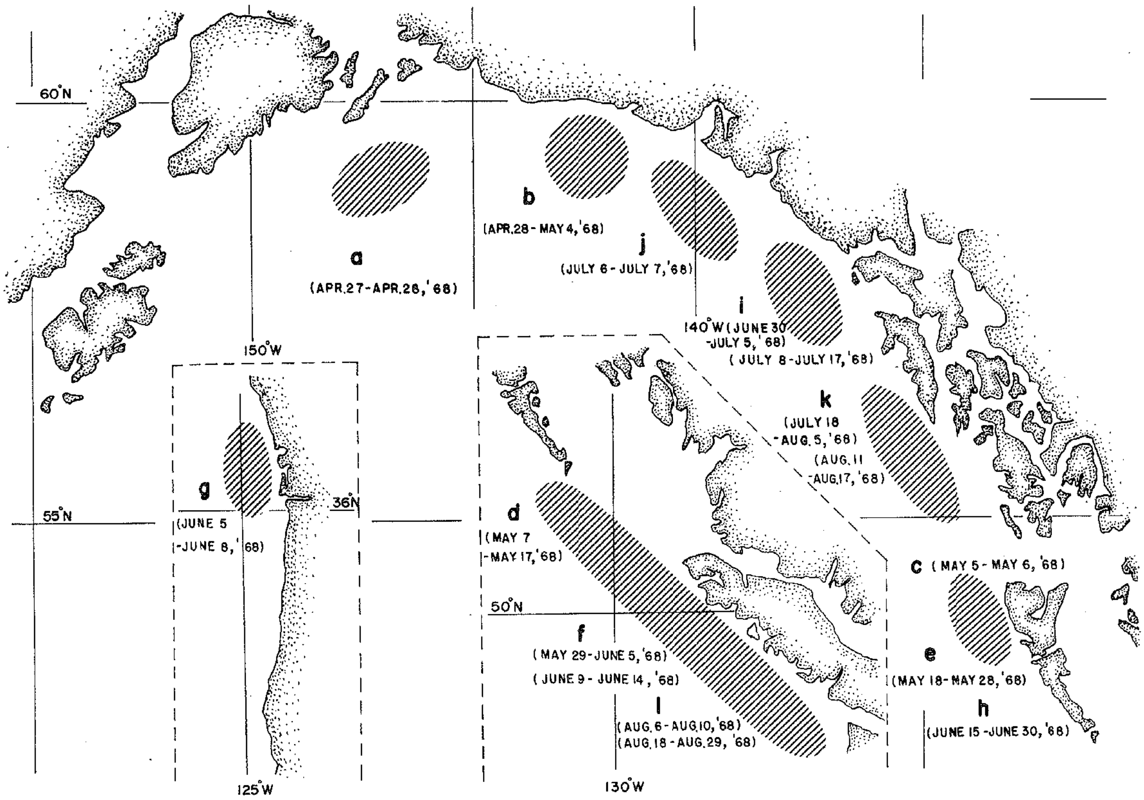
trawlers F and K, this was described chiefly in five tons and rarely in two or three tons when the catch was better than 15 tons a haul. The amount of catch (z in tons) by a haul of the trawler I ranged from 0 to 20 tons. This was aggregated into one-ton intervals and used after the transformation into the value of $\log(z+2)$. The amount of catch by a haul of the trawlers F and K ranged from 0 to 40 tons. This was aggregated into five-ton intervals, and used after the logarithmic transformation.

When the echogram of the school expected to be the objective of shooting the gear was detected, the depth of the bottom echo was recorded. The recorded depth ranged from 125m to 475m mainly from 200m to 400m. The records were, accordingly, stratified into the nine strata of 25m intervals, because the distribution, the sample size in respective grounds, and the accuracy of the depth measuring were taken into consideration.

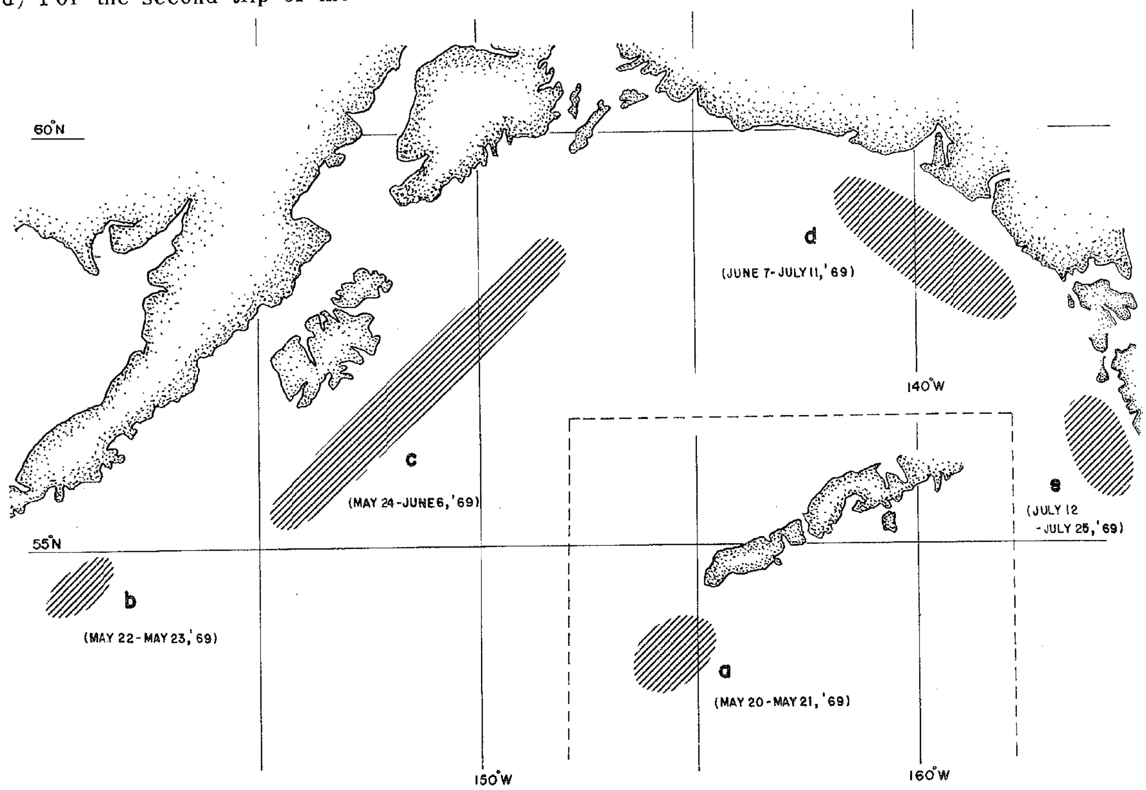
b) For the Trawler K



c) For the first trip of the Trawler I



d) For the second trip of the Trawler I



The echogram differs according to not only the performance of the echo sounder such as the power output, the beam angle, the frequency, and the pulse length, but also the conditions of the objectives such as the characteristics of the sound reflection, the density and distribution pattern. But, in the present case, the difference of the echogram due to the different performance is out of the problem, because the catch records by the different trawlers were not compared with one another. The other group of factors making different the echogram from the schools of the same condition is the recording conditions such as the depth and the steaming speed. This made it hard to examine the quantitative relation of catch to the echogram. In spite of these facts, there is no doubt that the skippers use the echogram as one of the most powerful bases of the decision of shooting the gear. One of the principal aims of the present report is to find how to apply the skipper effectively to the echo sounder. The descriptions on the echogram done by the skipper were classified into the 12 types (shown in the supplementary table) according to the relation to the bottom (contacting with or not contacting with—floating) and the density (thin, intermediate, or black). But there were some cases described in particular patterns, the representatives being the tower trace and the spotted one. And the different amount of catch according to the type of the echogram was examined.

The type of the frequency distribution of the amount of catch by a haul

The type of the frequency distribution of the hauls in respect of the amount of catch is one of the most important characteristics of the catch pattern, and differs according not only to the fishing methods but also to the seasons and the fishing grounds. And the recorded value of the amount of catch by a haul should be transformed according to the agreeable type of the frequency distribution, before the analysis.

The frequency distributions of the hauls in respect of the amount of catch were estimated after the stratification of the records according to the fishing grounds and the depth fished, because it is probable that the characteristics of the distribution differ according to them. As shown in the upper half of Table 1, the mode of them biased in the direction of the lower grade of catch. And the observed series of the frequency of the hauls by the trawlers F and K fit to the Gibrat-distribution. Here, the frequency of the hauls in the class of 0 ton included the hauls with a catch from 0 to 2 tons, because the amount of catch was aggregated into the classes of five-ton intervals. Accordingly, its class mark was one, although this class was, for convenience' sake, represented as the 0-ton class. And there was no problem to translate the amount of catch into the logarithmic value.

The frequency distribution of the hauls by the trawler I in respect of the amount of catch showed the bias of the mode in the direction of the lower grade of catch. But the normal deviate showed a concave relation to the logarithmic value of the amount of catch (z). The value of a making the normal deviate—log $(z + a)$ relation neither concave nor

Table 1. Fitness of the observed series of the frequency distribution of the hauls in the respect of the amount of catch to the expectant one.

Trawler-Fishing ground	F − b		F − e		K − a		K − d	
Depth (m)	225		325		350		275	
Type	Ob.	Gibrat	Ob.	Gibrat	Ob.	Gibrat	Ob.	Gibrat
Catch class (in tons) 0	24	23.92	3	3.05	21	20.14	45	45.64
5	36	36.31	8	10.47	42	45.99	31	29.23
10	10	9.68	7	5.02	16	11.63	6	7.42
15	5	} 7.09	3	} 6.45	2	} 6.24	3	} 7.71
20	2		2		3		1	
25			2				2	
30							1	
χ_0^2	0.015		1.411		2.271		0.453	
df.	1		1		1		1	
Prob.	0.95 − 0.90		0.25 − 0.10		0.25 − 0.10		0.75 − 0.50	

Trawler-Fishing ground	I_1 − h		I_1 − i		I_1 − l		I_2 − d		I_2 − e	
Depth (m)	All the depth zones being pooled		All the depth zones being pooled		200		250		300	
Type	Ob.	Gibrat	Ob.	Gibrat	Ob.	Gibrat	Ob.	Gibrat	Ob.	Gibrat
Catch class (in tons) 0	14	9.55	8	8.02	7	8.04	3	} 16.15	3	} 11.84
1	7	12.56	6	6.62	7	6.37	14		7	
2	13	12.09	8	6.07	4	5.65	13	13.79	11	10.38
3	13	9.99	4	} 13.47	6	} 8.66	8	8.33	8	8.63
4	5	7.77	4		3		5	} 6.73	9	6.14
5	5	5.90	5		5	} 22.28	1		3	} 11.01
6	6	} 7.78	4	} 5.87	4		1		2	
7	2		4		3				1	
8	3	} 11.36	5	} 19.25	3				0	
9	0		2		1				2	
10	5		2		1				1	
11	0		1							
12	1		1		1					
13	1									
14										
15	1		1		2					
16			3						1	
17	1		1							
18			1		1					
19										
20					1					
χ_0^2	6.677		1.724		0.755		0.114		1.794	
df.	5		3		2		1		2	
Prob.	0.50 − 0.25		0.75 − 0.50		0.75 − 0.50		0.75 − 0.50		0.50 − 0.25	

Note: Trawler-Fishing ground ..... The capital letter is the abbreviation of the trawler, and the small letter is the location of the fishing ground shown in Fig. 1.
Ob ..... Observed series
Gibrat ..... For the trawler I, the value of $(z+2)$ was used in stead of z.
df ..... Degrees of freedom for chi square value

convex to upward was seaked with the assistance of the logarithmic probability paper. And it was found out that the bias of the relation from a straight line was the smallest when a was 2. Then, the observed series of the frequencies were compared with the Gibrat-distribution, after the transformation of z into $(z+2)$. As shown in the lower half of Table 1, the observed series fit to the expectant ones.

Because of the agreeable type of the frequency distributions, the recorded values of the amount of catch by a haul (z) of the trawlers F and K after the aggregation into the classes of five-ton intervals were, accordingly, transformed into the logarithmic value. And those by the trawler I after the aggregation into the classes of one-ton intervals were into the value of $\log(z+2)$. These transformed values were used in all the examinations. In the diagrams, the ordinate was scaled in either $\log z$ or $\log(z+2)$. But the value of z was also represented, for the purpose of assisting an easy understanding of the results.

The bathymetric distribution of the amount of catch per haul

It is a well-known fact that the ground fishes show the seasonal bathymetric migration. And if the Pacific Ocean perch in a season prefer to live in a certain depth zone and the amount of catch per haul is in proportion to the density of fish, the amount of catch by a haul shows a maximum at an intermediate depth zone and decreases in accordance with the depth difference from this zone. In the case like this, the simplest representation of the relation of the amount of catch per haul to the depth fished may be the quadratic one. But, whether the relation like this is observable in the catch records of the present case or not is doubtful, because the working pattern of the trawling with a good assistance of the echo sounder is completely different from that without this device. Namely, the trawler steams seaking an echo of the presumably profitable school till she found it, and she attacks it selectively. But she does not attack the probably less profitable school, and she does not tow her net without any detection of the presence of the school. It is, accordingly, hard to be neglect of the following possibility: If the echogram is interpreted precisely, it is probable that the amount of catch by a haul does not show any clear bathymetric difference. But the bathymetric distribution of the fish may be found in the number of hauls.

To prove either of these possibilities, the quadratic regression relation of either $\log z$ or $\log(z+2)$ on the depth fished was examined. When the quadratic regression was insignificant, the linear regression relation was examined. The results of these examinations are shown in Table. 2 and Fig. 2. The clearest trend found through this step of the examination was the basic difference of the catch pattern between the trawlings with (the present case) and without (the traditional one) the assistance of echo sounder. Namely, the significant decrease of the catch in accordance with the depth difference from an intermediate zone, which is the most probable form in the catch records of the trawling without the assistance of the echo sounder, could be found only in the four of the examples out of the 27 ones examined. But there was an example showing the relation contrary to the expectation. And one of the examples showed the significant linear increase of the catch per haul in accordance with the depth fished, and the four examples showed significant linear decrease. The examples of the rest showed neither significant quadratic regression nor significant linear one on the depth fished.

It was, thus, hard to find the significant quadratic regression of the amount of catch by a haul on the depth fished. This may be due to either of the following two possibilities: (1) The density of the Pacific Ocean perch may not depend on the depth within the range examined here, probably because that depends on the other factors than the depth—for example, the bottom character and the bottom topography. (2) The trawlers attacked selectively the schools showing high possibility of good catch; otherwise they did not shoot the gear.

Table 2. The estimated quadratic regression equations and the linear ones of either log z or log $(z+2)$ on the depth fished, and the results of the test on the significance of the regression 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 − b	−1.434	1.553	−0.293	2.70	2.67	0.549	0.014	0.03	234
c	2.340	−1.567	0.350	0.62	0.65	0.541	0.032	0.05	15
d	1.284	−0.500	0.109	0.50	0.71	0.504	0.093	2.05	43
e	3.107	2.209	−0.403	0.58	0.69	1.379	−0.209	1.94	100
f	−8.557	7.826	−1.661	4.25	4.44*				23
g	−1.027	0.996	−0.159	2.73	2.40	0.264	0.066	1.50	144
K − a	0.488	−0.198	0.063	0.04	0.13	−0.045	0.174	5.30*	173
c	−36.827	29.228	−5.601	4.19	3.84	−11.607	2.306	10.28*	9
d	4.354	−2.270	0.313	1.19	0.75	1.774	−0.463	15.90**	246
e	−11.948	7.395	−1.084	0.88	0.79	−0.613	0.371	3.44	9
I_1 − b	−1.932	1.740	−0.301	5.36	5.19*				28
d	−4.031	3.683	−0.726	3.31	3.11	0.297	0.116	0.98	55
e	12.720	−10.020	2.079	8.55	8.10**				41
f	1.504	−0.932	0.202	1.62	1.88	0.322	0.067	1.34	51
g	−3.584	4.294	−1.136	0.60	0.51	−0.176	0.327	3.27	9
h	3.301	−1.925	0.332	3.36	2.65	1.193	−0.220	9.77**	77
i	−4.100	3.976	−0.788	12.48	13.06**				60
j	−4.505	4.169	−0.853	0.50	0.49	0.426	0.049	0.03	11
k	1.524	−0.500	0.072	0.64	0.38	1.023	−0.115	5.76*	124
l	3.106	−1.869	0.342	1.57	1.25	1.121	−0.200	6.87*	92
I_2 − a	3.464	−1.800	0.274	1.33	1.31	0.387	0.050	0.49	13
c	−2.822	2.786	−0.541	4.18	4.33*				24
d	−0.022	0.592	−0.139	0.73	0.85	0.695	−0.043	0.94	211
e	−1.675	1.560	−0.259	0.59	0.59	0.643	0.007	0.01	88

Note: log z or log $(z+2) = a_0 + a_1 y + a_2 y^2$
log z or log $(z+2) = b_0 + b_1 y$
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 coefficient in the i-th order regression equation
n .... Size of samples
y .... The depth in meters
z .... The amount of catch in tons
* ....Significant at 0.05 level
**....... Significant at 0.01 level

a) The relation in respective trawler-fishing ground strata

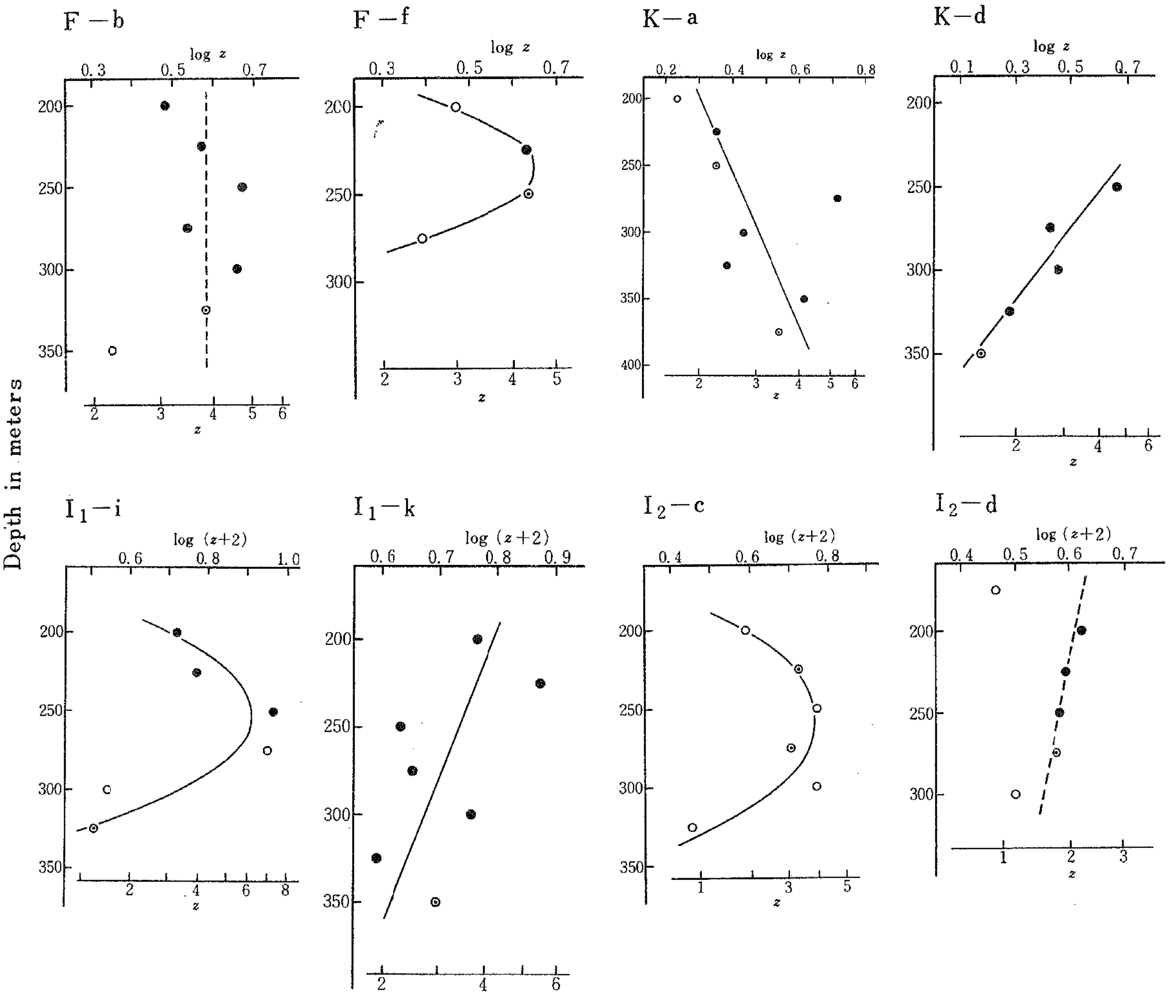


Fig. 2. The bathymetric change of the amount of catch per haul.

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

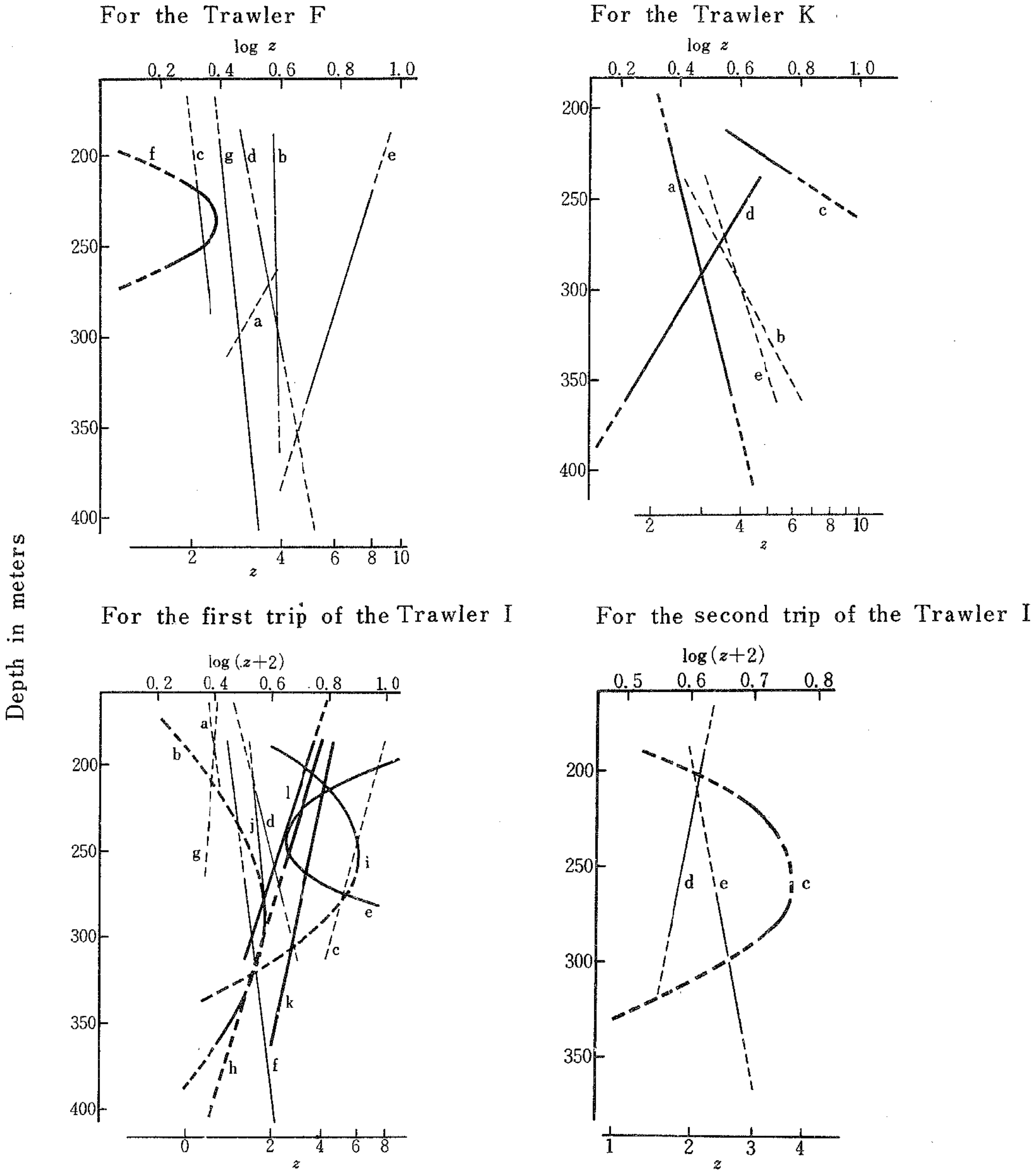
For a)

Solid line ..... The regressive relation with significant coefficient
Broken line ..... The regressive relation with insignificant coefficient
Solid circle ..... The amount of catch per haul conducted in the depth zone with more than 11 records
Circle with center dot ..... That in the zone with five to ten records
Open circle ..... That in the zone 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 depth zones with the records of more than five hauls
The part of broken line ..... The depth zones with the records of less than five hauls

b) The regression lines by respective trawlers



In the freezer trawlers catching the scattering fish, the adjustment of the length of the towing time of the net is one of the probable factors to equalize the amount of catch by a haul. But it was hard to consider the possibility like this in the present case, because of the different work pattern. Namely, in the trawling for the fish scattering on an even ground, the length of the towing time is adjusted, and about an equal amount of catch is yielded by a haul with the assistance of the electronic devices. The working reports of the present case have the description on the length of the towing time. But the meaning of it completely differs from that of the other freezer trawlers. In the present case, the boat steams round till she finds the fishable school. When she finds it, she turns her course to the counter direction after a short steaming. She shoots her gear and steams slowly holding her gear in a layer a little above the sea bed with the assistance of the net sonde. And when she passes over the school again, the engine is stopped and the brake of the trawl winch is released for the purpose of making the warp in free running and the net fallen down on the sea bed. Just after the sweeping of the net over the school, warp is wound up. The time of towing the gear in the present case, accordingly, means the time interval between the shooting of the net to the re-detection of the school. The working pattern like this made it hard to adjust its length with an intention of equalizing the amount of catch per haul.

The bathymetric difference of the number of hauls conducted

If the results of the preceding step of the examinations are due to an equal density of

Table 3. The estimated quadratic regression equations and the linear ones of the frequency of hauls on the depth fished, and the results of the test on the significance of the regression 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	−161.344	114.600	−20.000	13.77	13.89	2.400	− 0.400	0.02	4
b	−276.506	250.029	−48.260	4.99	5.68	68.350	−15.400	1.08	9
c	− 37.048	35.857	− 7.810	13.87	13.45*				7
d	− 24.683	22.573	− 4.065	4.64	5.49*				11
e	−155.676	120.009	−20.424	6.88	6.67*				10
f	− 42.625	38.548	− 7.714	1.95	2.17	8.000	− 1.952	0.47	8
g	− 56.267	47.191	− 7.506	6.38	6.44*				14
K − a	− 74.136	62.571	−10.030	1.88	1.49	− 7.060	7.407	1.13	13
b	− 7.465	6.321	− 1.119	1.66	1.54	0.081	0.262	0.35	6
c	− 23.214	21.191	− 4.381	1.91	2.06	3.071	− 0.714	0.24	7
d	−341.691	281.524	−50.286	1.19	1.49	132.881	−32.762	2.34	8
e	− 13.780	10.024	− 1.619	1.01	0.88	286.381	−78.629	33.18**	6
I_1 − a	− 2.930	2.851	− 0.476	8.23	8.55*				8
b	− 10.477	9.717	− 1.652	11.76	12.57**				12
c	− 14.000	9.000	− 1.333	12.89	13.09*				7
d	− 61.259	62.032	−13.178	7.34	6.81*				9
e	− 24.125	29.214	− 6.571	0.53	0.75	19.000	− 5.286	2.02	8
f	− 6.925	11.077	− 2.334	1.94	2.66	8.68	− 1.760	1.91	13
g	− 8.404	11.040	− 2.763	1.52	1.79	3.288	− 0.876	0.72	6
h	44.354	−17.776	1.660	0.23	0.07	30.455	− 7.818	3.67	11
i	− 1.205	7.629	− 1.640	0.38	0.71	13.143	− 2.677	2.54	12
j	− 53.021	47.614	−10.000	10.32	10.33*				6
k	−112.264	101.552	−19.204	12.83	14.02**				9
l	− 49.488	55.178	−11.523	0.54	0.66	24.353	− 5.529	0.59	9
I_2 − b	−104.000	58.000	− 8.000	9.6×10^6	9.7×10^6**				4
c	− 11.343	13.651	− 2.942	6.99	6.60*				9
d	−359.321	360.048	−78.667	4.40	4.80	58.595	−13.619	0.35	8
e	−157.722	124.089	−21.606	2.04	1.88	− 5.419	5.838	0.36	8

Note: $h = a_0 + a_1 y + a_2 y^2$

$h = b_0 + b_1 y$

y .... The depth in meters

h .... The frequency of hauls in respective depth zones

* .... Significant at 0.05 level

**....... Significant at 0.01 level

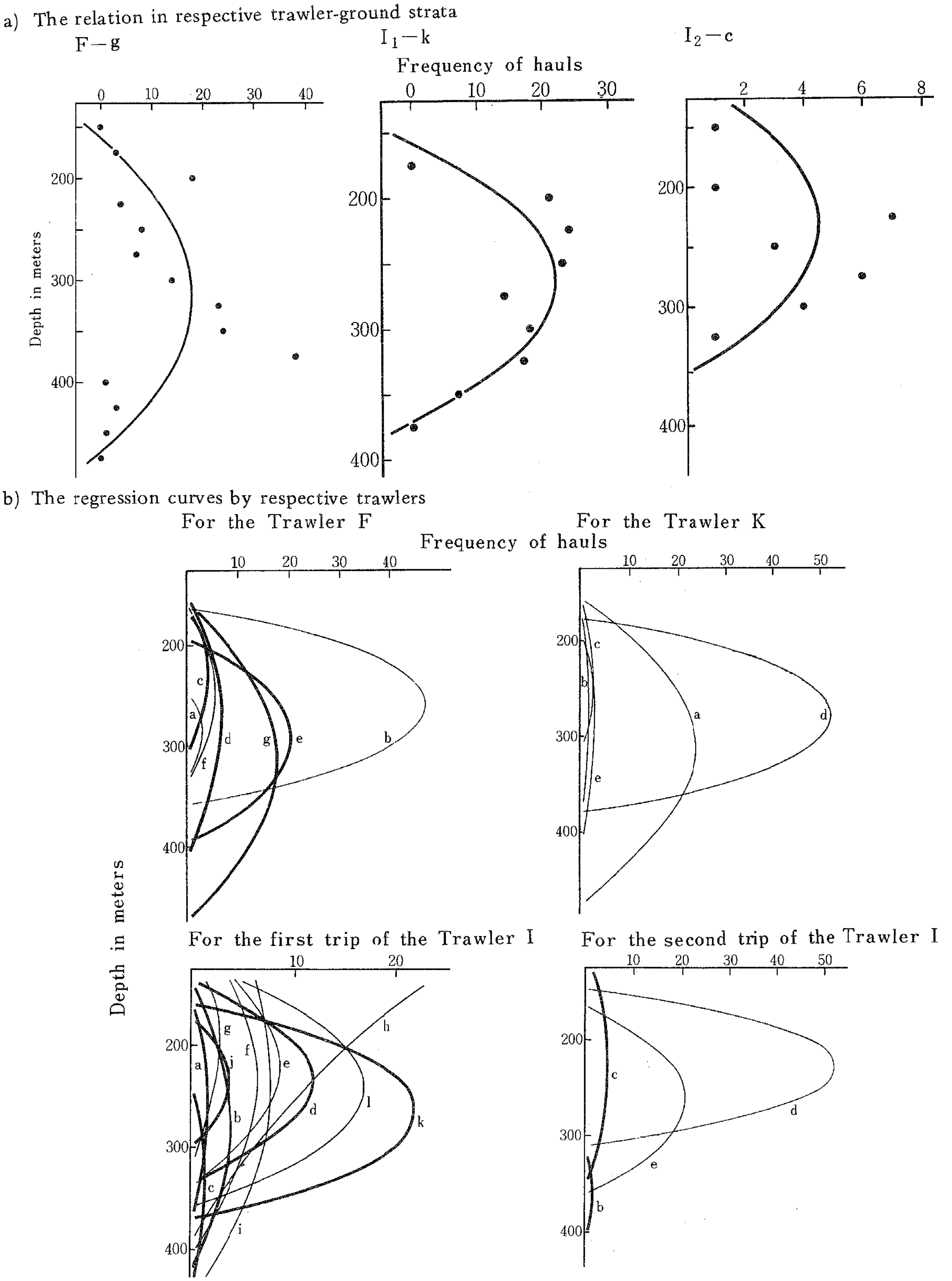
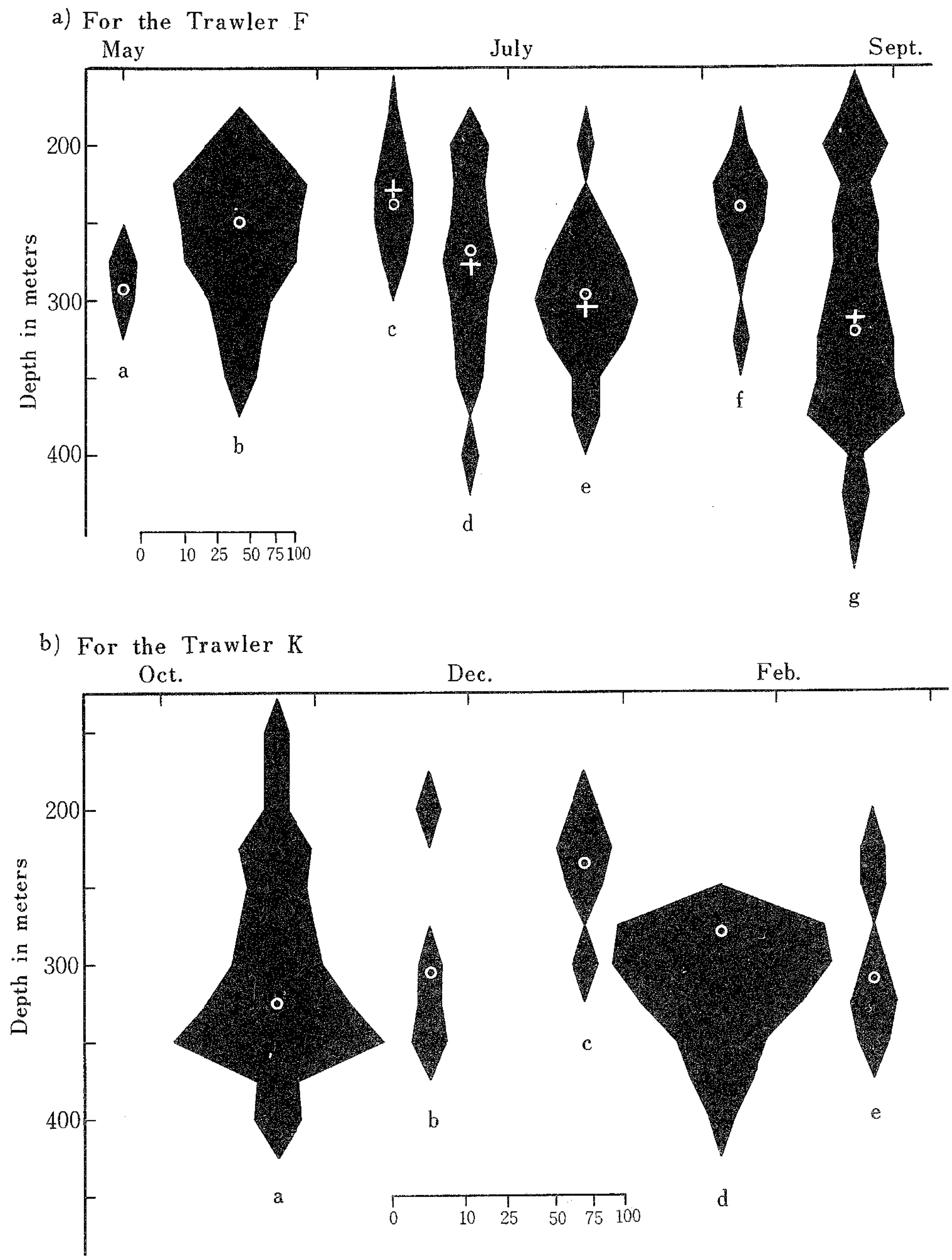


Fig. 3. The bathymetric change of the frequency of hauls.

Note: The capital letter ..... The abbreviation of the trawler
The small letter ..... The location of the fishing ground
Thick curve ..... The estimated quadratic curve with significant quadratic regression coefficient
Thin curve ..... That with insignificant one
Solid circle ..... The frequency of hauls conducted in respective depth zone of 25-m intervals

the objective fish throughout the depth zones fished, the frequency of the occurrence of the echogram of the school of sufficient size, i.e. the number of the hauls conducted, in respective depth zones should have no clear regression on the depth. If the results are due to the selective shooting, in contrast with this, the bathymetric change of the density of the fish may be found in that of the number of hauls conducted. The quadratic regression equations of the number of hauls on the depth fished were estimated, and the significance of their quadratic regression coefficients was examined, with an intention to find the reason causing the above-mentioned results. As shown in Table 3 and Fig. 3, the quadratic regression coefficient was significant in the 12 examples out of the 28 ones



c) For the first trip of the Trawler I

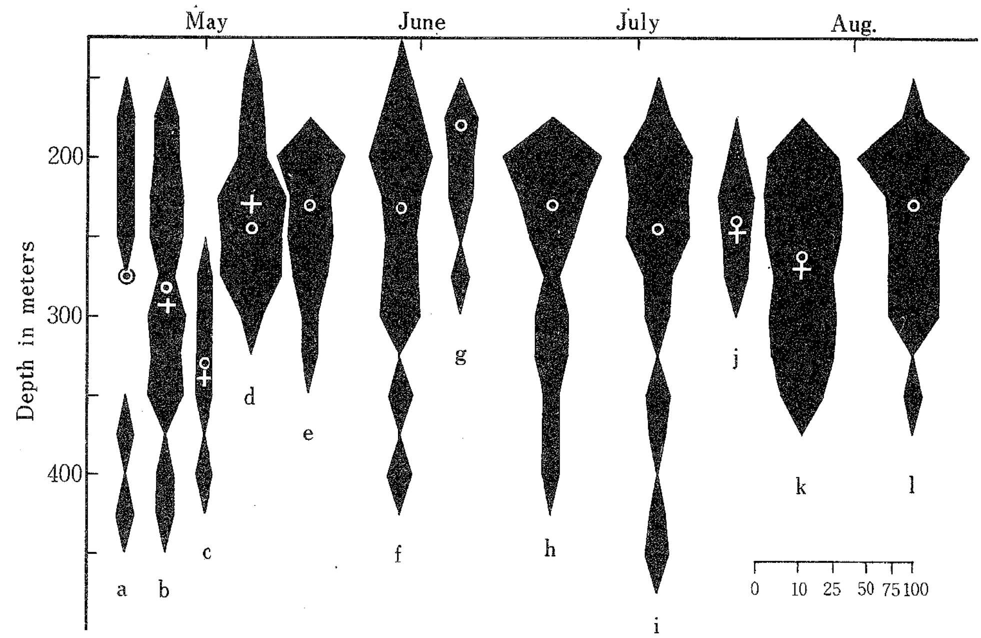


Fig. 4. The change of the bathymetric distribution of the hauls in accordance with the passing of season.

Note: The small letter ..... The season (or the location of the fishing ground) defined in Fig. 1
Spindle ..... The bathymetric distribution of the hauls
Solid circle ..... The average of the depth fished
The sign , + , ... The depth showing the maximum of haul number estimated from the regression equation
The scale shows the frequency of hauls

examined. All the examples showing no significant quadratic regression did not show any significant linear regression, too, except in one of them. There were no examples showing a tendency of increase of the number of hauls in accordance with the difference of the depth from an intermediate zone. All the examples by the trawler K did not show any significant quadratic regression of the number of hauls on the depth fished. These examples were on the winter months. But there were no records of the other trawlers fishing the Pacific Ocean perch in winter, and there were no records of this boat fishing it in the other seasons. These facts made it hard to tell whether the insignificant quadratic regression was one of the characteristics of this boat observable throughout the seasons or this was the characteristic of the work pattern in winter. The significant quadratic regression could be found in the four consecutive examples in May by the trawler I. But it was hard to regard that this was one of the characteristics of the work pattern in this month, because the example in this month by the trawler F did not show the similar relation. The significant quadratic regression could be found in the three consecutive examples by the trawler F in the summer season and in two of the examples by the trawler I in the same season. Any other trend could not be found in the distribution of the examples showing the significant quadratic regression. These facts made it hard to interprete the above-mentioned results.

The change of the bathymetric distribution of the hauls in accordance with the passing of season was shown in Fig. 4. The clearest trend found in this figure was a large variation of the depth of the hauls within the same examples.

It is a well-known fact that most of the groundfishes show a seasonal change in the bathymetric distribution. But, in the present case, this figure did not show any clear symptoms suggesting the phenomenon like this, although a clear concentration of the hauls in the 350m zone observable in the example K-a and that in the 300m zone in the example K-d suggested a possibility of the Pacific Ocean perch concentrated into a narrow depth zone in winter. The difficulty in finding out a clear seasonal bathymetric change of distribution may partly be due to the fact that the boat shifted her fishing grounds pursuing the seasonal migration of the objective fish, and this figure did not show the distribution of the fish within a ground. And the seasonal migration may be found in the shift of the location of the fishing ground shown in Fig. 1. But the following fact should be kept in mind: The migration of the objective fish is not the exclusive factor determining the shift of the fishing ground, but the influence of the heavy weather and the shift of the ice limit should be taken into consideration.

But, before the above-mentioned results being regarded as the fact that the Pacific Ocean perch did not show any clear bathymetric difference of the density within the zones examined, the uncertainty of the results due to the following possibilities should be swept out: The Pacific Ocean perch is one of the roundfishes fed on the planktonic crustaceans and the small fish. And the swimming layer of the Pacific Ocean perch is not strictly restricted within a layer very close to the sea bed. But it is probable that, as shown in the description of the echogram, that this fish shows a daily rhythmic change in its swimming layer and in its distribution pattern. The difficulty in finding out a significant quadratic regression of the number of hauls on the depth fished and a large bathymetric variation of the hauls within the same examples suggest the necessity of the examination on the relation to these factors. The results of the examinations taking the daily rhythmic change into consideration will be shown in the succeeding report.

The relation between the type of echogram and the amount of catch per haul

Another probable factor making complicated the interpretation of the results is the different distribution pattern of the schools according to the condition. There is much theoretical difficulty of forecasting the amount of catch per haul through the echogram. But the classification of the hauls according to the type of the skipper's description on the echogram may be available for the examination as one of the rough indicators of the distribution pattern of the objective fish, because it is probable that the schools showing different type of echogram may be different from one another in some of the respects.

Table 4. The homogeneity test of the echogram types in respect of the amount of catch per haul.

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

1) In the stratum F-g

	Type of the echogram				
	(t_c)	(s_c)	(i_f)	(t_f)	(T_c)
Catch class (in tons) 0		1	2	1	5
5	32	4	10	2	4
10	9	1	1		
15	2				
20	4		1		
Total frequency	47	6	14	3	9
$\overline{\log z}$	0.828	0.633	0.664	0.466	0.311
$\bar{z}$	6.73	4.29	4.61	2.92	2.05

$F_0=8.13^{**}$ $F^4_{70}(0.05)=2.49$ $F^4_{70}(0.01)=3.43$

2) In the stratum K-d

	Type of the echogram								
	(b_c)	(i_c)	(t_c)	(s_c)	(i_f)	(t_f)	(s_f)	(T_f)	(n_r)
Catch class (in tons) 0	5	1			34	30	1	9	10
5	5	2	3		24	19	1	14	
10	4	1			1	1	1	11	
15	1	1	1	2				4	
20	1							6	
25								3	
30	1								
40	1							2	
Total frequency	18	5	4	2	59	50	3	49	10
$\overline{\log z}$	0.725	0.715	0.818	1.176	0.301	0.286	0.566	0.833	
$\bar{z}$	5.31	5.19	6.58	15.00	2.00	1.93	3.68	6.80	0

$F_0=11.62^{**}$ $F^8_{150}(0.05)=1.90$ $F^8_{150}(0.01)=2.57$

b) The summarized results of the tests

Trawler-Fishing ground	F_0	$i-1$	$N-i$
F − b	7.727**	7	177
c	4.587	2	3
d	2.112	2	13
e	3.032*	4	50
f	1.336	4	2
g	8.133**	4	74
K − a	10.739**	4	56
b	1.455	2	1
c	1.505	4	4
d	11.622**	8	191
I_1 − b	9.275**	5	12
c	0.404	1	3
d	1.225	2	36
e	2.212	7	20
f	1.780	6	28
g	1.428	2	4
h	2.301*	8	62
i	7.242**	8	48
j	9.208	4	1
k	5.155**	9	99
l	5.275**	6	79
I_2 − c	6.871**	3	19
d	3.876**	9	191
e	14.667**	4	78

Note: The four 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 ...... With (i-1) and (N-i) degrees of freedom

And it is hard to deny the necessity of the examination on the catch records after the stratification according to the type of echogram, because of the following reason: The echogram is one of the most powerful bases for the skipper's decision of the detailes of the work pattern. The information on this problem may provide us with some clues to evaluate whether the skipper interpreted the echogram precisely or not. And the results may be useful as a field guidance to the skippers, although there is much doubt in the true meaning of the difference of the echogram type.

The results of the test on the homogeneity of the echogram types in respect of the catch per haul are shown in Table 4. The significant difference of the amount of catch per haul according to the echogram type could be found in the 13 examples out of the 24 ones examined. And it may be said that the amount of catch per haul from the trace contacting with the bottom echo was better than that from the trace not contacting with it and that from the dense trace was better than that from the thin one. In the 11 examples of the rest, the difference of the echogram type did not show any significant difference of the catch per haul, probably because of the insufficient variety of the echogram type and the small size of samples.

The bathymetric distribution of the amount of catch per haul observable among the hauls for the schools showing the echogram of respective types

As stated above, the catch per haul differed according to the type of the echogram. It is probable that the echogram from the schools in the same distribution pattern through the same echo sounder more or less differs in accordance with the recording depth. But it is hard to examine the difference like this through the catch records used here. The only and one possible method of examining the probable difference like this through the catch records is the examination on the bathymetric change of the catch per haul from the schools showing the echogram of the same type, although there remains some uncertainty. And, if any significant depth depending change of the amount of catch per haul could be found, the results should be kept in mind during the scouting. The other reason making it necessary to examine the bathymetric difference like this is as follows: The bathymetric difference of the composition of the schools showing respective types of echogram is one of the factors applicable to represent the bathymetric difference of the distribution pattern of the objective fish. But the meaning of the results of the examination on the bathymetric difference of the echogram type composition, from the practical point of view as well as from the theoretical point of view, differs according as the amount of catch per haul from the schools showing the same type of echogram shows any significant regression on the depth or the depth depending difference of the amount of catch per haul within the same type of echogram is larger than the difference according to the echogram type.

Table 5. The estimated quadratic regression equations and the linear ones of the amount of catch per haul on the depth fished, by trawler, fishing ground, and 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	−14.218	12.085	−2.363	4.33	3.86	−0.630	0.691	5.03*	16
	t_c	−2.581	2.571	−0.512	4.46	5.05*				77
	i_f	3.927	−2.572	0.502	1.01	1.08	0.481	0.078	0.21	48
e	t_c	6.876	−4.201	0.735	1.34	1.52	0.133	0.265	2.01	31
g	t_c	−1.353	1.393	−0.218	3.20	2.89	0.587	0.075	1.33	47
K − a	b_c	18.176	−10.884	1.700	3.30	3.22	1.334	−0.130	0.40	31
d	i_f	0.234	0.191	−0.058	0.01	0.02	0.748	−0.156	0.96	59
I_1 − d	t_c	6.034	−3.974	0.716	0.65	0.54	1.462	−0.339	3.44	23
f	t_c	2.377	−1.738	0.392	1.67	1.90	0.153	0.118	1.57	18
i	b_c	−4.037	4.259	−0.893	5.59	5.14*				31
	s_c	6.660	−5.857	1.409	1.62	1.77	0.113	0.250	0.93	12
k	t_c	2.166	−1.051	0.187	1.05	0.98	0.828	−0.040	0.20	39
I_2 − c	t_c	−1.863	1.968	−0.367	3.52	3.29	0.543	0.070	1.00	20
d	t_c	2.487	−1.720	0.402	0.93	1.02	0.491	0.080	0.79	51
	s_c	−7.649	7.915	−1.870	2.87	2.75	0.326	0.179	0.71	22
	i_f	0.062	0.618	−0.166	0.26	0.42	0.964	−0.160	4.68*	61
	t_f	1.079	−0.445	0.696	0.02	0.01	0.612	−0.921	0.25	30
e	t_c	−1.118	1.267	−0.216	0.16	0.17	0.786	−0.020	0.02	36
	n_r	52.881	−33.420	5.334	12.69	12.96**				35

Note: The note is the same to that of Table 2. And the abbreviation of the echogram type is shown in the supplementary table.

The regressive relation of the amount of catch per haul on the depth fished was examined, after the stratification of the records by the trawlers and the fishing grounds according to the echogram type. The results shown in Table 5 and Fig. 5 revealed the following fact: Among the 31 strata of the records examined (here, the strata having not more than ten records were excluded from the examination), the amount of catch per haul in the 24 strata showed neither any significant quadratic regression nor any significant

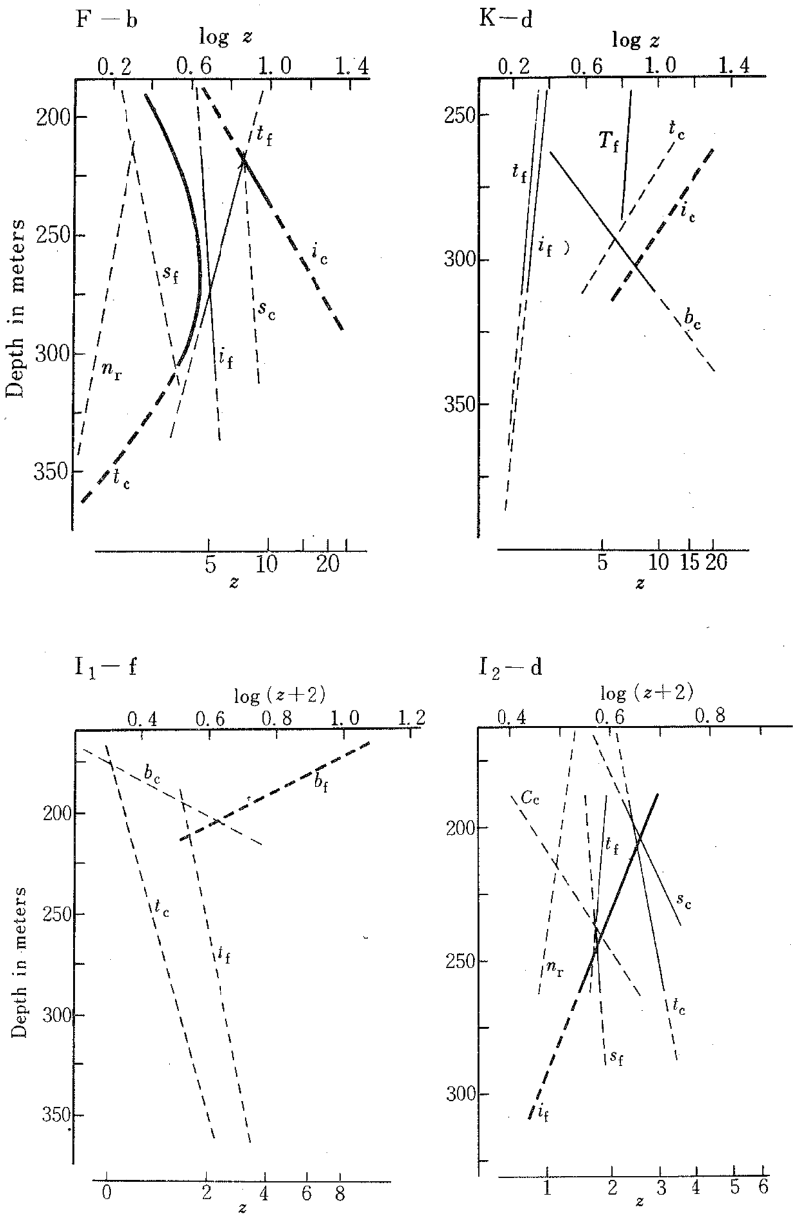


Fig. 5. The bathymetric change of the amount of catch per haul for the schools showing respective types of echogram, by trawler and fishing ground.

Note: The note is the same to that of Fig. 2 b). The abbreviation of the echogram type is shown in the supplementary table.

linear one on the depth fished. The catch in one of the strata (F-e, type t_c) showed a significant quadratic regression on the depth with the maximum catch at the 275m zone, but the trend within the range of the depth zones having the records of more than five hauls did not differ from those in the strata showing insignificant regression. And a significant linear regression on the depth could be found in the six strata. But some strata showed the increasing trend while the others showed the decreasing one in accordance with the depth. And their distribution was restricted neither within one or two trawlers, nor within a few of months, nor within a few of the echogram types. Namely, it was less probable that the amount of catch per haul from the schools showing the same type of echogram differed significantly in accordance with the depth fished.

The seasonal and bathymetric difference of the composition of the echogram type

The clearest trend found in Fig. 5 was the difference of the echogram types in respect of the amount of catch per haul and in respect of their bathymetric distribution. This fact suggested that the bathymetric difference of the distribution of the objective fish should be observable in the catch records of the present case through the echogram type, although this could not be found through the amount of catch per haul and the number of hauls.

The homogeneity of the depth zones in respect of the composition of the echogram types was examined through the chi square test (through the test on $m \times n$ table). As shown in Table 6 and Fig. 6, the composition of the echogram types significantly differed in accordance with the depth in all the set of the catch records by respective trawlers. The types of echogram responsible for the significant difference in the composition were the tower trace rising from the bottom echo (T_c, observed more frequently in the shallow ground than expected) in the trawler F, the tower trace not contacting with the bottom echo (T_f, more frequently in the shallow ground) in the trawler K, the black trace contacting with the bottom echo (b_c, more frequently in the shallow ground) in the first trip of the trawler I, and the spotted trace not contacting with the bottom echo(s_f, more frequently in the ground of an intermediate depth) in the second trip.

The examination of the difference of the composition of the echogram type according to the fishing ground (or season) revealed the following facts: The composition of the echogram types significantly differed in accordance with the fishing ground (or season). The types responsible for the significant difference were the trace of intermediate density contacting with the bottom echo (i_c, less frequently in the ground d–June 27 to July 10) and the tower trace rising from the bottom echo (T_c, more frequently in the ground g–Aug. 13 to Sept. 1) in the trawler F, both the black trace and the trace of intermediate density contacting with the bottom echo (b_c and i_c, more frequently in the ground a–Oct. 18 to Nov. 30) in the trawler K, the echogram of the former type (b_c, more frequently in the ground i–June 30 to July 17) in the first trip of the trawler I, and the thin trace contacting with the bottom echo (t_c, more frequently in the ground c—May 24 to June 6) in the second trip.

Because the composition of the echogram types differed according to the fishing ground (or the season), the bathymetric difference of the composition was examined again, after the stratification of the records by respective trawlers according to the fishing ground (or season) shown in Fig. 1. The results revealed the following facts: In the records by the trawler F, the significant bathymetric difference of the composition of echogram types could not be found in the ground b (May 18 to June 13) and in the ground d

Table 6. The homogeneity test on the depth zones or fishing grounds in respect of the composition of the echogram types observed therein.

a) The homogeneity of the depth zones

Trawler	Type of the echogram	m	n	χ^2_0	Prob.
F	i_c t_c i_f t_f s_c s_f [T_c]	6	7	115.91**	<0.005
K	b_c i_c i_f t_f [T_f] n_r	5	6	144.99**	<0.005
I_1	[b_c] t_c b_f i_f t_f s_c	5	6	84.91**	<0.005
I_2	t_c i_f t_f s_c [s_f]	5	5	88.95**	<0.005

b) The homogeneity of the fishing grounds (or seasons)

Trawler	Type of the echogram	g	n	χ^2_0	Prob.
F	[i_c] t_c i_f t_f s_c s_f [T_c]	4	7	119.16**	<0.005
K	[b_c][i_c] i_f t_f T_f n_r	3	6	125.07**	<0.005
I_1	[b_c] t_c b_f i_f i_f s_c	8	6	160.76**	<0.005
I_2	[t_c] i_f t_f s_c s_f	3	5	71.28**	<0.005

c) The homogeneity of the depth zones, after the stratification of the records according to the location of the fishing ground (or season)

Trawler-Fishing ground	Type of the echogram	m	n	χ^2_0	Prob.
F – b	i_c t_c i_f t_f s_f	6	5	17.80	0.75–0.50
d	i_c t_c	5	2	2.64	0.75–0.50
e	t_c [i_f] t_f	4	3	18.55**	0.01–0.005
g	t_c i_f [T_c]	6	3	33.71**	<0.005
K – a	b_c i_c i_f t_f	4	4	16.90	0.10–0.05
d	b_c i_c i_f t_f [T_f] n_r	5	6	77.86**	<0.005
I_1 – b	t_c i_f	4	2	5.76	0.25–0.10
d	t_c i_f	3	2	1.26	0.75–0.50
e	b_c i_c [i_c]	3	3	10.85*	0.05–0.025
f	b_c t_c b_f i_f t_f	6	5	17.89	0.75–0.50
h	b_c t_c b_f i_f t_f s_c	5	6	34.36*	0.025–0.01
i	b_c s_c	4	2	3.35	0.50–0.25
k	[b_c] t_c i_f t_f C_c	5	5	63.60**	<0.005
l	b_c [t_c] b_f i_f t_f	5	5	53.59**	<0.005
I_2 – d	t_c i_f t_f s_c [s_f] C_c	4	6	40.80**	<0.005
e	t_c t_f s_c	4	3	3.83	0.75–0.50

Note: The echogram types in the square brackets are those responsible for causing the significant (at 0.05 level) dishomogeneity.

m .... The number of depth zones

n .... The number of the echogram types observed

g .... The number of fishing ground (or season)

chi square .... With (m-1) (n-1) or (g-1) (n-1) degrees of freedom

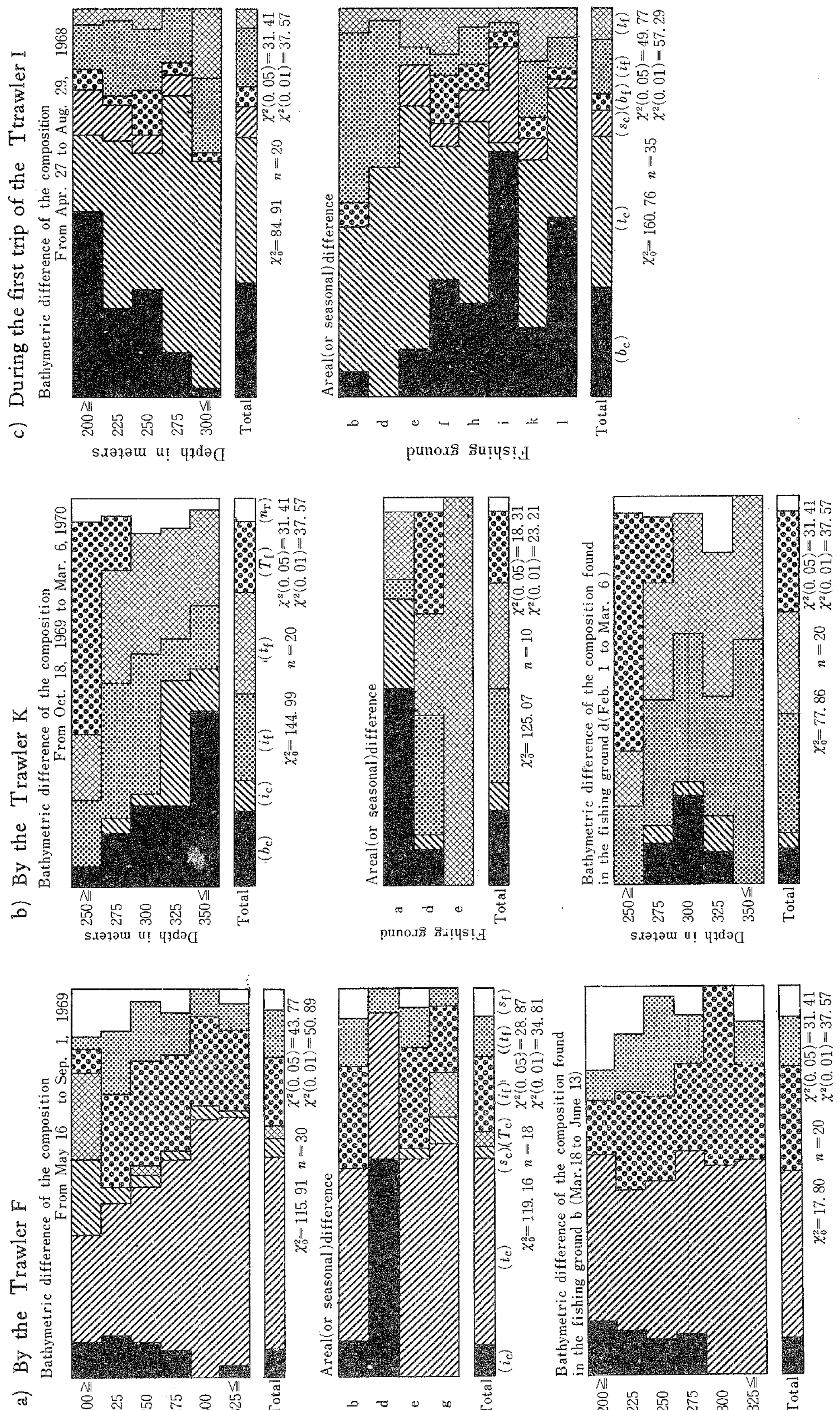


Fig. 6. The compositions of the echogram type observed.

(June 27 to July 10). But the significant difference was observable in the ground e (July 11 to Aug. 12) and in the ground g (Aug. 13 to Sept. 1), probably because of the frequent occurrence of the trace of intermediate density not contacting with the bottom echo (i_f) in the shallow zone of the ground e and that of the tower trace rising from the bottom echo (T_c) in the shallow zone of the ground g. In the records by the trawler K, the significant bathymetric difference of the echogram type composition could not seen in the autumnal season (Oct. 18 to Nov. 30). But this was observable in the winter season (Feb. 1 to 13) probably because of the frequent occurrence of the tower trace not contacting with the bottom echo (T_f) in the shallow zone. In the records by the first trip of the trawler I, the bathymetric difference of the composition could be found in the ground e (May 18 to 28, frequent occurrence of the thin trace contacting with the bottom echo–t_c–in the deep zone), the ground h (June 15 to 30, the responsible type being not certain), the ground k (July 18 to Aug. 17, the frequent occurrence of the black trace contacting with the bottom echo–b_c–in the shallow zone), and the ground l (Aug. 6 to 18, the less frequent occurrence of the thin trace contacting with the bottom echo–t_c–in the shallow zone). And in the second trip of this boat, the significant bathymetric difference in the composition could be found in the ground d (June 7 to July 11, the frequent occurrence of the spotted trace not contacting with the bottom echo–s_f–in the deep zone).

These results meant that the types of echogram responsible for either the significant bathymetric or the significant areal (or seasonal) difference of the composition were chiefly the black trace including the tower one and the trace contacting with the bottom echo. And they frequently occurred in the shallow grounds and in the late summer. These facts meant, from the biological point of view, that the concentration of the Pacific Ocean perch was frequently found in the shallow ground in the late summer, if the density of echogram has any close relation to the density of the fish. And, from the practical point of view, the trace with high possibility of a good catch showed the significant bathymetric and areal (or seasonal) difference of the relative occurrence.

The bathymetric change of the number of hauls for the schools showing respective types of echogram

The amount of catch per haul, either before or after the stratification of the records according to the type of the echogram, did not show any clear bathymetric difference. The same could be said to the number of hauls, in spite of the fact that the bathymetric difference of the distribution is well-known to the groundfishes. But the amount of catch per haul differed according to the type of echogram, and the composition of echogram type showed a bathymetric difference. These facts suggested the necessity of the examination of the bathymetric change of the number of schools showing respective type of echogram, i.e. that of the number of hauls. The examination like this may provide us with a semi-quantitative information on how to make it possible to find the bathymetric difference of the distribution of the fish through the catch records of the trawling fully supported by the echo sounder. This was examined through the test on the significance of the quadratic regression.

Table 7. The estimation and the significance test of the quadratic depth regression and the linear one of the number of hauls for the schools showing respective types of echogram. (I. The records in all the fishing grounds being pooled)

Trawler	Echogram type	a_0	a_1	a_2	$F_{2\cdot1}$	$F_{2\cdot2}$	b_0	b_1	$F_{1\cdot1}$	n
F	i_c	− 34.437	30.115	− 5.644	14.32	15.54*				8
	t_c	− 168.100	138.173	−24.182	231.35	237.12**				10
	s_c	− 9.533	10.509	− 2.253	0.48	0.62	5.250	− 1.356	1.16	7
	T_c	− 10.971	11.187	− 2.220	0.86	0.97	3.071	− 0.629	0.29	6
	i_f	− 10.188	14.159	− 2.573	1.32	2.01	16.360	− 3.150	3.14	13
	t_f	− 35.124	30.330	− 5.462	5.64	6.16*				9
	s_f	− 18.746	17.803	− 3.475	2.49	2.93	6.185	− 1.401	1.25	8
	n_r	− 11.003	8.519	− 1.478	10.42	10.65*				6
K	b_c	− 92.066	65.357	−10.381	1.66	1.40	− 9.667	5.667	1.56	8
	i_c	− 155.714	101.829	−16.000	2.39	2.32	− 2.381	1.829	0.17	6
	t_c	− 40.273	32.675	− 6.234	19.74	19.70*				5
	i_f	− 137.994	102.357	−17.238	3.47	3.87	24.690	− 5.381	1.02	8
	t_f	− 99.642	74.036	−12.121	10.41	11.01*				10
	T_f	−1300.950	1020.600	−196.000	2.97	3.03	34.300	− 8.400	0.06	4
	n_r	− 24.070	19.448	− 3.463	19.73	19.13**				9
I_1	b_c	− 157.839	164.927	−36.857	1.49	1.70	37.964	−10.143	0.46	8
	i_c	− 17.357	18.143	− 4.000	0.41	0.50	6.476	− 1.857	0.84	6
	t_c	− 63.019	63.956	−11.972	17.17	18.61**				13
	s_c	− 63.833	64.714	−14.667	2.88	3.02	6.750	− 1.286	0.09	7
	C_c	− 39.112	32.082	− 6.041	3.35	3.61	4.810	− 1.143	0.54	6
	b_f	− 22.500	22.762	− 4.952	3.33	3.60	3.810	− 0.762	0.24	8
	i_f	− 34.105	35.839	− 7.291	10.58	11.16*				11
	t_f	− 33.591	28.048	− 5.039	3.04	3.00	2.417	0.333	0.03	9
	n_r	− 8.540	8.168	− 1.341	9.58	9.58*				11
I_2	t_c	− 39.660	44.955	− 9.150	13.07	12.58**				11
	s_c	− 28.901	28.568	− 6.122	5.74	6.05	3.596	− 0.616	0.15	7
	C_c	− 66.114	61.714	−13.714	22.40	22.50*				5
	i_f	− 89.929	88.905	−19.238	1.90	2.24	25.500	− 7.286	1.37	7
	t_f	− 47.835	46.551	− 9.499	1.67	1.94	14.500	− 3.479	1.05	7
	s_f	− 67.407	60.957	−12.857	1.91	1.94	2.771	− 0.114	0.01	6
	n_r	− 36.605	30.839	− 5.394	1.45	1.24	− 2.218	2.521	0.66	10

Note: The note is the same to that of Table 3. The abbreviation of the echogram type is shown in the supplementary table.

The results, before the stratification of the records into the fishing ground (or season) groups, showed the following facts: Among the 31 trawler-echogram strata examined, the significant quadratic regression showing a maximum at an intermediate depth could be found in the 12 strata, the four being in the records of the trawler F, three in the records of the trawler K, the same number in the first trip of the trawler I, and the two in the second trip of the trawler I. And the significant linear regression could not be found in all the strata showing no significant quadratic regression. The frequency of the hauls for the thin trace contacting with the bottom echo showed a significant quadratic regression on the depth in the records of all of the four trawlers. The frequency of the hauls for the schools showing no reflection showed the significant one in the records of the three

a) The relation in two of the trawler-echogram strata, with the frequencies observed

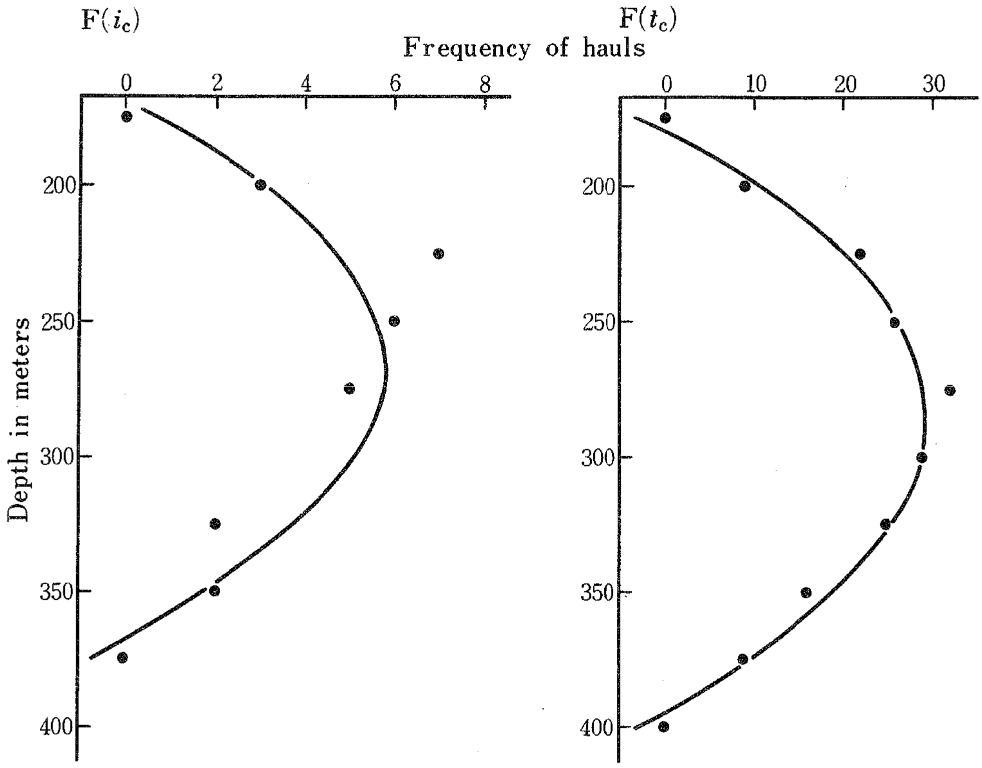


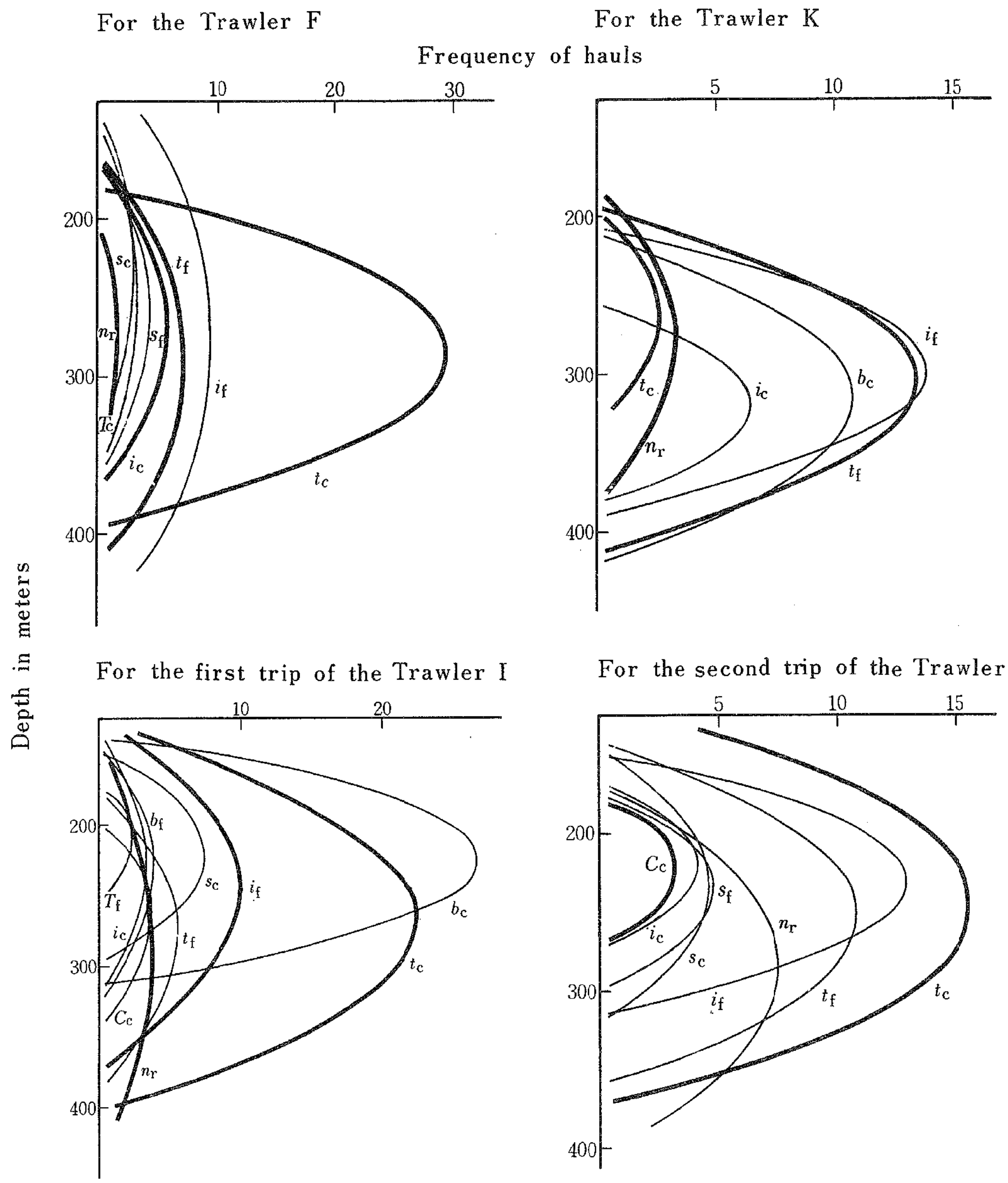
Fig. 7. The bathymetric changes of the frequency of the hauls for the schools showing respective types of echogram.

Note: The note is the same to that of Fig. 3. The abbreviation of the echogram type is shown in the supplementary table.

trawlers out of the four strata examined. But the type of echograms in the five strata of the rest showing a significant quadratic regression differed from one another. And it was hard to find any trend common to them in respect of either the density of the echogram or the relation to the bottom echo.

The disparity of the results due to the areal (or seasonal) difference should be excluded from the above-mentioned results of the bathymetric difference, because the preceding step of the examinations found out the significant areal (or seasonal) difference of the composition of the echogram type. But most of the trawler-ground strata were not suitable for this purpose, because of the small sample size, or the concentration of the hauls into a few of the echogram types, or the concentration into a few of the depth zones. And the records in the following four trawler-ground strata were applicable to this step of examination: The stratum by the trawler F in the ground b, that by the trawler K in the ground d, that by the first trip of the trawler I in the ground k, and that by the second trip in the season d. The significant quadratic regression could be found in all the types of the echogram in the stratum F-b, except the spotted trace not contacting with the bottom

b) The regression curves by respective trawlers



echo (s_f), the school without reflection (n_r) in the stratum K-d, and the thin trace contacting with the bottom echo (t_c) in the stratum I_1–k. And in all the other traces, neither significant quadratic regression nor significant linear one could be found out.

In the stratum F-b, the frequency of the hauls for the schools showing respective types of echogram showed a clear bathymetric difference. But the estimated depth showing a maximum frequency was the same in all the echogram types except both the spotted trace and the trace of an intermediate density contacting with the bottom echo, which were a little shallower than the others. But it was hard to regard that the clear bathymetric difference of the number of hauls for respective types of echograms was the characteristic

Table 8. The estimation and the significance test of the quadratic depth regression and the linear one of the number of hauls for the schools showing respective types of echogram. (II. After the stratification of the records according to the fishing ground)

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	−70.157	62.886	−13.143	19.48	19.31*				6
	t_c	−101.570	88.781	−16.797	10.33	11.30*				9
	s_c	−27.000	22.857	−4.571	39.86	40.00*				5
	i_f	−98.750	84.952	−16.381	14.93	15.44*				8
	t_f	−55.628	47.785	−9.205	11.61	12.13*				7
	s_f	−16.137	14.924	−2.854	1.69	1.94	2.000	−0.001	0.01	7
	n_r	−11.003	8.519	−1.478	10.42	10.65*				6
K − d	b_c	−261.857	182.343	−30.857	4.16	4.30	12.000	−2.800	0.19	5
	i_c	−57.457	40.343	−6.857	1.63	1.70	3.400	−0.800	0.21	5
	i_f	−124.720	93.643	−15.905	2.74	3.11	25.381	−5.762	1.21	8
	t_f	−195.429	143.286	−24.571	4.21	4.48	19.571	−4.143	0.40	7
	T_f	−1300.950	1020.600	−196.000	2.97	3.03	34.300	−8.400	0.06	4
	n_r	−62.343	45.771	−8.000	14.21	14.41*				6
I_1 − k	b_c	−283.400	273.600	−64.000	8.97	8.89	0.600	1.600	0.02	4
	t_c	−55.991	46.505	−8.468	17.18	17.42**				9
	s_c	−21.771	20.571	−4.571	0.62	0.63	0.800	−0.000	0.00	5
	C_c	−17.786	15.000	−2.857	1.05	1.15	3.107	−0.714	0.37	7
	b_f	−68.300	67.200	−16.000	2.16	2.22	2.700	−0.800	0.07	4
	i_f	−11.121	10.876	−2.147	0.95	1.13	4.122	−0.933	0.65	9
	t_f	−75.014	52.871	−8.857	2.78	2.59	−3.419	1.943	0.67	6
	n_r	−20.751	14.286	−2.286	0.59	0.55	−0.571	0.571	0.20	7
I_2 − d	t_c	−134.833	135.571	−30.667	4.46	4.67	12.750	−2.429	0.09	7
	s_c	−167.086	175.314	−43.429	2.60	2.56	1.200	1.600	0.03	5
	C_c	−59.771	56.171	−12.571	6.91	7.04	2.300	−0.400	0.03	5
	i_f	−134.214	127.000	−26.857	4.16	4.69	26.929	−7.286	1.06	7
	t_f	−228.543	217.543	−49.143	7.52	7.81	14.100	−3.600	0.15	5
	s_f	−67.407	60.957	−12.857	1.92	1.94	2.771	−0.114	0.01	6
	n_r	−18.886	19.543	−4.571	5.18	5.16	0.924	0.114	0.01	6

Note: The note is the same to that of Table 3.

of the pattern in the early summer. And whether this was the characteristic of the trawler K or not was doubtful.

It is a well-known fact that the groundfishes show a clear bathymetric difference of the distribution. The selective towing with a good assistance of the echo sounder made the bathymetric difference hardly observable in the amount of catch per haul. The number of hauls in the selective towing, which is the frequency of occurrence of the presumably profitable type of echogram, is one of the most probable factors representing the bathymetric difference of the distribution of the objective fish. But the result was contrary to the expectation. And the bathymetric difference was found only in the composition of the hauls in respect of the echogram types. The echogram types differed from one another in respect of the amount of catch per haul and in respect of the bathymetric distribution. But it was hard to find a clear bathymetric difference of the number of hauls for the schools showing respective types of echograms. The large depth variation of the hauls and the large variety of the echogram types observable within the records by a boat in the same ground suggested that the difficulty in finding out a clear result should be due to

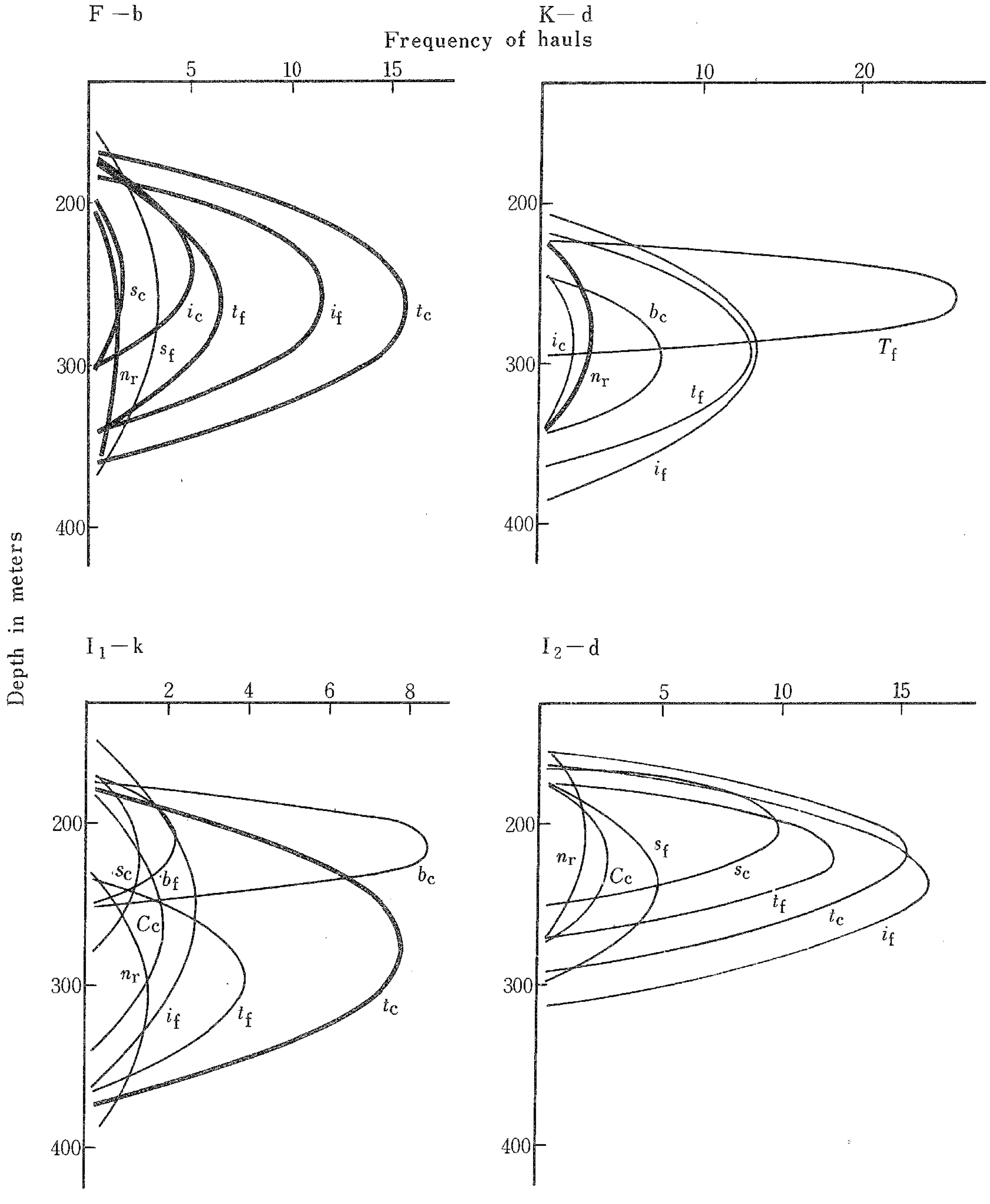


Fig. 8. The difference of the echogram types in respect of the bathymetric change of the frequencies observed.

Note: The letters attached to the curve are the abbreviation of the echogram type shown in the supplementary table.
Thick curve ..... The estimated quadratic regression curve with significant quadratic regression coefficient
Thin curve ..... The estimated quadratic curve with the insignificant regression coefficient

the presence of some other factors having a strong influence on the distribution. One of the most probable factors may be the daily rhythmic change of the behavior of the objective fish, because the Pacific Ocean perch is a roundfish fed on the planktonic animals and living somewhat free from the bottom. And the influence of this factor should be examined in the succeeding report.

The author wishes to express his hearty thanks to Dr. H. MAÉDA, Professor of fishing techniques of our university, for his kind guidance and criticisms given to the author throughout the present work. And the thanks are also due to the hearty cooperation in preparing the records used in the present work given by all the skippers and crew of the trawlers and due to their kindness of offering the author many valuable informations on the work on board.

Supplementary table
The classification of echograms and their abbreviations used in the present report.

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

Many of the characteristics of the echograms from the schools trawled were described in the working reports. They were classified into the above-mentioned 12 types chiefly according to their density and the relation to the bottom echo. But the size and the intensity were not used, chiefly because of their difference according to the recording conditions and partly because of the behavior of the net at catching the fish.

Summary

The recent advances of the technology relating to the fishery caused a basic change in all the fishing methods. The trawling fully supported by the electronic devices is one of the representatives accomplished with the basic change, because the trawling is the fishing method exposed to the severest conditions. In company with the complete change in the details of the working pattern, a basic change was brought into the fact shown by respective items in the working reports. The present series of reports dealt with the working reports of the three stern ramp trawlers fishing exclusively the Pacific Ocean perch during the season of April of 1968 to March of 1970 along the outer edge of the continental shelf of the Gulf of Alaska, with an intention to show the difference of the trends found in them brought by the recent change in the working pattern. And the bathymetric changes

of the amount of catch per haul and the number of hauls in relation to the types of the skipper's descriptions on the echograms were examined in the present report. And the results obtained were summarized as follows:

1. The amount of catch by a haul showed a significant decrease in accordance with the depth difference from an intermediate depth zone in only four of the trawler-ground strata out of the 28 ones examined, in spite of the well-known bathymetric difference of the distribution of all the groundfishes. The difficulty in finding out the significant quadratic depth regression may be due to the selective towing of the gear for the schools showing the echogram of preferable type.

2. The number of hauls, which is thought to show the relative abundance of the objective fish in the selective towing, showed a significant quadratic regression on the depth with maximum in an intermediate depth zone in the 12 trawler-ground strata out of the 28 ones examined. The strata of the rest, except one of them, showed neither significant quadratic regression nor significant linear one on the depth fished.

3. It was hard to find any clear seasonal change of the bathymetric distribution of the fish through the diagram showing the change of the bathymetric distribution of the hauls in accordance with the passing of the season (Fig. 4). This may be, at least partly, due to the fact that the trawlers shifted their fishing grounds pursuing the seasonal migration and the results did not show any change of the distribution within a fishing ground and may partly be due to the daily rhythmic migration.

4. The amount of catch per haul differed significantly in accordance with the echogram type in the 13 trawler-ground strata out of the 24 ones examined. The catch from the dense echo and from the trace contacting with the bottom echo was better than that from the thin echo and from the trace not contacting with the bottom echo. The difficulty in finding out the significant difference may be due to the insufficient variety of the echogram types and the small sample size.

5. Among the 31 groups of the records stratified according to the three factors–the trawler, the fishing ground, and the type of echogram–, the amount of catch per haul in the 24 groups of the records showed neither any significant quadratic regression nor any significant linear one on the depth fished. That in the six groups showed a significant linear regression, but either decreasing or increasing in accordance with the depth differed according to the case.

6. The composition of the echogram type observed showed a significant difference according to the depth zone and the fishing ground (or season). The black trace including the tower trace contacting with the bottom echo was the type responsible for the significant bathymetric and areal (or seasonal) difference of the composition. This was frequently observed in the shallow ground and in the late summer.

7. The frequency of respective types of echograms observed showed a significant quadratic depth regression in the 12 trawler-echogram type strata out of the 31 ones examined. Then, the difference among the echogram types in respect of the depth regression of the frequencies was examined. But it was hard to find any trends common to either respective types of echogram or the records in respective fishing grounds.