Working Time of Danish Seiners during Alaska Pollack Fishery-XI*

A Collective Consideration on the Time for Completing a Haul

By

Hiroshi MAÊDA and Shiro MINAMI

The fishing work of the Danish seiner consists of the laying step, the sinking-pulling one, and the hauling-brailing one. The preceding reports of this series[2)-7)] dealt with the influences of the four factors—the amount of catch, the depth fished, the power of main engine, and the wave height—on the time required for completing a haul and on the times for respective steps of works. And the following facts were found out: The time for completing a haul increased in accordance with the amount of catch at a rate of 3.17 min. per ton of catch, because of the similar trend in the time for the hauling-brailing step of work.[2)] When the difference in the other factors relating to the depth fished was not taken into account, the time for completing a haul increased in accordance with the depth at a rate of four minutes per 100 m increase in the depth, because of the similar trend in the time for the sinking-pulling step.[3)] But somewhat different results were found out, when the same relation was examined after the stratification of the records according to the amount of catch, although the similar relation to that before the stratification was found in the hauls yielding a catch of 1 to 5 tons of fish: When the catch was in the range from 6 to 8 tons a haul, the time for completing a haul did not show any significant difference according to the depth fished, because the decrease of the time for the hauling-brailing step of work and the increase of the time for the sinking-pulling step offset each other.[4)] The largest difference among the average lengths of the time for completing a haul under the wind wave of the different grades reached as large as 13 %, chiefly because of the difference in the time for the hauling-brailing step.[5)] And the examination on the influence of the wave height after the elimination of the predominating influence of the amount of catch revealed that the wind wave in the range from the grades 1 to 5 did not cause any significant retardation of the work for completing a haul but that over the grade 6 retarded it, because of the same trend in the time for the hauling-brailing step.[6)] When the

* Contribution from the Shimonoseki University of Fisheries, No. 665.
Received July 11, 1972.

different amount of catch relating to the power of the boat was not taken into account, the difference in the power of the boat did not cause any significant difference in the length of the time for completing a haul, because the decrease in the sinking-pulling time and the increase in the hauling-brailing time offset each other.[7] But the examination on the regressive relation of the time for completing a haul on the power after the stratification of the records according to the amount of catch and that on the amount of catch after the stratification of the records according to the power revealed the complicated influence of the power on the time for completing a haul, because the working speed was more strongly affected by the individuality of the boats rather than the power.[9]

A collective consideration on the influence of the factor complex on the length of the sinking-pulling time[8] and that of the hauling-brailing time[10] was given in the preceding reports. The variation in the time required for completing a haul took the similar form of that in the time for the hauling-brailing step, which occupied about 57 % of the time for completing a haul.[1]

The influence of respective factors on the working time differs according to the factor and the step of work. The proportion of the time for respective steps of works to the time for completing a haul differed according to the step. And the fact making the interpretation complicated was the different results of the influence of one of the factors according to the stratification of the records into the classes in respect of the factors of the rest. It was, accordingly, necessary to give a collective consideration on the influence of the factor complex on the time for completing a haul. And in the present report, the influence of the factor complex on the time for completing a haul was examined through the same methods as those used in the preceding report,[10] and the results were compared with those of the preceding reports of this series.

Material and Methods

Our boats fishing exclusively the Alaska pollack in the Bering Sea were classified into the two groups. One was the boats of the factory ship type fishery and the other was the stern ramp factory trawlers. The former type of fishery included the Danish seiners, the bull trawlers, and the small side-trawlers. The role of the small side-trawlers differed from that of the other boats. They steamed round for collecting the information on the distribution of fish. And the boats of the former two types supplied the factory ship with the material fish. The fleet examined in the present series of reports had the 22 Danish seiners and the three pairs of the bull trawlers. These boats sent telegrams several times a day throughout the season, for the purpose of smooth interchange of the information on the fishing conditions and of reporting the progress of the fishing work. The present series of reports[1)-10)] used a complete set of the routine telegrams sent from the 22 Danish seiners to the factory ship throughout the season of 1964.

From the same set of the telegrams used in the preceding reports, (those of each of the hauls on the 48 days—3 days × 16 strata of 10-day intervals), the intervals from the start of laying the warp to the finish of the brailing work were timed. The time required for completing a haul (abbreviated to t_c) denotes this interval. The length of t_c varied from less than 80 minutes to more than 150 minutes; and this was used in the present report after the aggregation into the classes of the nearest five-minute intervals, because the distribution range and the accuracy of the time measuring were taken into account. The present report dealt with the relation of t_c to the following four factors: The amount of catch (x in tons a haul), the depth fished (y in meters; 10-m intervals), the height of wind wave (w, in the grade number according to the standard settled by the Japanese Meteorological Agency), and the power of the main engine of the boat (z in Hp).

For the purpose of finding out an outline of the influence of the factor complex, the multiple linear regression equations of t_c on x, y, and z, were estimated after the stratification of the records according to the classes of the wave grades, because the wave height was described in the grade number covering unequal range and could not be dealt with as one of the independent variables. Then, the linear regression equations of t_c on x were estimated after the stratification of the records according to y, z, and w. And they were compared with one another, for the purpose of finding out the different influence of respective factors according to the difference of the factors of the rest after the elimination of the predominating influence of the amount of catch.

The boats fished in the zones from 40 m to 150 m deep. In the present report, the records were stratified into the zones of 10-m intervals; and those in the range from the 90 m to the 140 m zones were used. The wave during the season varied from the grades 1 to 9; but the boats could not fish on the days of the grades 8 and 9. The multiple linear regression equations were estimated from the records on the days of the grades 1 to 7. But the linear regression ones of t_c on x after manifold stratification were estimated from the records on the days of the grades 2 to 6. The power of the main engine of the boats ranged from 220 Hp to 340 Hp. The multiple linear regression equations were estimated from the records on all the boats. But the linear regression ones were estimated from the records on the boats of the 250 Hp, the 270 Hp, and the 320 Hp groups.

To simplify the representation, the strata were expressed by $y.z.w$. And the pair of strata was expressed either $(y_i : y_j)z.w$, or $y(z_i : z_j)w$, or $y.z(w_i : w_j)$, according to the factor showing the difference. Here, y and z were described omitting the numeral in the unit's place. The constant and the coefficients of the equations were expressed in the following way:

a_{iw} ..... The constant or the coefficient of the multiple linear regression equation of t_c on x, y, and z observable in the wind wave of the grade w. The notation of the first suffix was as follows:

$$t_c = a_{0w} + a_{1w}x + a_{2w}y + a_{3w}z$$

b_{iyzw} .... The constant or the coefficient of the linear regression equation of t_c on

x observable among the records in the stratum $(y.z.w)$. The notation of the first suffix was as follows:

$$t_c = b_{0yzw} + b_{1yzw} x$$

The suffix, y or z or w, left intact denotes indefinite stratum in respect of the factor represented by that suffix.

Results

1. The multiple linear regression equations of the time required for completing a haul

As shown in Table 1, the following outline of the influences of the factor complex was found out through the multiple linear regression equations: The amount of catch was the most influential factor among those examined. The regression coefficient on it, a_{1w} , was significant in the wind wave of all the grades. And t_c increased in accordance with the amount of catch at a rate of from 2.8 to 3.5 minutes per ton of catch. Namely, the difference of t_c due to the different amount of catch attained to 36 to 45 minutes, because the amount of catch varied from 0 to 21 tons a haul mainly from 0 to 13 tons.

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), the depth fished (y in m), and on the power of main engine of the boats (z in horse power) under respective grades of wind wave.

$$t_c = a_{0w} + a_{1w} x + a_{2w} y + a_{3w} z$$

Grade of wind wave (w)	a_{0w}	a_{1w}	a_{2w}	a_{3w}	F_x	F_y	F_z	n_2
1	81.93	2.78	0.187	−0.045	78.34 **	1.19	3.28	94
2	96.12	3.51	0.002	−0.028	735.5 **	0.03	16.57**	1094
3	94.67	3.17	0.018	−0.023	847.6 **	5.28*	10.65**	1280
4	89.24	2.77	0.085	−0.027	354.2 **	27.30**	9.29*	623
5	90.78	3.08	0.048	−0.020	1157.4 **	13.74**	6.36*	897
6	94.25	3.19	0.032	−0.016	932.8 **	8.06**	4.80*	1005
7	84.90	3.50	0.053	0.020	78.86 **	0.05	0.47	105

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

The regression coefficient on the depth fished, a_{2w}, was significant in the wind wave of the grades 3 to 6. And t_c increased in accordance with the depth fished at a rate of from 0.018 to 0.085 minutes per meter. The difference of t_c due to the depth difference attained to 2 to 9 minutes, because the depth fished varied from 40 m to 150 m. But the boats fished in the zone of 40 m to 80 m deep only within a limited season, and they did not fish in the other zones during this season. In the other seasons, they fished in the zones mainly from 90 m to 140 m deep, and the depth fished varied day by day. The difference of t_c due to the depth difference of this range attained to 1 to 5 minutes. Namely, the difference of t_c due to the depth difference was significant in the four wave grades, but it was practically negligible.

The regression coefficient of the power of the boat, a_{3_w}, was significant in the wave grades 2 to 6. And t_c decreased in accordance with the power of the boat at a rate of 0.016 to 0.028 minutes per horse power. The difference of t_c due to the power difference was 1.9 to 3.4 minutes, because the boats ranged from 220 Hp to 340 Hp. Namely, the difference of t_c due to the power difference was significant in the five

Table 2. The linear regression equations of the time required for completing a haul (t_c in min.) on the catch (x in tons), observable among the hauls in respective depth zones (y in 10-m intervals) conducted by the boats of respective power groups (z) under respective grades of wind wave (w).

$$t_c = b_{0yzw} + b_{1yzw}\, x$$

Power group (z) (Hp)		250				270				320			
Grade of wind wave (w)	Depth zone (y) (m)	b_{0y25w}	b_{1y25w}	F_b	n_2	b_{0y27w}	b_{1y27w}	F_b	n_2	b_{0y32w}	b_{1y32w}	F_b	n_2
2	90	86.06	5.02	56.01**	7	86.25	2.50	3.96	10	82.14	8.57	11.08*	4
	100	90.07	2.88	54.45**	83	87.46	3.58	84.07**	101	89.00	3.33	64.19**	61
	110	86.60	4.46	65.24**	60	86.90	3.24	50.97**	75	93.17	2.70	4.48*	23
	120	98.44	0.65	0.42	33	94.36	1.36	1.24	33	94.65	2.47	3.54	22
	130	95.05	2.38	1.52	18	93.19	2.03	13.15**	40	97.55	0.65	0.27	12
	140	90.85	3.26	12.44**	40	91.65	2.28	10.49**	36	97.13	−0.38	0.01	12
3	100	90.49	3.23	105.37**	41	86.97	3.26	127.67**	60	90.22	3.58	49.58**	40
	110	91.93	3.01	41.02**	29	91.68	3.03	21.17**	35	92.90	2.17	9.82**	17
	120	91.07	3.04	22.53**	59	89.73	3.19	28.08**	62	93.42	2.87	60.49**	48
	130	89.55	4.69	39.29**	12	88.33	4.17	30.28**	34	92.69	3.67	34.33**	13
	140	91.49	3.39	50.87**	94	88.85	3.64	30.73**	102	92.95	3.45	74.89**	59
4	90	92.70	1.47	1.89	30	84.26	4.40	7.81**	33	88.12	2.79	6.17*	14
	110	88.27	4.72	36.93**	31	92.17	2.55	18.23**	33	93.18	2.82	1.42	12
	120	101.25	1.25	0.57	4	86.48	4.09	13.05*	6	101.21	1.50	1.66	5
	130	93.62	3.02	24.76**	34	90.69	3:17	58.03**	44	90.57	3.24	13.81**	21
	140	90.47	3.55	47.99**	46	92.50	2.95	38.46**	51	100.89	1.80	21.53**	53
5	90	92.21	2.59	69.73**	76	89.84	2.74	102.57**	92	90.16	3.11	89.04**	44
	100	90.98	3.38	119.56**	53	86.60	3.37	203.64**	47	90.74	3.90	69.62**	39
	120	96.18	1.76	3.67	5	88.35	3.37	8.72**	25	90.44	3.44	7.23*	8
	130	91.66	3.07	100.81**	54	87.48	3.57	170.62**	49	94.83	3.02	16.10**	28
	140	93.51	2.75	12.52**	29	94.79	2.99	33.67**	34	94.12	3.27	57.36**	33
6	90	92.04	3.19	26.57**	48	89.37	3.42	81.94**	56	90.88	4.68	47.67**	34
	100	94.37	3.33	99.02**	72	95.19	2.78	66.07**	74	95.78	3.12	62.93**	53
	110	94.86	3.36	14.20**	11	110.62	1.29	0.24	8	107.36	1.50	1.25	9
	120	93.98	3.61	7.34*	20	91.44	2.72	15.12**	25	81.71	8.17	14.72**	8
	130	97.00	3.00	8.00*	7	102.14	1.43	0.46	12	95.00	5.42	6.92*	7
	140	95.58	2.94	76.85**	77	96.65	2.68	53.09**	81	95.87	3.22	56.99**	54

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

wave grades out of the seven ones, but was practically negligible.

The influence of the wave grade was examined through the change of the constant or the coefficients in accordance with the grade number. The regression coefficient on the power, a_{3_w}, showed a rough trend of increase in accordance with the grade of wind wave. Namely, the rough sea made the power less influential on t_c because a_{3_w} was negative. The other a_{i_w} did not show any clear relation to w.

2. The regression on the amount of catch after manifold stratification

The influence of the wind wave was not examined through the multiple linear regression equations. And the multiple linear regression equations are not concerned with the probable difference of the influence of one of the independent variables due to the difference in the others. For the purpose of examining these problems after the elimination of the predominating influence of the amount of catch, the linear regression equations of t_c on x were estimated after the manifold stratification of the records according to y,z, and w. And they were compared with one another.

Among the 81 y-z-w strata, the regression coefficients were significant in the 66 ones. There were the 15 strata showing insignificant regression, but it was hard to find any clear relation of their distribution to any of the factors or to the combinations of them. Among these 15 strata, the coefficients in the four strata —(9.27.2), (11.32.4), (12.32.2), and (13.25.2)—took the similar values of the significant ones. The regression coefficients in the 13 strata, including the above-mentioned four but excluding the strata (11.32.6) and (12.32.4), were insignificant because of the narrow range of x (not wider than six consecutive catch classes). Those in the three strata were insignificant because of the extremely small sample size (not more than five records); but it was hard to find the reason making the regression coefficient in one of the strata—(11.32.6)—insignificant.

3. The comparison between the regression coefficients, $b_{1_{yzw}}$, of the different wave grades—$y.z$ $(w_i : w_j)$

The regression coefficients varied from -0.38 in the stratum (14.32.2) to 8.57 in the stratum (9.32.2). When the insignificant values were not taken into account, they varied from 1.80 in the stratum (14.32.4) to 8.57 in the stratum (9.32.2). Among the four factors—x,y,z, and w—, the influences of x,y, and z were examined through the multiple linear regression equations, but that of the wave grade (w) could not be examined. This was examined through the comparison between $b_{1_{yzw}}$ of the different wave grades and through the comparison between the regression lines of the strata of the different w after the manifold stratification.

As shown in Tables 3 and 4, the difference between $b_{1_{yzw}}$ of the different wave grades under the same conditions of y and z was significant in the 12 combinations of the wave grades out of the 114 ones. The significant differences in these 12 combinations were chiefly due to either the small value of the coefficient in the wave grade 4 (the six combinations) or the wave grade 2 (the four combinations), or the large value of the coefficient in the wave grade 3 (the four combinations) or the wave grade 6 (the four combinations). Namely, the significant difference between the coefficients was mainly due to the different trends of those in some particular wave grades. But it was hard to find the relation between the grade number and whether the coefficients in a grade took larger values or smaller values than those in the other wave grades. The three combinations of the wave grades were in the 90 m zone, and the same number

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

Depth zone (y in 10-m intervals)		90		100		110		120		130		140	
Power group (z)(Hp)	Grade of wind wave (w)	t	n	t	n	t	n	t	n	t	n	t	n
250	2 − 3			−0.703	124	1.893	89	−2.058*	92	−0.977	30	−0.132	134
	2 − 4	2.355*	37			−0.276	91	−0.190	37	−0.378	52	−0.284	86
	2 − 5	1.788	83	−0.994	136			−0.525	38	−0.456	72	0.420	69
	2 − 6	1.518	55	−0.863	155	1.231	71	−1.541	53	−0.201	25	0.293	117
	3 − 4					−1.931	60	0.625	63	1.179	46	−0.223	140
	3 − 5			−0.328	94			0.677	64	1.149	66	0.756	123
	3 − 6			−0.220	113	−0.397	40	−0.329	79	1.320	19	0.756	171
	4 − 5	−0.937	106					−0.282	9	−0.075	88	0.905	75
	4 − 6	−1.451	78			1.210	42	−0.947	24	0.010	41	0.915	123
	5 − 6	−0.776	124	0.095	125			−1.006	25	0.039	61	−0.228	106
270	2 − 3			0.640	161	0.279	110	−1.519	95	−2.313*	74	−1.172	138
	2 − 4	−0.804	43			0.968	108	−1.250	39	−1.345	84	−0.737	87
	2 − 5	−0.135	102	0.457	148			−1.046	58	−2.187*	89	−0.776	70
	2 − 6	−0.625	66	1.484	175	0.939	83	−0.948	58	0.369	52	−0.418	117
	3 − 4					0.532	68	−0.647	68	1.021	78	0.821	153
	3 − 5			−0.292	107			−0.136	87	0.726	83	0.736	136
	3 − 6			1.078	134	0.694	43	0.488	87	1.436	46	1.287	183
	4 − 5	1.124	125					0.443	31	−0.827	93	−0.051	85
	4 − 6	0.712	89			0.480	41	1.017	31	0.829	56	0.433	132
	5 − 6	−1.343	148	1.419	121			0.486	50	1.225	61	0.458	115
320	2 − 3			−0.363	101	0.341	40	−0.366	70	−2.261*	25	−1.508	71
	2 − 4	2.164*	18			−0.050	35	0.534	27	−1.594	33	−0.828	65
	2 − 5	1.456	48	−0.867	100			−0.505	30	−1.213	40	−1.226	45
	2 − 6	1.083	38	0.360	114	0.647	32	−1.655	30	−1.808	19	−1.173	66
	3 − 4					−0.275	29	1.475	53	0.379	34	2.972**	112
	3 − 5			−0.466	79			−0.538	56	0.505	41	0.312	92
	3 − 6			0.732	93	0.483	26	−2.405*	56	−0.818	20	0.396	113
	4 − 5	−0.183	58					−1.125	13	0.172	49	−2.576*	86
	4 − 6	−1.117	48			0.459	21	−2.432*	13	−0.756	28	−2.434*	107
	5 − 6	−2.047*	78	1.296	92			−1.670	16	−0.626	35	0.089	87

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

of the combinations was in each of the 120 m, the 130 m, and the 140 m zones. The eight combinations were in the 320 Hp group, the two combinations in the 250 Hp group, and the same number of combinations in the 270 Hp group. And the significant difference in the seven combinations of the wave grades out of these 12 ones was due to

Table 4. Number of the combinations of the wave grades (w) showing the significant difference in b_{1yzw}.

Grade of wind wave (w)		2		3		4		5		6	
Power group (z)(Hp)	Depth (y)(m)	L	S	L	S	L	S	L	S	L	S
250	90	1					1				
	120		1	1							
270	130		2	1				1			
320	90	1					1		1	1	
	120				1		1			2	
	130		1	1							
	140			1			3	1		1	
Sum		2	4	4	1		6	2	1	4	

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

either or both of the small value of the coefficient in the wave grade 4 and the large value of the coefficient in the wave grade 6 both by the boats of the 320 Hp group. These facts suggested that, in some of the strata of the powerful boat under rough sea (in the wave grades 4 and 6), the amount of catch should show a different influence on t_c from in the other strata.

4. The comparison between the regression coefficients, b_{1yzw}, of the different depth zones—$(y_i : y_j)\,z.w$

As shown in Tables 5 and 6, the difference between b_{1yzw} of the different depth zones under the same conditions of z and w was significant in the 12 combinations of the depth zones out of the 180 ones. These significant differences were chiefly due to the large value of the coefficients in either the 90 m, or the 100 m, or the 110 m zones, or the small value of the coefficients in the 120 m zone or the 130 m zone. But it was hard to find any clear trend of decrease of the coefficient in accordance with the depth fished except in the strata (y.32.2). The combinations of the depth zones showing the significant difference of the coefficients were concentrated in the wave grade 2 (the nine combinations) and in the 250 Hp group (the six combinations) (the five combinations being in the wave grade 2 by the boats of the 250 Hp group). These facts meant that the influence of the amount of catch on t_c showed a bathymetric difference in the strata of the less powerful boats under the calm water.

5. The comparison between the regression coefficients, b_{1yzw}, of the different power groups— $y(z_i : z_j)w$

As shown in Tables 7 and 8, the coefficients between the different power groups

Table 5. The results of the comparison between b_{1yzw} of the different depth zones(y) through the t-test.

Grade of wind wave (w)		2		3		4		5		6	
Power group(z)(Hp)	Depth (y) (m)	t	n	t	n	t	n	t	n	t	n
250	90 — 100	2.064 *	90					−1.744	129	−0.192	120
	90 — 110	0.523	67			−2.487 *	61			−0.167	59
	90 — 120	3.008 **	40			0.066	34	0.361	81	−0.239	68
	90 — 130	1.182	25			1.302	64	−1.067	130	0.099	55
	90 — 140	1.285	47			−1.861	76	−0.177	105	0.331	125
	100 — 110	−2.322 *	143	0.307	70					−0.026	83
	100 — 120	2.261 *	116	0.264	100			0.841	58	−0.147	92
	100 — 130	0.356	101	−0.954	53			0.699	107	0.158	79
	100 — 140	−0.401	123	−0.281	135			0.792	82	0.827	149
	110 — 120	3.539 **	93	−0.030	88	1.388	35			−0.136	31
	110 — 130	1.379	78	−1.626	41	1.663	65			0.163	18
	110 — 140	1.158	100	−0.488	123	1.203	77			0.464	88
	120 — 130	−0.877	51	−1.129	71	−0.621	38	−0.704	59	0.325	27
	120 — 140	−1.915	73	−0.445	153	−0.835	50	−0.455	34	0.339	97
	130 — 140	−0.469	58	0.874	106	−0.672	80	0.417	83	0.026	84
270	90 — 100	−0.701	111					−1.753	139	1.129	130
	90 — 110	−0.476	85			1.106	66			1.059	64
	90 — 120	0.466	43			0.142	39	−0.452	117	0.864	81
	90 — 130	0.354	50			0.758	77	−2.105 *	141	1.199	68
	90 — 140	0.144	46			0.971	84	−0.406	126	1.319	137
	100 — 110	0.576	176	0.321	95					0.560	82
	100 — 120	2.210 *	134	0.104	122			0.000	72	0.058	99
	100 — 130	2.040 *	141	−0.971	94			−0.547	96	0.634	86
	100 — 140	1.509	137	−0.526	162			0.655	81	0.192	155
	110 — 120	1.749	108	−0.183	97	−0.933	39			−0.654	33
	110 — 130	1.549	115	−1.101	69	−0.848	77			−0.040	20
	110 — 140	1.081	111	−0.638	137	−0.540	84			−0.577	89
	120 — 130	−0.530	73	−1.005	96	0.564	50	−0.161	74	0.690	37
	120 — 140	−0.662	69	−0.479	164	0.822	57	0.289	59	0.042	106
	130 — 140	−0.289	76	0.467	136	0.333	95	1.003	83	−0.645	93
320	90 — 100	1.812	65					−1.419	83	1.950	87
	90 — 110	1.712	27			−0.010	26			2.539 *	43
	90 — 120	1.572	26			−0.824	19	−0.224	52	−1.084	42
	90 — 130	2.124 *	16			−0.229	35	0.117	72	−0.301	42
	90 — 140	1.908	16			0.676	67	−0.299	77	1.794	88
	100 — 110	0.514	84	1.536	57					1.490	62
	100 — 120	0.732	83	1.000	88			0.243	47	−1.474	61
	100 — 130	2.446 *	73	−0.082	53			1.040	67	−0.910	60
	100 — 140	1.507	73	0.197	99			0.953	72	−0.168	107
	110 — 120	0.122	45	−1.055	65	0.499	17			−1.611	17
	110 — 130	1.157	35	−1.528	30	−0.168	33			−1.198	16
	110 — 140	0.990	35	−1.838	76	0.554	65			−1.563	63
	120 — 130	1.002	34	−1.222	61	−1.030	26	0.181	36	0.894	15
	120 — 140	0.856	34	−1.030	107	−0.259	58	0.118	41	1.446	62
	130 — 140	0.310	24	0.293	72	1.751	74	−0.295	61	0.871	61

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

Table 6. Number of the combinations of the depth zones (y) showing the significant difference in b_{1yzw}.

Depth zone (y) (m)		90		100		110		120		130	
Grade of wind wave (w)	Power group (z) (Hp)	L	S	L	S	L	S	L	S	L	S
2	250	2		1	2	2			3		
	270			2					1		1
	320	1		1							2
4	250		1			1					
5	270		1							1	
6	320	1					1				
Sum		4	2	4	2	3	1		4	1	3

L .... Signifficantly larger than the other S ..... Significantly smaller than the other

Table 7. The results of the comparison between b_{1yzw} of the different power groups(z) through the t-test.

Depth zone (y)(m)		90		100		110		120		130		140	
Grade of wind wave (w)	Power group (z) (Hp)	t	n	t	n	t	n	t	n	t	n	t	n
2	250 − 270	1.804	17	−1.265	184	1.660	135	−0.430	66	0.227	58	0.842	76
	250 − 320	−1.542	11	−0.801	144	1.391	83	−1.126	55	0.752	30	1.293	52
	270 − 320	−2.121	14	0.432	162	0.417	98	−0.585	55	1.216	52	1.038	48
3	250 − 270			−0.067	101	−0.017	64	−0.171	121	0.353	46	−0.298	196
	250 − 320			−0.594	81	1.004	46	0.227	107	0.807	25	−0.090	153
	270 − 320			−0.576	100	0.917	52	0.449	110	0.510	47	0.238	161
4	250 − 270	−1.565	63			1.917	64	−1.132	10	−0.182	78	0.846	97
	250 − 320	−0.742	44			0.970	43	−0.089	9	−0.213	55	2.703**	99
	270 − 320	0.715	47			−0.118	45	1.585	11	−0.073	65	1.892	104
5	250 − 270	−0.361	168	0.014	100			−0.816	30	−1.211	103	−0.266	63
	250 − 320	−1.136	120	−0.966	92			−0.860	13	0.076	82	−0.587	62
	270 − 320	−0.872	136	−1.081	86			−0.045	33	0.818	77	−0.412	67
6	250 − 270	−0.311	104	1.136	146	0.763	19	0.540	45	0.560	19	0.518	158
	250 − 320	−1.636	82	0.423	125	1.187	20	−1.795	28	−1.058	14	−0.512	131
	270 − 320	−1.735	90	−0.638	127	−0.062	17	−2.063*	33	−1.253	19	−0.950	135

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

Table 8. Number of the combinations of the power groups (z) showing the significant difference in b_{1yzw}.

Power group (z) (Hp)		250		270		320	
Grade of wind wave (w)	Depth (y) (m)	L	S	L	S	L	S
4	140	1					1
6	120				1	1	
Sum		1			1	1	1

L ..... Significantly larger than the other S ..... Significantly smaller than the other under the same conditions of y and w were compared with one another, because the results of the analysis in the preceding two sections suggested a probable difference of the coefficients due to the power difference. But the significant difference was found only in the two combinations of the power groups out of the 81 ones. This fact suggested that the coefficients by the boats of the different power groups under the same conditions of y and w should take the similar values to one another. This may be due to either of the following two reasons: One is that the power of the boats did not cause any significant difference of the coefficient under the same conditions of the other factors. The other is that the coefficients of respective power groups were estimated from the records of the five to six boats of the different individuality being pooled, in spite of the fact that the working speed differed according to the individuality.

6. The comparison between the regression lines

The above-mentioned comparisons of the regression coefficients were not sufficient to examine the influence of the factors on t_c, because the difference of the constant, b_{0yzw}, was not taken into account. And it was hard to neglect the possibility of the influence of one of the factors being different according to the difference in the conditions of the rest.

The comparison among the regression lines of the different strata in respect of one of the factors shown in Figs. 1 and 2 revealed the following trends: In some of the z-w strata, all the regression lines observed in the different depth zones were similar to one another. In some other strata, they showed the different trend one another. And in the other strata, those of a few of the depth zones showed the different trend from the others. But it was hard to find the relations between the above-mentioned classification and either w, or z, or the combination of them. The relation between the position of the lines and the depth (y) in the strata of the latter two classifications differed case by case. And it was hard to find any clear trend of the change of the position-depth relation in accordance with either z, or w, or their combinations. The similar trends were found in the comparison of the regression lines within the same y-z strata and the comparison of them within the same y-w strata. The difficulty in finding out a clear conclusion of this step of examination lay in the following points: Even if a line for a depth zone in a z-w stratum showed a different trend from those for the other depth zones, it was necessary to compare this line with the other lines in the same y-z stratum and with those in the same y-w stratum. And at the same time it was necessary to compare the lines of this depth zones with those of the other depth zones in the other strata in respect of either z or w, for the purpose of finding out whether the different trend found out was common to that depth zone, or to that wave grade, or to that power group, or to the combination of any two of them, or not common to any other strata. But, in general, the trends found out differed case by case. This made the interpretation complicated.

For the purpose of comparing all the regression lines with one another, the relations between b_{0yzw} and b_{1yzw} of respective regression lines were plotted in Fig. 3. All the regression lines covering wide range of x, except those for (11.32.3) and (14.32.4) did not show any clearly different trend from the other lines, as shown in Figs. 1 and 2.

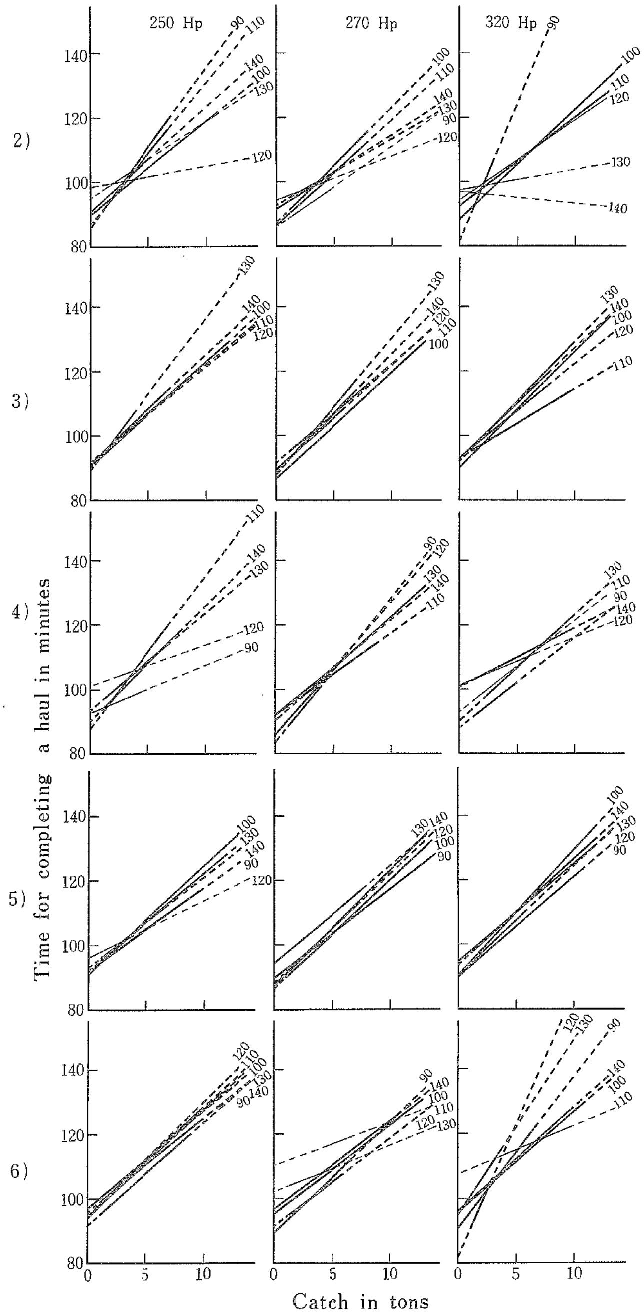

Fig. 1. The comparison of the regression lines of t_c on x of the different depth zones (y) within respective z - w strata.

Note: The thin line shows the $t_c - x$ relation with the insignificant regression coefficient. The effective range is shown by the solid line. The numeral in parenthesis is the wave grade, and that attached to the line is the depth fished in meters.

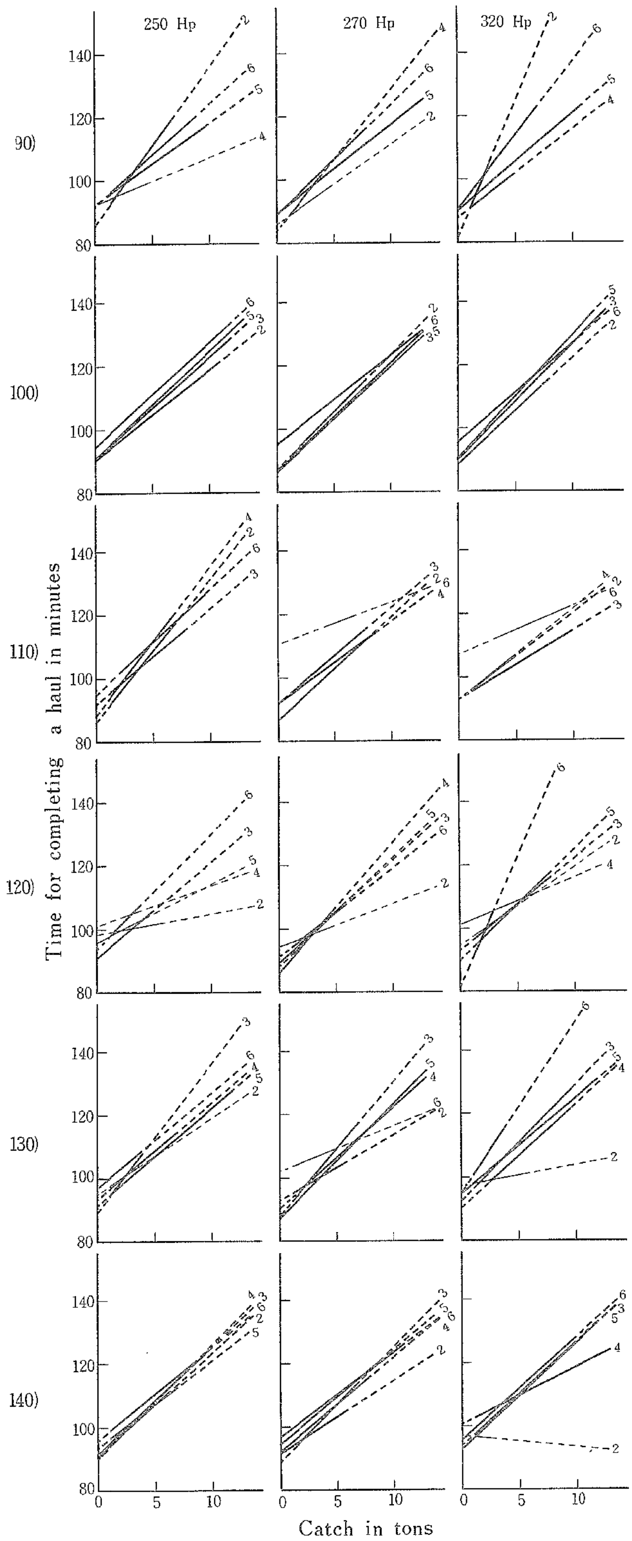

Fig. 2. The comparison of the regression lines of t_c on x of the different wave grades (w) within respective y - z strata.

Note. The numeral in parenthesis is the depth fished in meters, and that attached to the line is the wave grade.

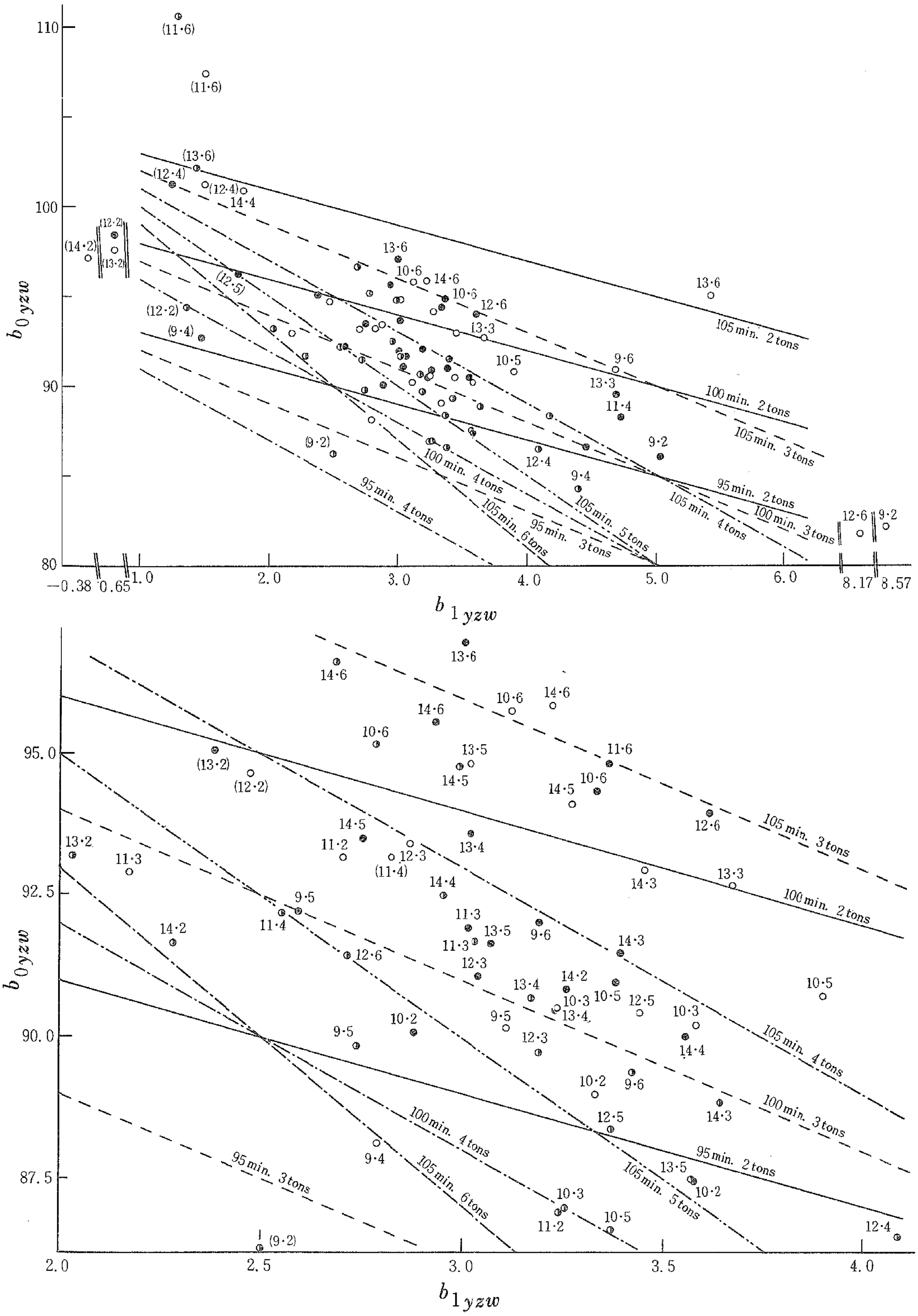

Fig. 3. The distribution of the y - z - w strata, in respect of the constant and the coefficient of the linear regression equation of t_c on x.

Note: Solid circle . . . . the 250 Hp group Open one . . . . the 270 Hp group
The circle with right half filled. . . . the 320 Hp group
The numeral attached to the mark is the depth fished (10-m intervals) and the wave grade. That in parenthesis indicates the point showing the equation with insignificant regression coefficient.

And the complexity in the time-catch relations was mainly in the range of the classes of poor catch. The lines showing the value of t_c at 2 to 6 tons of catch were, accordingly, added to Fig. 3, for the purpose of assisting the interpretation. The distribution of the points showing the regression lines revealed the following trends: Either b_{0yzw} or b_{1yzw} or both of them in some of the regression lines took quite different values from those of the other lines. It was hard to find any clear relation between their distribution and either y, or z, or w, or the combination of them. But they were the strata covering the narrow range of x; in consequence, the difference of t_c within the effective range of x did not attain to the noticeable size.

The other findings from these figures were as follows: Concerning the influence of the wave grade, the value of b_{0yz2} was smaller than all or most of the other b_{0yzw} in the six y-z strata, and b_{0yz6} was larger than all or most of the other b_{0yzw} in the 10 y-z strata out of the 18 ones, although it was hard to find the trend of the change of b_{0yzw} in the other wave grades. And the former trend was found mainly in the strata of the 90 m and the 110 m zones; and the latter trend was mainly in the 100 m, the 110 m, the 130 m, and the 140 m zones. But it was hard to find any clear relation between the distribution of these strata and z.

Concerning the influence of the depth fished, the following facts were found out: When the regression lines showing extremely different trends from the others and those showing insignificant regression—most of them were the strata covering the narrow range of x—were excluded, a rough trend of the increase of b_{0yzw} in accordance with y was found in most of the z-w strata, except those of the wave grades 3 and 6. The coefficients, b_{0yz3}, of the different depth zones took very closely similar values to one another. In the wave grade 6, $b_{0y25.6}$ took similar values to one another, while $b_{0y27.6}$ and $b_{0y32.6}$ showed large variation, but it was hard to find any clear relation to y.

The influence of the power of the boat on the position of the regression lines will be examined in the succeeding report, because of the following reasons: In the present report, the records by the boats of the same power groups were pooled, for the purpose of getting a sufficient number of records after the manifold stratification, in spite of the fact that the working speed differed according to the individuality of the boats rather than the power.

Discussions

1. The multiple linear regression equations

The time required for completing a haul consists of the time for the laying step of work (the laying time, abbreviated to t_l), that for the sinking and the pulling steps of work (the sinking-pulling time, abbreviated to t_s), and that for the hauling and the brailing steps of work (the hauling-brailing time, abbreviated to t_h). The laying time showed an extremely small variation, the average being 20.2 min.[1] And it was not necessary to examine the relation of t_l to any of the factors. It is less probable that the sinking-pulling time depends on the amount of catch, but it is rather probable that the latter depends on the former. The multiple linear regression equations of t_s on y and z after the stratification of the records according to w were shown in the preceding reports.[8] It is probable that the hauling-brailing time depends on either of the four factors examined. And the multiple linear regression equations of t_h on x, y, and z after the stratification of the records according to w were shown in the preceding report.[10] If the influences of respective factors on the time for completing a haul are the sum of those on the times for respective steps of work shown in the preceding reports,[1),8),10)] the coefficients of the multiple linear regression equations of t_c take the values shown in Table 9. The comparison of the results of the present report (Table 1) with those

Table 9. The presumable multiple linear regression equations of the time for completing a haul (t_c) on x,y, and z, under the wind wave of respective grades(w).

		a_{0w}	a_{1w}	a_{2w}	a_{3w}
Grade of wind wave (w)	1	94.79	2.52	0.112	−0.052
	2	96.67	3.70	0.001	−0.029
	3	96.15	3.19	0.020	−0.026
	4	89.90	3.00	0.091	−0.032
	5	90.59	2.96	0.050	−0.017
	6	90.93	3.18	0.048	−0.011
	7	95.22	3.29	0.023	0.007

of the preceding ones and Table 9 revealed the following facts: The regression coefficients of t_c on x at respective w, a_{1w}, took the values very closely similar to those of t_h on x. The difference between them was not larger than 0.23. This fact suggested that the influence of the amount of catch on the time for completing a haul should mainly be on the time for the hauling-brailing step of work. Even if the amount of catch had any relations to the times for the other steps of work, the difference of t_c due to this fact may be negligible.

The regression coefficient of t_s on y, a_{2w}, was significant in the five wave grades out of the seven ones. But that of t_h was significant only in one of the wave grades. That of t_c was significant in the four of the wave grades. These facts suggested that the influence of the depth fished on t_c should be mainly on t_s. But the difference of the coefficient of t_c from that of t_s varied from -0.022 to 0.246; when the grades 1 and 7 were excluded because they did not show any significant regression on the depth in all t_s, t_h, and t_c, the difference ranged from -0.022 to 0.015. In contrast with this, the difference of the coefficient of t_c from the sum of the coefficient of t_s and that of t_h ranged from -0.016 to 0.075; when the grades 1 and 7 were excluded, that ranged from -0.016 to 0.001. These facts suggested that the influence of the depth fished on the time for completing a haul should be mainly on the time for the sinking-pulling step, but the dimming due to the irregular relation of t_h to the depth fished was not negligible.

The regression coefficient of t_s on the power of the boat, a_{3_w}, was not significant in the four wave grades out of the seven ones. And that of t_h on the power was not significant in the five wave grades. But the former took negative value in the six wave grades; and the same could be said to the latter. The additional effect of these insignificant regressions resulted in the regression of t_c significant in all the wave grades except the wave grades 1 and 7. It is probable that the powerful boats can finish the laying work sooner than the less powerful ones. And if the influence of the power like this were not negligible, the difference of the regression coefficient of t_c from the sum of those of t_s and t_h should take negative value. But there was little possibility like this, because the difference took positive value in most of the wave grades.

2. The regression on the amount of catch after manifold stratification

Among t_l, t_s, and t_h, the regression on the amount of catch in the former two times was not examined, because they less probably depend on the amount of catch. The regression coefficients ($b_{1_{yzw}}$) of either t_c or t_h took the similar values to one another, both mainly in the range from 2 to 4, although a considerable difference was found out when $b_{1_{yzw}}$ of t_c in a *y-z-w* stratum was compared with that of t_h in the same *y-z-w* stratum. This fact meant that the increase of t_c in accordance with the amount of catch was mainly due to the same trend of t_h.

One of the clearest difference of the regression of t_c from that of t_h was the increase of the number of stratum showing insignificant regression: The regression of t_h was insignificant in the nine strata. The regression of t_c in these strata was also insignificant. The stratum (9.32.2) was the sole exception showing insignificant regression of t_h and significant one of t_c, although the coefficient of t_h of this stratum took the similar value to that of the other strata showing the significant regression. In the following strata, the coefficient of t_h was significant but that of t_c was insignificant: (9.25.4), (9.27.2), (12.25.2), (12.32.2), (12.32.4), (13.25.2), and (13.32.2). Namely, they were mainly in the wave grade 2 and partly in the wave grade 4, and mainly by the boats of the 250 Hp group and the 320 Hp one, although most of the strata in these wave grades or by the boats of these power groups showed the significant regression of t_c and t_h. These facts meant that the increase in the strata showing insignificant regression of t_c was due to the same trend observable in a few of the wave grades and in the particular power groups. But, it was hard to find the reason making the results different and the reason making these strata concentrated into the above-mentioned wave grades and the power groups but observable throughout the depth zones.

3. The comparison between the regression coefficients of the different wave grades

The regression coefficients, $b_{1_{yzw}}$ of either t_c or t_h of the different strata in respect of one of the factors were compared with one another. But there were some differences between the results of t_c and those of t_h.

The examination on the influence of the wave height after the elimination of the predominating influence of the amount of catch[6] revealed that the wind wave in the range from the grade 1 to the grade 5 did not cause any significant retardation of the work for completing a haul, but that over the grade 6 retarded it, because of the same trend in the time for the hauling-brailing step. The present examination added the following informations: The above-mentioned trend was found throughout the depth fished, but had some relations to the power group. Namely, the retardation of the work under the wave grade 6 was observable not in all the power groups but observable in one of them (the 320 Hp group).

The other finding of the present report was that the regression coefficients under the wave grades 2 and 4 inclined to take smaller values and those under the wave grade 3 inclined to take larger values than the others. This trend was clearest in the 320 Hp group. The former trend was found mainly in the *y-z-w* strata showing insignificant regression on x. These strata covered narrow range of x, and the constants were large. Accordingly, the difference of t_c of these strata from that of the other strata within the effective range of x was small. And it is natural that the difference due to the above-mentioned trend did not cause any notable difference of t_c when the records in all the *y-z* strata were pooled. The significant trend of b_{1yz3} taking larger values than the other b_{1yzw} was concerned mainly with the combination to the strata showing insignificant regression on x. And it is natural that the trend found here did not cause any notable difference of t_c.

The significant difference between the coefficients of t_c was found in the 12 combinations of the wave grades; while that between the coefficients of t_h was found in the 16 combinations each out of the 144 ones. Among the combinations of the wave grades showing the significant difference, the five combinations were common to both of t_c and t_h —[9.25(2 : 4), 9.32(5 : 6), 12.32(3 : 6), 12.32(4 : 6), and 14.32(3 : 4)]. In the 11 combinations of the wave grades, the significant difference between the coefficients was found only in t_h, although the *Student's t* of t_c took the same sign as those of t_h in all these combinations except 14.27(4 : 5)—[9.27(5 : 6), 11.25(2 : 3), 12.32 (2 : 6), 12.32(5 : 6), 13.25(3 : 4), 13.25(3 : 5), 13.25(3 : 6), 14.27(2 : 4), 14.27(3 : 5), 14.27(4 : 5), and 14.27(4 : 6)]. And in the seven combinations of the wave grades, the significant difference between the coefficients was found only in t_c, although the *Student's t* of t_h of these combinations took the same sign as those of t_c in all these combinations except 14.32(4 : 5)—[9.32(2 : 4), 12.25(2 : 3), 13.27(2 : 3), 13.27(2 : 5), 13.32(2 : 3), 14.32(4 : 5), and 14.32(4 : 6)].

It was hard to find any clear relation between the above-mentioned classification of the combinations and either y, or z, or the combination of w, or size of samples. This fact suggested that the results like these should not be due to the different influence of either x, or w, or the combination of them on the time required for some other steps of work than the hauling and brailing. And these differences between the results of t_c and those of t_h may be due to the very small difference of b_{1yzw} according to the wave grade.

4. The comparison between the regression coefficients of the different depth zones

The preceding report[3] found out the following facts: t_c showed a significant increase in accordance with the depth fished, mainly because of the same trend in t_s; but t_h did not show any significant depth depending change. When the influence of the depth depending change of the amount of catch was taken into account, the similar trend was found out for t_c of the hauls of the poor catch; but t_c of the hauls with good catch did not show any significant depth depending change, because the increase of t_s and the decrease of t_h in accordance with the depth fished offset each other. These facts meant that t_c of the deep zone was larger than that of the shallow zone at the classes of poor catch, but took the similar value to one another at the classes of good catch. And t_h of the deep zone was smaller than that of the shallow zone at the classes of good catch, but took the similar value to one another at the classes of poor catch. Namely, both of b_{1yzw} for t_c and for t_h may decrease in accordance with the depth fished. On the other hand, the depth depending change of the regression of t_c and t_h on x showed that b_{1yzw} of t_c and t_h took the similar values throughout the depth zones.

The preceding examination revealed the following facts: The significant difference between b_{1yzw} of t_c of the different depth zones was found only in the 12 combinations of the depth zones out of the 180 ones. The above-mentioned significant difference of b_{1yzw} was mainly due to the large value of that in the 90 m and the 100 m zones and the small value of that of the 120 m and the 130 m zones. But it was hard to find any clear trend of the decrease of b_{1yzw} in accordance with the depth fished. The significant difference between b_{1yzw} for t_h of the different depth zones was found in the 19 combinations of the depth zones. But it was hard to find the similar trends to those found in t_c. These facts suggested that the depth depending change of b_{1yzw} of t_c and t_h should be in the pattern suggested by that of the regression coefficient of them on the amount of catch before the stratification of the records according to z and w, but it was hard to deny completely the suggestion from the change of the depth regression in accordance with the amount of catch.

The preceding report[4] suggested that the comparison among b_{1yzw} for t_c of the different depth zones should show somewhat different results from that for t_h. And the probable difference found through this step of examination may be suggestive of the probable difference of the influence of the amount of catch according to either the step of work, or the depth fished, or the combination of them. The comparison between the regression coefficients of either t_c or t_h of the different strata in respect of the depth fished showed the following facts: Among the combinations of the depth zones showing the significant difference of the coefficients, the six combinations were common to both of t_c and t_h [(10 : 11)25.2, (11 : 12)25.2, (10 : 12)27.2, (9 : 11)25.4, (9 : 13)27.5, and (9 : 11)32.6]. In the 13 combinations, the significant difference between the coefficients was found only in t_h [(11 : 13)25.2, (11 : 14)25.2, (11 : 12)27.2, (10 : 12)25.3, (11 : 13)25.4, (9 : 10)27.5, (10 : 14)27.5, (13 : 14)27.5, (9 : 10)32.6, (9:14)32.6, (10:11)32.6, (11:14)32.6, and (12:13)32.6]. And in the six combinations, the significant difference was found only in t_c [(9 : 10)25.2, (9 : 12)25.2, (10 : 12)25.2, (10 ; 13)27.2, (9 : 13)32.2, and (10 : 13)32.2]. The above-mentioned classification had a rough relation to the wave grade. The combinations of the depth zones showing significant difference of the regression coefficients of t_c but not showing any significant difference of the coefficients of t_h were found in the wave grade 2 but not in the other wave grades. This may be because of the following reason: The significant coefficients took the similar values to one another, but most of the insignificant ones took the different values from those of the significant ones. The strata showing the significant regression of t_h but insignificant one of t_c were found in the wave grade 2.

The other trend found out was that the number of the combinations of the depth zones showing the significant difference of the coefficients for t_h but not for t_c increased roughly in accordance with the wave grade. This fact indicated that the different influence of the amount of catch according to the depth fished was more frequently found in t_c than in t_h under the calm water, but less frequently found in t_c than in t_h in accordance with the wave grade. It was hard to find the reason causing the above-mentioned trend, but it was also hard to consider that the other steps of work than the hauling-brailing was affected by the amount of catch.

5. The comparison between the regression coefficients of the different power groups

The power of the boats was one of the factors probable to have an influence on the working speed and probable to show the different influence according to the conditions and the combinations of them. But the results were contrary to the expectation, and the significant difference between b_{1yzw} of the different power groups was found least frequently among the factors chosen. The comparison between the coefficients for t_c of the different strata in respect of the power of the boats showed that the significant difference was found in the two combinations of the power groups out of the 27 ones examined, while the comparison between the coefficients for t_h of the different power groups showed that the significant difference was found in the 11 ones. And the two combinations were common to t_c and t_h [12(27 : 32)6 and 14(25 : 32)4]. In the other nine combinations, the significant difference was found only in t_h [9(27 : 32)5, 9(25 : 32)6, 9(27 : 32)6, 11(25 : 27)2, 11(25 : 32)2, 11(25 : 27)4, 12(25 : 27)3, 14(27 : 32)4, and 14(27 : 32)5].

The scarcity of the combinations of the power groups showing the significant difference of b_{1yzw} for t_c made it hard to give further consideration.

6. The comparison of the regression lines

The comparison of Figs. 1 and 2 of the present report with Fig. 1 of the preceding one[10] revealed the following facts: In general, the distributions of the lines in the same y-z or z-w strata of these figures were similar to one another. And the lines of t_c in a few of the y-z-w strata showed the different trends from the lines of t_h of the corresponding y-z-w strata. But they were mainly the strata of the narrow range of x. And it was hard to find the clear relation between their distribution and either y, or z, or

w or the combination of them. These facts suggested the slight difference of the influence of either y or z or w or the combination of them on the length of the working time of the other steps of work than the hauling-brailing one.

The comparisons of b_{1yzw} shown in the preceding sections were concerned with the different influence of the amount of catch according to the other factors. It was hard to neglect the other part of the influence of respective factors, i.e. the influence having no relation to the amount of catch. The part of the influence like this was examined through the comparison of b_{0yzw}, although attention should be paid to the following fact: To estimate the regression equation, first the regression coefficient was estimated; then the constant was determined so that the line might pass the mean of the dependent variable at the mean of the independent one.

As stated above, it is less probable that the times for the laying work and the sinking-pulling work depend on the amount of catch. It is, accordingly, probable that the comparisons of b_{1yzw} are not concerned with the influence of the factors or their combinations on the times for these steps of work. The length of the time for the hauling-brailing step was strongly affected by the amount of catch. But it is hard to deny the possibility of a part of the hauling-brailing time having some relations to the other factors. And it is probable that a part of the different influence of the other factors according to the amount of catch causes the difference of b_{0yzw}, too.

6–1. The comparions of the regression lines of the different wave grades

The preceding report[5] showed a slight increase of t_l in accordance with the wave grade, in spite of the fact that the variation of t_l was extremely small. Somewhat irregular and weak trend of increase in accordance with the wave grade was found in the sinking-pulling time. The examination before the stratification of the records according to y and z showed that the constant of the regression equations of t_h on x increased in accordance with the wave grade.[6] These findings in the preceding reports suggested that b_{0yzw} should show an increasing trend in accordance with w. The present examination revealed the following trend: The value of b_{0yz2} in the shallow zones inclined to be smaller and b_{0yz6} in the most of the depth zones to be larger than the other b_{0yzw}. These facts meant that the similar trend found in the preceding reports was found in the present examination, and the influence of the wave grade on t_c differed according to the depth zones—namely, the shortening effect of the calm water was found in the shallow zones while the elongating one of the rough sea was found in rather throughout the depth zones. The values of b_{1yz2} and b_{1yz4} inclined to take smaller values, while b_{1yz3} and b_{1yz6} inclined to take larger values than the others. And the smaller value of b_{1yz4} and the larger value of b_{1yz6} were mainly by the boats of the 320 Hp group. These facts revealed that the small value of t_c in the wave grade 2[5] and the larger value of t_c in the wave grade 6[5][6] found in the preceding reports were due to either or both of the difference of the constant and the coefficient of the regression equations.

6–2. The comparison of the regression lines of the different depth zones

Concerning the depth depending change of the working time, the preceding report[3] revealed that t_l increased in accordance with the depth fished at a rate of 0.0055 min. per meter, and t_s increased at a rate of 0.039 min. per meter. Among the constants and the coefficients of the regression equations of t_c or t_h on x, the constant of t_c increased in accordance with the depth fished, but the others had no clear relation to the depth. Concerning the coefficient of t_c, however, the depth depending change of the regression coefficient on the amount of catch and the change of the regression coefficient on depth in accordance with the amount of catch suggested somewhat different trends. The former suggested the increase in accordance with the depth but the latter suggested the independency on the depth. The present examination revealed that the rough trend of the increase of b_{0yzw} in accordance with the depth fished was found in most of the y-z strata except those of the wave grades 3 and 6. Some of b_{1yzw} for t_c in the shallow zone took larger values and in the deep zones took smaller values than the other b_{1yzw}. But it was hard to find any clear relation between the coefficients of t_c or t_h and the depth fished. It may be said, accordingly, that the results of the present examination coincided with the results and the suggestions of the preceding reports. These facts meant that it was probable that the depth depending change of the regression of t_c on x did not show any clearly different trend according to the power and the wave grade except the grades 3 and 6.

6—3 The comparison of the regression lines of the different power groups

When the different amount of catch relating to the power was not taken into account, t_c did not show any clear change in accordance with the power of the boats, because the decrease of t_s and the increase of t_h offset each other. It was hard to find the change of either t_c or t_h in accordance with the power, when the influence of the different amount of catch relating to the power was taken into account. This may be because of the following reason: The working speed was more strongly affected by the individuality of the boats rather than the power. In spite of the above-mentioned possibility, the records of several boats with the engine of the same power were pooled in the present examination, and the records of the other boats than the three power groups were not used in the present report, for the purpose of securing the records on a sufficient number of hauls after the manifold stratification. The present examination, however, found out some trends relating to the power groups. Some of $b_{1y32.6}$ inclined to take larger values than the other b_{1y32w} of the same y; $b_{1y32.2}$ showed a trend of decrease in accordance with y; $b_{1y25.2}$ of the different y frequently showed significant difference (in the five combinations of the depth zones out of the 15 ones). The strata showing significant catch regression of t_h and insignificant one of t_c were found in the 250 Hp group and the 320 Hp one. The retardation of the work under the rough sea was found in the 320 Hp group. The significant difference of b_{1yzw} according to w was most frequently found in the 320 Hp one.

It was hard to compare the results of the present examination with those of the preceding reports, because the results of the present examination were obtained from the records of the 17 boats being pooled into the three power groups while those of the preceding ones were obtained from the records of all the 22 boats. The other reason preventing the comparison of the results was, as stated above, high possibility of the individuality of the boat being more strongly influential on the working speed than the power. And this problem will be examined in the succeeding report.

Conclusion

From the results of the present examinations and the comparison with the results of the preceding reports, it may be concluded as follows: The variation of the time required for completing a haul (a little shorter than 80 min. to a little longer than 150 min.) was mainly due to that of the time for the hauling-brailing step. And the former was deeply affected by the amount of catch (about three minutes per ton), because of the same trend in the time for the latter step. The rough sea and the deep water elongated the work for completing a haul, the former being influential mainly on the sinking-pulling time and the latter being mainly on the hauling-brailing time. The influence of these factors was far weaker than that of the amount of catch. Some facts suggesting the different influence of one of the factors according to the difference of the other factors were found out, but the modification of the time for completing a haul due to this reason was far weaker than that of the single factors.

Summary

The fishing work of the Danish seiners consists of the laying step (t_l), the sinking-pulling one (t_s), and the hauling-brailing one (t_h). The influence of the four factors —the amount of catch (x in tons), the depth fished (y in meters), the wave height (w in the grade number), and the power of the main engine of the boats (z in Hp)— on the times required for respective steps of works and the time required for completing a haul were examined in the preceding reports of this series. The influences of these factors on the working speed differ according to the step of work, and the proportion of the time for respective steps of work to the time for completing a haul differs according to the step. And it is probable that the influence of one of the factors more or less differs according to the conditions of the factors of the rest. It is, accordingly, necessary to give a collective consideration on the influence of the factor complex on the time for completing a haul (t_c). In the present report, the influences of these factors on the time for completing a haul observable in the records of the Danish seiners fishing the Alaska pollack in the Bering Sea during the season of 1964 were examined through the multiple linear regression equations and through the comparison among the linear regression equations of the time on the amount of catch after the stratification of the records according to the three factors of the rest. And the results obtained were summarized as follows:

1. The amount of catch (0 to 21 tons, mainly 0 to 13 tons) was the most influential

factors among those examined. And t_c increased in accordance with x at a rate of 2.8 to 3.5 min. per ton. This was mainly because of the similar trend in t_h, and the influence of the amount of catch on the times for the other steps of work was, if any, negligible.

2. The influence of the depth fished (40 m to 150 m, mainly 90 m to 140 m) was far weaker than that of the amount of catch. And t_c increased in accordance with y at a rate of 0.02 to 0.85 min. per meter. This was mainly because of the same trend in t_s, but the dimming effect of the irregular depth depending change of t_h was not negligible.

3. The influence of the power of the boats (220 Hp to 340 Hp) was as weak as that of the depth fished. And t_c decreased in accordance with z at a rate of 0.016 to 0.028 min. per Hp, because of somewhat obscure trends of t_s and t_h.

4. The regression coefficient on the power in the multiple linear equation increased roughly in accordance with the wave grade. Namely, the rough sea made the power less influential, because the coefficients were negative.

5. Among the 81 y-z-w strata of the records, the significant linear regression of t_c on x was found in the 66 ones. Those showing insignificant one were mainly the strata covering narrow range of x or those of small sample size.

6. Among the 144 pairs of the wave grades found in the same conditions of y and z, the significant difference of the regression coefficients on x was found in the 12 pairs. They were mainly concentrated into the combinations to the wave grades 4 and 6 both by the 320 Hp group.

7. Among the 180 pairs of the depth zones found in the same conditions of z and w, the significant difference of the regression coefficients on x was found in the 12 pairs. They were concentrated mainly in the wave grade 2 and by the boats of the 250 Hp group.

8. Among the 27 pairs of the power groups found in the same conditions of y and w, the significant difference of the regression coefficients on x was found in the two pairs.

9. The comparison of the regression lines of t_c on x revealed the following trends: The constant of the equation in the wave grade 2 was smaller than that of the other lines in the six y-z strata, and that in the wave grade 6 was larger than the others in the 10 y-z strata each out of the 18 ones. The former trend was found mainly in the 90 m and the 110 m zones, and the latter was found rather throughout the depth zones. The rough trend of the increase of the constant in accordance with the depth fished was found in most of the z-w strata, except those in the wave grades 3 and 6.

10. The results found in the present examinations were compared with those of the preceding reports, and it may be concluded as follows: The variation of the time required for completing a haul was mainly due to that of the time for the hauling-brailing step. And the former was deeply affected by the amount of catch, because of the same trend in the time for the latter step. The rough sea and the deep water elongated the work for completing a haul, the former being influential mainly on the sinking-pulling step and the latter being on the hauling-brailing step. The other factors

than the amount of catch were far less influential on t_c than the amount of catch. Some facts suggesting the different influences of one of the factors according to the different conditions of the factors of the rest were found out, but the modification of the time for completing a haul due to this reason was far smaller than that of the single factors.

References

1) MAÉDA, H. and S. MINAMI, 1969: *Bull. Jap. Soc. Sci. Fish.*, 35, 964–969.
2) MAÉDA, H. and S. MINAMI, 1969: *ibid.*, 35, 970–974.
3) MAÉDA, H. and S. MINAMI, 1969: *ibid.*, 35, 1043–1048.
4) MAÉDA, H. and S. MINAMI, 1970: *ibid.*, 36, 455–461.
5) MAÉDA, H. and S. MINAMI, 1970: *ibid.*, 36, 549–555.
6) MAÉDA, H. and S. MINAMI, 1970: *ibid.*, 36, 1115–1121.
7) MAÉDA, H. and S. MINAMI, 1971: *ibid.*, 37, 592–597.
8) MAÉDA, H. and S. MINAMI, 1971: *This Jour.*, 20, 1–12.
9) MAÉDA, H. and S. MINAMI, 1971: *ibid.*, 20, 67–79.
10) MAÉDA, H. and S. MINAMI, 1972: *ibid.*, 20, 135–156.