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Working Time of Bull Trawlers during Alaska Pollack Fishing-III.*

The Variation of the Length of the Time for Completing a Haul Relating to the Amount of Catch, the Depth fished, and the Height of Wind Wave

By
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The fleet type Alaska pollack fishing in the Bering Sea is one of the newly developed and most important fisheries in Japan. The flotilla supplying the factory ship with the material fish consists of the two types of boats: one is the Danish seiner and the other is the bull trawler. The former type occupied a leading portion in an early stage of this fishery,but the latter type increased its importance and occupies the major portion on the present days. This is not only due to the different suitability of these two types of boats but also due to the complicated background of this fishery shown in the second report[13]of this series. In the preceding series[1−11] were examined the work pattern of the Danish seiner and its change relating to the working conditions. But there arose the necessity of examining the same problems in the bull trawler because of the increasing importance of this type of boat in this fishery.

The fishing work of bull trawler consists usually of the shooting work, the towing one, the hauling one, and the brailing one. The bull trawling is done by a pair of boats. And in some of the cases, the boat starts shooting the net before the finish of the preceding hauling and it is doubtful whether this step of work would be done at full speed or not. In addition, the variation of the time length for this step of work was small. These facts prevented us from examining the relation between the time lenght for this step and the working conditions. The second step of work is the towing one. In the ordinary way of bull trawling, it is highly probable that the time length for this step is decided by the skipper's preference and is less probable to be directly affected by the working conditions. But the catch in the present case was extremely good when this was compared with that in her home ground — in the Eastern Sea. And it is very troublesome and dangerous to handle the excess of catch unable to be packed into a cod end. On the other hand, it is inefficient to repeat the towings of poor catch for yielding a good daily catch. In consequence, it is probable that the length of towing work is adjusted to the density of the objective fish in the trawlable conditions and the

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skipper intends to yield a cod-end-ful of catch by a towing. For the purpose of clarifying this point, the variation of the time length for towing in relation to the working conditions was examined in the first report[12] of this series. The hauling work and the brailing work succeed to the towing one. In the present case, however, the work pattern after this step was modified: The extremely good catch in the present case made it hard to haul up the cod end containing full of catch on board, and the presence of the factory ship nearby made the bull trawler no need to do so. In consequence, after the net body being hauled up to boardside, the catch was not brailed out into the fish hold but was packed into the cod end, and the cod end containing the catch was kept in water, made fasten alongside the trawler, and was taken directly inboard the factory ship when the trawler approached to the factory ship. It is probable that the time length of this step of work is affected by the working conditions including the amount of catch. And this relation was examined in the second report[13] of this series. Because of the above-mentioned difference in the work pattern of the present case from the ordinary way of bull trawling, the examinations of the relation between the working speed of respective steps and the conditions provided us with many informations valuable to give improvement of the work pattern suitable for the present case.

The work for completing a haul in the present case consists of the shooting work, the towing one, and the hauling-fastening one. The time length for the first step of work showed a small variation; and that for the second one with the nature of being determined by the skipper's preference showed the clearest relations to the working conditions, especially to the amount of catch. The last one is the step with the highest possibility of being affected by the working conditions but practically it was hard to find any clear relations to the working conditions except to the amount of catch. The work for completing a haul consists of the above-mentioned three steps, but it is doubtful whether the results would be the simple sum of the relations in the component steps or not, for the factor showing the leading influence was the amount of catch but the influence of the other factors was different according to the steps. Nowadays, the backgrounds of this fishery are changing in many respects, and the informations for the working capacity of the boat under various conditions are indispensable for planning a fleet to supply the factory ship of the different capacity with the material fish. And the examination of the relation between the time length for completing a haul and the working conditions and their changes according to the conditions are needed for estimating the working capacity of the bull trawler. The present report were shown the results of examinations for the change in the time length for completing a haul according to the amount of catch, to the depth fished, and to the grade of wind wave.

Material and Method

The same materials as those in the preceding two reports of this series were used in the present report. They were the complete set of the routine telegrams of the working conditions and the results of each haul by the three pairs of the bull trawlers throughout the season of 1964 from April 19 to Sept. 20.

Among many items in the telegrams the following ones were chosen and used in the present report: the time to start shooting the net (t_1), the time at the finish of making fasten the cod end (t_4), the amount of catch, the echo-sounded depth just before shooting the net, and the grade of wind wave. The time required for completing a haul (abbreviated to t_c) in the present report defined the time interval between t_1 and t_4. In the original records, t_1 and t_4 were timed in minutes. But t_c reckoned were aggregated into the classes of the nearest 10-min. intervals and used after the $\log(t_c—59)$ transformation, for the accuracy of time measuring, the range of distribution of t_c, and the agreeable type of its frequency distribution were taken into account. The amounts of catch ranging 0 to 35 tons were recorded in tons. The echo-sounded depths ranging from 40 to 150 m were recorded in meters, but were used after the aggregation of them into the classes of the nearest 10-m intervals. The height of wind wave were recorded in the grade number according to the standard settled by the Japanese Meteorological Agency, which was shown in the first report of this series. This factor could not be used as one of the independent variables, and the difference of the results due to this factor was examined by stratifying the records according to this factor and comparing the results under the different conditions with one another.

As the present report dealt with the regression of the time length for completing a haul (t_c) on either or both of the amount of catch (x in tons) and the depth fished ($10y$ in meters) after the stratification of the records according to either of x and y and/or the grade of wind wave (w), the constant and the coefficient of the estimated regression equations were expressed by the following ways:

$a_{i \cdot w}$ ……. Those of the multiple linear regression equation of $\log(t_c—59)$ on x and y estimated from the records of the hauls under the wind wave of the grade w. The notation of the first suffix, i, was as follows:

$$\log(t_c—59) = a_{0w} + a_{1w}x + a_{2w}y$$

b_{iyw} ……. Those of the linear regression equation of $\log(t_c—59)$ on x estimated from the records of the hauls from $10y$ m zone under the wind wave of the grade w. If the equation was estimated pooling the records of all the depth zones, y was omitted. The notation of the first suffix, i, was as follows:

$$\log(t_c—59) = b_{0yw} + b_{1yw}x$$

c_{ixw} ……. Those of the linear regression equation of $\log(t_c—59)$ on y estimated from the records of the hauls yielding a catch of x tons under the wind wave of the grade w. If the equation was estimated pooling the records of all the catch-classes, x was omitted. The notation of the first suffix, i, was as follows:

$$\log(t_c—59) = c_{0xw} + c_{1xw}y$$

$(x.y.w)$…. The group of the records of the hauls yielding x tons of catch in the $10y$ m zone under the wind wave of the grade w. To indicate respective ones under the same conditions of either of the factors, the letter indicating that condition was not changed into numeral.

Results

1. The type of frequency distribution of the time length for completing a haul

As described in the first and the second reports of this series, the frequency distribution of either the time length of towing work (t_t) or that of hauling-fastening work (t_h) showed a tailing in the direction of long work. The time length for shooting work did not show any clear tailing. The observed frequency distribution of t_c after the stratification of the records according to the wave grade ranged mainly from the class of 80 min. rarely from 60 min. to that of 280 min., showing a tailing in the direction of long work, for t_c is the sum of the above-mentioned three steps of work. The observed distributions were accordingly compared with the estimated ones under the supposition that the distribution would be agreeable to the normal one when t_c is transformed into either $\log(t_c-79)$ or $\log(t_c-59)$. And it was found out that the latter transformation brought far better results than the former one. Four examples of the observed series and the estimated ones after the $\log(t_c-59)$ transformation

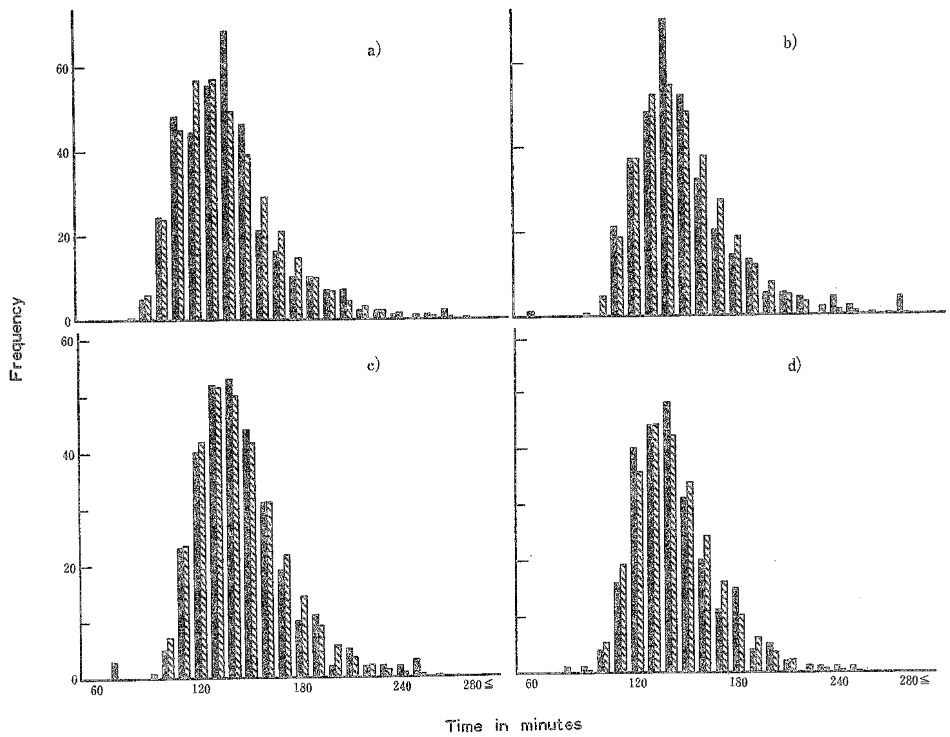

Fig.1. The frequency distribution of the length of the time for completing a haul.

Note: The length of the time for completing a haul (t_c) 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 $\log(t_c-59)$ series.

a) Under the wind wave of the grade 2 ($0.10 > \Pr\{\chi^2 > \chi_0^2\} > 0.05$) — $\chi_0^2 = 18.10$ with 11 degrees of freedom

b) Under the wind wave of the grade 4 ($0.25 > \Pr\{\chi^2 > \chi_0^2\} > 0.10$) — $\chi_0^2 = 13.40$ with 9 degrees of freedom

c) Under the wind wave of the grade 5 ($0.75 > \Pr\{\chi^2 > \chi_0^2\} > 0.50$) — $\chi_0^2 = 8.00$ with 9 degrees of freedom

d) Under the wind wave of the grade 6 ($0.50 > \Pr\{\chi^2 > \chi_0^2\} > 0.25$) — $\chi_0^2 = 8.02$ with 8 degrees of freedom were shown in Fig. 1. In the further examinations, accordingly, the observed value of t_c (in 10-minute intervals) was used after the log (t_c—59) transformation.

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

Among many factors described in the original records, the amount of catch (x in tons), the depth fished ($10y$ in meters), and the grade of wind wave (w) were chosen as the factors most probable to have a close relation to the working speed. But the last one could not be adopted as one of the independent variables, for that was recorded in the grade number covering unequal height range. It was hard to find any definite bases of considering that log (t_c—59) showed a quadratic or higher order regression either on x or on y.

For the purpose of finding out an outline of the influence of these factors on log (t_c—59), accordingly, the multiple linear regression of log (t_c—59) on x and y was examined after the stratification of the records according to w. As shown in Table 1, log (t_c—59) increased significantly (at 0.05 level) with x in all the wave grades except the roughest one and with y in all the wave grades except the roughest two ones. The regression coefficient on x was five times as large as that on y ; but at the present state of the examination, it was hard to say that the former was more influential than the latter because the magnitudes of the deviation of x and y were not taken into account.

Table 1. The multiple linear regression equations of the time required for completing a haul (t_c in min.) on the catch (x in tons) and the depth of the fishing ground (y in m) under respective grades of wind wave (w).

$$\log(t_c - 59) = a_{0w} + a_{1w}x + a_{2w}y$$

Grade of wind wave (w)	a_{0w}	a_{1w}	a_{2w}	F_x	F_y	n_2
1	1.5355	0.0125	0.0023	31.02**	12.30**	64
2	1.4865	0.0121	0.0029	112.29**	263.38**	366
3	1.5998	0.0092	0.0022	114.54**	133.13**	562
4	1.5492	0.0112	0.0023	195.63**	89.10**	327
5	1.5890	0.0120	0.0019	70.08**	18.62**	304
6	1.6081	0.0062	0.0021	12.19**	32.48**	242
7	1.3195	0.0166	0.0037	10.39**	2.32	97
8	4.1139	0.0131	−0.0178	1.002	5.77	5

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

For t_t and t_h, the regression coefficients either on x or on y were significantly positive in most of the wave grades. And these facts meant that the elongating trend of t_c with the amount of catch and with the depth fished was due to the same trend in the towing work and in the hauling-fastening one.

3. The linear regression on the amount of catch

The examination of the multiple linear regression revealed that it took significantly longer time for completing a haul of better catch. Through this method, however, it was hard to examine the probable difference in the influence of the amount of catch according to the wave grade and also it was hard to compare the influence of the amount of catch with that of the wave grade. For the purpose of examining these points, the linear regression equations of log (t_c—59) on x were examined after the stratification of the records according to the wave grade. As shown in Table 2, the estimated regression coefficient was significantly positive in all the wave grades except the roughest one (the grade 8). The boat could fish till the wave grade 8, but she fished along a different pattern only in a part of the workable hours on the days under this wave grade and the grade 7. The days in these wave grades were concentrated in a limited season. And the results relating to these wave grades should accordingly be excluded from the consideration.

Table 2. The linear regression equations of the time for completing a haul (t_c in min.) on the catch (x in tons) under respective grades of wind wave (w).

$$\log(t_c-59) = b_{0\cdot w}+b_{1\cdot w}x$$

Grade of wind wave (w)	Range of x	$b_{0\cdot w}$	$b_{1\cdot w}$	F_0	n_2
1	1 — 30	1.7661	0.0148	39.94**	65
2	0 — 30	1.8043	0.0082	31.23**	367
3	0 — 30	1.8490	0.0086	81.19**	563
4	1 — 39	1.8263	0.0112	154.29**	328
5	0 — 32	1.8064	0.0117	63.23**	305
6	0 — 20	1.8335	0.0082	19.94**	243
7	0 — 20	1.7027	0.0170	10.75**	98
8	3 — 15	2.0768	−0.0148	3.29	6

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

To examine the probable difference in the influence of the amount of catch on t_c according to the wave grade, the regression coefficients , b_{1w} , of the different wave grades were compared with one another through t-test. As shown in Table 3, the difference between b_{1w} was significant in the 10 pairs of b_{1w} out of the 28 ones, because of the large value of $b_{1.1}$ or $b_{1.7}$ or the small value of $b_{1.8}$. To compare the difference of log(t_c—59) due to the difference in catch with that due to the difference in the wave grade, the estimated regression lines were illustrated in Fig. 2. This figure revealed the following three trends : 1) The difference in log (t—59) due to that of catch was far larger than the difference due to that of the wave grade, 2) the significantly large value of $b_{1.7}$ was due to the small value of log(t_c—59) for the hauls of poor catch, but 3) the significantly large value of $b_{1.1}$ was due to the large value of log (t_c—59) for the hauls of good catch.

These results were compared with those of the examinations of t_t and t_h shown in the preceding reports, and the following three trends were found out: 1) In regard to the comparison of the influence of the amount of catch with that of the wave grade, the similar results were found in the preceding reports, suggesting that this trend should be due to the same one in both t_t and t_h. 2) In regard to the small value of log (t_c—59) for the hauls of poor catch under the wave grade 7, the similar trend was found out in t_t, but t_h under this wave grade was larger than that under the other wave grades throughout the catch-classes. These results meant that the small value of log(t_c—59) was not due to the acceleration of rough sea for the fishing work of the hauls of poor catch but was due to the disturbance of rough sea for smooth work through elongating the hauling-fastening work of the hauls of good catch and through leaving off the towing before yielding a sufficient amount of catch by a haul. And 3) the large value of $b_{1.1}$, in consequence the large value of log(t_c—59) for the hauls of good catch under the wind wave of the grade 1, was mainly due to the same trend in t_h and partly due to the same but somewhat unclear trend in t_t. These facts indicated that in calm water it was easy to haul

Table 3. The results of the comparison between $b_{1\cdot w}$ under different grades of wind wave (w) through the t -test.

Grade of wind wave ($\bar{w}$)	1		2		3		4		5		6		7		8	
	t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
Grade of wind wave (w) 1			2.04*	432	2.31*	628	1.53	393	0.99	370	2.14*	308	−0.38	163	2.69**	71
2					−0.24	930	−1.77	695	−1.68	672	0.00	610	−2.08*	465	1.64	373
3							−1.92	891	−1.84	868	0.19	806	−2.38*	661	1.97*	569
4									−0.30	633	1.54	571	−1.65	426	2.60**	334
5											1.44	548	−1.25	403	1.97*	311
6													−2.00*	341	1.92	249
7															1.51	104

Number of the combinations showing significant difference	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	
	4			2(2)	1(1)	2(2)	1(1)		1(1)			2(2)	3			4	10

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

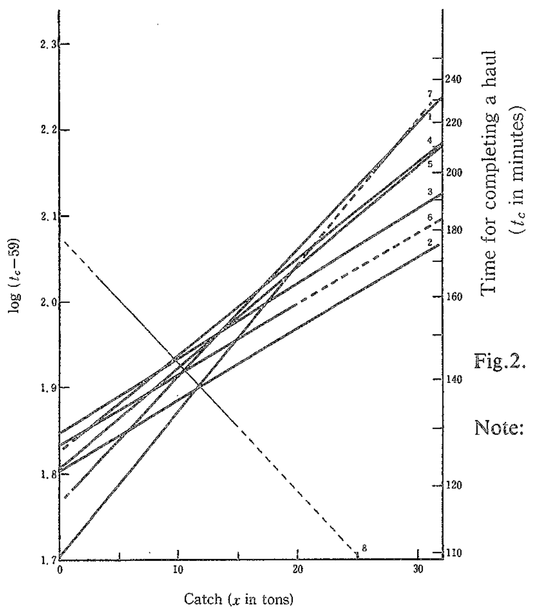

Fig.2. The estimated regression lines of log (t_c—59) on the amount of catch (x in tons).

Note: The part of solid line shows the applicable catch range. The thick line shows the relation with the significant (0.05 level) linear regression coefficient, but the thin one shows the relation with the insignificant one. The numeral attached to the line is the grade of wind wave.

up and make fasten the cod end of poor catch but the conditions were different in hauling up the cod end containing a good catch probably because of difficulty in using the wind drift and rolling of the boat for hauling up the net, and good catch in some of the hauls under calm water may be due to the long towing without any inconvenience to do so.

4. The linear regression on the depth fished

As shown in Tables 4 and 5, log (t_c—59) increased significantly with the depth along the similar pattern except under the roughest two wave grades. The comparison with the preceding reports revealed the following facts: 1) Under all the wave grades except the roughest two ones, log t_t increased with the depth along the similar pattern with one another; and that under the wave grade 7 showed a sharp increase but that under the wave grade 8

Table 4. The linear regression equations of the time for completing a haul (t_c in min.) on the depth of the fishing ground (y in m) under respective grades of wind wave (w).

$$\log(t_c-59) = c_{0\cdot w}+c_{1\cdot w}y$$

		Range of y	$c_{0\cdot w}$	$c_{1\cdot w}$	F_0	n_2
Grade of wind wave (w)	1	80 — 140	1.5361	0.0034	19.26**	65
	2	50 — 150	1.6373	0.0025	157.03**	367
	3	50 — 150	1.7045	0.0021	98.89**	563
	4	60 — 150	1.6572	0.0023	55.98**	328
	5	80 — 150	1.7135	0.0017	12.58**	305
	6	80 — 150	1.6294	0.0024	40.94**	243
	7	90 — 130	1.4257	0.0040	2.58	98
	8	120 — 140	3.3854	−0.0112	10.67*	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 5. The results of the comparison between $c_{1\cdot w}$ under different grades of wind wave (w) through the t-test.

Grade of wind wave (w)		1		2		3		4		5		6		7		8	
		t	n	t	n	t	n	t	n	t	n	t	n	t	n	t	n
Grade of wind wave (w)	1			1.13	432	1.69	628	1.40	393	1.69	370	1.21	308	−0.24	163	2.17*	71
	2					1.39	930	0.52	695	1.62	672	0.23	610	−0.88	465	2.00*	373
	3							−0.52	891	0.82	868	−0.69	806	−1.19	661	2.02*	569
	4									1.06	633	−0.19	571	−1.00	426	2.14*	334
	5											−1.13	548	−1.16	403	1.58	311
	6													−0.88	341	2.12*	249
	7															1.24	104

Number of the combinations showing significant difference	L	S	L	S	L	S	L	S	L	S	L	S	L	S	L	S	
	1(1)		1(1)		1(1)		1(1)				1(1)					5	5

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

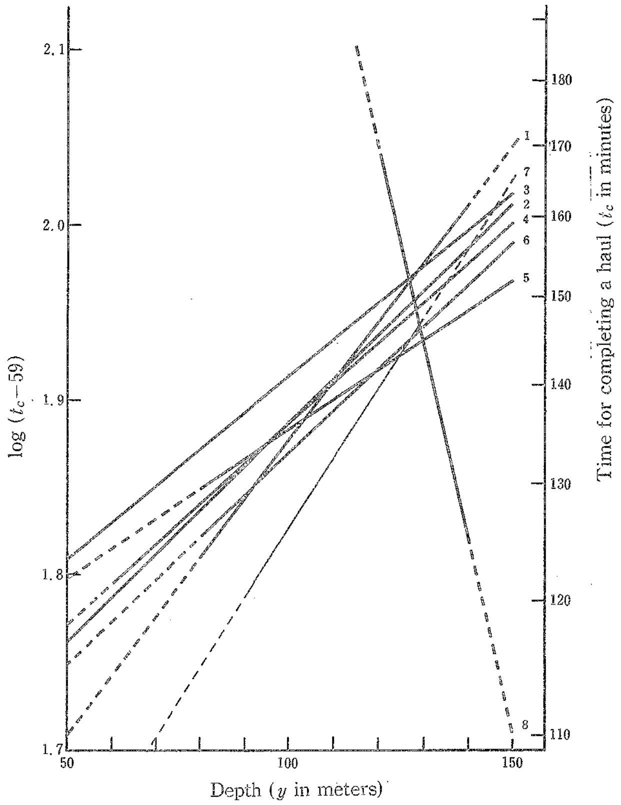

Fig.3. The estimated regression lines of log (t_c—59) on the depth fished.

covering a narrow depth range showed a sharp decrease with depth. On the other hand, log(t_h—19) showed the significant change with depth in the six wave grades out of the eight ones; but the pattern of depth regression differed greatly according to the wave grade. In spite of high possibility of the depth regression of log (t_c—59) mainly due to that in log (t_h—19), the general trend of the change of log (t_c—59) with wave grade was similar to that of log t_t, because of large coefficient of depth regression of log t_t but small one of log (t_h—19). As pointed out in the first report, it was hard to find the reason of log t_t showing a clear depth regression, and the possibility remained only in the interaction of the bathymetric difference of catch and the clear catch regression. If the depth regression of log (t_c—59) is derived from that of log t_t, it is necessary to examine whether the same is true to the depth regression of log(t_c—59) or not.

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

The examinations in the preceding sections revealed that log(t_c—59) showed a significant regression either on the amount of catch or on the depth fished. And the preceding report suggested that the depth regression of log t_t which showed the similar pattern to that of log (t_c —59) should have a close relation to the former and the bathymetric difference of catch. For the purpose of clarifying the change of working time for completing a haul according to the conditions in detail especially for clarifying the mechanism of the seeming depth regression, there are two ways: one is to examine the difference in the catch regression according to the depth and the wave grade, and the other is to examine the change of depth regression according to the difference in the catch and the wave grade. The results of the examinations along the former way after the twofold stratification of the records according to the depth and the wave grade were shown in this section, and those along the latter way were in the succeeding one.

5.1 The significance of catch regression

As shown in Table 6, the regression coefficient of log (t_c—59) on x was significantly positive in the 27 strata (the groups of the records in the same depth zone under the same

Table 6. The linear regression equations of the time for completing a haul (t_c in min.) on the catch (x in tons) after stratification of the records into the depth zones (y in m, 10-m intervals) and the grade of wind wave (w).

$$\log(t_c-59) = b_{0yw}+b_{1yw}x$$

Grade of wind wave (w)	1				2				3			
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
50					1.6621	0.0065	5.71*	108	1.7195	0.0047	0.98	54
60												
80												
90	1.7963	−0.0008	0.03	23					1.7454	0.0118	14.47**	30
100					1.8730	0.0091	9.55**	60	1.8728	0.0058	6.81*	90
110	1.8849	0.0095	5.04*	15	1.8368	0.0114	51.39**	45	1.8271	0.0125	62.24**	143
120	1.7120	0.0193	1.19	3	1.8470	0.0118	24.58**	48	1.9204	0.0062	18.44**	93
130					1.8248	0.0121	4.49*	32	1.8828	0.0113	6.07*	57
140	1.8707	0.0087	3.02	13	1.8221	0.0150	11.04**	60	1.8530	0.0094	34.23**	74
150									2.0814	−0.0281	0.96	6

Grade of wind wave (w)	4				5				6			
Depth zone (y)	b_{0y4}	b_{1y4}	F_0	n_2	b_{0y5}	b_{1y5}	F_0	n_2	b_{0y6}	b_{1y6}	F_0	n_2
50												
60	1.6472	0.0167	3.62	9								
80					1.7509	0.0232	1.23	4	1.8714	−0.0036	0.34	15
90	1.7543	0.0111	9.68**	43	1.7761	0.0119	31.89**	57	1.8785	0.0007	0.01	21
100	1.7522	0.0150	15.28**	26	1.7172	0.0161	16.48**	51	1.7818	0.0079	5.30*	72
110	1.8487	0.0115	73.18**	40	1.7685	0.0125	11.12**	41	1.8421	0.0051	1.02	41
120	1.8373	0.0088	19.40**	51	1.7739	0.0171	14.25**	51				
130	1.8512	0.0112	30.44**	64	1.8940	0.0067	5.32*	45	1.9391	0.0002	0.001	15
140	1.8962	0.0082	17.21**	69	1.9157	0.0052	1.61	40	1.8658	0.0120	21.09**	60
150	1.9198	0.0124	2.37	11	1.9332	0.0076	0.02	2	1.9522	−0.0012	0.11	5

Table 6. (cont'd.)

Grade of wind wave (w)	7					
	b_{0y7}	b_{1y7}	F_0	n_2		
Depth zone (y) 50						
60						
80						
90						
100	1.6555	0.0199	7.41**	59		
110	1.7654	0.0103	2.01	25		
120						
130	1.9942	−0.0022	0.05	7		
140						
150						

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

wave grade) out of the 44 ones, insignificantly positive in the 13 ones, but insignificantly negative in the four ones. The strata taking the insignificantly positive one or the insignificantly negative one were found mainly in the extreme wave grades and/or in the extreme depth zones. These facts meant that the time for completing a haul elongated with the amount of catch.

5. 2 The difference of catch regression according to the wave grade

The wave grade was unable to be used as one of the independent variables in the multiple linear regression equations. And its influence was indirectly examined through comparing the regression equations of log(t_c—59) either on x or on y under the different wave grades with one another. To sweep away the uncertainty in the results due to the probable difference of the bathymetric distribution of the records, the estimated linear regression equations in the same depth zones under the different wave grades were compared with one another.

As shown in Tables 7 and 8, the estimated regression coefficients showed a significant difference in the 10 pairs out of the 94 ones of the coefficients of the strata in the same depth zones under the different wave grades; and these significant differences were due to the small value of either $b_{1.9.1}$, or $b_{1.10.3}$, or $b_{1.12.3}$. The small value of the first one was due to the narrow applicable range of catch. But it was hard to find the reason why the latter two were small.

Comparison of the results of the present section with those of the corresponding ones in the preceding reports revealed the following trends: 1)There were no large differences between t_c and either t_t or t_h in regard to the rate of the combinations of b_{1yw} showing the significant difference. 2)The small value of $b_{1.9.1}$ for t_c was due to the same trend in that for t_h, and 3) the small value of either $b_{1.10.3}$ or $b_{1.12.3}$ was due to the same trend in that for t_t.

For the purpose of showing the difference of t_c—x relations under the different wave grade in the same depth zones, the estimated equations were illustrated in Fig.4. This figure showed that the difference in t_c due to the catch difference was far larger than that due to the difference in the wave grade. Some of the estimated equations took the large coefficient, as if

Table 7. The results of the comparison between b_{1yw} under the different grades of wind wave (w) through the t -test

Depth (y)	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									−0.53	60	0.81	51			−0.69	73		
1 − 3					−2.15*	53			−0.75	158	1.61	96			−0.12	87		
1 − 4					−1.81	66			−0.58	55	1.24	54			0.08	82		
1 − 5					−2.09*	80			−0.51	56	0.14	54			0.46	53		
1 − 6					−0.17	44			0.63	55					−0.55	73		
1 − 7									−0.10	40								
2 − 3	0.34	162					0.89	150	−0.42	188	2.07*	141	0.10	89	1.32	134		
2 − 4							−1.19	86	−0.05	85	0.97	99	0.16	96	1.49	129		
2 − 5							−1.39	111	−0.29	86	−1.04	99	0.89	77	1.56	100		
2 − 6							0.26	132	1.34	86			1.00	47	0.59	120		
2 − 7							−1.39	119	0.19	70			1.08	39				
3 − 4					0.15	73	−1.96	116	0.41	183	−1.04	144	0.02	121	0.47	143	−1.72	17
3 − 5					−0.03	87	−2.47*	141	0.00	184	−2.82**	144	0.85	102	1.04	114	−0.53	8
3 − 6					1.29	51	−0.53	162	1.75	184			0.82	72	−0.84	134	−1.12	11
3 − 7							−2.21*	149	0.37	168			0.90	64				
4 − 5					−0.19	100	−0.16	77	−0.27	81	−1.73	102	1.26	109	0.68	109	0.14	13
4 − 6					1.12	64	1.23	98	1.39	81			1.09	79	−1.11	129	1.52	16
4 − 7							−0.46	85	0.21	65			1.21	71				
5 − 6			1.51	19	1.29	78	1.58	123	1.18	82			0.65	60	−1.46	100	0.26	7
5 − 7							−0.47	110	0.27	66			0.81	52				
6 − 7							−1.57	131	−0.57	66			0.20	22				

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

suggesting the different trend. But t_c in these strata did not show any large differences from the others because of the small constant and the narrow applicable range of catch. The notable difference in the t_c— x relation found in this figure could be classified into the following four types .... 1) long work for the hauls of poor catch because of large constant in (x .10.2), 2) long work for the hauls of poor catch but short one for the hauls of good catch because of large constant but small coefficient in (x.10.3) and (x.12.3), 3) short work for the hauls of good catch because of small coefficient in (x.10.6) and (x.12.4) , and 4) long work for the hauls of intermediate amount of catch because of narrow catch range and large coefficient in (x.14.2) and (x.14.3). All of these differences were derived from the same trend in t_r. In some of the strata, the estimated regression equation of t_h on x showed the different trend from the others in the same depth zone under the different wave grades. But neither of them caused any notable differences in the t_c—x relation because of small variation of t_h relating to the amount of catch.

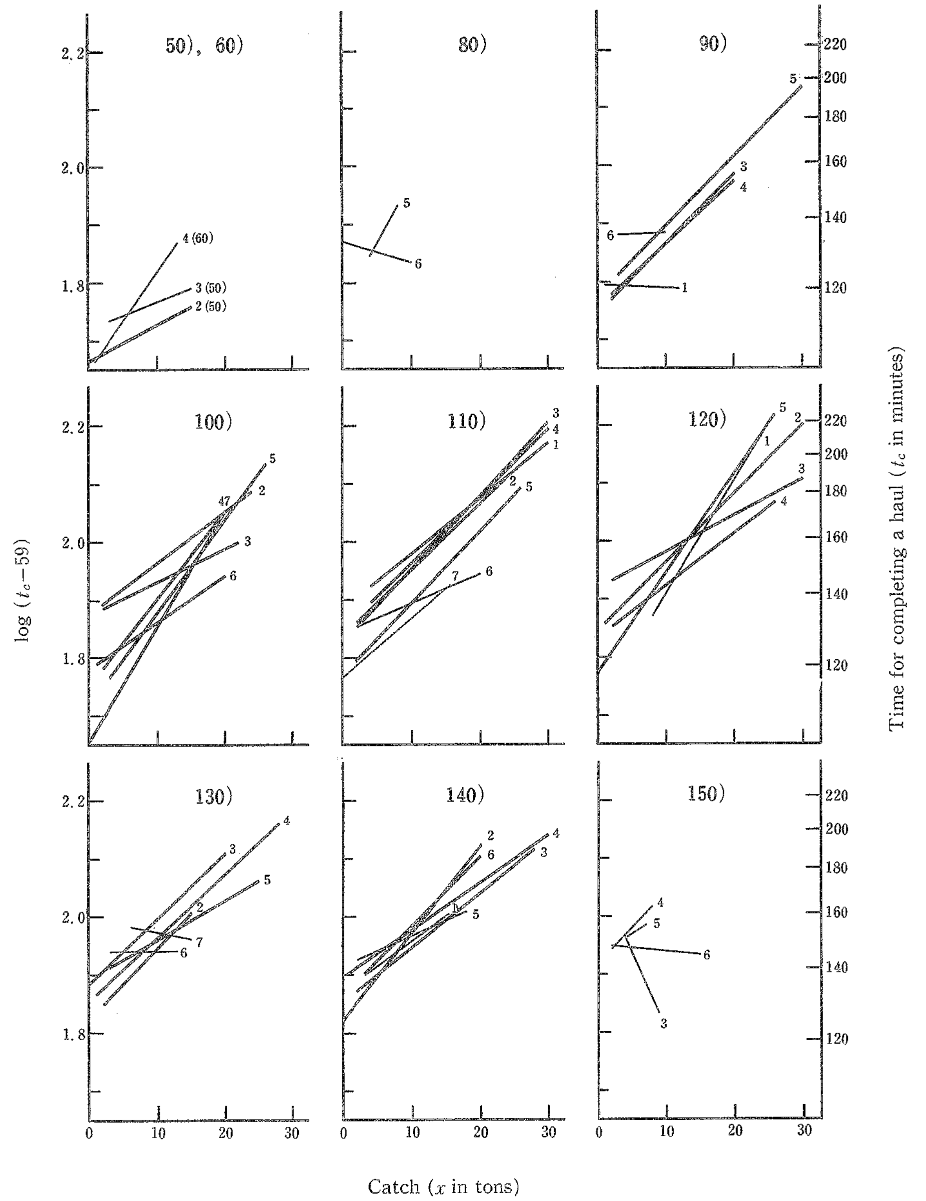

Fig.4. The difference of the log (t_c—59) — x relations according to the grade of wind wave observable within the records of the same depth zones.

Note: The numeral with parenthesis is the depth zone (the echo-sounded depth, 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 one.

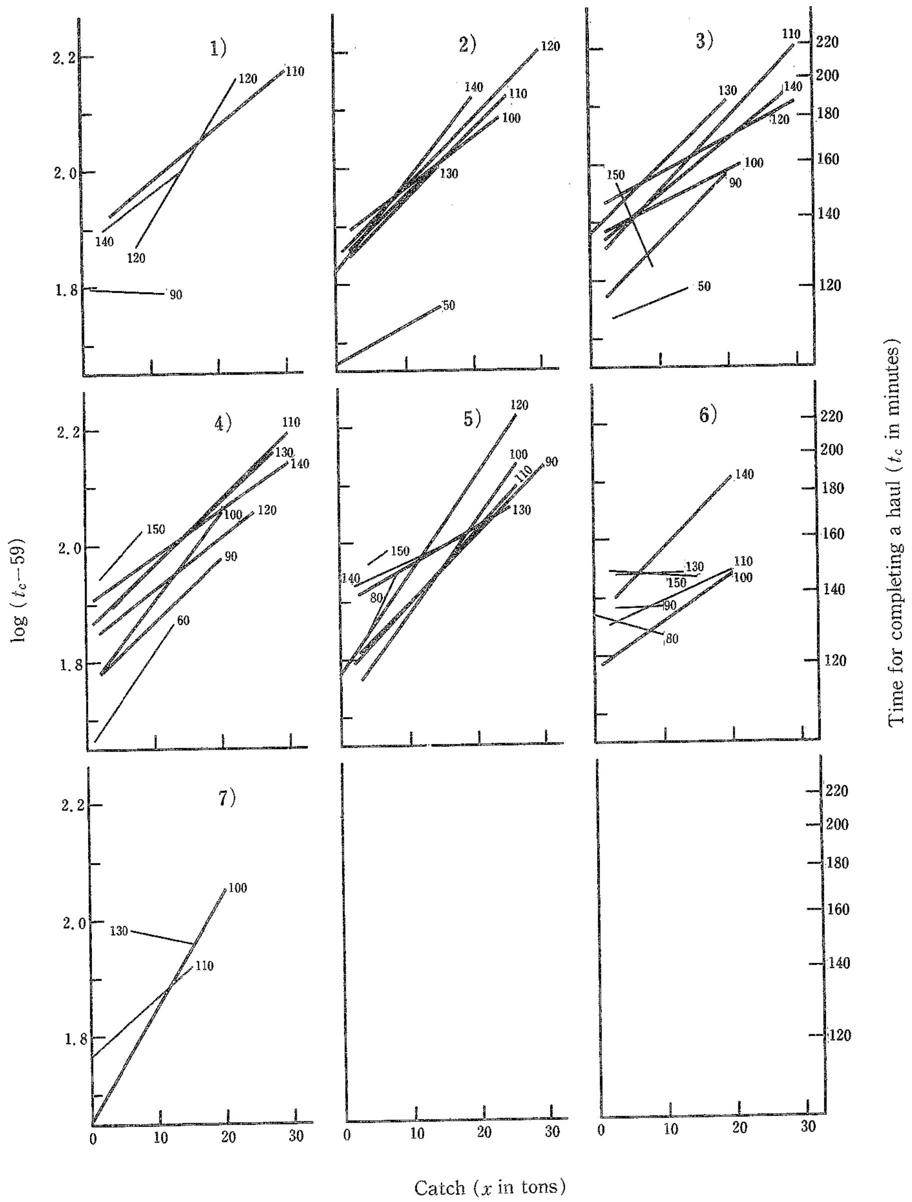

Fig.5. The difference of the log (t_c—59) —x relations according to the depth observable within the records under the wind wave of the same grade.

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).

Table 8. 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														
60														
80														
90		2			1				1					
100						2			1				1	
110														
120			1			2			1					
130														
140														
150														
Sum		2	1		1	4			3				1	

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

5.3 The difference in catch regression according to the difference in the depth fished

As shown in Table 9, the significant difference between b_{1yw} for the strata in the different depth zones under the same wave grades could be found only in the four pairs out of the 129 ones. These significant differences were in the wave grade 3 and were either due to the large value of $b_{1.11.3}$ or due to the small value of $b_{1.15.3}$. These examinations concerned only with the difference in b_{1yw}, in spite of the fact that the t_c—x relation is defined not only by b_{1yw} but also by b_{0yw} and the applicable catch range. For the purpose of clarifying the difference in the estimated relations taking into account the difference in b_{0yw} and the applicable range, the estimated regression equations were illustrated in Fig. 5. This figure revealed that the time for completing a haul got longer with the depth mainly because of the difference in b_{0yw}. This trend was clear under the wave grade 4 but rough under the wave grades 3 and 6. This figure was compared with the corresponding ones in the preceding reports, but it was hard to find any clear results.

5.4 The comparison of the estimated regression equations in the different depth zones under the different wave grades

The examinations in the preceding sections clarified the influences of the three factors under consideration, but it was hard to find the clue to the question whether the depth would be more influential than the wave grade or not. When a line in a stratum showed a different trend from the other lines in the same depth zone, it is necessary to examine carefully whether that trend would be common to the lines in that wave grade or not. This problem was examined in the section 5.2,but that was insufficient because the relation to the other lines in the same depth zone was not taken into account.

For the purpose of taking the variation of all the lines into account and comparing all the lines with one another, the estimated equations were plotted in Fig. 6. This figure revealed the following facts: The numeral attached to the marks increased in the direction perpendicular to the lines showing the b_{0yw}—b_{1yw} relation for the hauls of 10 tons of catch, but very roughly in the direction perpendicular to the lines showing the relation of the hauls of 30 tons. The width of the distribution of the points in the former direction was similar to that in the latter direction. The intervals between the b_{0yw}—b_{1yw} lines showing the same difference of log (t_c—59) became narrower with increase in the amount of catch and log(t_c—59). This fact suggested that the depth regression should be clear for the hauls of poor catch, and become less clear with increase in catch but the difference among the estimated log(t_c—59) become larger, although whether all the estimated equations would be applicable to the classes of good catch and to the deep zones or not was doubtful.

Table 9. 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 (y)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
50 — 60														
50 — 80														
50 — 90					−1.24	84								
50 — 100			−0.66	168	−0.21	144								
50 — 110			−1.54	153	−1.51	197								
50 — 120			−1.48	156	−0.32	147								
50 — 130			−0.99	140	−0.96	111								
50 — 140			−1.73	168	−1.03	128								
50 — 150					1.42	60								
60 — 80														
60 — 90							0.59	52						
60 — 100							0.17	35						
60 — 110							0.69	49						
60 — 120							0.88	60						
60 — 130							0.55	73						
60 — 140							0.93	78						
60 — 150							0.34	20						
80 — 90									0.52	61	−0.40	36		
80 — 100									0.18	55	−0.92	87		
80 — 110									0.31	45	−0.57	56		
80 — 120									0.14	55				
80 — 130									0.68	49	−0.38	30		
80 — 140									0.72	44	−1.93	75		
8 — 150									0.30	6	−0.30	20		

Table 9. (cont'd.)

Grade of wind wave (w)	1		2		3		4		5		6		7	
Depth (y)	t	n	t	n	t	n	t	n	t	n	t	n	t	n
90 — 100					1.34	120	−0.75	69	−0.95	108	−0.60	93		
90 — 110	−1.39	38			−0.16	173	−0.11	83	−0.15	98	−0.30	62		
90 — 120	−1.98	26			1.48	123	0.56	94	−1.07	108				
90 — 130					0.08	87	−0.02	107	1.48	102	0.04	36		
90 — 140	−1.46	36			0.67	104	0.70	112	1.52	97	−1.36	81		
90 — 150					2.03*	36	−0.11	54	0.10	59	0.17	26		
100 — 110			−0.70	105	−2.43*	233	0.97	66	0.65	92	0.48	113	0.74	84
100 — 120			−0.71	108	−0.15	183	1.48	77	−0.17	102				
100 — 130			−0.49	92	−1.16	147	0.86	90	1.78	96	0.60	87	0.81	66
100 — 140			−1.12	120	−1.30	164	1.61	95	1.63	91	−0.88	132		
100 — 150					1.46	96	0.21	37	0.11	53	0.71	77		
110 — 120	−0.76	18	−0.14	93	2.86**	236	1.13	91	−0.77	92				
110 — 130			−0.14	77	0.28	200	0.12	104	1.21	86	0.31	56	0.76	32
110 — 140	0.09	28	−0.81	105	1.26	217	1.36	109	1.22	81	−1.26	101		
110 — 150					1.72	149	−0.09	51	0.07	43	0.39	46		
120 — 130			−0.05	80	−1.23	150	−0.83	115	1.81	96				
120 — 140	0.87	16	−0.65	108	−1.44	167	0.21	120	1.64	91				
120 — 150					1.68	99	−0.31	62	0.11	53				
130 — 140			−0.39	92	0.45	131	1.06	133	0.30	85	−1.39	75		
130 — 150					1.35	63	−0.09	75	−0.02	47	0.14	20		
140 — 150					2.02*	80	−0.35	80	−0.05	42	1.66	65		

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

Depth zone	90		100		110		120		130		140		150	
Number of the combinations showing significant difference	L	S	L	S	L	S	L	S	L	S	L	S	L	S
	1			1	2			1			1			2

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

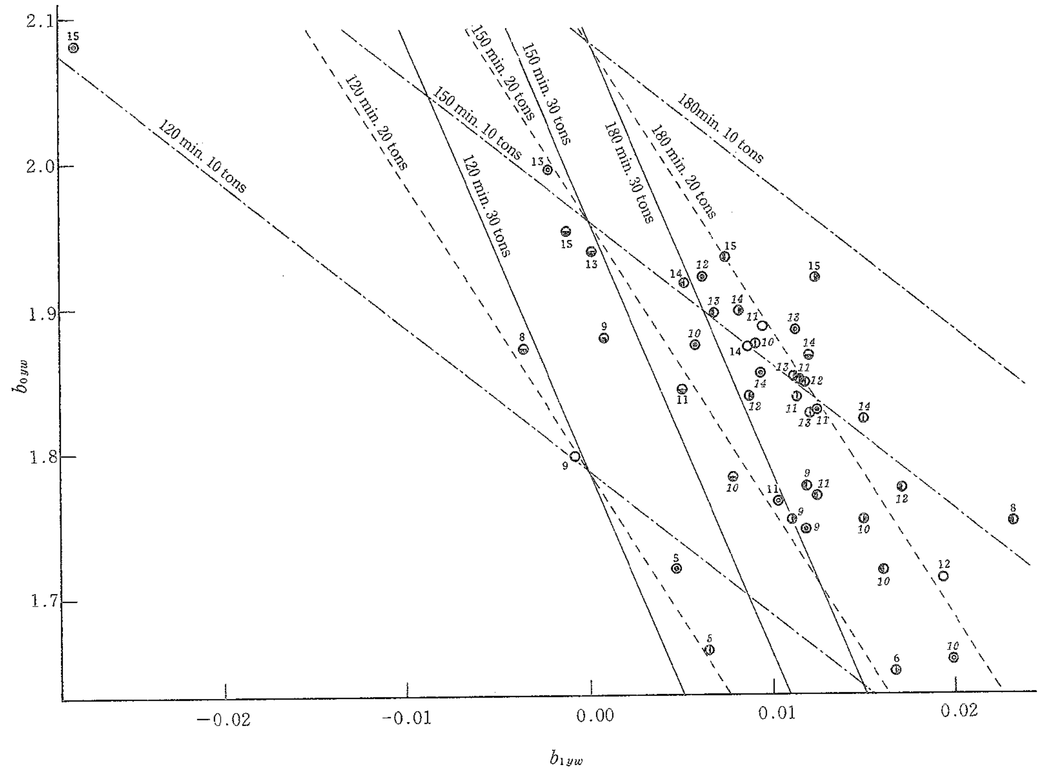

Fig.6. The comparison of the estimated regression lines of log (t_c—59) on x.

$$\log(t_c - 59) = b_{0yw} + b_{1yw}x$$

Legends:

8...... 80 m zone   11...... 110 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

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

The examinations on the multiple linear regression and the linear one on the amount of catch revealed that 1) the time for completing a haul increased with depth, 2) this may be mainly due to the difference in b_{0yw}, and that 3) the depth regression may differ according to the amount of catch. The examinations in the preceding sections made it possible to compare the influence of either the wave grade or the depth with that of the amount of catch . And it was found out that the influence of the amonut of catch was far larger than that of either the wave grade or the depth fished. But it was hard to compare the influence of the latter two factors with each other. To examine these points the records were stratified according to the wave grade and the amount of catch, and the linear regression equations of log(t_c—59) on depth were estimated and compared with one another.

6.1 The significance of depth regression

As shown in Table 10, the estimated regression coefficient was significantly positive in the 20 strata (the groups of the records of the hauls yielded the same amount of catch under the wind wave of the same grade) out of the 92 ones, insignificantly positive in the 53 ones, but insignificantly negative in the 17 ones and significantly negative in the two ones. Most of the strata taking the negative coefficient were concentrated in the wave grade 2. There were five strata in this wave grade taking the positive coefficient but they were small in the sample size. In spite of these facts, the examination on the multiple linear regression and the linear regression on depth before stratification of the records according to the amount of catch showed the significantly positive regression on depth even in this wave grade. These facts suggested that the positive depth regression of log(t_c—59) under the wave grade 2 should be due to the bathymetric difference of catch and the clear catch regression.

For other wave grades, it was less probable that the significant depth regression found in the preceding sections was simply due to the same reason, but it was probable that log(t_c—59) increased with depth after the exclusion of the influence of the bathymetric difference of catch.

6.2 The difference of depth regression according to the wave grade

For the purpose of comparing the influence of depth with that of the wave grade, the estimated regression coefficients on depth for the hauls yielding the same amount of catch under the different wave grades were compared with one another. As shown in Table 11, the significant difference between c_{1xw} of the same x under the different w was found in the 27 pairs of them out of the 212 ones. All the significant differences were due to the small value of c_{1xw} in the following nine strata and the large value of $c_{1.6.7}$: (3.y.2), (4.y.2), (5.y.2), (7.y.2), (8.y.2), (13.y.2). (5.y.3), (7.y.3), and (8.y.7).

In the examination on the depth regression of log t_t, it was found out that the two thirds of the significant differences between the regression coefficients were due to the small value of those under the wave grade 2. In the preceding section, the close relation between t_c and t_t was found out in the catch regression. The examination in the present section added such information that there was close relation between t_c and t_t in the pattern of the change of the depth regression, too. These facts suggested the possibility of the variation of t_c strongly depending on that of t_t.

For the purpose of comparing the influence of the wave grade with that of the depth, the estimated regression lines were stratified according to the amount of catch and illustrated in Fig. 7. This figure revealed the following facts: 1) The clearest trend observable in this figure was the gradual increase of log(t_c—59) with the amount of catch, indicating the clear catch regression, although this was not the principal aim of this figure. 2) The influence of either the wave grade or the depth was not serious. And it was hard to tell whether the wave grade was more influential or less influential than the depth, for the results varied according to catch class. 3) In many catch classes, the lines under the wave grade 7 showed the different trend from those for the other wave grades. But it was hard to give much importance

Table 10. The linear regression equations of the time for completing a haul (t_c in min.) on the depth of the fishing ground (y in m) after stratification of the records according to the catch (x in tons) and the grade of wind wave (w).

$$\log(t_c-59) = c_{0xw} + c_{1xw}y$$

Grade of wind wave (w)	1				2				3				4			
Catch (x tons)	c_{0x1}	c_{1x1}	F_0	n_2	c_{0x2}	c_{1x2}	F_0	n_2	c_{0x3}	c_{1x3}	F_0	n_2	c_{0x4}	c_{1x4}	F_0	n_2
2					2.2661	−0.0035	1.01	8					1.6441	0.0020	4.12	16
3	1.5207	0.0029	5.11	4	2.0377	−0.0016	1.46	15	1.9065	−0.00003	0.0003	24	1.4486	0.0033	11.26**	15
4	1.6329	0.0026	1.38	5	1.8974	−0.0002	0.04	29	1.9041	0.0001	0.004	32	1.5128	0.0031	5.45*	24
5	1.7903	−0.00005	0.0001	6	2.0390	−0.0012	1.11	38	1.9172	0.00003	0.002	44	1.6455	0.0018	6.12*	33
6					1.9274	−0.0002	0.03	25	1.6711	0.0022	6.28*	41	1.7580	0.0012	1.88	21
7					2.3892	−0.0033	2.73	16	2.1270	−0.0016	1.69	52	1.5628	0.0029	15.24**	26
8	1.6562	0.0018	15.88*	5	2.3748	−0.0034	7.83*	11	1.7419	0.0016	4.56*	48	1.5640	0.0031	10.27**	24
9									1.4830	0.0036	10.49**	16	1.4567	0.0039	3.47	6
10	1.9158	0.0003	0.004	5	1.4856	0.0041	6.29*	19	1.7121	0.0021	2.73	41	1.7640	0.0015	1.31	23
11					1.9230	0.0013	0.15	5	1.2100	0.0064	6.21*	12	1.5339	0.0031	2.25	5
12	1.4152	0.0043	8.43*	5					1.6953	0.0022	1.64	18	1.6638	0.0025	2.30	10
13					2.5472	−0.0051	24.47**	8	1.6181	0.0030	4.03	26	1.6642	0.0026	1.85	17
14					1.5264	0.0039	1.16	5	1.9433	0.0001	0.004	14				
15					1.6409	0.0033	2.25	17	1.8821	0.0009	0.39	33	2.0925	−0.0010	0.56	24
17									1.5605	0.0048	4.13	9	1.6672	0.0033	0.72	4
18									2.3729	−0.0029	0.48	8	1.9340	0.0014	0.22	5
20					2.0752	−0.0003	0.01	6	1.5976	0.0041	5.81*	13	1.9888	0.0006	0.06	8
25					1.8663	0.0021	0.04	4	2.3514	−0.0024	0.19	5	1.8911	0.0018	0.13	7

Grade of wind wave (w)	5				6				7			
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	0.4379	0.0115	2.27	4								
3	1.2054	0.0053	3.55	18	1.5966	0.0028	4.10	12	−0.2377	0.0173	0.08	5
4	1.4882	0.0035	8.29**	26	1.5201	0.0032	1.18	19	2.6545	−0.0086	0.34	5
5	1.6311	0.0022	10.15**	49	1.5560	0.0026	5.60*	33	1.7964	0.00005	0.0001	8
6	1.6978	0.0018	2.57	23	1.9034	−0.0001	0.01	15	1.0071	0.0078	8.45*	7
7	1.7591	0.0011	0.37	28	1.5638	0.0029	7.02*	14	1.7049	0.0011	0.03	4
8	1.7612	0.0013	1.12	28	1.7101	0.0019	3.55	22	1.1795	0.0064	6.78*	7
9	1.2011	0.0054	7.01	4	1.4973	0.0032	2.81	8	0.5291	0.0130	0.49	3
10	1.5128	0.0035	7.44*	15	1.7482	0.0015	2.08	19	1.7393	0.0014	0.27	13
11	1.1945	0.0059	3.77	6	1.4261	0.0041	2.16	7				
12	1.9738	0.0002	0.004	8								
13	1.8222	0.0011	0.39	17	1.6857	0.0020	0.69	21	2.2265	−0.0034	0.09	12
14	1.7732	0.0015	0.30	8								
15	1.9881	0.0005	0.03	8	1.6538	0.0028	0.74	9				
17												
18	2.1798	−0.0012	1.23	4								
20	1.2340	0.0068	1.04	6	1.2544	0.0066	3.22	6				
25	1.8746	0.0019	0.27	5								

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

on these differences because of the following three reasons: Most of them covered narrow depth range, this was the wave grade near the roughest limit to work, and the records on the days in this wave grade were concentrated into a few days in a limited season. 4) In the examination on the difference of c_{1xw} for the hauls of the same x under the different w, the significant difference was found in the 19 pairs due to the small coefficient in the nine strata and the large value in one of the strata. These differences in c_{1xw} resulted in the short work for deep ground in (3.y.2) and (4.y.2), the long work for shallow ground in (5.y.2), (5.y.3),

(7.*y*.2), (7.*y*.3), (8.*y*.2), and (13.*y*.2), and the short work for shallow ground and the long work for deep ground in (6.*y*.7). When the difference in c_{0xw} was taken into account the following facts were found out : (8.*y*.7) with small coefficient did not show any difference in t_c, (9.*y*.5) showed the short work throughout the depth zones, and (11.*y*.2) and (12.*y*.5) showed the long work for shallow ground. The trend of short work in deep ground was found in (18.*y*.3), (18.*y*.5), (20.*y*.2), (20.*y*.4), and (25.*y*.3) ; but it was hard to give meaning on these seeming differences, for the number of the hauls relating to them was extremely small.

Table 11. 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			2.43*	19	1.43	34	0.18	44					3.30**	16			−1.13	24
1 — 3			1.11	28	0.82	37	0.00	50					0.11	53			−0.56	46
1 — 4			−0.23	19	−0.20	29	−0.38	39					−0.63	29			−0.36	28
1 — 5			−0.60	22	−0.37	31	−0.44	55					0.20	33			−1.00	20
1 — 6			0.00	16	−0.15	24	−0.40	39					−0.05	27			−0.41	24
1 — 7			−0.30	9	0.90	10	−0.01	14					−1.92	12			−0.25	18
2 — 3			−0.64	39	−0.17	61	−0.92	82	−1.74	66	−0.67	68	−3.19**	59			0.88	60
2 — 4	−1.95	24	−2.93**	30	−2.21*	53	−2.24*	71	−1.06	46	−3.43**	42	−3.50**	35			1.18	42
2 — 5	−1.69	12	−2.03	33	−2.60*	55	−2.68**	87	−1.35	48	−1.34	44	−2.17*	39			0.29	34
2 — 6			−2.29*	27	−1.33	48	−2.39*	71	−0.06	40	−2.82**	30	−3.04**	33			1.36	38
2 — 7			−0.58	20	1.01	34	−0.17	46	−3.30**	32	−0.44	20	−3.85**	18			0.88	32
3 — 4			−1.52	39	−1.46	56	−1.67	77	0.77	62	−2.75**	78	−1.28	72	−0.10	22	0.32	64
3 — 5			−1.50	42	−1.76	58	−2.09*	93	0.28	64	−1.29	80	0.21	76	−0.83	20	−0.71	56
3 — 6			−1.16	36	−0.92	51	−1.95	77	1.43	56	−2.26*	66	−0.24	70	0.15	24	0.34	60
3 — 7			−0.62	29	0.76	37	−0.00	52	−2.04*	48	−0.22	56	−2.05*	55	−0.83	19	0.21	54
4 — 5	−1.99	20	−0.70	33	−0.22	50	−0.39	82	−0.41	44	0.86	54	1.15	52	−0.49	10	−1.05	38
4 — 6			0.28	27	−0.03	43	−0.60	66	0.74	36	0.00	40	0.86	46	0.22	14	0.00	42
4 — 7			−0.44	20	1.20	29	0.32	41	−2.61*	28	0.28	30	−1.16	31	−0.61	9	0.03	36
5 — 6			0.77	30	0.10	45	−0.32	82	1.00	38	−0.68	42	−0.37	50	0.80	12	1.23	34
5 — 7			−0.36	23	1.25	31	0.36	57	−2.12*	30	0.00	32	−1.58	35	−0.51	7	0.73	28
6 — 7			−0.41	17	1.01	24	0.34	41	−2.09*	22	0.23	18	−1.71	29	−0.80	11	0.04	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			0.86	23														
1 — 4			0.80	15														
1 — 5			1.07	13														
1 — 6																		
1 — 7																		
2 — 3	−1.21	17			−2.29*	34	1.28	19	0.95	50					−1.45	19	0.32	9
2 — 4	−0.35	10			−2.10*	25			1.75	41					−0.24	14	0.02	11
2 — 5	−1.01	11			−1.67	25	0.54	13	0.76	25					−1.09	12	0.01	9
2 — 6	−0.63	12			−1.60	29			0.13	26					−1.51	12		
2 — 7					−0.17	20												
3 — 4	0.60	17	−0.11	28	0.15	43			0.96	57	0.34	13	−0.83	13	1.22	21	−0.57	12
3 — 5	0.12	18	0.63	26	0.82	43	−0.54	22	0.13	41			−0.39	12	−0.49	19	−0.65	10
3 — 6	0.62	19			0.36	47			−0.68	42					−0.71	19		
3 — 7					0.78	38												
4 — 5	−0.58	11	0.66	18	0.57	34			−0.54	32			0.83	9	−0.95	14	−0.02	12
4 — 6	−0.18	12			0.19	38			−1.31	33					−1.41	14		
4 — 7					0.66	29												
5 — 6	0.43	13			−0.29	38			−0.47	17					0.03	12		
5 — 7					0.50	29												
6 — 7					0.57	33												

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

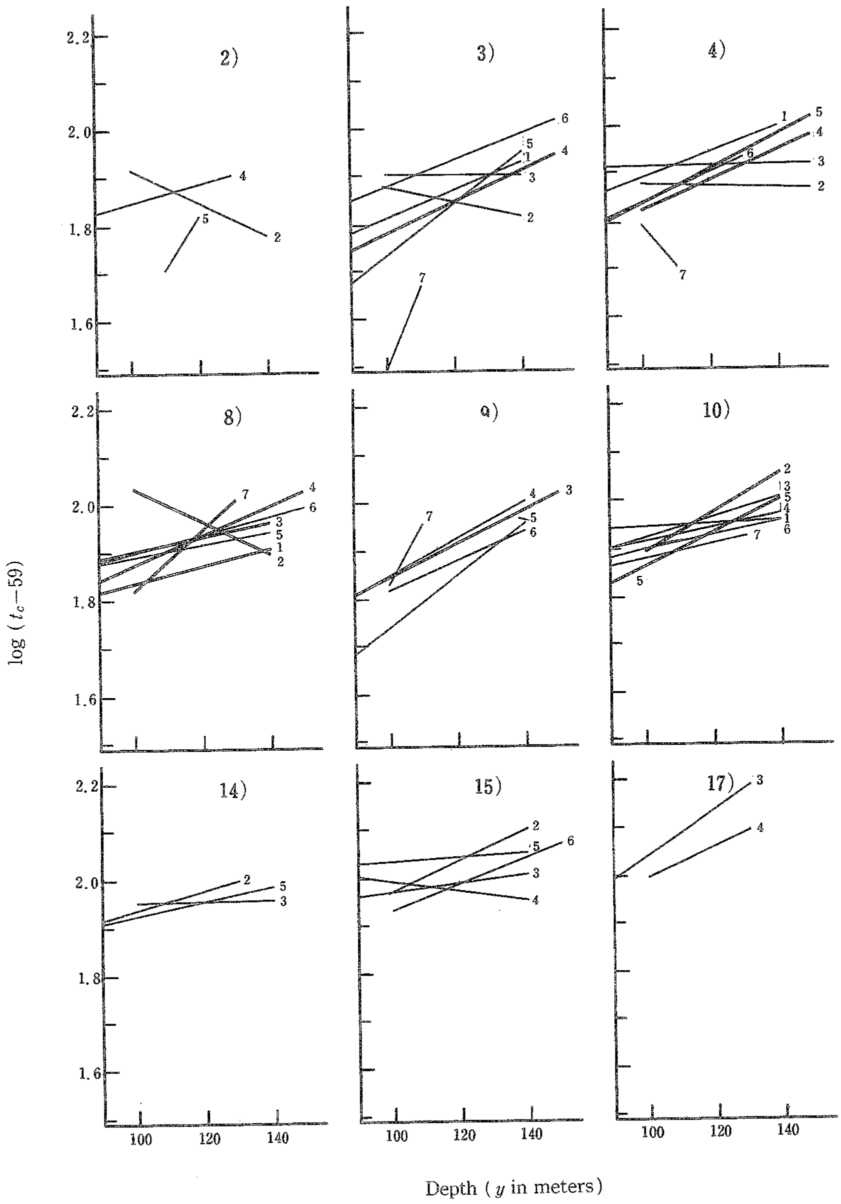

Fig.7. The difference of the estimated log (t_c— 59) — y relations according to the amount of catch and the wave grade.

Note : The numeral with parenthesis is the catch class, and that attached to the line is the wave grade.

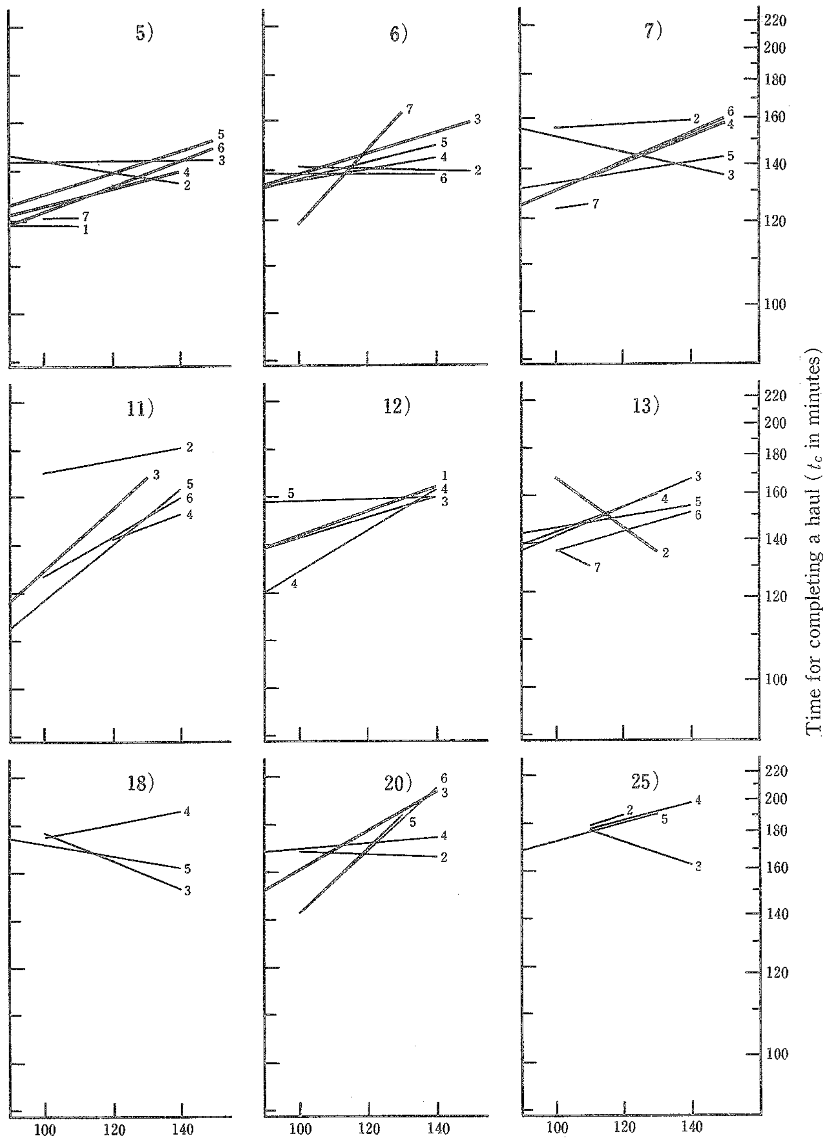

Fig. 7 (cont'd.)

The comparison with the corresponding figures for t_l and t_h revealed that the trends similar to the above-mentioned ones were found out in the figure for t_l, which suggested that not only the trend of the catch regression of t_c but also that of the depth regression should have a close relation to those of t_l.

Table 12. 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	
	L	S	L	S	L	S	L	S	L	S	L	S	L	S
Catch class (x in tons) 2														
3	1			3			1				1			
4				2			1		1					
5				3		1	1		2		1			
6				1		1		1		1		1	5	
7				2		2	2				2			
8	1			6	1	1	1		1		1		2	
9														
10														
11														
12														
13				2	1		1							
14														
15														
17														
18														
20														
25														
Sum	2			19	2	5	7	1	4	1	5	1	7	

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

6.3 The difference of depth regression according to the catch class

The clearest result of the preceding examinations was the clear catch regression. The comparison of the regression equations on catch suggested the following possibilities relating to change of depth regression according to the amount of catch : The depth regression should be clear for the hauls of poor catch while become less clear with increase of catch but the difference among the estimated t_c become larger with the latter, although whether all the estimated equations would be applicable to the classes of good catch and deep zones or not was doubtful. These possibilities were examined through the comparison of the regression lines on depth for the hauls under the wind wave of the same grade but yielding the different amount of catch one another.

As shown in Tables 13 and 14, the significant difference between c_{1xw} was found in the 40 pairs out of the 616 ones. And most of these significant differences were due to the extreme values in a few of the strata: Under the wave grade 2,the significant difference was found in the 16 pairs, and among them those in the 15 pairs were due to either the large value of $c_{1.10.2}$ or the small value of $c_{1.8.2}$ or $c_{1.13.2}$. Under the wave grade 3, the significant difference was found in the 17 pairs ; and among them those in the 16 pairs were due to the large value of $c_{1.11.3}$ or the small values of $c_{1.5.3}$ or $c_{1.7.3}$. Under the wave grade 4, the significant difference was found in the five pairs due to the small value of $c_{1.15.4}$. And under the wave grade 5, the

Table 13. The results of the comparison between c_{1xw_i} of the different catch classes (x) 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			−0.59	23			0.93	31	0.69	22				
2 — 4			−1.39	37			−0.66	40	1.54	30				
2 — 5			−0.83	46			0.11	49	1.97	53				
2 — 6			−1.29	33			0.59	37	1.93	27				
2 — 7			0.00	24			−0.74	42	1.13	32				
2 — 8			0.00	19			−0.74	40	1.76	32				
2 — 9							−0.96	22	0.89	8				
2 — 10			−2.32*	27			0.27	39	1.47	19				
2 — 11			−0.92	13			−0.36	21	0.75	10				
2 — 12							−0.27	26	1.25	12				
2 — 13			0.32	16			−0.28	33	1.62	21				
2 — 14			−1.37	13					1.39	12				
2 — 15			−1.76	25			1.81	40	1.46	12				
2 — 17							−0.40	20						
2 — 18							0.23	21	2.03	8				
2 — 20			−0.65	14			0.63	24	0.47	10				
2 — 25			−0.31	12			0.00	23	1.17	9				
3 — 4	0.00	9	−0.90	44	0.00	56	0.10	39	0.65	44	−0.11	31	0.40	10
3 — 5	0.61	10	−0.18	53	0.00	68	1.19	48	1.48	67	0.08	45	0.35	13
3 — 6			−0.87	40	−1.09	65	1.57	36	1.27	41	1.31	27	0.22	12
3 — 7			0.70	31	0.58	76	0.32	41	1.23	46	0.00	26	0.24	9
3 — 8	0.77	9	0.99	26	−0.86	72	0.11	39	1.47	46	0.54	34	0.25	12
3 — 9					−1.61	40	−0.28	21	0.00	22	−0.15	20	0.05	8
3 — 10	0.64	9	−2.68*	34	−0.85	65	1.04	38	0.58	33	0.77	31	0.45	18
3 — 11			−1.02	20	−2.06*	36	0.00	20	−0.12	24	−0.47	19		
3 — 12	−0.69	9			−0.85	42	0.44	25	1.21	26				
3 — 13			1.48	23	−1.19	50	0.33	32	1.26	35	0.28	33	0.47	17
3 — 14			−1.85	20	0.00	38			0.85	26				
3 — 15			−1.94	32	−0.39	57	2.57*	39	0.98	26	0.00	21		
3 — 17					−1.47	33	0.00	19						
3 — 18					0.69	32	0.70	20	1.42	22				
3 — 20			−0.51	21	−1.55	37	1.17	23	−0.18	24	−1.15	18		
3 — 25			−0.42	19	0.49	29	0.40	22	0.66	23				
4 — 5	0.47	11	0.68	67	0.00	76	0.89	57	0.95	75	0.18	52	−0.67	13
4 — 6			0.00	54	−1.30	73	1.21	45	1.03	49	0.96	34	−1.37	12
4 — 7			1.68	45	0.87	84	0.14	50	0.98	54	0.08	33	−0.57	9
4 — 8	0.36	10	2.08*	40	−1.00	80	0.00	48	1.26	54	0.46	41	−1.27	12
4 — 9					−1.74	48	−0.34	30	−0.78	30	0.00	27	−0.89	8
4 — 10	0.50	10	−2.53*	48	−1.03	73	0.84	47	0.00	41	0.59	38	−0.92	18
4 — 11			−0.64	34	−2.22*	44	0.00	29	−0.86	32	−0.23	26		
4 — 12	−0.64	10			−0.91	50	0.28	34	1.27	34				
4 — 13			2.07*	37	−1.36	58	0.22	41	1.16	43	0.30	40	−0.27	17

Table 13. (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 — 14			−1.66	34	0.00	46			0.78	34				
4 — 15			−1.67	46	−0.38	65	2.13*	48	1.05	34	0.09	28		
4 — 17					−1.39	41	−0.05	28						
4 — 18					0.70	40	0.56	29	2.03	30				
4 — 20			0.00	35	−1.60	45	1.00	32	−0.67	32	−0.78	25		
4 — 25			−0.26	33	0.48	37	0.34	31	0.55	31				
5 — 6			−0.60	63	−1.88	85	0.50	54	0.29	72	1.41	48	−1.33	15
5 — 7			0.94	54	1.09	96	−1.03	59	0.66	77	−0.17	47	−0.13	12
5 — 8	−0.45	11	1.01	49	−1.48	92	−1.09	57	0.68	77	0.43	55	−1.12	15
5 — 9					−2.66**	60	−1.10	39	−1.47	53	−0.18	41	−0.96	11
5 — 10	−0.004	11	−2.46*	57	−1.42	85	0.21	56	−0.90	64	0.67	52	−0.22	21
5 — 11			−0.80	43	−3.16**	56	−0.36	38	−1.51	55	−0.57	40		
5 — 12	−0.85	11			−1.33	62	−0.41	43	0.98	57				
5 — 13			1.08	46	−1.92	70	−0.45	50	0.66	66	0.23	54	0.25	20
5 — 14			−1.56	43	0.00	58			0.31	57				
5 — 15			−1.70	55	−0.56	77	1.75	57	0.68	57	−0.05	42		
5 — 17					−2.08*	53	−0.44	37						
5 — 18					0.97	52	0.15	38	1.61	53				
5 — 20			−0.29	44	−2.38*	57	0.58	41	−1.03	55	−1.25	42		
5 — 25			−0.26	42	0.68	49	0.00	40	0.11	54				
6 — 7			1.57	41	2.40*	93	−1.47	47	0.28	51	−1.52	29	0.82	11
6 — 8			2.03	36	0.53	89	−1.40	45	0.28	51	−1.12	37	0.38	14
6 — 9					−0.95	57	−1.40	27	−1.57	27	−0.98	23	−0.37	10
6 — 10			−2.39*	44	0.00	82	−0.16	44	−1.00	38	−0.86	34	1.72	20
6 — 11			−0.62	30	−1.93	53	−0.58	26	−1.53	29	−1.37	22		
6 — 12					0.00	59	−0.75	31	0.62	31				
6 — 13			2.14*	33	−0.48	67	−0.72	38	0.34	40	−0.72	36	1.07	19
6 — 14			−1.62	30	1.34	55			0.10	31				
6 — 15			−1.61	42	0.78	74	1.36	45	0.47	31	−0.86	24		
6 — 17					−1.04	50	−0.64	25						
6 — 18					1.56	49	−0.08	26	1.39	27				
6 — 20			0.00	31	−1.02	54	0.27	29	−1.04	29	−1.83	21		
6 — 25			−0.27	29	1.18	46	−0.17	28	0.00	28				
7 — 8			0.00	27	−2.16*	100	−0.16	50	−0.08	56	0.67	36	−0.67	11
7 — 9					−2.50*	68	−0.57	32	−0.95	32	−0.09	22	−0.68	7
7 — 10			−2.91**	35	−2.00*	93	0.96	49	−0.86	43	0.92	33	−0.03	17
7 — 11			−1.26	21	−2.77**	64	−0.06	31	−0.99	34	−0.48	21		
7 — 12					−1.61	70	0.23	36	0.24	36				
7 — 13			0.49	24	−2.17*	78	0.15	43	0.00	45	0.34	35	0.24	16
7 — 14			−1.88	21	−0.76	66			−0.09	36				
7 — 15			−2.18*	33	−1.13	85	2.58*	50	0.12	36	0.00	23		
7 — 17					−1.76	61	−0.12	30						
7 — 18					0.29	60	0.64	31	0.52	32				

Table 13. (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
7 — 20			−0.86	22	−2.18*	65	1.17	34	−0.67	34	−1.23	20		
7 — 25			−0.42	20	0.14	57	0.34	33	−0.16	33				
8 — 9					−1.51	64	−0.36	30	−1.49	32	−0.53	30	−0.48	10
8 — 10	0.39	10	−3.51**	30	−0.35	89	0.98	47	−1.17	43	0.27	41	1.39	20
8 — 11			−1.61	16	−2.43*	60	0.00	29	−1.49	34	−0.95	29		
8 — 12	−1.49	10			−0.37	66	0.31	34	0.41	36				
8 — 13			0.80	19	−0.92	74	0.24	41	0.07	45	0.00	43	0.95	19
8 — 14			−2.40*	16	1.07	62			−0.06	36				
8 — 15			−2.62*	28	0.45	81	2.30*	48	0.26	36	−0.34	31		
8 — 17					−1.42	57	−0.05	28						
8 — 18					1.53	56	0.57	29	0.94	32				
8 — 20			−1.24	17	−1.49	61	1.06	32	−1.00	34	−1.70	28		
8 — 25			−0.64	15	1.15	53	0.34	31	−0.18	33				
9 — 10					0.78	57	0.95	29	0.78	19	0.69	27	0.90	16
9 — 11					−1.11	28	0.20	11	−0.12	10	−0.24	15		
9 — 12					0.70	34	0.54	16	1.13	12				
9 — 13					0.31	42	0.44	23	1.38	21	0.30	29	0.67	15
9 — 14					2.15*	30			1.09	12				
9 — 15					1.50	49	2.24*	30	1.24	12	0.08	17		
9 — 17					−0.48	25	0.12	10						
9 — 18					1.87	24	0.68	11	2.83*	9				
9 — 20					−0.25	29	1.02	14	−0.21	10	−0.82	14		
9 — 25					1.49	21	0.42	13	0.84	9				
10 — 11			0.89	24	−1.61	53	−0.35	28	−0.83	21	−1.09	26		
10 — 12	−1.00	10			0.00	59	−0.45	33	1.13	23				
10 — 13			3.04**	27	−0.44	67	−0.47	40	1.09	32	−0.20	40	0.51	25
10 — 14			0.00	24	0.98	55			0.74	23				
10 — 15			0.29	36	0.59	74	1.23	47	1.00	23	−0.47	28		
10 — 17					−0.84	50	−0.41	27						
10 — 18					1.23	49	0.00	28	2.10*	19				
10 — 20			1.49	25	−0.84	54	0.33	31	−0.63	21	−1.79	25		
10 — 25			0.19	23	0.92	46	−0.06	30	0.52	20				
11 — 12					1.42	30	0.15	15	1.16	14				
11 — 13			1.75	13	1.22	38	0.10	22	1.37	23	0.58	28		
11 — 14			−0.52	10	2.39*	26			1.08	14				
11 — 15			−0.55	22	2.16*	45	1.22	29	1.22	14	0.30	16		
11 — 17					0.42	21	0.00	9						
11 — 18					1.88	20	0.39	10	2.11	10				
11 — 20			0.38	11	0.76	25	0.53	13	−0.12	12	−0.55	13		
11 — 25			−0.05	9	1.49	17	0.20	12	0.86	11				
12 — 13					−0.35	44	0.00	27	−0.27	25				
12 — 14					1.00	32			−0.30	16				

Table 13. (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
12 — 15					0.61	51	1.74	34	−0.05	16				
12 — 17					−0.83	27	−0.19	14						
12 — 18					1.24	26	0.34	15	0.31	12				
12 — 20					−0.77	31	0.67	18	−0.80	14				
12 — 25					0.94	23	0.16	17	−0.33	13				
13 — 14			−2.40*	13	1.41	40			−0.12	25				
13 — 15			−2.46*	25	1.01	59	1.57	41	0.17	25	−0.21	30		
13 — 17					−0.57	35	−0.14	21						
13 — 18					1.46	34	0.32	22	0.77	21				
13 — 20			−1.70	14	−0.46	39	0.65	25	−0.94	23	−1.11	27		
13 — 25			−1.06	12	1.12	31	0.17	24	−0.22	22				
14 — 15			0.15	22	−0.43	47			0.24	16				
14 — 17					−1.84	23								
14 — 18					0.84	22			0.81	12				
14 — 20			0.98	11	−1.94	27			−0.79	14				
14 — 25			0.13	9	0.60	19			−0.09	13				
15 — 17					−1.43	42	−1.27	28						
15 — 18					1.09	41	−0.88	29	0.46	12				
15 — 20			1.89	23	−1.48	46	−0.66	32	−0.89	14	−0.75	15		
15 — 25			0.21	21	0.81	38	−0.78	31	−0.29	13				
17 — 18					1.68	17	0.38	9						
17 — 20					0.23	22	0.55	12						
17 — 25					1.39	14	0.22	11						
18 — 20					−1.73	21	0.20	13	−1.33	10				
18 — 25					−0.07	13	−0.05	12	−0.82	9				
20 — 25			−0.22	10	1.38	18	−0.23	15	0.65	11				

Note : * significant at 0.05 level ** significant at 0.01 level significant difference was found in the two pairs due to the small value of $c_{1.18.5}$.

For the purpose of taking the difference of c_{0xw} and the applicable depth range into account, some representatives of the estimated regression lines on depth were classified according to the wave grade and illustrated in Fig.8. This figure showed the trend of increase of log (t_c—59) with the amount of catch, but its pattern differed according to the wave grade. Under the wave grade 2, c_{1x2} was negative in many catch-classes. Both c_{0x2} and c_{1x2} varied according to the catch-class, and log (t_c—59) showed a large difference according to the catch-class throughout the depth zones, but the interaction between c_{0x2} and c_{1x2} resulted in a rough trend of increase in log (t_c—59) with the amount of catch regardless of the depth zones. Under the wave grade 3, the catch regression was clear in deep zone but less clear in shallow zone for the catch regression was mainly due to the difference in c_{1x3} according to x. Under the wave grade 4, the catch regression was clear in shallow zone but less clear in deep zone for this was mainly due to the difference in c_{0x4} according to x. The same was true to the wave grade 5. The pattern under the wave grade 6 was same to that under the wave grade 3. And under the wave grade 7, the applicable depth range was narrow, but the catch regression should be clear for this was mainly due to the difference in c_{1x7}.

Table 14. Number of c_{1xw} showing the significant difference from that of the different catch class (x).

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

Catch class (w)	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						5	2		3									
3	7				1			2		1	1				2			
4										5								
5														2				
6																		
7																		
Sum	7				1	5	2	2	3	6	1			2	2			

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

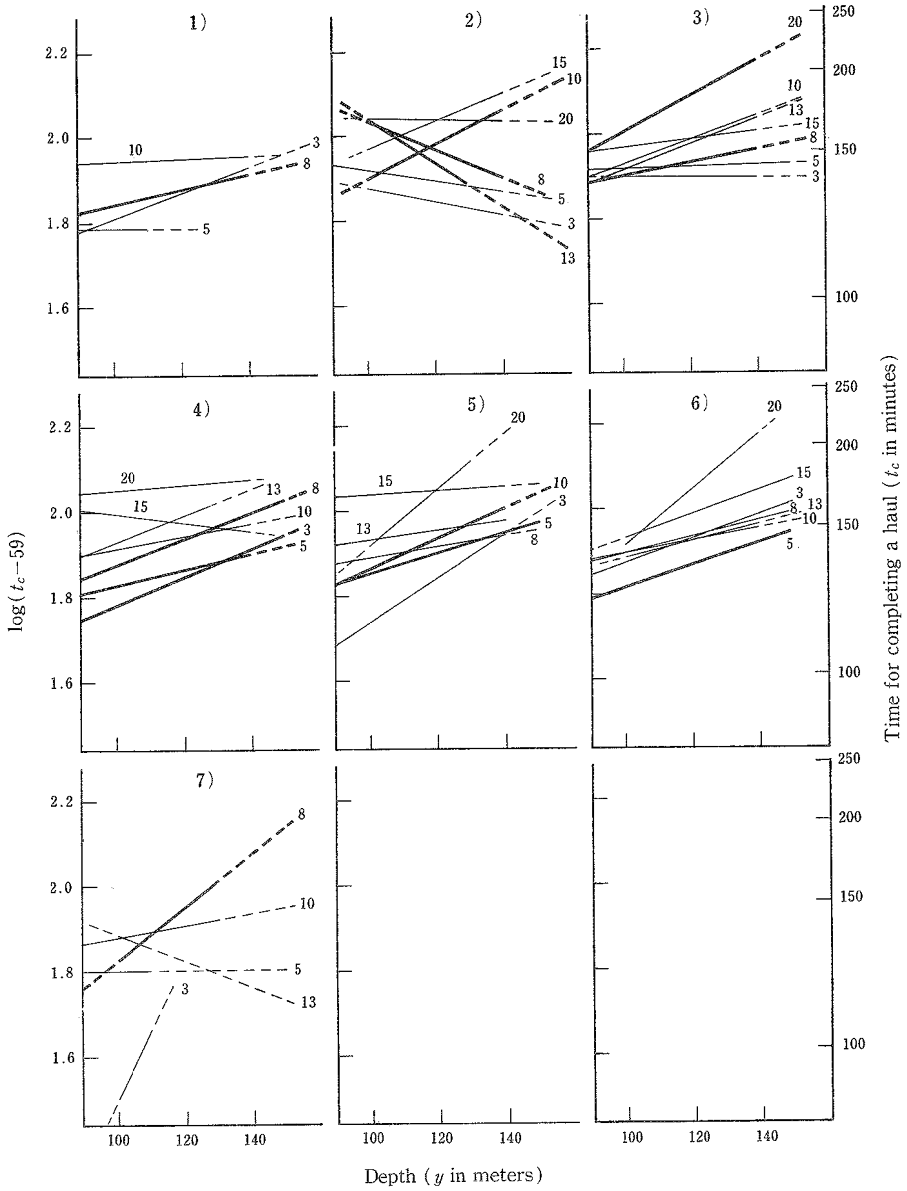

Fig.8. The difference of the log (t_c—59) — y relations according to the amount of catch observable within the records under the wind wave of the same grade.

Note: The numeral with parenthesis is the wave grade. That attached to the line is the amount of catch (in tons).

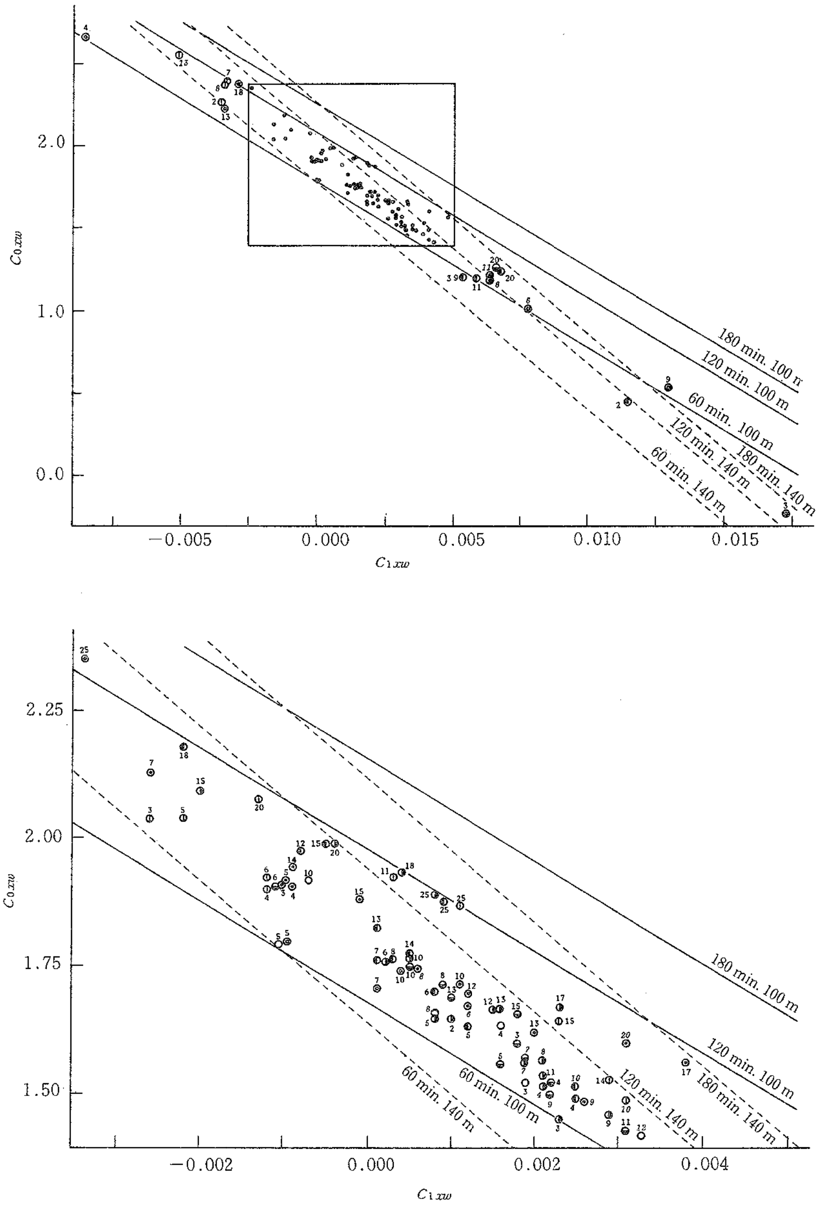

Fig.9. The comparison of the estimated regression lines of log (t_c—59) on y.

$$\log(t_c - 59) = c_{0xw} + c_{1xw}y$$

Note: The numeral shows the catch-class (in tons). The mark with italic numeral shows the regression line with the significant coefficient.
For the mark of the wave grade, see Fig. 6.

6.4 The comparison of the depth regression equations in the different catch-classes under the different wave grades

The present report dealt with the variation of the length of the time for completing a haul according to the three conditions. And in this section, this problem was examined through the comparison of the estimated t_c - depth relations of either the hauls of the same amount of catch but under the different wave grade or those of the different amount of catch under the same wave grade with one another. And some trends were found out. But these comparisons were insufficient. For the purpose of taking the difference of both the amount of catch and the wave grade into account, all the estimated lines were plotted in Fig. 9. This figure revealed the following trends:

1. Both c_{0xw} and c_{1xw} showed a large variation, but a linear relation was found between them, suggesting that all the estimated lines should not show any large difference.
2. The equations under the wave grade 2 inclined to take large c_{0x2} but small c_{1x2}. The variation of both c_{0x7} and c_{1x7} was large, but the equations under this wave grade showed the similar value of log (t_c—59) with one another at the 100 m zone. They showed a large variation at the 140 m zone. But most of the hauls under this wave grade were in the 100 m and 110 m zones, and the seeming difference in log (t_c—59) at the 140 m zone was not worthy to be given importance.
3. The equation for the 2-ton class under the wave grade 5 seemed to show the different relation from the others. This was as shown in Fig. 7 due to the short work in the 110 m zone. But this stratum consisted of only six hauls and this seeming difference was derived from only two hauls, accordingly this was also not worthy to be given much importance.
4. The numeral attached to the marks increased in the direction perpendicular to the lines showing the relation in the 140 m zone or those in the 100 m zone. This fact meant that the time for completing a haul increased with the amount of catch.

Conclusion

From all the results and discussion, it may be concluded that the length of the time for completing a haul increased clearly with the amount of catch because of the similar trend found in the time for the towing work. And the influence of both the depth fished and the wave grade was far smaller than that of the amount of catch, and it was hard to tell whether the depth fished was more influential than the wave grade or not. The pattern of the change of the time for completing a haul was similar to that of the towing time in many points because of the large variation of the time for this step of work but the small one for the shooting and the hauling-fastening works.

Summary

The present report dealt with the variation of the time length for completing a haul by the bull trawlers working for supplying the factory ship with the Alaska pollack as the materials of the minced product during the season of 1964 along the outer edge of the continental shelf of the Eastern Bering Sea. And the following results were obtained through 1) the examination on the multiple linear regression of the time on the amount of catch and on the depth

fished, 2) the linear regression either on the amount of catch or on the depth after the stratification of the records according to the wave grade, and 3) the linear one either on the amount of catch or on the depth fished after the twofold stratification of the records according to the other two factors:

1. The time for completing a haul (t_c) varied from 60 min. to 280 min. Its frequency distribution under the same wave grade was agreeable to the log (t_c—59) normal distribution as shown in Fig. 1.

2. The examination through the multiple linear regression equation revealed that log(t_c—59) increased significantly with the amount of catch in all the wave grades except the roughest one and with the depth in all the wave grades except the roughest two ones.

3. The examination of the linear regression on the amount of catch revealed that the value of log (t_c—59) increased with the amount of catch and its difference due to that of the amount of catch was far larger than that due to the difference in the wave grade.

4. The examination on the depth regression revealed that the value of log (t_c—59) increased significantly with the depth in all the wave grades except the roughest two ones along the similar pattern to that of log t_t.

5. The examination on the catch regression after the twofold stratification of the records according to the depth and the wave grade revealed the following facts: the regression coefficient was significantly positive in the 27 strata out of the 44 ones, insignificantly positive in the 13 ones, but insignificantly negative in the four ones. The insignificantly positive coefficient and the insignificantly negative one were mainly in the extreme depth zones and/or under the extreme wave grades.

6. The comparison of the estimated regression equations on the amount of catch revealed the following facts: the time for completing a haul got longer with depth mainly because of the difference in the constant of the regression equation.

7. The distribution of the points showing the relation between the constant and the coefficient of the catch regression lines showed that the depth regression may be clear for the hauls of poor catch while became less clear with increase in catch but the difference among the estimated t_c became large with the latter.

8. The examination of the depth regression after the twofold stratification of the records according to the amount of catch and the wave grade revealed that the regression coefficient was significantly positive in the 20 strata out of the 92 ones, insignificantly positive in the 53 ones, but insignificantly negative in the 17 ones and significantly negative in the two ones. The strata taking the negative coefficient were mainly under the wave grade 2.

9. The clearest trend found out in the comparison of the estimated lines of the depth regression was the increase of log(t_c—59) with the amount of catch suggesting the catch regression; and both the influence of the wave grade and the depth was far smaller than that of the amount of catch, and it was hard to tell whether the depth was more influential than the wave grade or not.

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