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Working Time of Bull Trawlers during Alaska Pollack Fishing—I.*

The Variaton of the Length of Towing Time due to the Difference in the Amount of Catch, the Depth Fished, and the Height of Wind Wave

By

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The Alaska pollack fishery in the Bering Sea as the material of the minced product is one of the newly developed and most important fisheries in Japan. This fishery is conducted by the two types, one being the stern ramp factory trawler and the other being the factory ship type.

The flotilla supplying a factory ship with the material of minced fish consists of the two types of boats using the different fishing methods. They are the Danish seiners and the bull trawlers. And whether the major composition is the Danish seiner or the bull trawler depends not only on the intrinsic difference in the suitability of these fishing methods according to the ground but also on the different work pattern specific to the present case. The other leading factors to choose the major composition of the flotilla include some social factors such as the preference of the commandant and the different fishing method prevalent in the districts furnishing the foothold for the flotilla. The flotilla studied in the preceding and the present series of reports consisted of the 22 Danish seiners and the three pairs of the bull trawlers. The preceding series of the reports[1)-9)] dealt with change of the working time of the Danish seiners in accordance with the following four factors: the amount of catch, the depth fished, the height of wind wave, and the power of main engine of the boats. The six bull trawlers studied here were the same size with the engine of the same power, being 100 gross tons with the engine of 250 Hp. This fact prevented us from examining the relation between the working time and either the size or the power of the boats. In consequence, the present series of reports dealt with the relation between the working time of the bull trawlers and the other three factors.

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The fishing work of the bull trawlers consists of the work of shooting the gear, towing it, hauling up it after towing, and separating the codend from the body of the net and making it fasten alongside the boat. The relation of the time required for the first step of work was not examined in the present series because of the reasons mentioned in the second section of the next paragraph. The towing work succeeds to the shooting work, and its relations to the three factors were shown in the present report.

Material and Method

The materials used in the present series of reports were the complete set of the routine telegrams sent from each of the three pairs of the bull trawlers to the factory ship several times a day throughout the season extending over from April 18 to Sept. 20 of 1964. The telegram for each of the hauls comprized of the following records: the identification number of the pair, the hauling order on the day by the pair, the direction and distance from the factory ship at shooting the gear, the time to start shooting the gear (t_1), the echo-sounded depth just before the shooting work, the time to finish the shooting (t_2), the towing speed and towing direction, the echo-sounded depth just before the finish of towing, the boundary time between the towing and the hauling work (t_3), the direction and distance from the factory ship at the finish of towing, the time at the finish of making fasten the codend (t_4), the amount of catch, the catch composition, remarks if necessary, the temperature of the bottom layer, and the surface conditions.

The boats worked about from dawn to dusk or a little later, but it was very rare that the boats began to shoot the gear after the sunset, because of daily rhythmic change of behavior of the objective fish and the labor contract to maintain the fishermen in good health over the long season. The fishing work by a pair of the boats progressed along the following way: the net was shot from one of the boats (A), and was towed by both of them, then hauled up by one of them, usually by the boat shot the net. The other boat (B) was waiting for the hauling work. The net of the next towing was usually shot from this boat (B). Here a question arose. It was doubtful whether it is necessary to conduct the shooting work at the full speed or at a reduced one. Sometimes, the boat B finished the shooting work a little before the finish of the work of making fasten the codend. And the relation between the length of shooting work and the environmental conditions was not examined in the present series of reports, because of the complicated relation between t_1 of the succeeding haul and t_4. The work pattern of the present case did not differ from the ordinary way of fishing till this step of work. But the specific way of handling the catch in the present case made the work pattern after this step different from that of the ordinary one, for extremely good catch and for convenience of transshipping it to the factory ship. Namely, the bull trawlers employed here were constructed suitable for fishing in the Eastern Sea. The derrick and the work pattern to handle the catch were designed for the fishing in this water, where the catch was far poorer than in the present case. It was, accordingly, hard and dangerous to take inboard the catch of the present case. After hauling up the main body of the net, the codend containing the catch was kept in water and separated from the body of the net, then was made fasten alongside the boat. And when the boat approached to the factory ship, the codends were connected with the cargo wires from the factory ship and were directly taken inboard of the factory ship. The fishing work to complete a haul consists, accordingly, of the shooting step, the towing step, and the hauling step including the work of separating and making fasten the codend. The time required for the shooting work denotes hereafter the time length of the interval between the time to start shooting the net (t_1) and the time to start towing it (t_2). The time for towing work or simply towing time (abbreviated to t_t) indicates the time length of the interval between t_2 and t_3, where t_2 is the time to start towing the net and t_3 is the boundary time between the towing work and the hauling work. The time required for hauling up the net and making fasten the codend or simply the hauling-fastening time (abbreviated to t_h) defines the time length of the interval between t_3 and t_4, where t_4 is the time to finish the work of making fasten the codend. And the time required for completing a haul (abbreviated to t_c) is the sum of the time lengths for these three steps of works, which is the time length of the interval between t_1 and t_4. The present report dealt with the towing time (t_t). In the original records, all the boundary times were measured in minutes. But t_t reckoned were aggregated into the classes of the nearest 10-minute intervals, because the accuracy of the time measuring was taken into account. The frequency distribution of t_t agreed with the Gibrat distribution, as shown in Fig. 1. The value of t_t was used in the present report after the logarithmic transformation.

The amount of catch was recorded in tons, ranging from 0 to 39 tons a haul, although the catch over 10 tons was inclined to be described in the classes of the nearest 5-ton intervals. When the length of the towing time was adjusted according to the amount of catch in the codend estimated from the relation between the towing speed and the towing power or from the vibration or the included angle of the warps, the amount of catch by largely variating t_t was similar to one another. When the length of the towing time was assigned by the skipper basing on the results of the preceding towings, t_t depends on the amount of catch by the preceding haul. The relation between t_t and the amount of catch either by that haul or by the preceding one was examined in the present report, for the purpose of finding out either of these possibilities.

The flotilla fished mainly aiming at the Alaska pollack in the southern parts of the continental shelf in the eastern half of the Bering Sea. The objective fish distributes to the zone as deep as 500 m. And the stern ramp factory trawler working for the same purpose fishes mainly in the zone from 200 m to 400 m deep; but the flotilla studied here fished in the zone from 40 m to 150 m deep, because of the legal restriction. The depth fished was measured with the echo-sounder twice a towing, just before shooting the net and just before the finish of towing. In most of the towings, the echo-sounded depth just before shooting the net was aggregated into the classes of the nearest 10-m intervals and used in the examinations, because the pair of the echo-sounded depths took the similar value each other, the difference being mainly within 20 m. But there were some hauls showing a depth difference of over 20 m; in these towings, the average of the pair of the echo-sounded depths was adopted.

The height of the wind wave was recorded in the grade number according to the standard settled by the Japanese Meteorological Agency. This is the standard most commonly used by Japanese fleets. It is difficult to measure the height of wave without any special device. But the height of wind wave has a close relation to the aspect of sea surface. The standard table has the description of how to determine the grade of wind wave from the aspect of sea surface. The grade was determined basing on this table. Respective grades correspond to the following range of wave height: grade 1 = 0 to 0.5 m, grade 2 = 0.5 to 1 m, grade 3 = 1 to 2 m, grade 4 = 2 to 3 m, grade 5 = 3 to 4 m, grade 6 = 4 to 6 m, grade 7 = 6 to 9 m, grade 8 = 9 to 14 m, and grade 9 = over 14 m. As above-mentioned, respective grades cover unequal range of wave height; and the grade number could not be dealt with as one of the independent variables.

As the present report dealt with the regression of the length of towing time (t_t) on the amount of catch (x in tons) and the depth (y in 10 meters) after the stratification of the records according to the grade of wind wave, the constant and the coefficient of the regression equations were expressed as follows:

a_{iw} ..... those of the multiple linear regression equations of $\log t_t$ on x and y observable among the hauls conducted under the wind wave of the grade w. The notation of the first suffix, i, was as follows:

$$\log t_t = a_{0w} = a_{1w} x + a_{2w} y$$

b_{iyw} ..... those of the linear regression equations of $\log t_t$ on x observable among the hauls from the $10y$ m zone under the wind wave of the grade w. The notation of the first suffix, i, was as follows:

$$\log t_t = b_{0yw'} + b_{1yw}\, x$$

c_{ixw} ..... those of the linear regression equations of $\log t_t$ on y observable among the hauls yielding a catch of x tons under the wind wave of the grade w. The notation of the first suffix, i, was as follows:

$$\log t_t = c_{0xw} + c_{1xw}\, y$$

Those on the amount of catch by the haul were represented without dush, but those on the amount of catch by the preceding haul were with dush. The suffix left intact denotes either the constant or the coefficient of the equations for indefinite strata in respect of the factor defined by it.

1. The type of frequency distribution of towing time

The fishing work of the bull trawler of the present case consists of the following steps: the shooting step, the towing one, and the hauling one including the work to separate the codend from the net body and to make fasten the codend alongside the boat. The length of the towing time differs basically from that of the other steps, and is determined mainly by the skipper's preference, and the influence of the environmental conditions including the amount of catch may be indirect—through the different preference by the skipper according to the conditions. In addition, the special conditions of the present case restricted the boat from the free preference: the boats could not haul up the codend on their deck, and the codend was hauled up directly on the factory ship. The boats had to finish the towing, accordingly, near the factory ship at regular intervals—every two or three towings. The flotilla consisted of the three pairs of the bull trawlers and the 22 Danish seiners; all the boats fished around the

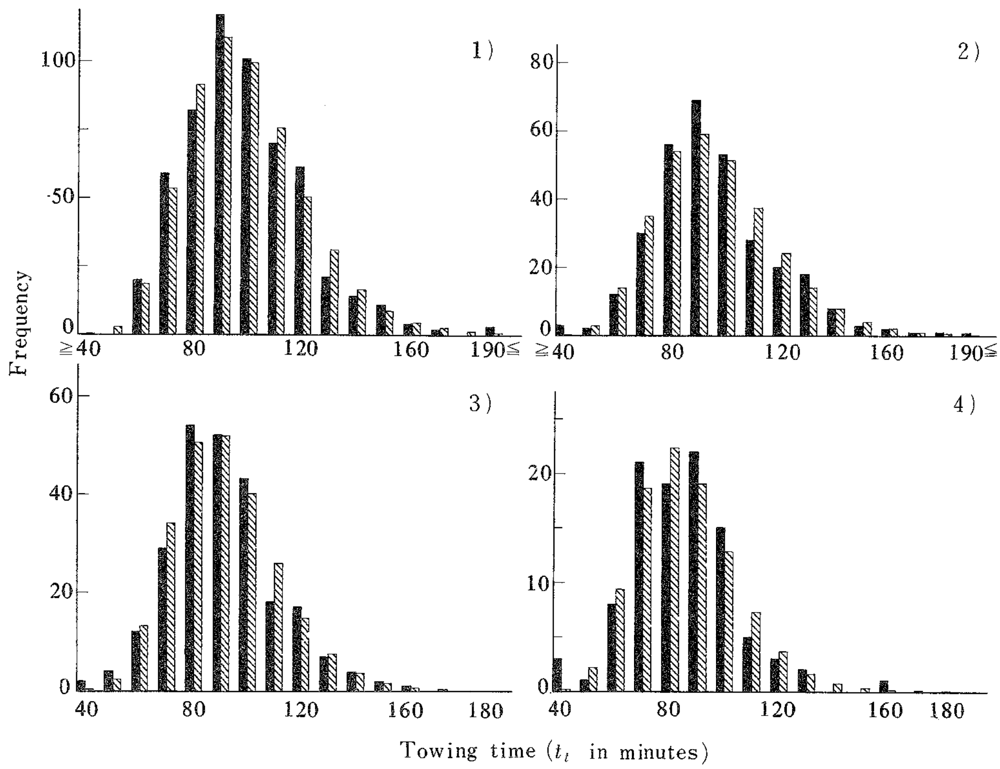


Fig. 1. The frequency distributions of the length of towing time.

Note: The length of towing time (t_t) was aggregated into the classes of the nearest 10-min. intervals. The solid histogram shows the observed series; and the hatched one shows the estimated Gibrat (logarithmic normal) series.

1) Under the wind wave of the grade 3 $\chi_0^2 = 8.86$ with 8 degrees of freedom ($0.50 > Pr\{\chi_0^2 > \chi^2\} > 0.25$)

2) Under the wind wave of the grade 5 $\chi_0^2 = 7.19$ with 8 degrees of freedom ($0.75 > Pr\{\chi_0^2 > \chi^2\} > 0.50$)

3) Under the wind wave of the grade 6 $\chi_0^2 = 4.53$ with 6 degrees of freedom ($0.75 > Pr\{\chi_0^2 > \chi^2\} > 0.50$)

4) Under the wind wave of the grade 7 $\chi_0^2 = 2.41$ with 4 degrees of freedom ($0.75 > Pr\{\chi_0^2 > \chi^2\} > 0.50$)

factory ship. And the bull trawlers had to choose their towing course and distance paying attention to the distribution and movement of all the fellow boats. These facts raised a doubt whether it is possible to find some relations between the length of towing time and the working conditions.

As the preliminary step of the examinations, the records were stratified according to the grade of wind wave, and the type of the frequency distribution of the length of towing time was examined. The observed frequencies showed a simple form with a tailing in the direction of the class of long towing. This fact suggested a possibility of the observed distribution agreeable to some theoretical ones and of the presence of some relations between the length of towing time and the working conditions, despite of the presumable difficulty in finding out it because of its basic nature. And it was found out that the observed distribution fit the Gibrat (logarithmic normal) distribution as shown in Fig. 1. In the further examinations, accordingly, the value of t_t was used after the logarithmic transformation.

2. The multiple linear regression on the amount of catch and the depth fished

For the purpose of finding out the outline of the change of t_t in accordance with the three factors—the amount of catch, the depth fished, and the height of wind wave—, the multiple linear regression of $\log t_t$ on the former two factors was examined after the stratification of the records according to the last one, and the following trends were found out (Tables 1 and 2):

1) The length of towing time increased in accordance with the depth, in all the wave grades except in the both extreme ones.

2) The towing time for the hauls of better catch inclined to be longer, in all the wave grades including the calm water but excluding the rough sea.

Table 1 The multiple linear regression equations of the towing time (t_t in min.) on the amount of catch (x in tons) and the depth fished (y in m) under the wind wave of respective grades (w).

$$\log t_t = a_{0w} + a_{1w}x + a_{2w}y$$

Grade of wind wave (w)	a_{0w}	a_{1w}	a_{2w}	F_x	F_y	n_2
1	1.8037	0.0076	0.0008	19.82**	2.59	64
2	1.6957	0.0038	0.0022	14.28**	198.28**	366
3	1.7597	0.0040	0.0017	38.55**	130.04**	562
4	1.7120	0.0064	0.0018	98.34**	78.79**	327
5	1.7726	0.0063	0.0012	35.26**	14.05**	304
6	1.8227	−0.0008	0.0012	0.31	14.78**	242
7	1.4515	0.0097	0.0035	7.49**	4.39*	97
8	3.9673	0.0130	−0.0164	1.12	5.56	5

Notes: df . . . . . $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

Table 2. The multiple linear regression equations of the towing time (t_t in min.) on the amount of catch by the preceding haul (x' in tons) and the depth fished (y in m) under the wind wave of respective grades (w).

$$\log t_t = a'_{0w} + a'_{1w} x' + a'_{2w} y$$

Grade of wind wave (w)	a'_{0w}	a'_{1w}	a'_{2w}	F'_x	F'_y	n_2
1	1.7989	0.0053	0.0010	10.81**	3.86	61
2	1.6884	0.0039	0.0023	14.31**	203.80**	345
3	1.7832	0.0021	0.0016	8.85**	114.57**	534
4	1.8649	−0.0056	0.0014	65.48**	40.97**	300
5	1.8121	0.0036	0.0010	9.72**	8.43**	285
6	1.8500	−0.0040	0.0012	7.33**	14.88**	228
7	1.5570	−0.0001	0.0034	0.002	5.03*	90
8	3.1409	−0.0034	−0.0088	0.15	3.86	5

Note: df .... $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

3) Good catch by the preceding haul resulted in long towing under the calm water, but resulted in short towing under the rough sea.

3. The linear regression on the amount of catch

In the ordinary way of bull trawling, the codend containing catch was hauled up on deck with the assistance of the gypsy drum and the tackle hanging on the main mast. And it is probable that the amount of catch is the dependent variable and the length of towing time is the independent one. The present case was different from the above-mentioned ordinary way, in respect of handling the catch. The catch in the present case was far better than that on the ground where the boats used to work. And the codend capable of containing 15 tons of fish was connected with the net body; especially when an extremely good catch was expected, two or more codends were connected in series. After the body of the net being gathered alongside or hauled up on deck, the codend containing the catch was made fasten alongside. When the catch was too good to be packed in a codend, a part of catch was kept in the net body, the other empty codend was connected, and the catch was packed into it. The work pattern like this not only needed much manual work but also was very troublesome and dangerous especially in cold water under rough sea. In consequence, it is probable that the towing time was adjusted for the purpose of yielding an adequate amount of catch by a haul. Namely, it is probable that a good catch and the different work pattern make the amount of catch adopted as one of the independent variables and the towing time adopted as the dependent one.

When the length of towing time is adequately adjusted, a haul yields an equal amount of catch regardless of the length of towing time, i.e. the regression coefficient is insignificant. When the length of towing time is insufficiently adjusted, the towing time for

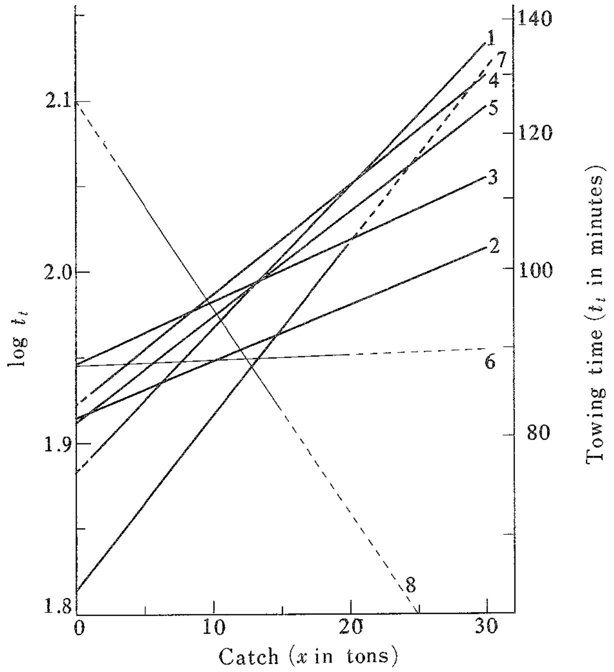


Fig. 2. The regression lines of log t_t on the amount of catch (x in tons).
Note: The part of solid line shows the applicable catch range. The thick line shows the relation with the significant linear regression coefficient, but the thin one shows the relation with the insignificant coefficient. The numeral attached to the line is the grade of wind wave.

Table 3. The linear regression equations of the towing time (t_t in min.) on the amount of catch (x in tons) under respective grades of wind wave (w).

$$\log t_t = b_{0w} + b_{1w}x$$

		Range of x	b_{0w}	b_{1w}	F_0	n_2
Grade of wind wave (w)	1	1 – 30	1.8836	0.0083	25.58**	65
	2	0 – 30	1.9144	0.0033	7.40**	367
	3	0 – 30	1.9460	0.0036	24.78**	563
	4	1 – 39	1.9222	0.0064	79.54**	328
	5	0 – 32	1.9125	0.0061	31.92**	305
	6	1 – 20	1.9453	0.0003	0.05	243
	7	0 – 20	1.8148	0.0101	7.80**	98
	8	3 – 15	2.0981	−0.0120	3.55	6

Note: df .... $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

Table 4. The results of the comparison between b_{1w} under different grades of wind wave (w) through the t-test.

Grade of wind wave (w)	1		2		3		4	
	t	n	t	n	t	n	t	n
Grade of wind wave (w) 1			1.91	432	2.34*	628	1.03	393
2					−0.23	930	−2.24*	695
3							−2.69**	891
4								
5								
6								
7								
Number of the combinations showing significant difference	L	S	L	S	L	S	L	S
	3		1	2	2	4	4	

Grade of wind wave (w)	5		6		7		8	
	t	n	t	n	t	n	t	n
Grade of wind wave (w) 1	0.96	370	3.38**	308	−0.45	163	6.97**	71
2	−1.71	672	1.50	610	−2.07*	465	4.01**	373
3	−1.99*	868	2.09*	806	−2.50*	661	5.36**	569
4	0.24	633	3.97**	571	−1.42	426	7.04**	334
5			3.18**	548	−1.32	403	5.49**	311
6					−3.03**	341	3.79**	249
7							3.86**	104
Number of the combinations showing significant difference	L	S	L	S	L	S	L	S
	3		1	5	4			7

Note: * significant at 0.05 level   ** significant at 0.01 level
L: significantly larger than the other   S: significantly smaller than the other

poor catch is longer than that of good catch, i.e. the regression coefficient is significantly negative. While when the towing time is over-adjusted, the towing time for good catch is longer than that for poor catch, i.e. the regression coefficient is significantly positive. The narrow range of the catch under the wind wave of the grades 6 to 8 and the insignificant regression in the grades 6 and 8 shown in Table 3 were in support of the adjustment of the length of towing time according to the amount of catch and to the surface conditions. The regression coefficient of $\log t_t$ on the amount of catch was significant in all the other wave grades (the grades 1 to 5). The coefficient in the wave grades 2 and 3 was smaller than the others. In these wave grades, the increase of towing time was far smaller than that of the catch. This fact suggested that the length of towing time was slightly over adjusted. In the wave grades 1, 4, and 5, the regression coefficient was significant, and was larger than that of the wave grades 2 and 3. These facts suggested the over adjustment.

The above-mentioned difference in the adjustment of the length of towing time according to the wave grades may be due to the different difficulty in estimating the amount of catch during towing and due to the different importance of the correct adjustment.

4. The regression on the amount of catch by the preceding haul

There was little doubt as to the adjustment of the length of towing time according to the estimated amount of catch during towing, for the purpose of safety handling of codend. In the bull trawling, a net is towed by a pair of boats. And it is inconvenient to change the work pattern during towing according to the conditions. In

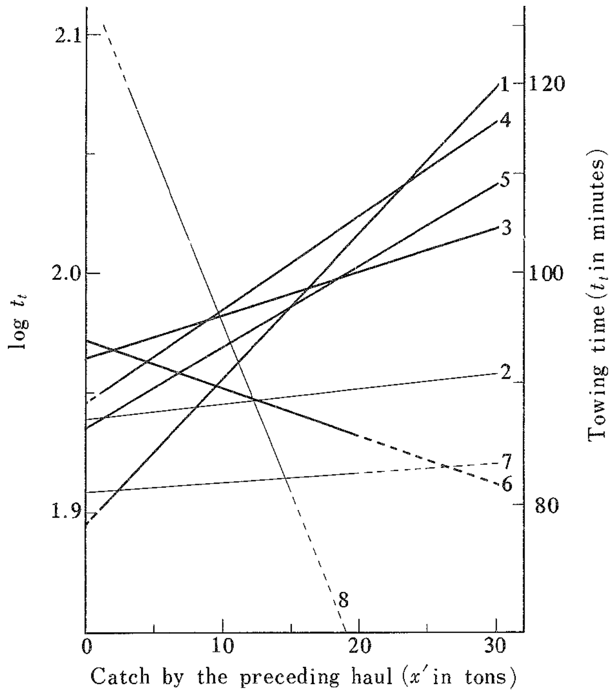


Fig. 3. The regression lines of log t_t on the amount of catch by the preceding haul (x' in tons).

consequence, the results of the preceding hauls were taken into account, and the length of towing time was assigned before shooting or just after the start of towing work. It is, accordingly, probable that the length of towing time depends on the amount of catch by the preceding haul. To confirm this possibility, the linear regression on the amount of catch by the preceding haul was examined (Tables 5 and 6). And the following trends were found out:

1) The clearest difference of the result of this section from that of the preceding

Table 5. The linear regression equations of the towing time (t_t in min.) on the amount of catch by the preceding haul (x' in tons) under respective grades of wind wave (w).

$\log t_t = b'_{0w} + b'_{1w} x'$

Grade of wind wave (w)	Range of x'	b'_{0w}	b'_{1w}	F'_0	n_2
1	1 – 30	1.8951	0.0061	14.79**	62
2	0 – 30	1.9390	0.0006	0.23	346
3	0 – 30	1.9645	0.0018	5.22*	535
4	1 – 39	1.9461	0.0039	25.46**	301
5	0 – 32	1.9351	0.0034	8.48**	286
6	0 – 20	1.9719	−0.0030	3.98*	229
7	0 – 20	1.9086	0.0006	0.03	91
8	3 – 15	2.1208	−0.0142	2.83	6

Note: df .... $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

Table 6. The results of the comparison between b'_{1w} under different grades of wind wave (w) through the t-test.

Grade of wind wave (w)	1		2		3		4	
	t	n	t	n	t	n	t	n
Grade of wind wave (w) 1			2.08*	408	2.09*	597	1.16	363
2					−0.85	881	−2.26*	647
3							−1.88	836
4								
5								
6								
7								
Number of the combinations showing significant difference	L	S	L	S	L	S	L	S
	4			2	1	1	2	

Grade of wind wave (w)	5		6		7		8	
	t	n	t	n	t	n	t	n
Grade of wind wave (w) 1	1.14	348	3.90**	291	1.53	153	2.40*	68
2	−1.62	632	1.69	575	0.00	437	1.14	352
3	−1.18	821	2.81**	764	0.46	626	1.56	541
4	0.37	587	4.19**	530	1.29	392	1.95	307
5			3.26**	515	0.93	377	1.53	292
6					−1.17	320	1.12	235
7							1.04	97
Number of the combinations showing significant difference	L	S	L	S	L	S	L	S
	1			4				1

Note: * significant at 0.05 level ** significant at 0.01 level
L: significantly larger than the other S: significantly smaller than the other

one was the small regression coefficient.

2) The regression coefficient was insignificant in the three wave grades (2, 7, and 8).

3) The different length of towing time due to the catch regression was within 25 min. except in the wave grade 1.

4) The narrow range of the catch in the rough sea (the wave grades 6 to 8) indicated the adequate adjustment of the length of towing time for the purpose of preventing the crew from the inconvenient handling of an extremely good catch.

These results suggested the following facts: if the skipper inclined to assigne the length of towing time basing on the results of the preceding haul, the length of towing time should show the negative regression on the amount of catch by the preceding haul. But the results showed little possibility like this.

5. The regression on the depth fished

The length of towing time showed the significant regression on the depth fished in all the wave grades; that in deep ground was longer than that in shallow one except under the wave grade 8, the difference due to the depth regression being 25 min. to 30 min. And the regression coefficient of the different wave grade did not show any signi-

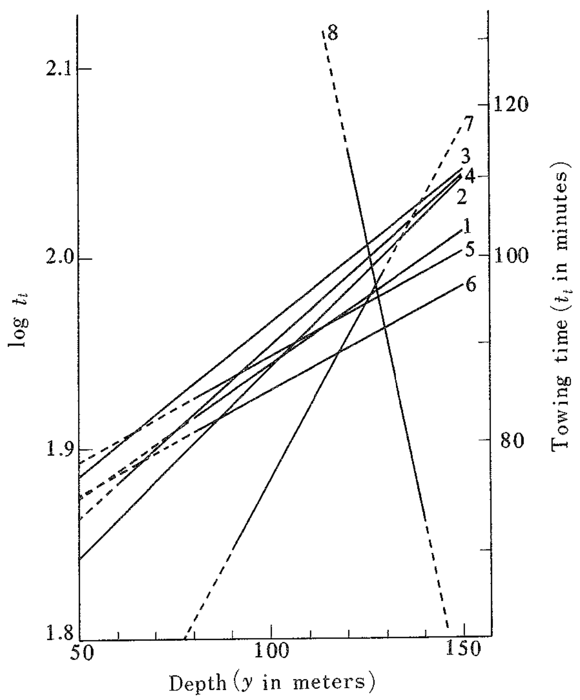


Fig. 4. The regression lines of log t_t on the depth fished.

Table 7. The linear regression equations of the towing time (t_t in min.) on the depth fished (y in m) under respective grades of wind wave (w).

$\log t_t = c_{0w} + c_{1w} y$

Grade of wind wave (w)	Range of y	c_{0w}	c_{1w}	F_0	n_2
1	80 – 140	1.8040	0.0014	6.96*	65
2	50 – 150	1.7428	0.0020	178.21**	367
3	50 – 150	1.8056	0.0016	114.31**	563
4	60 – 150	1.7737	0.0018	60.81**	328
5	80 – 150	1.8381	0.0011	10.85**	305
6	80 – 150	1.8200	0.0011	14.57**	243
7	90 – 130	1.5137	0.0037	4.66*	98
8	120 – 140	3.2450	−0.0099	9.20*	6

Note: df .... $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

Table 8. The results of the comparison between c_{1w} under different grades of wind wave (w) through the t-test.

Grade of wind wave (w)	1		2		3		4	
	t	n	t	n	t	n	t	n
1			−0.98	432	−0.36	628	−0.70	393
2					1.87	930	0.69	695
3							−0.72	891
4								
5								
6								
7								
Number of the combinations showing significant difference	L	S	L	S	L	S	L	S
	1		2		1		1	

Grade of wind wave (w)	5		6		7		8	
	t	n	t	n	t	n	t	n
1	0.42	370	0.28	308	−1.38	163	2.35*	71
2	2.46*	672	0.92	610	−1.35	465	2.22*	373
3	1.45	868	0.01	806	−1.88	661	2.45*	569
4	1.74	633	0.76	571	−1.59	426	2.55*	334
5			0.00	548	−1.88	403	1.91	311
6					−1.52	341	2.14*	249
7							1.63	104
Number of the combinations showing significant difference	L	S	L	S	L	S	L	S
		1	1					5

Note: * significant at 0.05 level
L: significantly larger than the other S: significantly smaller than the other

ficant difference, except between the wave grades 2 and 5 and between the wave grade 8 and the others. In spite of clear depth regression of the length of towing time, it was hard to find inevitable reason for it. The possibility remained only in the relation to the bathymetric difference of the density of the fishable population. And such possibility as this will be examined in the succeeding sections.

6. The regression on the amount of catch after the twofold stratification of the records according to the wave grade and the depth fished

As shown in the multiple linear regression on the amount of catch and the depth fished (Table 1), the length of towing time differed according to them and according to the wave grade. And it was hard to consider that the bathymetric distribution of the hauls and the amount of catch were the same throughout the wave grades. It is, accordingly, necessary to examine the regression on either of the factors after the stratification of the records according to the factors of the rest. And the influence of one of the factors should be examined by comparing the regression equations on the second factor observable under the different condition of the first factor but the same condition of the third one.

The amount of catch varied from 0 to 39 tons a haul, showing a large between-day variation as well as a large within-day one. The depth fished ranged from 40 m to 150 m; its within-day variation was small. The records were, accordingly, stratified according to the wave grade and the depth fished; and the regression lines of the length of towing time on the amount of catch were compared with one another.

6.1 The significance of the regression on the amount of catch

As shown in Table 9, $\log t_t$ took insignificantly positive regression coefficient in the 22 *y-w* strata out of the 44 ones, and insignificantly negative one in the five strata. These facts meant that the length of towing time was adequately adjusted in the two thirds of the strata. In the 17 strata, $\log t_t$ showed significantly positive regression. And they were mainly in the wave grades 3, 4, and 5, and mainly in the 100 m to 120 m zones. Namely, the length of towing time inclined to be over adjusted under the intermediate wave grades in the intermediate depth zones. These results may be due to the following reasons: the records in the extreme depth zones or in the extreme wave grades were found in the limited seasons. In these cases the time-catch relation may be free from the influence of seasonal changes in the density of the fishable population, and it may be easy to adjust the length of towing time for the purpose of yielding similar amount of catch by a haul. The following fact may be one of the evidence in support of this possibility: the range of the amount of catch by a haul was narrow, as shown in Figs. 2, 4, and 5, being roughly in the range capable of being packed into a codend. In contrast with this, the records on the intermediate depth zones or in the intermediate wave grades were found throughout the seasons. It is hard to consider that the density of the fishable population is the same throughout the seasons, and the boats fished over a wide area pursuing the migration of the objective fish. And the

Table 9. The linear regression equations of the towing time (t_t in min.) on the amount of catch (x in tons) after the stratification of the records into the depth zones (y in m, 10-m intervals) and the grade of wind wave (w).

$$\log t_t = b_{0yw} + b_{1yw}x$$

Grade of wind wave (w)	1				2				3				4			
Depth zone (y in meters)	b_{0y1}	b_{1y1}	F_0	n_2	b_{0y2}	b_{1y2}	F_0	n_2	b_{0y3}	b_{1y3}	F_0	n_2	b_{0y4}	b_{1y4}	F_0	n_2
50					1.7947	0.0025	2.03	108	1.8239	0.0031	1.59	54				
60													1.7763	0.0102	1.50	9
80	1.9315	0.0013	0.005	3												
90	1.8946	0.0010	0.08	23					1.8608	0.0062	11.23**	30	1.8867	0.0050	3.09	43
100					1.9716	0.0045	3.17	60	1.9698	0.0011	0.32	90	1.8857	0.0076	6.10*	26
110	1.9571	0.0050	2.05	15	1.9468	0.0049	10.84**	45	1.9460	0.0056	18.16**	143	1.9416	0.0067	36.27**	40
120	1.8222	0.0127	0.86	3	1.9465	0.0067	8.87**	48	1.9927	0.0015	1.53	93	1.9383	0.0038	5.55*	51
130					1.9336	0.0077	2.79	32	1.9430	0.0081	9.01**	57	1.9288	0.0077	24.34**	64
140	1.9277	0.0049	3.86	13	1.9229	0.0080	3.54	60	1.9477	0.0047	13.96**	74	1.9764	0.0030	3.05	69
150									2.0620	−0.0105	0.26	6	1.9353	0.0203	5.91*	11

Grade of wind wave (w)	5				6				7			
Depth zone (y in meters)	b_{0y5}	b_{1y5}	F_0	n_2	b_{0y6}	b_{1y6}	F_0	n_2	b_{0y7}	b_{1y7}	F_0	n_2
50												
60												
80	1.8683	0.0141	0.52	4	1.9417	0.0019	0.20	15				
90	1.9050	0.0057	14.15**	57	1.9488	0.0029	0.18	21				
100	1.8423	0.0091	8.51**	51	1.9277	−0.0014	0.28	72	1.7886	0.0105	4.26*	59
110	1.8486	0.0087	8.10**	41	1.9375	−0.0025	0.51	41	1.8348	0.0089	4.21	25
120	1.9057	0.0107	17.33**	51								
130	1.9690	0.0024	0.86	45	1.8878	0.0078	0.54	15	2.0201	−0.0011	0.02	7
140	1.9905	0.0009	0.09	40	1.9488	0.0056	5.31*	60				
150					1.9928	−0.0049	3.31	5				

Note: df .... $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

relative evaluation of a certain level of population density may differ according to the seasonal change of the distribution pattern of the objective fish, being low in the grounds (or the seasons) of concentrated population but high in the grounds (or seasons) of scattering one. These facts may make it hard to adjust the length of towing time for the purpose of yielding similar amount of catch throughout the seasons. These facts may result in the over adjustment when the records throughout the seasons were pooled in the examinations on the time-catch relation. The wide variation of the amount of catch by a haul may be the fact in support of this supposition.

6.2 The difference of the catch regression according to the grade of wind wave

The influence of the wave height on the length of towing time was not dealt in the multiple linear regression equations as one of the independent variables, for the height

Table 10. The results of the comparison between b_{1yw} under different grades of wind wave (w) through the t-test.

Depth (y in meters)	50		80		90		100		110		120		130		140		150	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1 – 2									0.03	60	0.71	51			−0.37	73		
1 – 3					−1.30	53			−0.18	158	1.65	96			0.05	87		
1 – 4					−0.76	66			−0.60	55	1.32	54			0.35	82		
1 – 5			−0.47	7	−1.04	80			−0.78	56	0.22	54			0.70	53		
1 – 6			−0.04	18	−0.26	44			1.51	56					−0.13	73		
1 – 7									−0.69	40								
2 – 3	−0.19	162					1.07	150	−0.31	188	2.17*	141	−0.08	89	0.87	134		
2 – 4							−0.74	86	−0.97	85	1.06	99	0.00	96	1.20	129		
2 – 5							−1.12	111	−1.18	86	−1.17	99	1.03	77	1.26	100		
2 – 6							1.59	132	2.13*	86			−0.01	47	0.50	120		
2 – 7							−1.06	119	−0.96	70			0.82	39				
3 – 4					0.35	73	−1.65	116	−0.54	183	−1.10	144	0.13	121	0.82	143	−1.61	17
3 – 5					0.19	87	−2.36*	141	−1.05	184	−3.56**	144	1.53	102	1.21	114		
3 – 6					0.54	51	0.78	162	2.46*	184			0.03	72	−0.34	134	−0.32	11
3 – 7							−2.01*	149	−0.71	168			1.01	64				
4 – 5					−0.23	100	−0.28	77	−0.67	81	−2.32*	102	1.81	109	0.58	109		
4 – 6					0.28	64	1.99*	98	2.84**	81			−0.01	79	−0.86	129	2.83*	16
4 – 7							−0.39	85	−0.58	65			1.01	71				
5 – 6			0.89	19	0.43	78	2.58*	123	2.43*	82			0.56	60	−1.19	100		
5 – 7							−0.24	110	−0.03	66			0.36	52				
6 – 7							−2.17*	131	−1.90	66			0.62	22				

Note: * significant at 0.05 level ** significant at 0.01 level

Table 11. Number of b_{1yw} showing the significant difference from that of the different wave grade (w).

Grade of wind wave (w)	1		2		3		4		5		6		7	
Dpeth zone (y in meters)	L	S	L	S	L	S	L	S	L	S	L	S	L	S
50														
80														
90														
100						2	1		2			3	2	
110			1		1		1		1			4		
120			1			2		1	2					
130														
140														
150							1					1		
Sum			2		1	4	3	1	5			8	2	

Note: L ..... significantly larger than the other
S ..... significantly smaller than the other

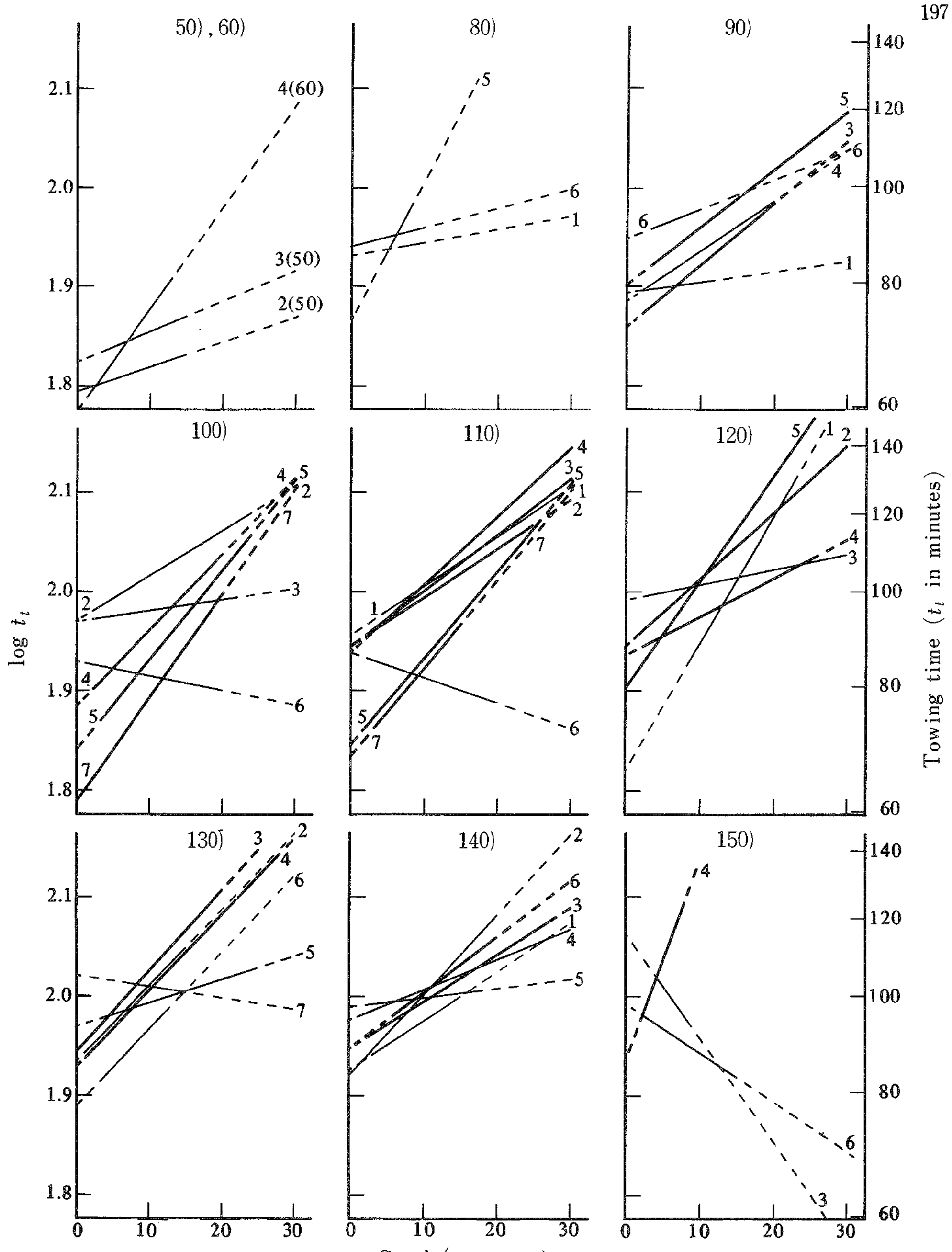


Fig. 5. The difference of the t_l-x relations according to the grade of wind wave observable within the records of the same depth zones.

Note: The numeral with parenthesis is the depth zone (the echo-sounded depth was aggregated into the zones of the nearest 10-m intervals). That attached to the line is the grade of wind wave. The range of solid line shows the applicable catch range. The thick line shows the relation with the significant linear regression coefficient, but the thin one shows the relation with the insignificant coefficient.

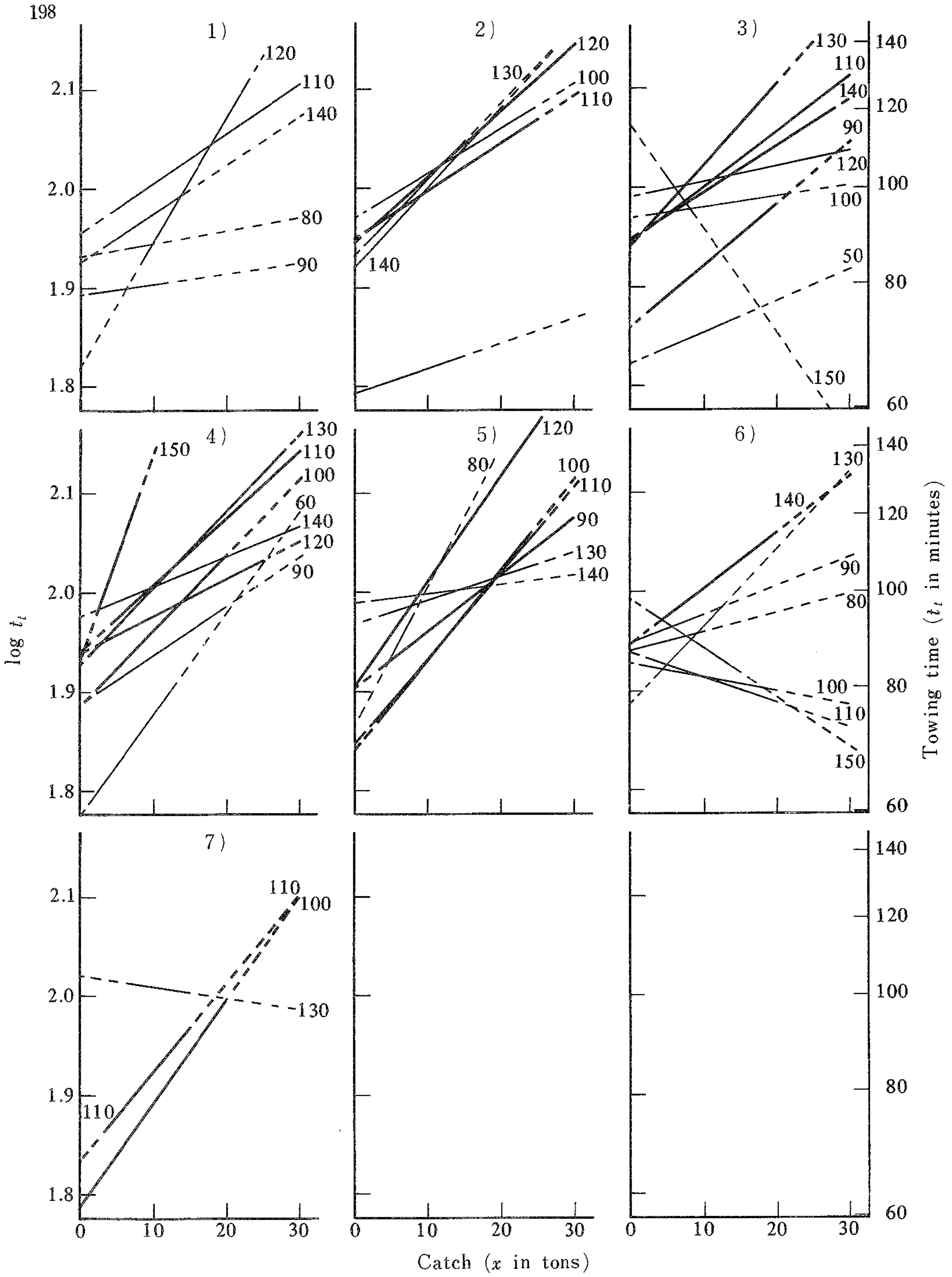


Fig. 6. The difference of the t_l-x relations according to the depth observable within the records under the wind wave of the same grade.

Note: The numeral with parenthesis is the wave grade. That attached to the line is the depth fished (aggregated into the zones of the nearest 10-m intervals).

of wind wave was described in the grade number covering unequal range of wave height. And this was examined through the comparison of the regression equations of the different wave grades with one another. To sweep up the probable uncertainty in the results due to the probable difference of the bathymetric distribution of the records according to the wave grades, the regression equations on the amount of catch observable in the same depth zones under the different wave grades were compared with one another.

As shown in Table 10, the significant difference of the regression coefficient was found in the 13 pairs of the wave grades out of the 93 ones. And most of these significant differences were due to the small value of either the wave grades 3 and 6 in the 100 m zone, or the wave grade 6 in the 110 m zone, or the wave grades 3 in the 120 m zone. Namely, the significant differences between the regression coefficients of the different wave grades were found in 14% of pairs of wave grades mainly because of the small coefficient in 9% of the strata in the two wave grades. The equations of these y-w strata took large constant; consequently, most of these strata did not show any notable difference from the others in the length of towing time in the range of catch from 0 to 10 or 15 tons. These facts meant that the different wave grade less frequently caused the different results of adjustment of the length of towing time; and the different results were due to better adjustment or insufficient one in some of the strata in some of the wave grades. Besides these findings, the following characteristics of the wave grades in respect of the time-catch relation were found out: in the wave grade 2, the time-catch relations of the different depth zones showed small variation; in the wave grades 3 and 4, the time-catch relation of the different depth zones showed a large variation. The inverse relation between the constant and coefficient was found in the regression equations in the wave grade 5, i.e. the lines crossing one another at the point (20 tons, 2.0 of $\log t_t$). The constants of the regression equations of the different depth zones in the wave grade 6 took similar value to one another, and the coefficient showed a large variation.

6.3 The difference of the catch regression according to the depth fished

The multiple linear regression equations and the linear regression ones on the depth fished revealed that the towing time increased in accordance with the depth fished. But it was hard to find any inevitable reason of showing the significant depth regression. The possibility remained only in the bathymetric difference of the density. In this section, this possibility was examined through the comparison of the regression equations on the amount of catch observable among the records in the different depth zones under the same wave grades with one another.

As shown in Table 12, the regression coefficients in the 120 pairs of the depth zones under the same wave grades out of the 126 ones did not show any significant difference. And Fig. 6 did not show any clear trend of the change of the time-catch relations in accordance with the depth, except short towing in the 50 m zone. These facts suggested that the significant depth regression should be due to the bathymetric difference of the density of the fishable population. And this possibility will be examined in the

Table 12. The results of the comparison between b_{1yw} of the different depth zone (y) under the same grades of wind wave (w) through the t-test.

Grade of wind wave (w)	1		2		3		4		5		6		7	
Depth zone (y in meters)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
50 – 60														
50 – 80														
50 – 90					–0.99	84								
50 – 100			–0.68	168	0.50	144								
50 – 110			–1.05	153	–0.63	197								
50 – 120			–1.54	156	0.47	147								
50 – 130			–1.31	140	–1.28	111								
50 – 140			–1.39	168	–0.54	128								
50 – 150					1.05	60								
60 – 80														
60 – 90							0.67	52						
60 – 100							0.31	35						
60 – 110							0.54	49						
60 – 120							0.86	60						
60 – 130							0.32	73						
60 – 140							0.90	78						
60 – 150							–0.83	20						
80 – 90	0.02	26							0.53	61	–0.12	36		
80 – 100									0.16	55	0.34	87		
80 – 110	–0.13	18							0.19	45	0.42	56		
80 – 120	–0.31	6							0.13	55				
80 – 130									0.55	49	–0.52	30		
80 – 140	–0.30	16							0.67	44	–0.51	75		
80 – 150											1.27	20		
90 – 100					1.40	120	–0.63	69	–0.99	108	0.45	93		
90 – 110	–0.65	38			0.17	173	–0.59	83	–0.94	98	0.53	62		
90 – 120	–1.44	26			1.54	123	0.37	94	–1.71	108				
90 – 130					–0.52	87	–0.80	107	1.16	102	–0.41	36		
90 – 140	–0.84	36			0.58	104	0.58	112	1.45	97	–0.36	81		
90 – 150					1.32	36	–1.56	54			0.87	26		
100 – 110			–0.14	105	–1.95	233	0.31	66	0.09	92	0.26	113	0.18	84
100 – 120			–0.65	108	–0.18	183	1.13	77	–0.39	102				
100 – 130			–0.62	92	–2.03*	147	–0.03	90	1.57	96	–0.87	87	0.61	66
100 – 140			–0.73	120	–1.58	164	1.30	95	1.56	91	–1.85	132		
100 – 150					0.60	96	–1.23	37			0.35	77		
110 – 120	–0.74	18	–0.67	93	2.22*	236	1.49	91	–0.51	92				
110 – 130			–0.64	77	–0.77	200	–0.51	104	1.57	86	–0.88	56	0.98	32
110 – 140	0.02	28	–0.74	105	0.44	217	1.79	109	1.62	81	–1.97	101		
110 – 150					0.82	149	–1.66	51			0.22	46		
120 – 130			–0.19	80	–2.24*	150	–1.71	115	2.25*	96				
120 – 140	0.91	16	–0.28	108	–1.76	167	0.34	120	2.20*	91				
120 – 150					0.71	99	–1.69	62						
130 – 140			–0.04	92	1.22	131	2.03*	133	0.36	85	0.26	75		
130 – 150					1.05	63	–1.20	75			0.99	20		
140 – 150					1.07	80	–1.64	80			1.43	65		

Note: * significant at 0.05 level ** significant at 0.01 level

Table 13. Number of b_{1yw}'s showing the significant difference from that of the different depth zone (y).

Depth zone (y in m)		80		90		100		110		120		130		140		150	
		L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Grade of wind wave (w)	1																
	2																
	3						1	1			2	2					
	4											1			1		
	5									2			1		1		
	6																
	7																
Sum							1	1		2	2	3	1		2		

Note: L ...... significantly larger than the other
S ...... significantly smaller than the other

succeeding section through the depth regression after the twofold stratification of the records according to the amount of catch and the wave grade.

Besides these facts, the following trend were found out as the characteristics of respective depth zones; the narrow range of the amount of catch and the insignificant catch regression in the 50 m, 60 m, and the 80 m zones meant the adequate adjustment of the length of towing time in these depth zones. This may be due to the following reasons: these depth zones were exploited in a limited season; consequently, the towings therein were free from the influence of the seasonal change of the distribution pattern. In the other depth zones, the time-catch relation lines showed a large variation according to the wave grades, and the amount of catch by a haul covered wide range. This may be due to the fact that these zones were exploited throughout the seasons and the seasonal change of distribution may make it hard to adjust adequately the length of towing time, because the evaluation of a certain density level differs seasonally according to the seasonal change of the distribution pattern.

6.4 The comparison of the regression lines of the different depth zones under the different wave grades

The differences in the time-catch relations due to the difference either in the wave grade or in the depth observable under the same condition of the factor of the rest were examined in the preceding sections. There lacked, however, the comparison among all the y-w strata with one another. Some of the regression lines took large constants or large coefficients. Some others took small ones. The length of towing time for a catch level depends on the relation between the constant and the coefficient. And the amount of catch by a haul was mainly in the range of 10 to 20 tons. With the assistance of the lines in Fig. 7, the following trends were found out:

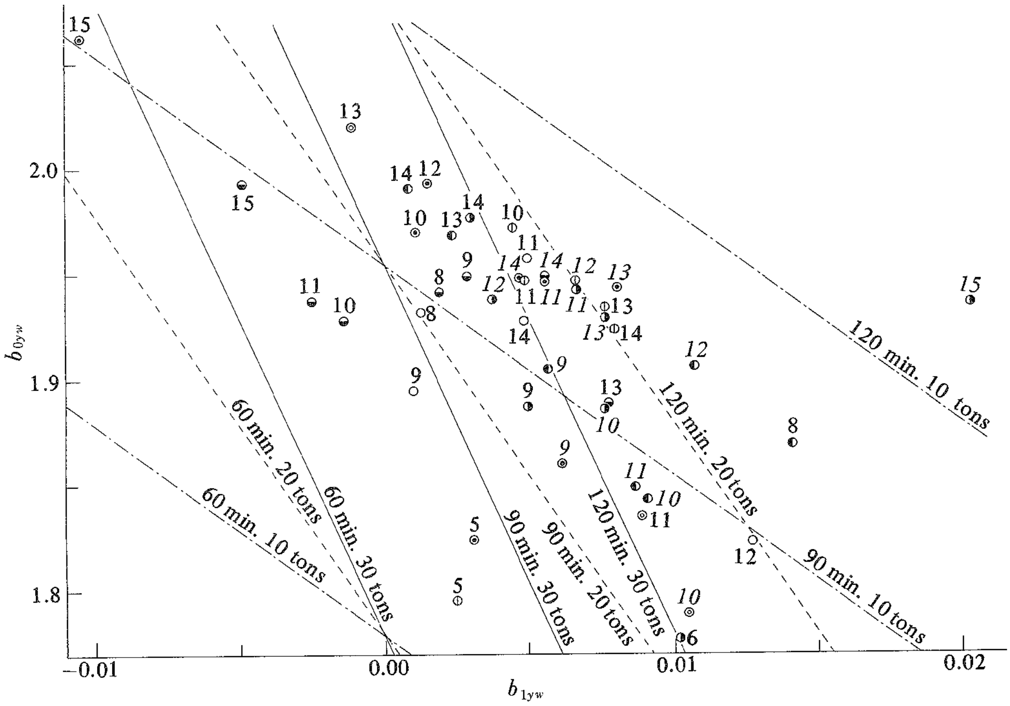


Fig. 7. The comparison of the regression lines log t_t on x

$$\log t_t = b_{0yw} + b_{1yw} x$$

Legend:

5 . . . . . 50 m zone 10 . . . . . 100 m zone

The mark with italic numeral shows the regression line with the significant coefficient.

○ Wave grade 1 ⦶ Wave grade 2
⊙ Wave grade 3 ◑ Wave grade 4
◐ Wave grade 5 ◒ Wave grade 6
◎ Wave grade 7

1) There were no clear differences between the strata showing the significant catch regression and those showing the insignificant one, in respect of the length of towing time of the hauls yielding the same amount of catch.

2) The towing times in most of the strata did not show any large difference, according to either the depth or the wave grade, being 80 to 110 min. for the hauls yielding 10 tons of catch, 90 to 120 min. for the hauls yielding 20 tons of catch.

3) The towing time in the 50 m, 60 m, and 80 m zones was shorter than that in the other depth zones. The towing time in the 90 m zone was a slightly shorter than that in deep zones. The towing time under the wave grade 6 was shorter, and that under the wave grade 2 was longer than that under the other wave grades.

7. The regression on the amount of catch by the preceding haul after the twofold stratification of the records according to the wave grade and the depth fished

7.1 The significance of the catch regression

The examinations in the preceding sections (Table 5) showed that the regression coefficient on the amount of catch by the preceding haul was far smaller than that of the amount of catch by the haul. The same trend was more clearly shown in the results of the examination after the twofold stratification of the records according to both of the depth fished and the wave grade. The coefficient was smaller than 0.0082. And the regression coefficient was significantly positive in the six strata out of the 44 ones, insignificantly positive in the 19 ones, and insignificantly negative in the 19 ones.

Table 14. The linear regression equations of the towing time (t_t in min.) on the amount of catch by the preceding haul (x' in tons) after the stratification of the records into the depth zones (y in m, 10-m intervals) and the grade of wind wave (w).

$$\log t_t = b'_{0yw} + b'_{1yw} x'$$

Grade of wind wave (w)	1				2				3				4			
Depth zone (y)	b'_{0y1}	b'_{1y1}	F_0	n_2	b'_{0y2}	b'_{1y2}	F_0	n_2	b'_{0y3}	b'_{1y3}	F_0	n_2	b'_{0y4}	b'_{1y4}	F_0	n_2
50					1.8347	−0.0014	0.52	105	1.8703	−0.0015	0.39	54				
60													1.9348	−0.0158	1.23	5
80	1.9026	0.0059	0.14	3												
90	1.8990	0.0002	0.003	23					1.9215	−0.0004	0.05	26	1.8981	0.0038	1.34	41
100					1.9957	0.0017	0.38	58	1.9719	0.0011	0.34	88	1.9077	0.0057	1.67	22
110	2.2792	−0.0285	3.35	13	1.9653	0.0037	6.37*	43	1.9710	0.0037	6.83*	137	2.0014	0.0020	1.43	36
120	2.0782	−0.0035	0.05	3	1.9811	0.0031	1.37	47	2.0230	−0.0016	1.08	86	1.9413	0.0031	5.38*	47
130					2.0251	−0.0060	0.87	30	1.9689	0.0043	3.55	55	1.9582	0.0052	9.43**	57
140	2.0069	−0.0035	1.20	12	1.9387	0.0052	-1.09	49	1.9653	0.0029	3.97	68	1.9790	0.0023	|1.76|	67
150									2.0751	−0.0142	0.43	5	2.0049	0.0012	0.02	11

Grade of wind wave (w)	5				6				7			
Depth zone (y)	b'_{0y5}	b'_{1y5}	F_0	n_2	b'_{0y6}	b'_{1y6}	F_0	n_2	b'_{0y7}	b'_{1y7}	F_0	n_2
50												
60												
80	1.9075	0.0070	0.26	4	2.0084	−0.0015	0.13	15				
90	1.9055	0.0063	17.17**	49	1.9801	−0.0034	0.25	20				
100	1.8682	0.0059	3.52	47	1.9397	−0.0028	1.05	73	1.9016	−0.0008	0.03	56
110	1.8492	0.0082	5.82*	40	1.9708	−0.0052	1.88	37	1.8928	0.0025	0.44	22
120	1.9702	0.0010	0.06	49								
130	1.9626	0.0032	1.25	44	2.0026	−0.0043	0.73	14	2.1149	−0.0101	0.79	6
140	2.0010	−0.0004	0.03	37	1.9968	−0.0003	0.01	51				
150					1.9525	0.0010	0.07	5				

Note: df .... $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

In the preceding section, it was found out that the towing time in deep zones was longer than that in shallow ones. If the skipper assigned the length of towing time for the purpose of yielding similar amount of catch by a haul basing on the results of the preceding haul, the length of towing time after good catch should be short. If the records in shallow zone were in the classes of poor catch and those in the deep zone were in the classes of good catch, the above-mentioned trend results in the insignificant regression of the length of towing time on the amount of catch by the preceding haul. The results of the present section swept out the possibility like this. Namely, the insignificant regression of the length of towing time on the amount of catch by the preceding haul before the stratification of the records according to the depth was not due to the compensatory influence of the depth for that of the catch by the preceding haul. And the insignificant regression casted a doubt as to the length of towing time being assigned before or just after the start of towing.

7.2 The difference of the catch regression according to the grade of wind wave

As pointed out in the preceding section, the importance of the adjustment of the length of towing time for the purpose of yielding similar amount of catch by a haul

Table 15. The results of the comparison between b'_{1yw} under different grades of wind wave (w) through the t-test.

Depth (y in meters)	50		80		90		100		110		120		130		140		150	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1 – 2									–3.53**	56	–0.72	50			–0.90	61		
1 – 3					0.16	49			–5.35**	150	–0.27	89			–1.16	80		
1 – 4					–0.67	64			–3.05**	49	–0.96	50			–0.88	79		
1 – 5			–0.05	7	–1.46	72			–3.22**	53	–0.39	52			–0.50	49		
1 – 6			0.64	18	0.50	43			–1.90	50					–0.48	63		
1 – 7									–1.98	35								
2 – 3	0.03	159					0.18	146	0.00	180	1.67	133	–1.64	85	0.52	117		
2 – 4							–0.74	80	0.76	79	0.00	94	–1.87	87	0.61	116		
2 – 5							–0.94	105	–1.32	83	0.45	96	–1.37	74	1.01	86		
2 – 6							1.14	131	2.41*	80			–0.18	44	0.95	100		
2 – 7							0.46	114	0.32	65			0.26	36				
3 – 4					–1.11	67	–0.93	110	0.69	173	–2.28*	133	–0.32	112	0.26	135	–0.75	16
3 – 5					–2.62*	75	–1.39	135	–1.33	177	–0.71	135	0.31	99	1.14	105		
3 – 6					0.49	46	1.19	161	2.41*	174			1.19	69	0.97	119	–0.82	10
3 – 7							0.43	144	0.29	159			1.13	61				
4 – 5					–0.73	90	–0.03	69	–1.71	76	0.55	96	0.62	101	0.83	104		
4 – 6					0.94	61	1.52	95	1.85	73			1.37	71	0.71	118	0.02	16
4 – 7							0.81	78	–0.13	58			1.24	63				
5 – 6			0.84	19	1.54	69	2.10*	120	2.63*	77			0.98	58	–0.02	88		
5 – 7							1.19	103	1.06	62			0.99	50				
6 – 7							–0.39	129	–1.37	59			0.52	20				

Note: * significant at 0.05 level ** significant at 0.01 level

differed according to the wave grade. For the purpose of finding out the probable difference after sweeping up the influence of depth, the regression equations in the same depth zones under the different wave grades were compared with one another. As shown in Tables 15 and 16, the significant difference between the regression coeffi-

Table 16. The number of b'_{1yw} showing the significant difference from that of the different wave grade (w).

Grade of wind wave (w)	1		2		3		4		5		6		7	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Depth zone (y in meters) 50														
80														
90						1			1					
100									1			1		
110		4	2		2		1		2			3		
120						1	1							
130														
140														
150														
Sum		4	2		2	2	2		4			4		

Note: L ...... significantly larger than the other
S ...... significantly smaller than the other

cient was found out only in the 10 pairs of the strata out of the 93 pairs. And the seven pairs out of these 10 ones were in the 110 m zone; and they were due to either the small value of the coefficient under the wave grade 1 or the wave grade 6. These facts meant that most of the regression coefficient under the different wave grades in the same depth zones took similar value to one another. In the wave grades 2,4,5, and 6, most of the regression lines of the different depth zones showed the similar trend to one another. Those in the former three wave grades inclined to show very slight increase of the towing time, and most of the lines showing the significant regression were in these wave grades. In the last wave grade, they showed very slight decrease. The relations in the different depth zones under either the wave grade 1 or 3 showed a large variation. It may be roughly said that the towing times under the wave grades 2 inclined to be longer, and those under the wave grades 6 and 7 inclined to be shorter than those under the other wave grades. If some meanings were given to the insignificant trend observed commonly, these facts meant that the possibility of the length of towing time being adjusted according to the result of the preceding haul under the rough sea may be slightly higher than that under the calm water.

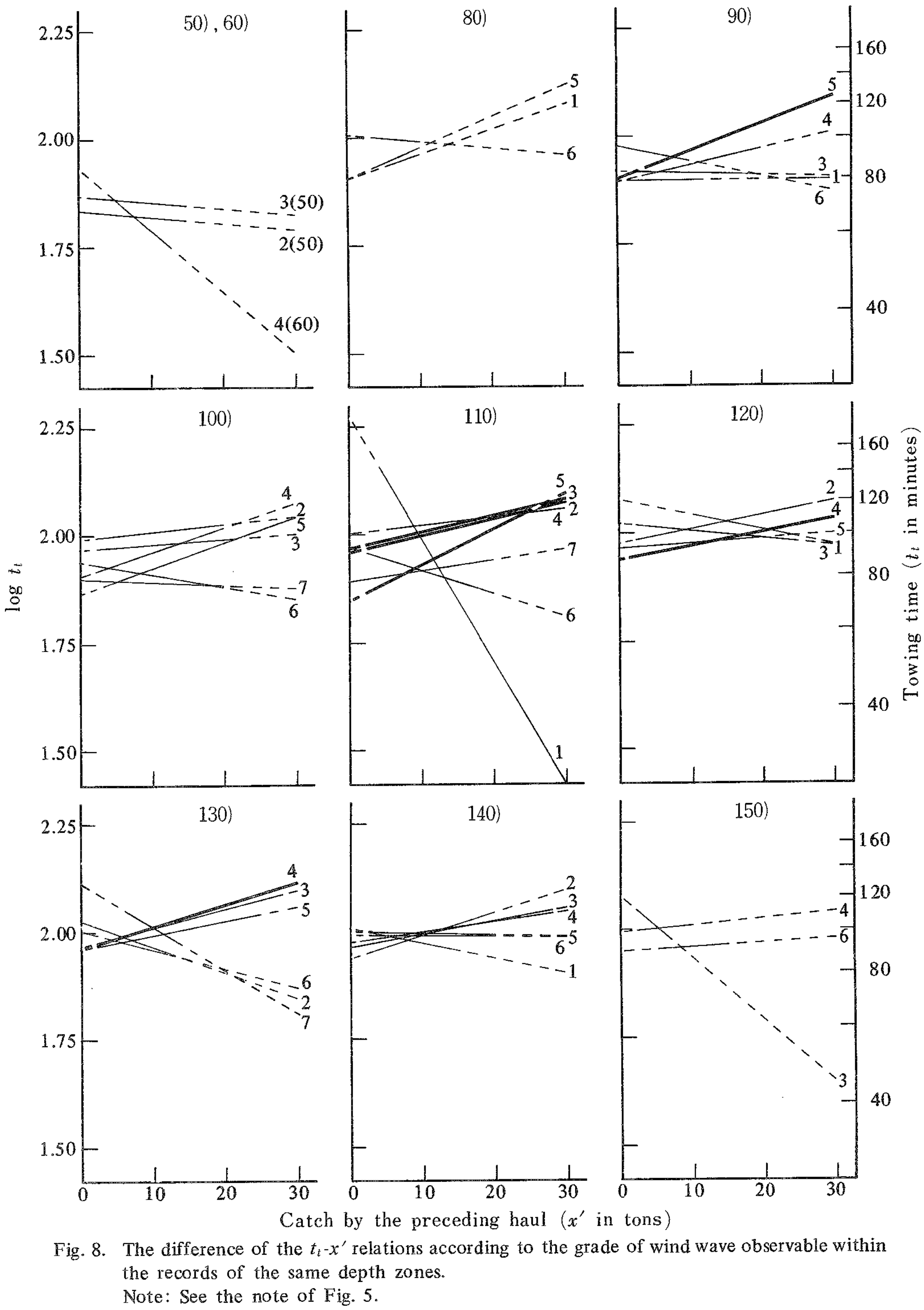


Fig. 8. The difference of the t_l-x' relations according to the grade of wind wave observable within the records of the same depth zones.
Note: See the note of Fig. 5.

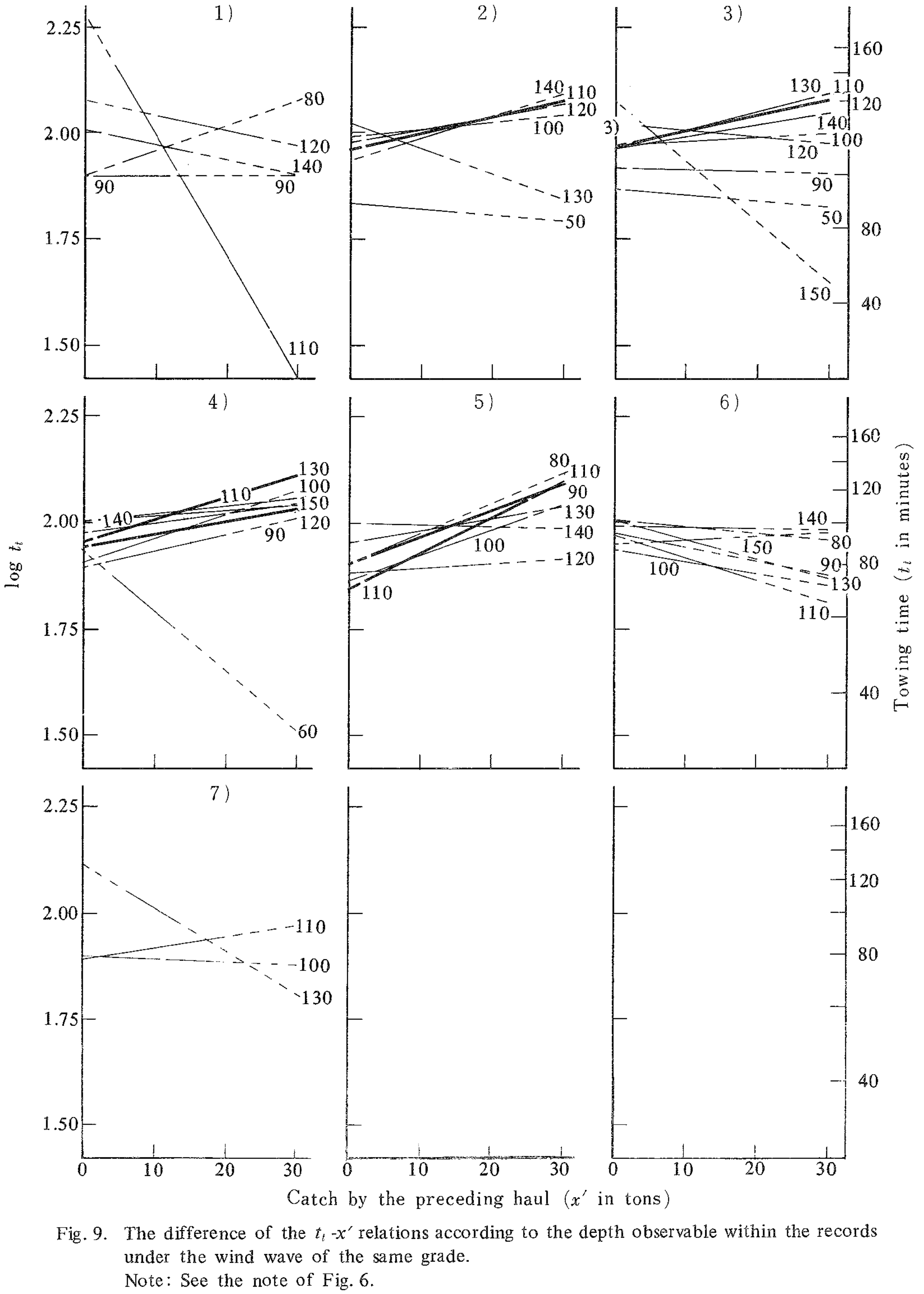


Fig. 9. The difference of the t_t-x' relations according to the depth observable within the records under the wind wave of the same grade.
Note: See the note of Fig. 6.

7.3 The difference of the catch regression according to the depth fished

The significant depth regression of the length of towing time was found out in the multiple linear regression equations of the length of towing time on the depth fished and the amount of catch by the preceding haul. But the significant difference between the regression coefficients of the different depth zones under the same wave grades was found only in the five pairs of depth zones out of the 126 ones. And the three pairs were in the wave grade 3, because of the small value of $b'_{1.12.3}$. This fact meant that the depth difference hardly caused any significant difference in the regression coefficient of the length of towing time on the amount of catch by the preceding haul. Accord-

Table 17. The results of the comparison between b'_{1yw} of the different depth zones (y) through the t-test.

Grade of wind wave (w)	1		2		3		4		5		6		7	
Depth zones (y in meters)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
50 – 60														
50 – 80														
50 – 90					−0.36	80								
50 – 100			−0.97	163	−0.66	142								
50 – 110			−2.13*	148	−1.26	191								
50 – 120			−1.47	152	0.03	140								
50 – 130			0.90	135	−1.57	109								
50 – 140			−1.50	154	−1.40	122								
50 – 150					0.97	59								
60 – 80														
60 – 90							−1.81	46						
60 – 100							−1.66	27						
60 – 110							−1.63	41						
60 – 120							−1.82	52						
60 – 130							−1.88	62						
60 – 140							−1.58	72						
60 – 150							−1.10	16						
80 – 90	0.42	26							0.07	53	0.22	35		
80 – 100									0.05	51	0.12	88		
80 – 110	0.32	16							−0.06	44	0.33	52		
80 – 120	0.25	6							0.27	53				
80 – 130									0.25	48	0.41	29		
80 – 140	0.80	15							−0.55	41	−0.14	66		
80 – 150											−0.43	20		
90 – 100					−0.42	114	−0.36	63	0.11	96	−0.06	93		
90 – 110	1.33	36			−1.12	163	0.48	77	−0.55	89	0.18	57		
90 – 120	0.44	26			0.39	112	0.20	88	1.31	98				
90 – 130					−1.38	81	−0.37	98	1.02	93	0.10	34		
90 – 140	0.73	35			−1.20	94	0.38	108	2.33*	86	−0.39	71		
90 – 150					1.06	31	0.28	52			−0.44	25		
100 – 110			−0.64	101	−1.05	225	0.83	58	−0.47	87	0.53	110	−0.47	78
100 – 120			−0.36	105	1.10	174	0.62	69	0.95	96				
100 – 130			1.13	88	−1.05	143	0.11	79	0.58	91	0.17	87	0.42	62
100 – 140			−0.63	107	−0.73	156	0.73	89	1.31	84	−0.57	124		
100 – 150					0.79	93	0.42	33			−0.33	78		
110 – 120	−0.67	16	0.21	90	2.44*	223	−0.51	83	1.35	89				
110 – 130			1.67	73	−0.21	192	−1.32	93	1.13	84	−0.09	51	0.89	28
110 – 140	−0.83	25	−0.32	92	0.35	205	−0.12	103	1.96	77	−1.00	88		
110 – 150					0.87	142	0.09	47			−0.49	42		
120 – 130			1.28	77	−2.19*	141	−0.97	104	−0.44	93				
120 – 140	0.00	15	−0.38	96	−2.11*	154	0.36	114	0.27	86				
120 – 150					0.73	91	0.22	58						
130 – 140			−1.31	79	0.54	123	1.18	124	0.92	81	−0.55	65		
130 – 150					1.03	60	0.42	68			−0.70	19		
140 – 150					1.11	73	0.11	78			−0.14	56		

Note: * significant at 0.05 level

Table 18. Number of b'_{1yw} showing the significant difference from that of the different depth zone (y).

Depth zone (y in m)	50		90		100		110		120		130		140		150	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Grade of wind wave (w) 1																
2		1					1									
3							1			3	1		1			
4																
5			1											1		
6																
7																
Sum		1	1				2			3	1		1	1		

Note: L ...... significantly larger than the other
S ...... significantly smaller than the other

ingly, the difference of the length of towing time of the different depth zone may be not in the coefficient but in the constant of the regression equation. As shown in Figs. 8 and 9, the following trends were found out:

1) When the relations in the 50 m and 60 m zones and a few of the y-w strata showing quite different trends from the others were excluded, the variation of the regression lines due to the depth difference was small in most of the wave grades.

2) A half of the y-w strata showing the significant regression on the amount of catch by the preceding haul was concentrated into the 110 m zone.

3) The variation of the regression lines in the 90 m to 110 m zone, especially that in the latter depth zone, was larger than that in the other depth zones.

4) The boats inclined to tow the net in short time in the 50 m and 60 m zones.

5) The towing time in the 120 m to 150 m zones was a little longer than that in the 80 m to 110 m zones. These trends resulted in the significant depth regression.

7.4 The comparison of the regression lines of the different depth zones under the different wave grades

Most of the hauls yielded a catch of 10 to 20 tons. With an assistance of the lines in Fig. 10, the following trends were found out: the towing time after the haul with 10 tons of catch estimated from the regression lines showed a large variation (mainly 70 min. to 110 min.). That after the haul with 20 tons of catch was 60 min. to 120 min. There were the five y-w strata showing the significant regression on the amount of catch by the preceding haul. They took larger coefficient than the others. The towing time after good catch in these strata was longer than the others; but there were

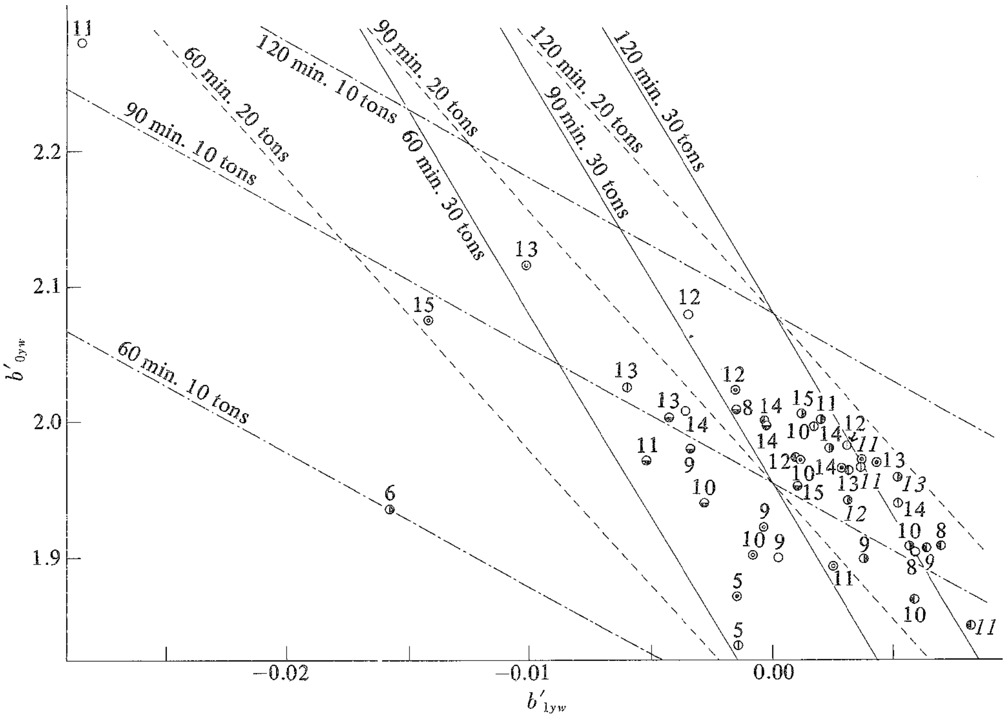


Fig. 10. The comparison of the regression lines of log t_t on x'.
$\log t_t = b'_{0yw} + b'_{1yw} x'$
For legend, see Fig. 7.

many strata taking the similar length of towing time to these strata, when the catch by the preceding haul was poor. No other notable trends than those pointed out in the preceding sections were found out.

8. The regression on the depth fished after the twofold stratification of the records according to the wave grade and the amount of catch

A trend of the elongation of towing time in accordance with depth was found in the multiple linear regression equation on the amount of catch and the depth and the linear one on the depth after the stratification of the records according to the wave grades. But it was hard to find any inevitable reason for it. Some relations were found out between the depth and the regression line of the length of towing time on the amount of catch, as shown in the preceding section. These facts necessitated the examination on the relation between the length of towing time and the depth, after the elimination of the discrepancy in the time-catch relation due to the bathymetric difference of the amount of catch.

The depth fished showed a rough trend capable of being regarded the seasonal change, and showed a small within-day variation. The records were stratified according to the wave grade and the amount of catch; and the regression of the length of towing time on the depth was examined. During the examination, the following fact should be kept in mind: the records on the same days were usually in the same wave grades but were distributed over many catch strata. The records in the same *x-w* strata consisted of the records of several days in the different seasons. The relative evaluation of a certain density level differs according to the seasonal change of the catch. And the stratification according to the amount of catch could not separate completely the influence of the within-day variation of the density from that of the seasonal change and the distribution pattern of the objective fish relating to the seasonal change of bathymetric distribution.

8.1 The significance of the depth regression after the stratification of the records according to the amount of catch by the haul

For the purpose of uniformalizing the conditions, the records were stratified according to the grade of wind wave and the amount of catch yielded by the haul. And the linear regression equations of $\log t_t$ on the depth observable in the strata with more than five records were estimated and the significance of their regression coefficients was tested.

As shown in Table 19, the regression coefficient took the significantly positive value in the eight *x-w* strata out of the 95 ones, the insignificantly positive value in the 62 ones, the insignificantly negative value in the 22 ones, and the significantly negative value in the three ones. The significantly positive coefficient was found mainly in the strata of poor catch in the wave grades 4 and 5. The significantly negative one was in the wave grade 2. The insignificantly negative one was in the wave grades 2, 3, and 7. These facts meant that the significant depth regression found in the multiple linear regression and the linear one before the stratification of the records according to the amount of catch may be either due to the additional effect of the insignificantly positive regression in most of the *x-w* strata or due to the different density probably relating to the seasonal bathymetric migration of the objective fish. It was found out in the comparison of the time-catch relation in the different depth zones that the length of towing time did not show any clear bathymetric difference. But this finding did not deny the latter possibility. On the other hand, the significant catch regression was found in the multiple linear regression and the linear one on the amount of catch. But these facts were not sufficient in support of the latter possibility. The examination of the regression of the amount of catch on the depth after the stratification of the records according to the length of towing time may be one of the probable methods of finding out the fact supporting the latter possibility. But the meaning of the same depth zones differs according to the seasonal difference of the bathymetric distribution, and this method is not free from the discrepancy due to these reasons. The examination after the stratification of the records according to the season may be one of the other probable methods; but the depth range of the hauls within a season was too narrow to examine the influence of the depth fished.

Table 19. The linear regression equations of the towing time (t_t in min.) on the depth of the fishing ground (y in m) after the stratification of the records according to the catch (x in tons) and the grade of wind wave (w).

$$\log t_t = c_{0xw} + c_{1xw}\, y$$

Grade of wind wave (w)	1				2			
Amount of catch (x tons)	c_{0x1}	c_{1x1}	F_0	n_2	c_{0x2}	c_{1x2}	F_0	n_2
2					2.3873	−0.0042	2.07	8
3	1.8117	0.0008	0.97	4	1.9000	0.0004	0.05	15
4	1.8702	0.0010	0.38	5	2.0042	−0.0004	0.38	29
5	1.8301	0.0007	0.03	6	2.0154	−0.0004	0.21	38
6					2.0321	−0.0004	0.25	25
7					2.4850	−0.0035	4.88*	16
8	1.8008	0.0010	12.86*	5	2.3560	−0.0028	8.93*	11
9								
10	1.9491	0.0005	0.02	5	1.7460	0.0024	2.54	19
11					2.1104	0.0001	0.00002	5
12	1.7433	0.0019	6.12	5				
13					2.4931	−0.0041	7.86*	8
14					1.7206	0.0027	1.47	5
15					1.7400	0.0026	1.33	17
17								
18								
20					2.0154	−0.0002	0.01	6
25					1.7941	0.0024	0.05	4

Grade of wind wave (w)	3							
Amount of catch (x tons)	c_{0x3}	c_{1x3}	F_0	n_2	c_{0x4}	c_{1x4}	F_0	n_2
2	1.7153	0.0020	1.32	11	1.8574	0.0008	1.39	16
3	2.0532	−0.0008	0.22	24	1.6119	0.0026	9.70**	15
4	1.9581	0.0002	0.04	32	1.5660	0.0032	9.03**	24
5	1.9807	−0.00001	0.003	44	1.8254	0.0009	2.31	33
6	1.8262	0.0013	2.74	41	1.9742	−0.0001	0.01	21
7	2.0723	−0.0006	0.73	52	1.7315	0.0020	10.02**	26
8	1.8521	0.0011	2.63	48	1.7856	0.0017	4.08	24
9	1.7040	0.0023	9.46**	16	1.7233	0.0021	2.07	6
10	1.9726	0.0003	0.10	41	1.8416	0.0014	1.40	23
11	1.5237	0.0042	3.81	12	1.8568	0.0010	0.21	5
12	1.7165	0.0023	2.65	18	1.8830	0.0011	0.67	10
13	1.7377	0.0024	3.37	26	1.7272	0.0026	2.98	17
14	2.0164	−0.0001	0.01	14				
15	1.8281	0.0016	1.66	33	1.8963	0.0008	0.53	24
17	1.5500	0.0045	3.19	9	1.6774	0.0032	1.01	4
18	2.3848	−0.0029	0.84	8	1.8553	0.0016	0.46	5
20	1.6237	0.0038	3.90	13	1.8795	0.0017	0.63	8
25	2.0262	−0.0002	0.001	5	2.3527	−0.0024	0.65	7

Grade of wind wave (w)	5				6				7			
Amount of catch (x tons)	c_{0x5}	c_{1x5}	F_0	n_2	c_{0x6}	c_{1x6}	F_0	n_2	c_{0x7}	c_{1x7}	F_0	n_2
2	0.5905	0.0080	1.96	4	1.8443	0.0007	1.28	3				
3	1.5361	0.0032	2.28	18	1.7473	0.0020	4.45	12	1.2513	0.0048	0.02	5
4	1.6264	0.0027	5.35*	26	2.0180	−0.0007	0.10	19	2.0906	−0.0023	0.04	5
5	1.7856	0.0014	7.64**	49	1.8439	0.0008	0.97	33	2.2541	−0.0036	1.86	8
6	1.8457	0.0010	1.21	23	2.0489	−0.0009	0.54	15	0.5152	0.0119	1.95	7
7	1.8954	0.0008	1.00	28	1.8184	0.0010	0.53	14	2.0805	−0.0018	0.05	4
8	1.8097	0.0013	1.44	28	1.8226	0.0013	2.50	22	1.4009	0.0050	7.82*	7
9	1.6143	0.0027	2.07	4	1.5679	0.0031	2.94	8	0.9639	0.0094	0.56	3
10	1.7620	0.0017	2.22	15	1.8068	0.0013	2.01	19	1.9306	−0.00001	0.00003	13
11	1.5905	0.0033	1.06	6	1.5173	0.0036	4.38	7				
12	1.9253	0.0009	0.24	8								
13	2.0582	−0.0006	0.12	17	1.7340	0.0016	0.53	21	1.7627	0.0016	0.10	12
14	1.8847	0.0009	0.10	8								
15	2.1511	−0.0008	0.10	8	1.8443	0.0013	0.51	9				
17												
18	2.1667	−0.0013	0.69	4								
20	1.8418	0.0016	0.09	6	1.2796	0.0060	4.84	6				
25	1.8045	0.0022	0.40	5								

Note: df .... $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level   ** significant at 0.01 level

8.2 The difference of the depth regression according to the wave grade

For the purpose of finding out the different influence of the wave grade observable in the difference of $\log t_t$ per meter of the depth of fishing ground, the regression coefficients for the same catch classes under the different wave grades were compared with one another. As shown in Tables 20 and 21, the significant difference was found in the 23 pairs of the wave grades out of the 219 ones. These pairs were mainly in the catch classes of poorer than 8 tons, namely the classes of poor catch. The two thirds of them were due to the small coefficients for the wave grade 2 especially in the 8-ton class, and the one third was due to the large coefficients for the wave grades 4 and 7. The pairs of *x-w* strata showing the significant difference in the regression coefficients under the wave grade 4 distributed over different catch classes; but those in the wave grade 7 were in the 6-ton class.

The significant differences due to the extreme value of these *x-w* strata were excluded; then it was hard to find any clear relation between the distribution of the strata showing small (or large) coefficient and either the wave grade or the catch class or the combination of them.

The length of towing time is illustrated by the constant and coefficient of the re-

Table 20. The results of the comparison between c_{1xw} under the different grades of wind wave (w) through the t-test.

Catch class (x)	2		3		4		5		6		7		8		9		10	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1 – 2			0.16	19	0.94	34	0.23	44					3.24**	16			−0.64	24
1 – 3			0.77	28	0.37	37	0.16	50					−0.07	53			0.09	46
1 – 4			−1.28	19	−1.11	29	−0.05	39					−0.39	29			−0.32	28
1 – 5			−0.79	22	−0.74	31	−0.18	55					−0.14	33			−0.44	20
1 – 6			−0.85	16	0.56	24	−0.02	39					−0.19	27			−0.33	24
1 – 7			−0.17	9	0.34	10	0.89	14					−2.34*	12			0.14	18
2 – 3	−1.88	19	0.49	39	−0.50	61	−0.34	82	−1.33	66	−1.91	68	−2.80**	59			1.24	60
2 – 4	−2.21*	24	−1.13	30	−3.06**	53	−1.21	71	−0.26	46	−3.72**	42	−2.81**	35			0.51	42
2 – 5	−1.69	12	−0.95	33	−2.43*	55	−1.84	87	−1.12	48	−2.54*	44	−2.20*	39			0.37	34
2 – 6	−1.23	11	−0.77	27	0.15	48	−1.02	71	0.35	40	−2.07*	30	−2.85**	33			0.64	38
2 – 7			−0.25	20	0.30	34	0.57	46	−2.57*	32	−0.20	20	−4.18**	18			0.90	32
3 – 4	0.75	27	−1.92	39	−2.01*	56	−0.94	77	1.20	62	−2.68**	78	−0.57	72	0.14	22	−0.78	64
3 – 5	−1.22	15	−1.46	42	−1.62	58	−1.58	93	0.24	64	−1.36	80	−0.17	76	−0.25	20	−0.99	56
3 – 6	0.54	14	−1.50	36	0.36	51	−0.76	77	1.64	56	−1.22	66	−0.19	70	−0.45	24	−0.80	60
3 – 7			−0.38	29	0.30	37	0.71	52	−2.55*	48	0.18	56	−1.89	55	−0.93	19	0.13	54
4 – 5	−2.12*	20	−0.27	33	0.31	50	−0.62	82	−0.95	44	1.16	54	0.29	52	−0.26	10	−0.18	38
4 – 6	0.08	19	0.47	27	1.61	43	0.10	66	0.60	36	0.74	40	0.33	46	−0.42	14	0.07	42
4 – 7			−0.13	20	0.71	29	1.02	41	−2.44*	28	0.65	30	−1.36	31	−0.70	9	0.52	36
5 – 6	1.49	7	0.49	30	1.29	45	0.67	82	1.34	38	−0.13	42	0.00	50	−0.16	12	0.28	34
5 – 7			−0.09	23	0.57	31	1.12	57	−2.23*	30	0.34	32	−1.34	35	−0.60	7	0.71	28
6 – 7			−0.16	17	0.17	24	0.85	41	−2.22*	22	0.28	18	−1.72	29	−0.66	11	0.59	32

Catch class (x)	11		12		13		14		15		17		18		20		25	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1 – 2																		
1 – 3			−0.21	23														
1 – 4			0.48	15														
1 – 5			0.46	13														
1 – 6																		
1 – 7																		
2 – 3	−1.19	17			−2.12*	34	1.27	19	0.42	50					−1.23	19	0.20	9
2 – 4	−0.22	10			−2.28*	25			0.78	41					−0.57	14	0.43	11
2 – 5	−0.77	11			−0.91	25	0.45	13	1.00	25					−0.33	12	0.01	9
2 – 6	−1.13	12			−1.44	29			0.45	26					−1.68	12		
2 – 7					−1.18	20												
3 – 4	0.69	17	0.60	28	−0.10	43			0.45	57	0.31	13	−1.13	13	0.73	21	0.41	12
3 – 5	0.25	18	0.64	26	1.39	43	−0.39	22	0.96	41			−0.46	12	0.42	19	−0.39	10
3 – 6	0.21	19			0.33	47			0.14	42					−0.68	19		
3 – 7					0.15	38												
4 – 5	−0.46	11	0.09	18	1.34	34			0.68	32			1.02	9	0.02	14	−0.97	12
4 – 6	−0.71	12			0.38	38			−0.26	33					−1.25	14		
4 – 7					0.19	29												
5 – 6	−0.09	13			−0.78	38			−0.66	17					−0.75	12		
5 – 7					−0.34	29												
6 – 7					0.00	33												

Note: * significant at 0.05 level ** significant at 0.01 level

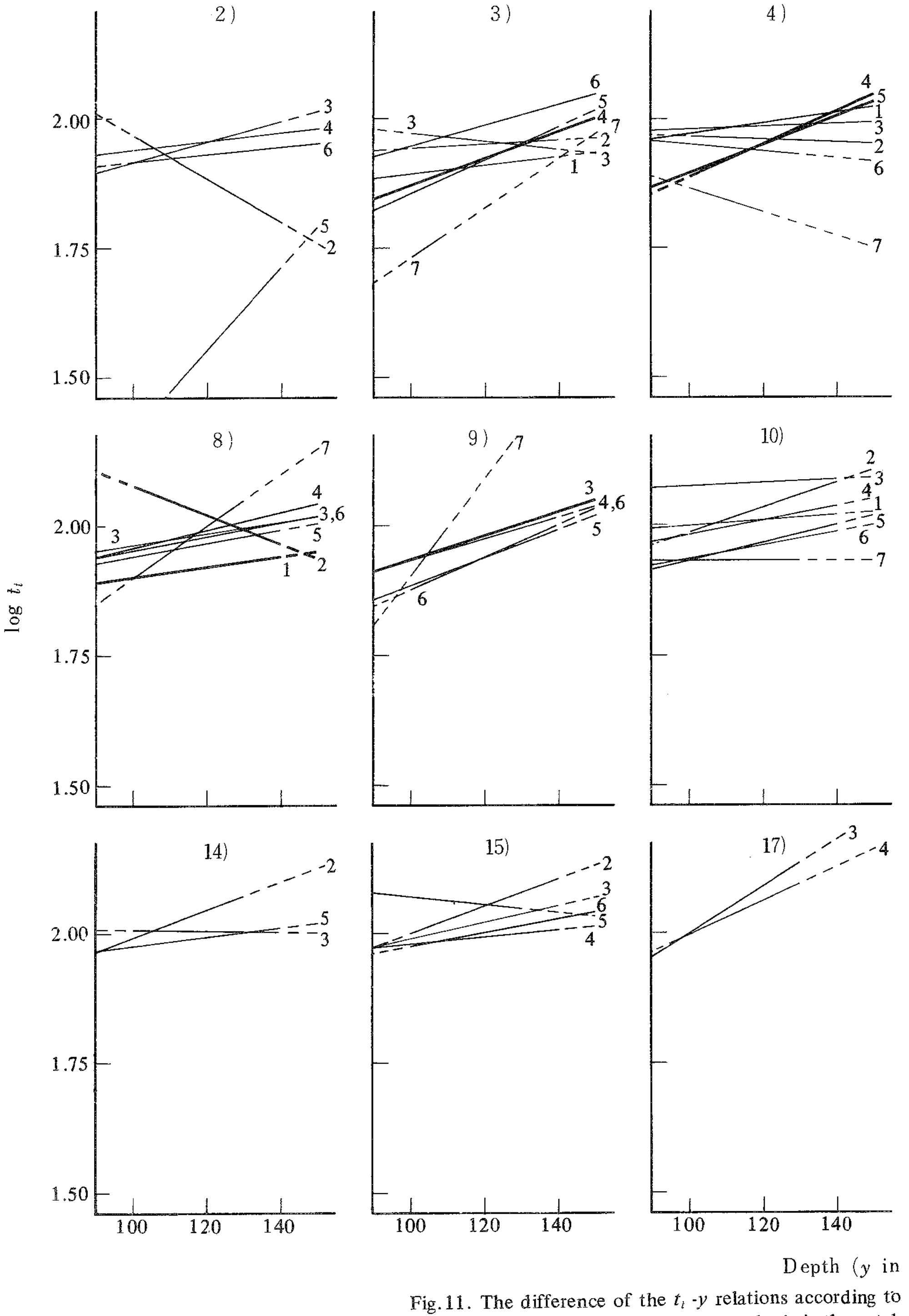
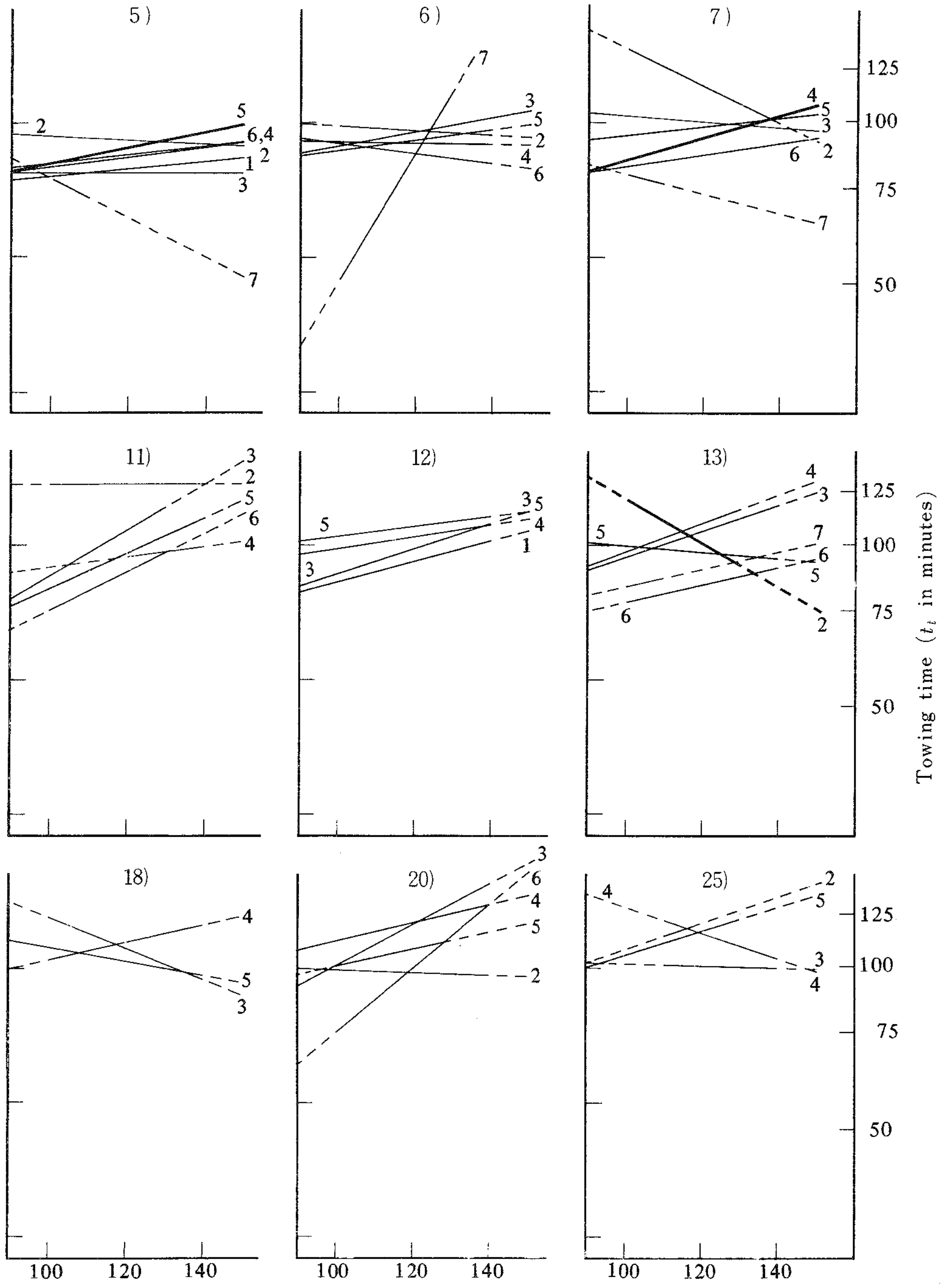


Fig. 11. The difference of the t_l -y relations according to
Note: The numeral with parenthesis is the catch wave grade.



meters)

the amount of catch and the wave grade.
class, and that attached to the line is the

Table 21. Number of c_{1xw} showing the significant difference from that of the different wave grade (w).

Grade of wind wave (w)	1		2		3		4		5		6		7	
Catch class (x in tons)	L	S	L	S	L	S	L	S	L	S	L	S	L	S
2				1			1	1	1					
3														
4				2		1	2		1					
5														
6				1		1		1		1		1	5	
7				3		1	2		1		1			
8	1	1		6	1		1		1		1		2	
9														
10														
11														
12														
13		2			1		1							
14														
15														
17														
18														
20														
25														
Sum	1	3		13	2	3	7	2	4	1	2	1	7	

Note: L .... significantly larger than the other
S .... significantly smaller than the other

gression equation and the applicable depth-range of the equation. The boats fished in the 40 m to 150 m zones, mainly in the 90 m to 140 m zones. For the purpose of easy comparison of the length of towing time, the regression lines were shown in Fig. 11. This figure revealed the following facts: the clearest trend was that the regression lines under the wave grade 7 showed the different trend from those of the other wave grades. They were either the small coefficient and large constant or the large coefficient and small constant as shown in Fig. 12. But the applicable range of depth of these regression lines was, in general, very narrow, being mainly in the 100 m and 110 m zones, because the records in this wave grade were found in a limited season. The length of towing time under the wave grade 7 in these depth zones was shorter than that under the other wave grades, although the difference was not so large as the impression from the different value either of the constant or of the coefficient.

The regression lines for most of the poor catch classes (poorer than 13 tons) under the wave grade 2 took larger constant and smaller coefficient than those of the other wave grades. Namely, under the calm water the boats towed the net over long time in shallow zone than in deep zone. No other notable trend was found out.

8.3 The difference of the depth regression according to the amount of catch

The regression coefficient varied from −0.0042 to 0.0119. But the significant difference between the coefficients of the different catch classes under the same wave grades was found only in the 29 pairs of x-w strata out of the 645 pairs. The 11 pairs were under the wave grade 2, the 10 were under the wave grade 3, the three were under the wave grade 4, the four were under the wave grade 6 and one was under the wave grade 7. Namely, most of the significant differences of the influence of the depth were found in the wave grade 2 and 3. And in these 29 pairs of the strata, the coefficient in the classes of poor catch (less than 8 tons) inclined to be smaller than that in the classes of good catch (more than 9 tons). Namely, under the calm water, the depth was less influential in the length of towing time for the hauls of poor catch than that of good catch.

Table 22. The results of the comparison between c_{1xw} of the different catch classes through the t-test.

Grade of wind wave (w)	1		2		3		4		5		6		7	
Catch class (x)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
2 – 3			−1.41	23	1.20	35	−1.68	31	0.70	22	−0.78	15		
2 – 4			−1.97	37	0.89	43	−1.88	40	1.12	30	0.46	22		
2 – 5			−1.70	46	1.12	55	−0.10	49	1.85	53	−0.05	36		
2 – 6			−1.71	33	0.38	52	0.87	37	1.81	27	0.68	18		
2 – 7			−0.24	24	1.53	63	−1.25	42	1.67	32	−0.11	17		
2 – 8			−0.50	19	0.54	59	−0.73	40	1.36	32	−0.32	25		
2 – 9					−0.18	27	−0.95	22	0.98	8	−1.13	11		
2 – 10			−2.30*	27	0.92	52	−0.41	39	1.40	19	−0.31	22		
2 – 11			−0.97	13	−0.79	23	−0.09	21	0.70	10	−1.22	10		
2 – 12					−0.13	29	−0.22	26	1.25	12				
2 – 13			−0.02	16	−0.18	37	−1.16	33	1.42	21	−0.27	24		
2 – 14			−1.63	13	1.09	25			1.06	12				
2 – 15			−1.94	25	0.19	44	0.00	40	1.48	12	−0.23	12		
2 – 17					−0.84	20	−1.03	20						
2 – 18					1.42	19	−0.43	21	1.81	8				
2 – 20			−0.95	14	−0.69	24	−0.51	24	0.83	10	−1.64	9		
2 – 25			−0.42	12	0.51	16	1.40	23	0.82	9				
3 – 4	−0.11	9	0.49	44	−0.52	56	−0.44	39	0.22	44	1.10	31	0.22	10
3 – 5	0.03	10	0.42	53	−0.46	68	1.62	48	1.13	67	0.89	45	0.34	13
3 – 6			0.43	40	−1.18	65	2.40*	36	1.04	41	1.85	27	−0.24	12
3 – 7			1.59	31	−0.12	76	0.59	41	1.22	46	0.55	26	0.19	9
3 – 8	−0.22	9	1.43	26	−1.18	72	0.71	39	0.87	46	0.54	34	−0.01	12
3 – 9					−1.80	40	0.31	21	0.14	22	−0.54	20	−0.11	8
3 – 10	0.09	9	−0.83	34	−0.62	65	0.80	38	0.62	33	0.52	31	0.27	18
3 – 11			0.12	20	−1.97	36	0.55	20	−0.03	24	−0.88	19		
3 – 12	−0.96	9			−1.46	42	0.98	25	0.77	26				
3 – 13			1.32	23	−1.52	50	0.00	32	1.35	35	0.17	33	0.15	17
3 – 14			−0.71	20	−0.37	38			0.63	26				
3 – 15			−0.75	32	−1.18	57	1.26	39	1.06	26	0.36	21		
3 – 17					−1.89	33	−0.21	19						
3 – 18					0.65	32	0.45	20	1.27	22				
3 – 20			0.18	21	−1.91	37	0.45	23	0.25	24	−1.69	18		
3 – 25			−0.17	19	−0.15	29	1.86	22	0.25	23				
4 – 5	0.07	11	0.00	67	0.17	76	1.92	57	1.13	75	−0.64	52	0.13	13
4 – 6			0.00	54	−0.86	73	2.56*	45	1.15	49	0.08	34	−0.64	12
4 – 7			2.14*	45	0.68	84	1.01	50	1.36	54	−0.59	33	−0.03	9
4 – 8	0.00	10	2.04*	40	−0.77	80	1.07	48	0.87	54	−0.86	41	−0.81	12
4 – 9					−1.50	48	0.61	30	0.00	30	−1.18	27	−0.65	8
4 – 10	0.14	10	−1.92	48	−0.08	73	1.12	47	0.60	41	−0.84	38	−0.27	18
4 – 11			−0.22	34	−1.90	44	0.68	29	−0.22	32	−1.46	26		

Table 22. —(Cont'd)

Grade of wind wave (w)	1		2		3		4		5		6		7	
Catch class (x)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
4 – 12	-0.52	10			-1.23	50	1.24	34	0.88	34				
4 – 13			1.93	37	-1.36	58	0.34	41	1.60	43	-0.69	40	-0.36	17
4 – 14			-1.76	34	0.19	46			0.69	34				
4 – 15			-1.59	46	-0.85	65	1.52	48	1.32	34	-0.66	28		
4 – 17					-1.69	41	0.00	28						
4 – 18					1.02	40	0.66	29	1.73	30				
4 – 20			-0.11	35	-1.82	45	0.72	32	0.24	32	-1.95	25		
4 – 25			-0.39	33	0.11	37	1.99	31	0.18	31				
5 – 6			0.00	63	-1.20	85	1.01	54	0.39	72	1.28	48	-1.04	15
5 – 7			1.76	54	0.59	96	-1.23	59	0.66	77	-0.14	47	-0.27	12
5 – 8	-0.09	11	1.42	49	-1.11	92	-0.78	57	0.09	77	-0.43	55	-2.27*	15
5 – 9					-1.89	60	-0.78	39	-0.78	53	-1.01	41	-1.48	11
5 – 10	-0.03	11	-1.57	57	-0.27	85	-0.40	56	-0.26	64	-0.42	52	-0.83	21
5 – 11			-0.17	43	-2.27*	56	-0.03	38	-0.95	55	-1.58	40		
5 – 12	-0.34	11			-1.54	62	-0.14	43	0.36	57				
5 – 13			1.28	46	-1.70	70	-1.18	50	1.39	66	-0.40	54	-0.82	20
5 – 14			-1.25	43	0.07	58			0.27	57				
5 – 15			-1.34	55	-1.10	77	0.07	57	1.13	57	-0.28	42		
5 – 17					-1.97	53	-0.81	37						
5 – 18					1.05	52	-0.33	38	1.64	53				
5 – 20			-0.08	44	-2.19*	57	-0.46	41	-0.06	55	-2.34*	39		
5 – 25			-0.27	42	0.06	49	1.31	40	-0.39	54				
6 – 7			1.85	41	1.82	93	-2.15*	47	0.16	51	-1.04	29	0.60	11
6 – 8			1.73	36	0.19	89	-1.52	45	-0.21	51	-1.59	37	0.81	14
6 – 9					-0.78	57	-1.42	27	-0.92	27	-1.57	23	0.08	10
6 – 10			-1.67	44	0.84	82	-1.07	44	-0.50	38	-1.53	34	1.61	20
6 – 11			-0.19	30	-1.50	53	-0.39	26	-0.98	29	-2.13*	22		
6 – 12					-0.64	59	-0.83	31	0.06	31				
6 – 13			1.68	33	-0.75	67	-1.74	38	0.85	40	-1.05	36	0.85	19
6 – 14			-1.52	30	0.99	55			0.04	31				
6 – 15			-1.42	42	-0.20	74	-0.65	45	0.81	31	-1.02	24		
6 – 17					-1.35	50	-1.21	25						
6 – 18					1.47	49	-0.81	26	1.28	27				
6 – 20			-0.09	31	-1.38	54	-0.98	29	-0.16	29	-2.59*	21		
6 – 25			-0.35	29	0.42	46	0.91	28	-0.50	28				
7 – 8			-0.36	27	-1.77	100	0.28	50	-0.38	56	-0.19	36	-0.99	11
7 – 9					-2.49*	68	-0.07	32	-0.92	32	-0.71	22	-0.79	7
7 – 10			-2.70*	35	-0.82	93	0.47	49	-0.64	43	-0.19	33	-0.26	17
7 – 11			-1.18	21	-2.73**	64	0.38	31	-1.01	34	-1.07	21		
7 – 12					-2.03*	70	0.68	36	-0.06	36				
7 – 13			0.20	24	-2.23**	78	-0.42	43	0.79	45	-0.23	35	-0.36	16
7 – 14			-2.17*	21	-0.39	66			-0.04	36				
7 – 15			-2.26*	33	-.156	85	0.93	50	0.68	36	-0.12	23		
7 – 17					-2.35*	61	-0.47	30						
7 – 18					0.88	60	0.20	31	1.04	32				
7 – 20			-1.13	22	-2.66**	65	0.18	34	-0.19	34	-1.65	20		
7 – 25			-0.54	20	-0.12	57	1.87	33	-0.56	33				
8 – 9					-1.06	64	-0.21	30	-0.58	32	-0.85	30	-0.46	10
8 – 10	0.16	10	-2.72*	30	0.73	89	0.21	47	-0.24	43	0.00	41	1.88	20
8 – 11			-1.20	16	-1.79	60	0.19	29	-0.71	34	-1.32	29		
8 – 12	-1.02	10			-0.86	66	0.35	34	0.20	36				
8 – 13			0.71	19	-0.97	74	-0.53	41	0.95	45	-0.14	43	0.68	19
8 – 14			-2.73*	16	0.95	62			0.15	36				
8 – 15			-2.23*	28	-0.36	81	0.58	48	0.78	36	0.00	31		
8 – 17					-1.61	57	-0.44	28						
8 – 18					1.58	56	0.04	29	1.09	32				
8 – 20			-1.19	17	-1.66	61	0.00	32	-0.06	34	-2.13*	28		
8 – 25			-0.68	15	0.41	53	1.36	31	-0.31	33				
9 – 10					1.55	57	0.33	29	0.46	19	0.83	27	1.01	16
9 – 11					-0.96	28	0.35	11	-0.16	10	-0.19	15		
9 – 12					0.00	34	0.50	16	0.63	12				
9 – 13					-0.06	42	-0.22	23	1.05	21	0.43	29	0.65	15
9 – 14					1.91	30			0.49	12				

Table 22. — (Cont'd)

Grade of wind wave (w)	1		2		3		4		5		6		7	
Catch class (x)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
9 – 15					0.46	49	0.73	30	1.06	12	0.64	17		
9 – 17					–1.03	25	–0.32	10						
9 – 18					2.07*	24	0.18	11	1.65	8				
9 – 20					–0.81	29	0.15	14	0.21	10	–0.89	14		
9 – 25					0.80	21	1.39	13	0.13	9				
10 – 11			0.84	24	–2.02*	53	0.10	28	–0.58	21	–1.28	26		
10 – 12	–0.46	10			–1.27	59	0.15	33	0.40	23				
10 – 13			2.23*	27	–1.40	67	–0.62	40	1.07	32	–0.14	40	–0.33	25
10 – 14			–0.11	24	0.28	55			0.30	23				
10 – 15			–0.08	36	–0.85	74	0.34	47	0.97	23	0.00	28		
10 – 17					–1.80	50	–0.47	27						
10 – 18					1.15	49	–0.07	28	1.43	19				
10 – 20			0.93	25	–1.93	54	–0.13	31	0.02	21	–2.05	25		
10 – 25			0.00	23	0.14	46	1.13	30	–0.18	20				
11 – 12					0.78	30	–0.03	15	0.68	14				
11 – 13			1.26	13	0.77	38	–0.41	22	1.09	23	0.68	28		
11 – 14			–0.74	10	1.94	26			0.56	14				
11 – 15			–0.75	22	1.17	45	0.07	29	1.01	14	0.90	16		
11 – 17					–0.09	21	–0.57	9						
11 – 18					1.79	20	–0.16	10	1.27	10				
11 – 20			0.06	11	0.14	25	–0.17	13	0.27	12	–0.77	13		
11 – 25			–0.19	9	0.88	17	0.81	12	0.23	11				
12 – 13					–0.05	44	–0.73	27	0.56	25				
12 – 14					1.36	32			0.00	16				
12 – 15					0.38	51	0.18	34	0.53	16				
12 – 17					–0.79	27	–0.64	14						
12 – 18					1.58	26	–0.19	15	0.80	12				
12 – 20					–0.65	31	–0.25	18	–0.13	14				
12 – 25					0.61	23	1.14	17	–0.36	13				
13 – 14			–2.58*	13	1.43	40			–0.45	25				
13 – 15			–1.93	25	0.44	59	0.98	41	0.06	25	0.10	30		
13 – 17					–0.75	35	–0.16	21						
13 – 18					1.60	34	0.34	22	0.23	21				
13 – 20			–1.33	14	–0.63	39	0.36	25	–0.39	23	–1.26	27		
13 – 25			–0.82	12	0.63	31	1.50	24	–0.76	22				
14 – 15			0.03	22	–1.01	47			0.43	16				
14 – 17					–1.90	23								
14 – 18					0.98	22			0.61	12				
14 – 20			0.88	11	–1.88	27			–0.11	14				
14 – 25			0.03	9	0.03	19			–0.29	13				
15 – 17					–1.13	42	–0.84	28						
15 – 18					1.50	41	–0.35	29	0.16	12				
15 – 20			0.83	23	–1.04	46	–0.43	32	–0.42	14	–1.47	15		
15 – 25			0.02	21	0.49	38	1.20	31	–0.71	13				
17 – 18					1.85	17	0.40	9						
17 – 20					0.22	22	0.35	12						
17 – 25					0.95	14	1.25	11						
18 – 20					–1.77	21	–0.03	13	–0.58	10				
18 – 25					–0.50	13	1.04	12	–0.91	9				
20 – 25			–0.24	10	0.84	18	1.07	15	–0.09	11				

Note: * significant at 0.05 level ** significant at 0.01 level

Table 23. Number of c_{1xw} showing the significant difference from that of the different catch class (x).

Catch class (x)	1		2		3		4		5		6		7		8		9		10	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Grade of wind wave (w) 1																				
2				1			2							4		4			4	
3										2				6			2			1
4					1		1					3	1							
5																				
6										1		2				1				
7										1					1					
Sum				1	1		3			4		5	1	10	1	5	2		4	1

Catch class (x)	11		12		13		14		15		17		18		20		25		
	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	
Grade of wind wave (w) 1																			
2						2	3		2										
3	3		1		1						1			1	2				
4																			
5																			
6	1														3				
7																			
Sum	4		1		1	2	3		2		1			1	5				

Note: L . . . . . significantly larger than the other
S . . . . . significantly smaller than the other

The regression lines of the different catch classes under the same wave grades were compared with one another, and the lines in the following strata showed the different trend from those of the other catch classes:

1) Long towing throughout the depth zones, because of large constant
. . . . 11-ton class under the wave grade 2, abbreviated to (11.2)

2) Short towing throughout the depth zones, because of small constant
. . . . (2.5)

3) Long towing in shallow zone, although the towing of an ordinary length in deep zone, because of large constant and small coefficient
. . . . (7.2), (18.3), and (25.4)

4) Long towing in deep zone, although the towing of an ordinary length in shallow zone, because of large coefficient
. . . . (8.7), (9.7), (17.3), (20.3), (20.6), (25.2), and (25.5)

5) Short towing in shallow zone, although the towing of an ordinary length in deep zone, because of small constant and large coefficient
. . . . (3.7)

6) Short towing in deep zone, although the towing of an ordinary length in shallow zone, because of small coefficient
.... (2.2), (4.7), and (5.7)

7) Short towing in shallow zone and long towing in deep zone, because of large coefficient
.... (6.7)

Namely, the different trend of the influence of the depth shown in the type 4—influential in deep zone—inclined to be found in the strata of good catch.

8.4 The comparison of the regression lines of the different catch classes under the different wave grades

The trends shown in the preceding sections were the trends observable either among the strata of the same catch classes or among the same wave grades. If a line in a *x-w* stratum showed the different trend from the other lines in the same catch class (or the same wave grade), whether or not the line showed the different trend from the other lines in the same wave grade (or the same catch class) was out of the problem dealt in the preceding sections; in other words, the preceding sections did not concern with the question as to whether the difference was within the variation of the lines in the same wave grade (or the same catch class).

The clearest trend found in Fig. 12 was that the points showing respective regression equations were distributed along a line with few exceptions. This fact meant that most of the lines in the applicable depth range showed similar trend to one another, in spite of large variation of either the constant or the coefficient. The points for the 2-ton class under the wave grade 5 and the classes of poor catch under the wave grade 7 took smaller constant than that expected from the relation between the constant and the coefficient of the lines. The regression lines for the adjacent catch classes within the same wave grade or the same catch classes in the adjacent wave grades to the former *x-w* stratum did not show any notable difference from the others in respect of either the constant or the coefficient.

The other trends found in this figure were the wide variation of the lines in the wave grade 7, the narrow one of those in the wave grade 1 in respect of either the constant or the coefficient, and the large constant and small coefficient of those in the wave grade 2, as already shown in the preceding sections. No other notable trend was found out.

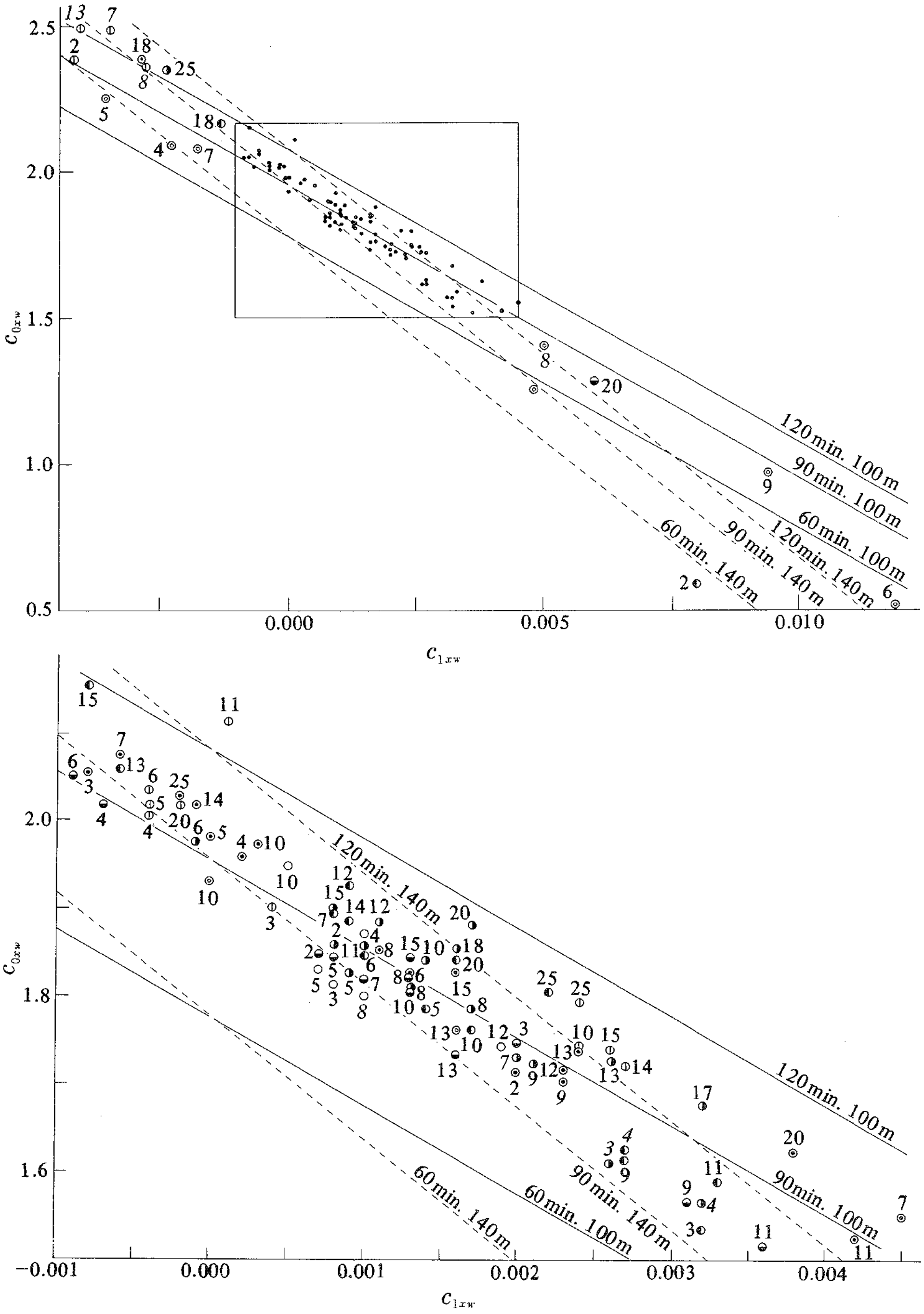


Fig. 12. The comparison of the regression lines of log t_t on y.

$\log t_t = c_{0xw} + c_{1xw}\, y$

Legend: The numeral shows the catch-class (in tons). The mark with italic numeral shows the regression line with significant coefficient.

For the mark of the wave grade, see Fig. 7.

9. The regression on the depth after the twofold stratification of the records according to the wave grade and the amount of catch by the preceding haul

As stated in the preceding sections, the towing work of the bull trawling is conducted in coordination of a pair of boats. The popularization of handy wireless telephone facilitates unintermittent communication between them. But there remained a difficulty in changing the work plane according to the conditions. And it is probable that the towing course and the length of towing time are assigned before or just after the start of towing; but the assigned plane is changed and the towing is cut off only when an extraordinary good catch is yielded during the towing. It is, accordingly, probable that the length of towing time depends on the result of the preceding haul, i.e. the amount of catch by the preceding haul. Because of this reason, the records were

Table 24. The linear regression equations of the towing time (t_t in min.) on the depth of the fishing ground (y in m) after the stratification of the records according to the amount of catch by the preceding haul (x' in tons) and the grade of wind wave (w).

$$\log t_t = c'_{0x'w} + c'_{1x'w}\,y$$

Grade of wind wave (w)	1				2				3				4			
Amount of catch by the preceding haul (x' tons)	$c'_{0x'1}$	$c'_{1x'1}$	F_0	n_2	$c'_{0x'2}$	$c'_{1x'2}$	F_0	n_2	$c'_{0x'3}$	$c'_{1x'3}$	F_0	n_2	$c'_{0x'4}$	$c'_{1x'4}$	F_0	n_2
2					1.9970	−0.0005	0.05	8	1.9425	0.0005	0.07	12	1.7439	0.0016	1.87	15
3					2.1071	−0.0008	0.10	11	1.7150	0.0026	2.90	23	1.9366	0.0003	0.11	18
4					2.1839	−0.0017	2.33	27	1.7697	0.0018	3.06	34	1.5044	0.0035	18.68**	24
5	1.2118	0.0072	25.44**	4	1.8852	0.0008	0.60	35	2.0085	−0.0003	0.10	42	1.7312	0.0021	7.83**	34
6					2.1234	−0.0010	0.49	25	1.9469	0.0004	0.11	35	1.9090	0.0004	0.13	16
7	1.8468	0.0008	1.80	3	2.4000	−0.0033	10.87**	13	1.9855	0.00003	0.002	49	1.6500	0.0030	12.70**	29
8	1.7318	0.0016	1.79	5	2.2370	−0.0017	0.63	10	1.9861	0.00001	0.001	46	1.8232	0.0013	1.43	19
9									1.7307	0.0020	2.90	14	1.7007	0.0026	3.30	4
10	1.8788	0.0007	1.36	7	2.0925	−0.0008	0.22	18	1.9724	0.0001	0.02	37	1.9362	0.0005	0.18	21
11					1.7900	0.0022	1.00	6	1.5446	0.0040	5.06*	13	1.7532	0.0019	0.24	3
12	1.7024	0.0019	10.65*	3	2.0949	−0.0006	0.09	4	1.8934	0.0009	0.31	17	1.8910	0.0009	0.48	10
13					2.0276	−0.0001	0.002	7	1.7499	0.0022	4.68*	25	2.0115	−0.0002	0.02	15
14					2.7343	−0.0062	2.63	3	1.8497	0.0011	0.88	13				
15					1.8947	0.0011	0.41	20	1.9172	0.0009	0.31	28	2.3590	−0.0027	2.62	17
17									2.2834	−0.0016	0.94	7	2.2139	−0.0015	0.24	3
18									2.1359	−0.0010	0.21	10				
20					1.9589	−0.0002	0.003	5	1.7130	0.0026	1.61	13	1.8250	0.0018	2.77	9
25					1.8415	0.0024	0.09	5	1.9279	0.0009	0.04	4	1.4505	0.0047	2.01	5

Grade of wind wave (w)	5				6				7			
Amount of catch by the preceding haul (x' tons)	$c'_{0x'5}$	$c'_{1x'5}$	F_0	n_2	$c'_{0x'6}$	$c'_{1x'6}$	F_0	n_2	$c'_{0x'7}$	$c'_{1x'7}$	F_0	n_2
2					1.7178	0.0025	3.61	4				
3	1.7814	0.0016	1.45	16	1.8673	0.0010	0.14	10	1.8952	0.0002	0.002	5
4	1.6255	0.0028	7.64*	19	1.8448	0.0011	0.43	21	1.8941	0.0001	0.0001	5
5	1.8382	0.0010	1.63	44	1.8740	0.0006	1.13	26	2.8777	−0.0098	9.18*	8
6	1.8732	0.0008	0.33	22	1.8081	0.0011	1.68	19	1.7411	0.0018	0.53	3
7	1.7657	0.0018	3.31	23	1.8346	0.0009	0.45	13				
8	1.7597	0.0015	1.23	33	1.7641	0.0018	3.66	20	1.7536	0.0020	0.43	8
9	2.7375	−0.0056	1.76	3	2.3066	−0.0023	0.93	5				
10	1.8452	0.0006	0.14	13	1.7967	0.0012	0.74	16	0.8050	0.0101	3.08	15
11	1.8917	0.0003	0.01	5	1.4083	0.0046	11.82*	6				
12									2.0512	−0.0008	0.05	3
13	1.7060	0.0021	1.40	23	1.8914	0.00003	0.0001	22	1.7508	0.0014	0.14	10
14	1.8002	0.0014	0.51	7								
15	1.9743	0.0010	0.20	8	1.8009	0.0011	0.24	9				
17												
18	2.2885	−0.0025	1.31	6								
20	2.2371	−0.0019	0.78	10								
25	2.4294	−0.0038	2.04	4								

Note: df .... $n_1 = 1$ n_2 = the value shown in the table
* significant at 0.05 level ** significant at 0.01 level

stratified according to the wave grade (w) and the amount of catch by the preceding haul (x'), the depth regression lines observable among the records of respective x'-w strata were estimated, and the difference in the regression lines due to the difference either in x' or in w was examined through the same methods as those used in the preceding sections.

9.1 The significance of the depth regression

As shown in Table 24, the regression coefficient varied from −0.0098 to 0.0101. The regression coefficient in the 65 x'-w strata out of the 89 ones took the positive value. Among them, the coefficient in the nine strata was significant. The negative depth-regression was found in the 24 x'-w strata, although all except two were insignificant. They were mainly under the wave grade 2 and the classes of good catch by the preceding haul. These facts suggested that, as stated in the preceding section, the significant depth regression of the length of towing time was either due to the additional effect of the insignificantly positive regression in most of the x'-w strata or due to the bathymetric difference of the density of the objective fish probably relating to the seasonal bathymetric migration.

All the results of the examinations on the depth regression summarized, it may be concluded that the length of towing time did not differ in accordance with depth, although the bathymetric difference of the composition of the hauls in respect of the amount of catch resulted in the false regression on depth; accordingly, it is natural that it is difficult to find any inebitable reason for the depth regression found in the preceding sections.

9.2 The difference of the depth regression according to the wave grade

In the preceding section, it was found out that the regression coefficient took negative value under the wave grade 2, and in the classes of good catch, but the coefficient took positive value in the other wave grades or in the other catch classes. These facts suggested a probable difference of the influence of depth according to these factors. For the purpose of examining the former possibility, the regression lines of the same catch classes under the different wave grades were compared with one another. As shown in Table 25, the significant difference was found between the regression coefficients of the 21 pairs of the x'-w strata out of the 191 ones. Table 26 showed that most of the significant differences were due to the large values in the wave grade 3 or the small values in the wave grade 2 or in the wave grade 7. But the following facts threw a doubt whether the conclusion like this would be meaningful most of these significant differences found in respective catch classes were due to the different value in a few of the x'-w strata. Namely, all the significant differences of the three pairs in the 4-ton class were due to the small value in the wave grade 2; in the 5-ton class, the significant differences in the six pairs out of the seven ones were due to the small value in the wave grade 7; in the 7-ton class, those of the five pairs out of the six ones were due to the small value in the wave grade 5; and in the 10-ton class, all the significant differences in the three pairs were due to the large value in the wave grade 7.

For the purpose of examining this point, the results of the comparison were checked again, and the following trends were found out: whether the regression coefficient would be significant or not was not taken into account, then, the coefficient in the wave grade 2 was smaller than that of the other wave grades in the 52 pairs out of the 66 ones. The coefficient of the wave grade 3 was larger than that of the other wave grades in the 36 pairs out of the 71 ones. The coefficient of the wave grade 7 was smaller than that of the other wave grades in the 20 pairs out of the 42 ones. These facts meant that the towing time showed very faint elongation in accordance with depth, but this trend was far less clear in the wave grades 2 and 7 than in the other wave grades, and in the former

Table 25. The results of the comparison between $c'_{1x'w}$ under the different grades of wind wave (w) through the t-test.

Catch class (x')	2		3		4		5		6		7		8		9		10	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1 – 2							1.21	39			2.65*	16	1.16	15			0.68	25
1 – 3							1.67	46			0.38	52	1.09	51			0.44	44
1 – 4							1.15	38			−1.01	32	0.14	24			0.12	28
1 – 5							1.12	48			−0.50	26	0.03	38			0.05	20
1 – 6							1.92	30			−0.04	16	−0.13	25			−0.25	23
1 – 7							4.15**	12					−0.12	13			−1.60	22
2 – 3	−0.34	20	−1.22	34	−2.27*	61	0.86	77	−0.73	60	−2.10*	62	−1.10	56			−0.55	55
2 – 4	−0.91	23	−0.47	29	−3.48**	51	−1.05	69	−0.78	41	−3.87**	42	−1.35	29			−0.66	39
2 – 5			−0.93	27	−2.87**	46	−0.16	79	−0.94	47	−3.24**	36	−1.22	43			−0.59	31
2 – 6	−1.02	12	−0.50	21	−1.34	48	0.17	61	−1.30	44	−2.29*	26	−1.77	30			−0.90	34
2 – 7			−0.12	16	−0.17	32	2.23*	43	−0.67	28			−0.96	18			−2.11*	33
3 – 4	−0.49	27	1.29	41	−1.23	58	2.19*	76	0.00	51	−2.60*	78	−1.15	65	−0.34	18	−0.31	58
3 – 5			0.48	39	−0.69	53	−1.12	86	−0.21	57	−1.39	72	−1.05	79	2.34*	17	−0.32	50
3 – 6	−0.70	16	0.57	33	0.36	55	−0.87	68	−0.43	54	−0.60	62	−1.62	66	1.09	19	−0.77	53
3 – 7			0.31	28	0.19	39	2.32*	50	−0.30	38			−0.93	54			−2.68**	52
4 – 5			−0.79	34	0.53	43	1.00	78	−0.23	38	0.91	52	−0.11	52	2.06	7	−0.05	34
4 – 6	−0.50	19	−0.30	28	1.34	45	1.55	60	−0.52	35	1.37	42	−0.33	39	1.27	9	−0.39	37
4 – 7			0.02	23	0.46	29	2.94**	42	−0.42	19			−0.23	27			−2.10*	36
5 – 6			0.22	26	0.86	40	0.37	70	−0.19	41	0.56	36	−0.15	53	−0.61	8	−0.27	29
5 – 7			0.23	21	0.28	24	2.19*	52	−0.26	25			−0.13	41			−1.74	28
6 – 7			0.09	15	0.09	26	3.16**	34	−0.24	22			−0.08	28			−1.77	31

Catch class (x')	11		12		13		14		15		17		18		20		25	
Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
1 – 2			1.21	7														
1 – 3			0.43	20														
1 – 4			0.60	13														
1 – 5																		
1 – 6																		
1 – 7			0.94	6														
2 – 3	−0.59	19	−0.52	21	−0.75	32	−2.48*	16	0.08	48					−0.70	18	0.15	9
2 – 4	0.07	9	−0.66	14	0.03	22			1.59	37					−0.68	14	−0.27	10
2 – 5	0.51	11			−0.41	30	−1.98	10	0.04	28					0.43	15	0.75	9
2 – 6	−0.96	12			−0.03	29			0.00	29								
2 – 7			0.05	7	−0.29	17												
3 – 4	0.48	16	0.00	27	1.45	40			1.44	45	−0.03	10			0.33	22	−0.68	9
3 – 5	1.07	18			0.05	48	−0.14	20	−0.03	36			0.50	16	1.51	23	0.92	8
3 – 6	−0.25	19			0.68	47			−0.08	37								
3 – 7			0.42	20	0.17	35												
4 – 5	0.31	8			−0.88	38			−1.37	25					1.56	19	1.99	9
4 – 6	−0.76	9			−0.06	37			−1.40	26								
4 – 7			0.54	13	−0.33	25												
5 – 6	−1.40	11			0.47	45			−0.03	17								
5 – 7					0.08	33												
6 – 7					−0.20	32												

Note: * significant at 0.05 level ** significant at 0.01 level

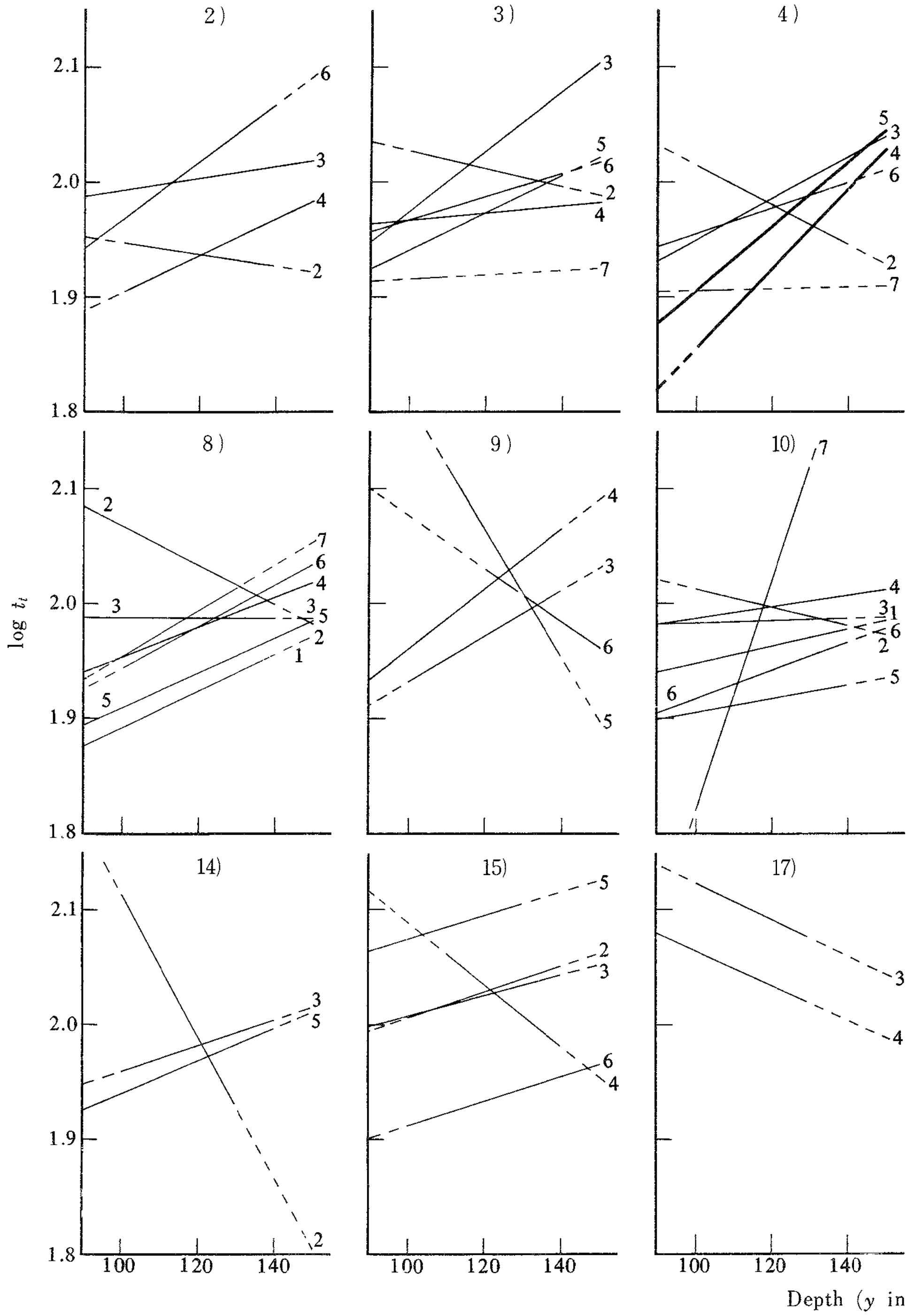
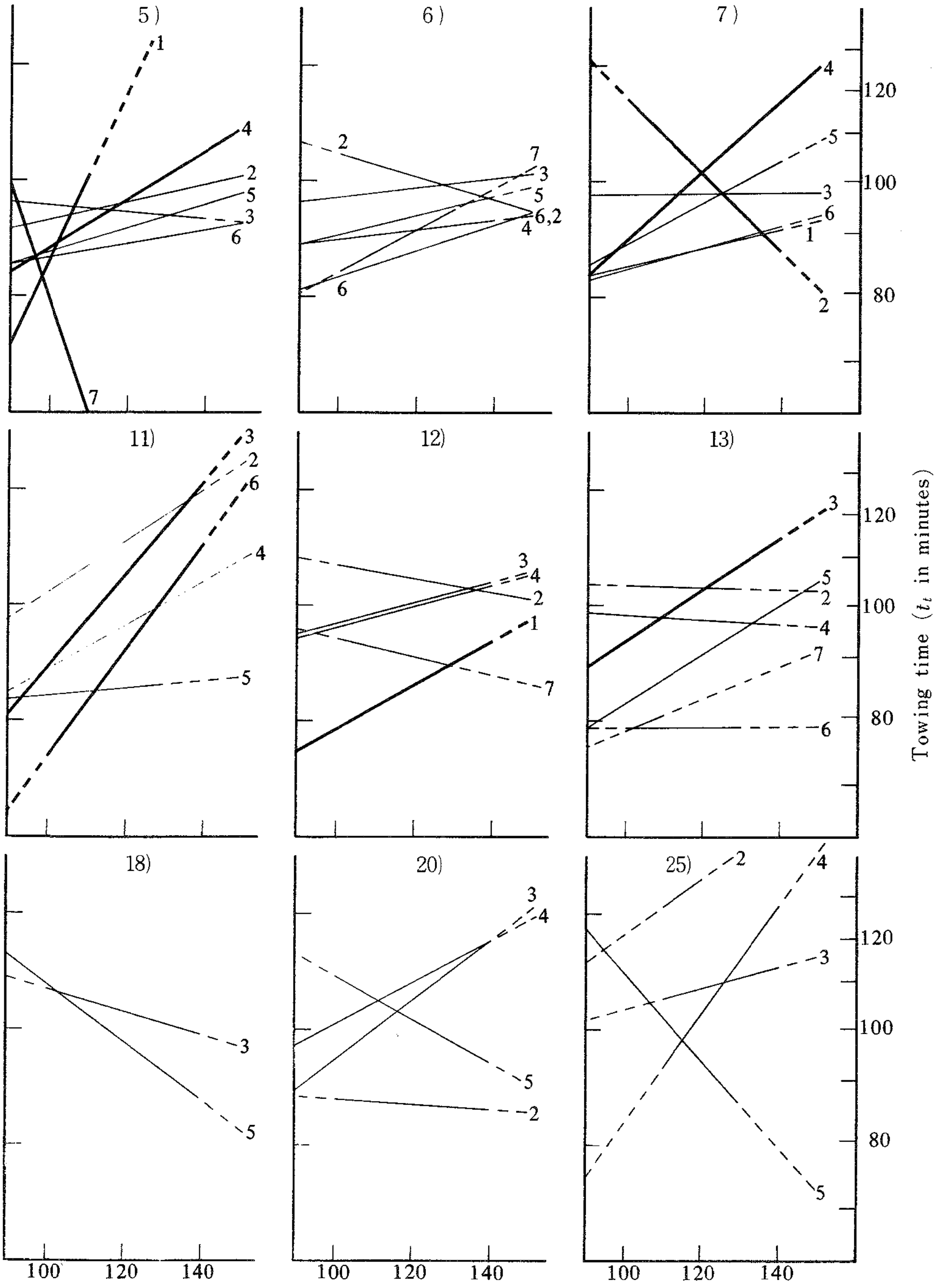


Fig. 13. The difference of the t_l -y relations according and the wave grade.
Note: For the note, see that of Fig. 11.



meters)
to the amount of catch by the preceding haul

Table 26. Number of $c'_{1x'w}$ showing the significant difference from that of the different wave grade (w).

Grade of wind wave (w)	1		2		3		4		5		6		7	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Catch class (x' in tons) 2														
3														
4				3	1		1		1					
5	1		1		2		1	1	1		1			6
6														
7	1			5	1	1	2		1		1			
8														
9					1					1				
10				1		1		1					3	
11														
12														
13														
14				1	1									
15														
17														
18														
20														
25														
Sum	2		1	10	6	2	4	2	3	1	2		3	6

Note: L .... significantly larger than the other
S .... significantly smaller than the other

wave grade, the towing time showed a very faint trend of shortening.

The above-mentioned results did not concern with the difference of the constant, in spite of the fact that the length of towing time depends on both of the coefficient and the constant. With an assistance of Fig. 13, the depth regression lines of the different wave grades in the same catch classes were compared with one another, and the following trends were found out: the towing time under the wave grade 1 was shorter than that of the other wave grades, the line in the 5-ton class (in the wave grade 1) seemed to show slightly longer towing in the intermediate depth zones, but this was due to the trend of the strata of insufficient sample size, and it was not reasonable to give too much importance. The constant of the regression line of the wave grade 2 was larger than that of the other wave grades; and the small coefficient pointed out in the preceding section resulted in longer towing than that of the other wave grades in shallow zones and the towing of ordinary length in deep zones. The towing time under the wave grades 3 and 5 did not show any notable difference from that of the other wave grades, except a few exceptions. The towing time under the wave grade 6 in deep zone inclined to be shorter than that under the other wave grades, although this trend was not notable in some of the catch classes.

The applicable depth-range of the regression lines under the wave grade 7 showed a large variation according to the catch class. In the other catch classes than the 6-, 8-, and 10-ton ones, the applicable range was narrow, and the short towing was the characteristic of these catch classes. The towing time in the 6- or 8-ton class did not show any notable difference from that in the other wave grades.

9.3 The difference of the depth regression according to the amount of catch by the preceding haul

The significant difference between the regression coefficient of the different catch classes under the same wave grades was found in the 34 pairs of the x'-w strata out of the 587 ones. Among them, the significant difference in all the three pairs under the wave grade 1 was due to the large value of the 5-ton class; that in all the four pairs under the wave grade 3 was due to the large value of the 11-ton class; that in the 12 pairs out of the 13 ones under the wave grade 4 was due to either the large value of the 4-ton class or the small value of the 15-ton class; that in the four pairs out of the five ones under the wave grade 5 was due to the large value of the 4-ton class; that in all the two pairs under the wave grade 6 was due to the large value of the 11-ton class; and that in all the three pairs under the wave grade 7 was due to the small value of the

Table 27. The results of the comparison between $c'_{1x'w}$ of the different class of catch by the preceding haul (x') through the t-test.

Grade of wind wave (w)	1		2		3		4		5		6		7	
Class of catch by the preceding haul (x')	t	n	t	n	t	n	t	n	t	n	t	n	t	n
2 – 3			0.09	19	−0.91	35	0.78	33			0.42	14		
2 – 4			0.51	35	−0.72	46	−1.35	39			0.54	25		
2 – 5			−0.56	43	0.48	54	−0.30	49			1.20	30		
2 – 6			0.19	33	0.05	47	0.69	31			0.77	23		
2 – 7			1.27	21	0.28	61	−0.77	44			0.63	17		
2 – 8			0.38	18	0.34	58	0.15	34			0.40	24		
2 – 9					−0.65	26	−0.56	19			1.39	9		
2 – 10			0.1,1	26	0.25	49	0.60	36			0.48	20		
2 – 11			0.82	14	−1.39	25	−0.10	18			−1.07	10		
2 – 12			0.03	12	−0.17	29	0.41	25						
2 – 13			−0.10	15	−0.92	37	0.96	30			0.59	26		
2 – 14			1.37	11	−0.28	25								
2 – 15			−0.61	28	−0.18	40	2.09*	32			0.46	13		
2 – 17					0.68	19	1.19	18						
2 – 18					0.51	22								
2 – 20			−0.07	13	−0.76	25	−0.12	24						
2 – 25			−0.32	13	−0.08	16	−1.05	20						
3 – 4			0.37	38	0.45	57	−2.50*	42	−0.72	35	−0.03	31	0.01	10
3 – 5			−0.66	46	1.81	65	−1.48	52	0.34	60	0.21	36	1.69	13
3 – 6			0.07	36	1.08	58	−0.07	34	0.42	38	−0.04	29	−0.29	8
3 – 7			1.02	24	1.61	72	−2.04*	47	−0.12	39	0.04	23		
3 – 8			0.28	21	1.83	69	−0.68	37	0.04	49	−0.35	30	−0.22	13
3 – 9					0.26	37	−1.19	22	1.85	19	0.40	15		
3 – 10			0.00	29	1.61	60	−0.14	39	0.48	29	−0.07	26	−0.58	20
3 – 11			−0.84	17	−0.60	36	−0.46	21	0.46	21	−1.15	16		
3 – 12			−0.06	15	0.77	40	−0.37	28					0.15	8
3 – 13			−0.16	18	0.22	48	0.30	33	−0.19	39	0.22	32	−0.19	15
3 – 14			1.24	14	0.72	36			0.09	23				
3 – 15			−0.67	31	0.79	51	1.50	35	0.24	24	−0.03	19		
3 – 17					1.41	30	0.60	21						
3 – 18					1.30	33			1.77	22				

Table 27. — (Cont'd)

Grade of wind wave (w) / Class of catch by the preceding haul (x')	1		2		3		4		5		6		7	
	t	n	t	n	t	n	t	n	t	n	t	n	t	n
3 – 20			−0.14	16	0.00	36	−0.89	27	1.47	26				
3 – 25			−0.33	16	0.37	27	−1.31	23	1.91	20				
4 – 5			−1.63	62	1.57	76	1.12	58	1.26	63	0.30	47	1.00	13
4 – 6			−0.39	52	0.82	69	2.34*	40	1.20	41	0.00	40	−0.16	8
4 – 7			0.90	40	1.32	83	0.37	53	0.70	42	0.09	34		
4 – 8			0.00	37	1.53	80	1.51	43	0.67	52	−0.37	41	−0.15	13
4 – 9					−0.11	48	0.61	28	2.19*	22	0.54	26		
4 – 10			−0.45	45	1.33	71	2.14*	45	1.19	32	−0.04	37	−0.42	20
4 – 11			−1.46	33	−1.18	47	0.62	27	0.93	24	−1.49	27		
4 – 12			−0.44	31	0.51	51	1.90	34					0.08	8
4 – 13			−0.46	34	−0.27	59	2.51*	39	0.32	42	0.29	43	−0.13	15
4 – 14			1.41	30	0.43	47			0.68	26				
4 – 15			−1.30	47	0.50	62	3.59**	41	0.77	27	0.00	30		
4 – 17					1.48	41	2.24*	27						
4 – 18					1.28	44			2.53*	25				
4 – 20			−0.45	32	−0.39	47	1.26	33	2.16*	29				
4 – 25			−0.51	32	0.25	38	−0.47	29	2.43*	23				
5 – 6			1.05	60	−0.48	77	1.32	50	0.13	66	−0.50	45	−2.86*	11
5 – 7	4.17**	7	2.26*	48	−0.29	91	−0.81	63	−0.60	67	−0.23	39		
5 – 8	2.04	9	1.20	45	−0.30	88	0.65	53	−0.34	77	−1.11	46	−2.22*	16
5 – 9					−1.30	56	−0.27	38	1.43	47	0.66	31		
5 – 10	3.40**	11	0.83	53	−0.36	79	1.22	55	0.22	57	−0.44	42	−1.82	23
5 – 11			−0.51	41	−2.48*	55	0.06	37	0.24	49	−2.89**	32		
5 – 12	3.19*	7	0.55	39	−0.74	59	0.78	44					−1.96	11
5 – 13			0.25	42	−1.90	67	1.53	49	−0.65	67	0.20	48	−2.22*	18
5 – 14			2.16*	38	−0.90	55			−0.18	51				
5 – 15			−0.14	55	−0.73	70	2.47*	51	0.00	52	−0.29	35		
5 – 17					0.56	49	1.22	37						
5 – 18					0.33	52			1.61	50				
5 – 20			0.29	40	−1.48	55	0.18	43	1.26	54				
5 – 25			−0.19	40	−0.33	46	−0.79	39	1.50	48				
6 – 7			1.15	38	0.26	84	−1.86	45	−0.62	45	0.13	32		
6 – 8			0.29	35	0.29	81	−0.57	35	−0.34	55	−0.56	39	−0.04	11
6 – 9					−0.66	49	−1.10	20	1.44	25	0.70	24		
6 – 10			−0.09	43	0.21	72	−0.06	37	0.10	35	−0.06	35	−0.82	18
6 – 11			−1.07	31	−1.57	48	−0.42	19	0.16	27	−2.18*	25		
6 – 12			−0.14	29	−0.24	52	−0.30	26					0.61	6
6 – 13			−0.23	32	−1.04	60	0.35	31	−0.55	45	0.34	41	0.09	13
6 – 14			1.46	28	−0.33	48			−0.25	29				
6 – 15			−0.89	45	−0.24	63	1.51	33	−0.07	30	0.00	28		
6 – 17					0.62	42	0.61	19						
6 – 18					0.48	45			1.38	28				
6 – 20			−0.22	30	−0.85	48	−0.80	25	1.10	32				
6 – 25			−0.38	30	−0.10	39	−1.24	21	1.45	26				
7 – 8	−0.55	8	−0.71	23	0.02	95	1.27	48	0.17	56	−0.57	33		
7 – 9					−1.08	63	0.19	33	1.89	26	0.48	18		
7 – 10	0.11	10	−1.17	31	−0.06	86	1.77	50	0.67	36	−0.15	29		
7 – 11			−2.59	19	−2.27*	62	0.29	32	0.56	28	−1.69	19		
7 – 12	−1.31	6	−1.38	17	−0.53	66	1.24	39						
7 – 13			−1.15	20	−1.64	74	1.96	44	−0.15	46	0.24	35		
7 – 14			1.10	16	−0.68	62			0.20	30				
7 – 15			−2.24*	33	−0.53	77	2.71**	46	0.34	31	−0.08	22		
7 – 17					0.68	56	1.37	32						
7 – 18					0.47	59			2.08*	29				
7 – 20			−1.12	18	−1.29	62	0.65	38	1.71	33				
7 – 25			−0.92	18	−0.23	53	−0.46	34	2.02	27				
8 – 9					−1.36	60	−0.55	23	1.16	36	0.90	25		
8 – 10	0.73	12	−0.34	28	−0.09	83	0.51	40	0.37	46	0.36	36	−1.10	23
8 – 11			−1.11	16	−2.68**	59	−0.14	22	0.30	38	−1.76	26		
8 – 12	−0.22	8	−0.32	14	−0.63	63	0.21	29					0.57	11
8 – 13			−0.36	17	−1.92	71	0.83	34	−0.27	56	0.56	42	0.10	18
8 – 14			1.03	13	−0.84	59			0.03	40				

Table 27. — (Cont'd)

Grade of wind wave (w) / Class of catch by the preceding haul (x')	1		2		3		4		5		6		7	
	t	n	t	n	t	n	t	n	t	n	t	n	t	n
8 – 15			−1.06	30	−0.61	74	1.76	36	0.14	41	0.34	29		
8 – 17					0.86	53	0.76	22						
8 – 18					0.56	56			1.36	39				
8 – 20			−0.34	15	−1.54	59	−0.25	28	1.12	43				
8 – 25			−0.40	15	−0.30	50	−0.84	24	1.23	37				
9 – 10					1.19	51	1.00	25	−1.30	16	−0.49	21		
9 – 11					−0.89	27	0.19	7	−1.06	8	−1.64	11		
9 – 12					0.49	31	0.87	14						
9 – 13					−0.11	39	1.28	19	−1.10	26	−0.28	27		
9 – 14					0.52	27			−1.51	10				
9 – 15					0.48	42	2.32*	21	−1.41	11	−0.48	14		
9 – 17					1.78	21	1.30	7						
9 – 18					1.33	24			−0.59	9				
9 – 20					−0.25	27	0.47	13	−0.76	13				
9 – 25					0.32	18	−0.60	9	−0.37	7				
10 – 11			−0.94	24	−2.38*	50	−0.38	24	0.09	18	−1.46	22		
10 – 12	−1.36	10	−0.07	22	−0.51	54	−0.23	31					1.14	18
10 – 13			−0.17	25	−1.68	62	0.40	36	−0.54	36	0.32	38	0.71	25
10 – 14			1.41	21	−0.70	50			−0.31	20				
10 – 15			−0.76	38	−0.50	65	1.51	38	−0.14	21	0.04	25		
10 – 17					0.82	44	0.62	24						
10 – 18					0.56	47			1.16	19				
10 – 20			−0.15	23	−1.35	50	−0.70	30	0.93	23				
10 – 25			−0.35	23	−0.24	41	−1.18	26	1.29	17				
11 – 12			0.93	10	1.30	30	0.29	13						
11 – 13			0.61	13	0.95	38	0.56	18	−0.40	28	1.19	28		
11 – 14			2.11	9	1.36	26			−0.31	12				
11 – 15			0.41	26	1.33	41	1.28	20	−0.19	13	1.29	15		
11 – 17					1.91	20	0.68	6						
11 – 18					1.76	23			0.73	11				
11 – 20			0.61	11	0.51	26	0.03	12	0.60	15				
11 – 25			−0.03	11	0.65	17	−0.55	8	0.98	9				
12 – 13			−0.13	11	−0.72	42	0.59	25					−0.43	13
12 – 14			1.38	7	−0.10	30								
12 – 15			−0.66	24	0.00	45	1.72	27						
12 – 17					0.86	24	0.81	13						
12 – 18					0.68	27								
12 – 20			−0.10	9	−0.65	30	−0.54	19						
12 – 25			−0.37	9	0.00	21	−1.16	15						
13 – 14			1.30	10	0.68	38			0.20	30				
13 – 15			−0.36	27	0.71	53	1.13	32	0.28	31	−0.26	31		
13 – 17					1.66	32	0.40	18						
13 – 18					1.45	35			1.35	29				
13 – 20			0.02	12	−0.19	38	−1.05	24	1.15	33				
13 – 25			−0.30	12	0.35	29	−1.36	20	1.20	27				
14 – 15			−2.28*	23	0.10	41			0.13	15				
14 – 17					1.23	20								
14 – 18					0.91	23			1.32	13				
14 – 20			−1.18	8	−0.64	26			1.14	17				
14 – 25			−0.88	8	0.05	17			1.53	11				
15 – 17					0.86	35	−0.38	20						
15 – 18					0.69	38			1.09	14				
15 – 20			0.39	25	−0.67	41	−2.19*	26	0.92	18				
15 – 25			−0.18	25	0.00	32	−2.12*	22	1.36	12				
17 – 18					−0.21	17								
17 – 20					−1.37	20	−1.29	12						
17 – 25					−0.61	11	−1.37	8						
18 – 20					−1.20	23			−0.20	16				
18 – 25					−0.42	14			0.34	10				
20 – 25			−0.28	10	0.35	17	−0.99	14	0.53	14				

Note: * significant at 0.05 level ** significant at 0.01 level

Table 28. Number of $c'_{1x'w}$ showing the significant difference from that of the different catch class (x').

Catch class (x')	2		3		4		5		6		7		8		9		10	
Grade of wind wave (w)	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
1							3					1						1
2							2					2						
3								1				1		1				1
4	1			2	6		1			1	2				1			1
5					4						1					1		
6								1		1								
7								3	1				1					
Sum	1			2	10		6	5	1	2	3	4	1	1	1	1		3

Catch class (x')	11		12		13		14		15		17		18		20		25	
Grade of wind wave (w)	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S
1				1														
2								2	2									
3	4																	
4						1				7		1			1		1	
5														2		1		1
6	2																	
7					1													
Sum	6			1	1	1		2	2	7		1		2	1	1	1	1

Note: L .... significantly larger than the other
S .... significantly smaller than the other

5-ton class. Namely, most of the significant differences were due to the peculiar values in the seven x'-w strata. This fact and the low rate of occurrence of the significant difference suggested that the different amount of catch by the preceding haul should hardly cause any significant difference in the regression coefficient.

9.4 The comparison of the regression lines of the different catch classes under the different wave grades

The clearest trend found in Fig. 14 was that the points showing respective regression equations were distributed along a line, in spite of large variation of the constant and the coefficient. This fact meant that the difference of the towing time of the different x'-w strata was not so large as the impression from the variation of the constants and the coefficients. Most of the strata taking the extreme value of the coefficient or the constant and most of those apart from the constant-coefficient line were applicable to

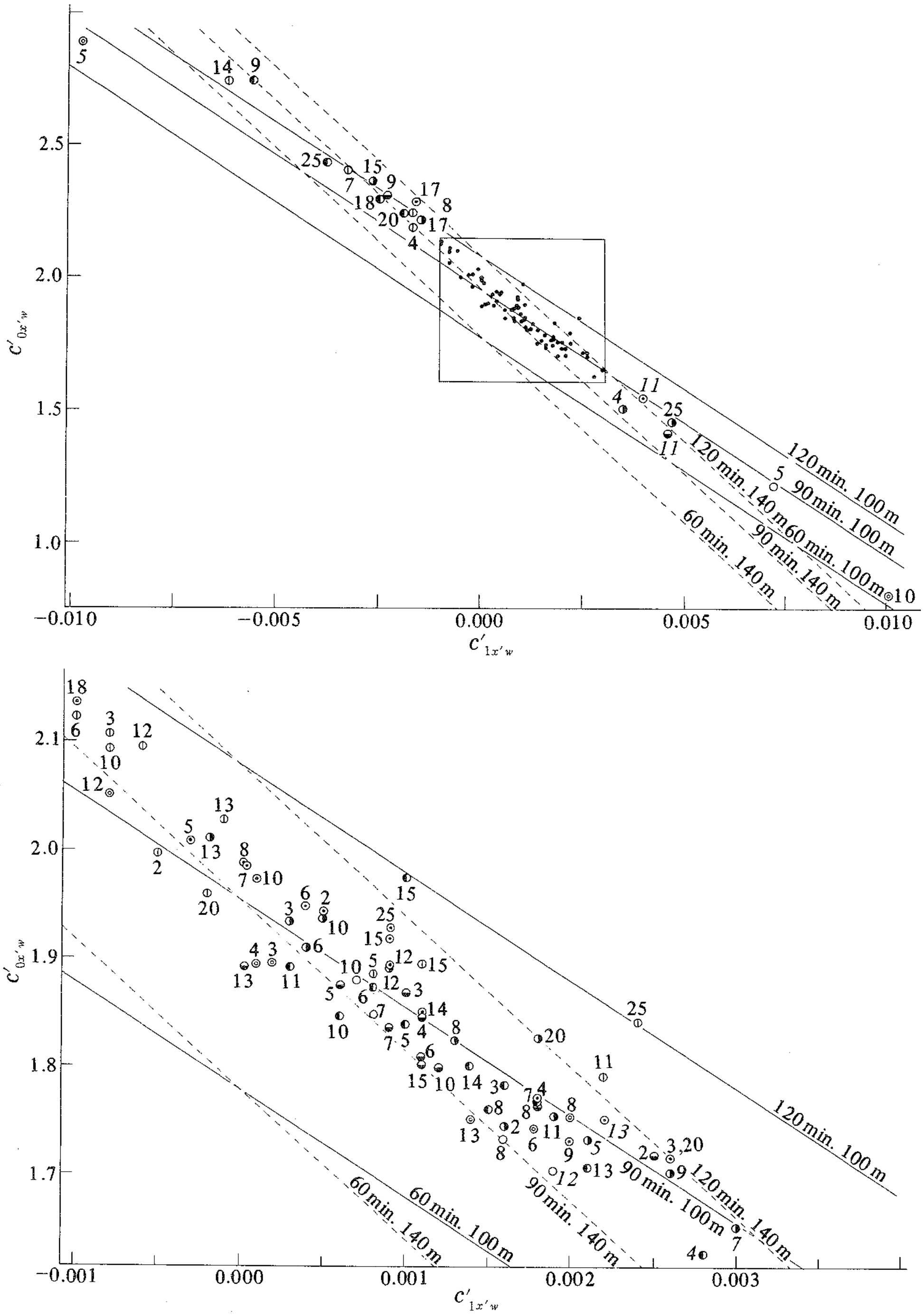


Fig.14. The comparison of the regression lines of log t_l on y.

$\log t_l = c'_{0x'w} + c'_{1x'w} y$

For legend, see Fig. 12.

the narrow depth-range. And the towing time of these strata in the applicable range did not show any notable difference from that of the other strata—for example, (5.1) and (5.7); otherwise, the notable difference was found either only in shallow zone [long towing—(14.2), (9.5), (17.3), (15.5), and (25.2)] or only in deep zone [long towing —(11.2), (11.3), and (25.4)]. The stratum (10.7) taking the extreme constant and coefficient was the sole exception, the towing time in shallow zone was short and that in deep zone was long. Namely, the differences were found in the long towing of the classes of good catch in calm or moderate waters. This fact suggested the following possibility: when the exact adjustment of towing time for the purpose of yielding similar amount of catch by a haul basing on the result of the preceding haul was not important, the boats may occasionally tow the net over long time, probably because of approaching to the factory ship for the purpose of transshipping the catch and because of using efficiently the time not sufficiently long to conduct another towing.

Conclusion

The multiple linear regression of the length of towing time on the amount of catch either by that haul or by the preceding one and on the depth fished showed that the towing time was elongated in accordance with either of these three factors. But the difference of the length of towing time due to the differences in either of these three factors and in the wave grade was small. The length of towing time hardly showed any clear regression on either of these three factors after the twofold stratification of the records according to the wave grade and the factor of the rest. These facts meant that, in most of the cases, the length of towing time was adequately adjusted during the towing according to the density of the fishable population for the purpose of yielding a similar amount of catch by a haul, probably because of the special way of handling the catch described in the second section of the material and method.

Summary

The Alaska pollack fishery in the Bering Sea for supplying the material of the minced product is one of the newly developed and most important fisheries in Japan. This fishery is conducted by the two types: the stern ramp factory trawler and the factory ship type. The flotilla supplying the factory ship with the material fish consists of the Danish seiners and the bull trawlers. The working times of the Danish seiners were examined in the preceding series of the reports. The present series dealt, accordingly, with the working time of the bull trawlers observable in the set of the records of a flotilla in the entire season of 1964. The fishing work of the bull trawler consist of the shooting work, the towing one, and the work of hauling up and making fasten the codend containing the catch. The towing work is the longest step. The present report dealt with the change of the length of towing time (t_t) in accordance with the grade of wind wave (w), the amount of catch (x or x'), and the depth fished (y), although

the length of towing time has the nature of being determined mainly by the skipper's preference and being indirectly modified by the influence of these environmental conditions. And the following trends were found out:

1. The frequency distribution of the towing time (aggregated into the classes of the nearest 10-min. intervals) under the same grade of wind wave was agreeable to the logarithmic normal series, as shown in Fig. 1.

2. The multiple linear regression of $\log t_t$ on the amount of catch and the depth and the linear regression on either of these factors revealed that 1) the length of towing time increased in accordance with depth, in all the wave grades except in both the extreme ones, 2) the towing time for the hauls of better catch inclined to be longer, in all the wave grades including the calm water but excluding the rough sea, 3) the regression coefficient on the amount of catch by the preceding haul was far smaller than that of the amount of catch by that haul, and 4) good catch by the preceding haul resulted in long towing under calm water but resulted in short towing under rough sea.

3. The regression on the amount of catch after the twofold stratification of the records according to depth and wave grade revealed that 1) $\log t_t$ took the significantly positive coefficient in the 17 *y-w* strata out of the 44 ones, the insignificantly positive one in the 22 strata, and the insignificantly negative one in the five strata, 2) the length of towing time did not show any clear difference according to the difference of these factors (the wave grade, the depth, and the amount of catch), being 80 min. to 110 min. for the hauls yielding 10 tons of catch and being 90 min. to 120 min. for the hauls yielding 20 tons of catch, and 3) the towing time in the 50 m, 60 m, and 80 m zones was shorter than that in the other depth zones; that in the 90 m zone was a slightly shorter than that in deep zones; that under the wave grade 6 was shorter, and that under the wave grade 2 was longer than that under the other wave grades.

4. The regression on the amount of catch by the preceding haul after the twofold stratification of the records according to depth and wave grade revealed that, as shown in Fig. 7, 1) the regression coefficient was small and took the significantly positive value in the six strata out of the 44 ones, the insignificantly positive value in the 19 ones, and the insignificantly negative value in the 19 ones, 2) the regression coefficients under the different wave grades in the same depth zones took similar value to one another, but 3) those under the same wave grades slightly increased with depth.

5. The regression coefficient on depth after the twofold stratification of the records according to wave grade and amount of catch took the significantly positive value in the eight *x-w* strata out of the 95 ones, the insignificantly positive value in the 62 ones the insignificantly negative value in the 22 ones, and the significantly negative value in the three ones. And as shown in Fig. 12, the points showing the constants and the coefficients of the estimated regression lines were distributed along a line. This fact meant that most of the lines in the applicable depth range showed similar trend to one another, in spite of large variation of either the constant or the coefficient.

6. The similar results were obtained in the examination of the regression on depth after the twofold stratification of the records according to wave grade and the amount

of catch by the preceding haul. The coefficient was significantly positive in the nine strata, insignificantly positive in the 80 ones, insignificantly negative in the 22 ones and significantly negative in the two ones. And the points showing the constants and the coefficients of the estimated regression lines were, as shown in Fig. 14, distributed along a line.

7. These results suggested the adjustment of the length of towing time during the towing according to the density of the fishable population for the purpose of yielding a similar amount of catch by a towing, probably because of special way of handling the catch described in the second section of the material and method.

8. It may be concluded that the difference of the length of towing time due to the difference either in the amount of catch by that haul, or that by the preceding haul, or the depth fished, or the grade of wind wave was very faint.

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