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An Analysis of the Catch Records of the Alaska Pollack Trawling - IV.*

The Daily Rhythmic and Seasonal Change of Catch by a Towing of the Same Time Length

By
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The fishing techniques showed a remarkable advance in these one or two decades. In some of the fishing methods, the fishing capacity of a boat of the same size is increased mainly by changing the deck equipments and gear materials, without showing any basic change in the gear construction and gear handling; the representatives are the longlining, gill-netting, and purse seining. In the other fishing methods, the application of the modern equipments causes a basic change in the gear handling. And it is hard to analyse the catch records without a sufficient understanding of the work pattern of the fishing boat. The stern ramp trawling, especially that for the roundfishes on rough grounds, is one of the best examples of this group of fishing methods. For the purpose of clarifying the change in the meanings of respective items of the catch records caused by the basic change in the work pattern, the present series of reports dealt with the seasonal bathymetric change of the relation between the catch and the length of towing time observable in the catch records of the Alaska pollack by a large stern ramp factory trawler fully equipped with the modern electronic supporting devices. The clearest finding in the first report[1] was that it was hard to find the bathymetric change of the density of the fishable population through the amount of catch per unit hour of towing, probably because of the adjustment of the length of towing time either according to the amount of catch in the net estimated during towing or according to the distribution of the objective fish detected through the echo-sounder also during towing. For the purpose of eliminating the influence of the different length of towing time from the catch records, the catch-time relation after the twofold stratification of the records according to the season and the depth and the bathymetric change of the catch after the twofold stratification of the records according to the season and the length of towing time, were examined in the second report[2]. And it was found out that the catch by a short towing inclined to be

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better than that by a long towing but the boat sometimes towed her net over many hours for yielding a poor catch. In consequence, the amount of catch per minute of towing showed a sharp decrease in accordance with the increase of towing time. This fact made the problem complicated. And there remained a doubt that the well-equipped modern factory trawler commanded by a skillful skipper would work along the above-mentioned seemingly inefficient pattern. The density of the fishable population (that of the fish living near the sea floor) varies according to time and space; and the variation relating to time is inavoidable regardless of our effort while that relating to space is avoidable by effective use of the modern electronic supporting devices. And the above-mentioned seemingly inefficient work pattern is convincible only when the inefficient work is due to the density variation relating to time, but is inconvincible when that is due to the variation relating to space. The third report[3] revealed that the probable density variation of the population in the fishable state showed a clear daily rhythmic change; in consequence, the boat towed her net over many hours at night and yielded a poor catch, while she repeated the towings of short hours and yielded a good catch in the daytime. These findings aroused the necessity of examining again whether the large variation of the length of towing time and the inefficient work pattern could be observable even in the records stratified according to the hour of shooting the gear or the amount of catch would show a linear increase in accordance with the increase of towing time. To discern this point, the catch-time relation after the threefold stratification of the records according to the ground, the month, and according to the hour of shooting the gear, was examined in the present report.

Material and Method

The same set of the materials as those used in the preceding reports of this series were used in the present report. They were the catch records of the 2,736 towings (more than 90% of the catch being the Alaska pollack, excluding those for the accidental towings) by a minced fish factory stern ramp trawler of about 4,000 gross tons during the season from December 23 in 1968 to May 2 in 1970 along the outer edge of the continental shelf of the Eastern Bering Sea. In the original records, the amount of catch was described in tons, and the length of towing time was in minutes; however, the former was aggregated into the classes of the 10-ton intervals and the latter was into the classes of the 5-minute intervals, because the range of the distribution and the accuracy of measurement were taken into account. The records were stratified according to the month, the ground shown in Fig. 1 of the first report, and according to the hour of shooting the gear into the 2-hour classes. Among the strata thus classified, some were consisted of the records of less than five towings. These strata were excluded from the present examination. And the quadratic and linear regressions of the amount of catch on the length of towing time observable among the records in respective strata were examined.

Results

1. The quadratic and linear regression

As shown in Table 1, about a half of the hour-month groups took the positive quadratic regression coefficient and the other half took the negative one, and most of the coefficients were insignificant at 0.05 level. The positive coefficient in the four groups out of the 97 ones was significant at 0.05 level, and the negative one in the six groups out of the 90 ones was significant. However, there was no need to give much importance to the presence of the significant coefficient, because the phrase "significant at 0.05 level" means that there are 5% of the groups taking larger F_0 than that shown in F-table. Thus, it was hard to find any clear results in respect of the quadratic regression of the amount of catch by a towing on the length of towing time. Before concluding that the catch by a towing changed independently of the length of towing time, however, attention should be paid to the following two points: one is whether the distribution of the groups either taking the positive coefficient or taking the negative one shows seasonal and hourly change or not. The other is as follows: the quadratic regression coefficient is apt to be insignificant either when the maximum (or the minimum) of catch is strongly biased in the direction of the long (or the short) towing or when the similar amount of catch is yielded by a towing regardless of its length. In the former case, the leading trend differs according to the relation between the distribution of the records in respect of the length of towing time and the length of the towing time at the maximum (or the minimum) of catch. The catch by a towing shows an increasing (or decreasing) trend in accordance with the increase of towing time when most of the records are in the range from the shortest (or the longest) limit of the applicable range of the towing time to the maximum of the convex curve or in the range from the minimum of the concave curve to the longest (or the shortest) limit of the applicable range. The applicable range showed a seasonal and daily rhythmic change (narrow in the earlier half of the season and wide in the latter half; short in the daytime and long at night). The examination of the quadratic regression coefficient is, accordingly, not sufficient to find the trend of the change of the amount of catch by a towing in accordance with the increase of towing time, but it is necessary to examine the relation within the applicable range.

The seasonal and daily rhythmic change of the general trends of the catch-time relations within the applicable range was shown in Table 2, by classifying the estimated quadratic regression curves into the following types according to concave or convex and according to the length of towing time at the maximum (or the minimum) of catch in relation to the applicable range:

Table 1. The estimated quadratic and linear regression equations.

	Hour	a_0	a_1	a_2	F_2	b_0	b_1	F_1	n
Jan. '69	1	42	-0.56	-0.0025	0.38	30	-0.19	3.09	16
	3	26	-0.35	0.0017	0.16	18	-0.10	0.83	14
	5	23	-0.36	0.0031	0.31	16	-0.03	0.07	16
	7	39	-0.42	0.0023	0.20	31	-0.13	1.12	16
	9	27	-0.20	0.0026	0.13	23	0.04	0.08	28
	11	22	0.86	-0.0191	3.04	40	-0.41	5.30*	26
	13	35	0.02	-0.0068	1.25	44	-0.54	26.04**	21
	15	13	0.61	-0.0058	4.44*	30	-0.12	2.36	25
	17	4	0.22	-0.0009	0.12	9	0.07	1.17	9
	19	79	-1.32	0.0065	2.27	26	-0.10	2.01	7
	21	-39	1.61	-0.0107	0.21	36	-0.21	0.49	6
	23	-4	0.34	-0.0017	0.13	7	0.05	0.25	11
Feb.	1	5	0.53	-0.0040	0.85	24	-0.08	0.39	10
	3	-23	0.90	-0.0051	1.47	2	0.15	1.55	11
	5	136	-3.23	0.0215	1.00	18	-0.01	0.00	10
	7	16	0.19	-0.0010	0.00	17	0.13	0.37	17
	9	21	0.76	-0.0135	3.47	37	-0.27	4.32*	25
	11	26	-0.09	0.0025	0.12	22	0.13	1.02	22
	13	21	0.36	-0.0071	0.27	28	-0.12	0.44	20
	15	32	-0.27	0.0014	0.40	28	-0.09	1.60	20
	17	37	-0.41	0.0021	0.83	32	-0.16	4.81	8
	19	55	-0.69	0.0027	0.04	31	-0.17	1.27	9
	21	183	-3.69	0.0196	1.37	8	0.10	0.38	6
	23	-212	5.09	-0.0243	42.08**	12	-0.01	0.00	6
March	1	35	-0.16	0.0007	0.008	33	-0.07	1.11	20
	3	26	-0.10	0.0010	1.91	20	0.07	2.39	18
	5	19	0.45	-0.0058	7.56*	27	-0.08	1.45	15
	7	32	-0.28	0.0031	1.26	24	0.06	0.39	22
	9	37	-0.39	0.0044	1.77	28	0.06	0.40	21
	11	20	0.56	-0.0072	1.68	29	-0.04	0.12	20
	13	36	-0.39	0.0048	2.54	29	0.04	0.18	27
	15	30	-0.05	0.0001	0.00	30	-0.04	0.73	17
	17	41	-0.51	0.0031	2.66	29	-0.07	1.90	14
	19	61	-1.08	0.0066	1.42	24	-0.01	0.00	12
	21	25	0.01	0.0000	0.00	24	0.02	0.07	17
	23	36	-0.51	0.0042	0.69	12	0.15	1.92	9
April (A)	1								
	3								
	5	-20	1.31	-0.0097	6.86*	16	0.04	0.24	10
	7	7	0.60	-0.0052	0.57	21	0.03	0.04	10
	9	31	0.02	-0.0012	0.02	34	-0.09	0.52	12
	11	90	-3.88	0.0469	6.52*	32	-0.13	0.58	9
	13	8	0.83	-0.0075	1.15	21	0.10	1.12	12
	15	55	-1.42	0.0138	3.74	30	-0.09	0.37	10
	17	33	-0.09	-0.0003	0.00	34	-0.13	2.87	7
	19								
	21								
	23								

Table 1. – (cont'd)

	Hour	a_0	a_1	a_2	F_2	b_0	b_1	F_1	n
April (B)	1	41	-0.15	-0.0008	0.01	48	-0.29	2.54	7
	3	50	-0.39	0.0010	0.04	45	-0.25	3.49	11
	5	314	-8.40	0.0569	1.38	-8	0.30	1.28	8
	7	73	-2.17	0.0180	4.59	13	0.04	0.04	10
	9	-51	2.00	-0.0136	1.60	7	0.16	1.04	10
	11	-3	0.78	-0.0059	0.41	28	-0.11	0.59	14
	13	17	-0.02	0.0005	0.02	15	0.05	0.30	13
	15	-4	0.38	-0.0014	0.13	1	0.20	3.43	13
	17	-490	10.17	-0.0500	1.41	58	-0.33	0.59	8
	19	3	0.90	-0.0100	0.11	45	-0.41	2.83	6
	21	48	-0.68	0.0036	0.82	26	-0.09	0.79	9
	23	-37	1.98	-0.0157	0.82	60	-0.52	4.52	7
May	1	62	-0.55	0.0010	0.00	52	-0.34	1.25	5
	3	-41	1.53	-0.0087	1.31	-4	0.32	2.33	8
	5	43	-0.38	0.0007	0.00	39	-0.28	1.30	10
	7	155	-2.71	0.0125	4.93	73	-0.58	12.39*	6
	9	13	0.29	-0.0022	0.64	26	-0.08	1.22	7
	11	-17	0.85	-0.0042	0.35	12	0.12	0.87	8
	13	47	-0.42	0.0011	0.01	41	-0.25	2.18	9
	15	60	-1.07	0.0079	0.07	25	0.03	0.01	9
	17	906	-16.92	0.0792	103.14**	4	0.16	0.15	6
	19	-158	3.33	-0.0154	0.27	28	-0.09	0.06	6
	21	8	0.21	-0.0014	0.11	19	-0.05	0.38	6
	23	72	-1.39	0.0075	0.67	12	-0.01	0.00	6
July	1	-20	0.76	-0.0035	0.35	25	-0.05	0.10	12
	3	-11	0.50	0.0018	1.17	10	0.09	2.14	16
	5	11	0.10	0.0001	0.00	10	0.12	2.52	18
	7	62	-0.99	0.0060	2.01	13	0.12	1.33	21
	9	37	-0.19	0.0009	0.24	30	-0.03	0.29	21
	11	44	-0.41	0.0018	2.33	33	-0.10	4.01	24
	13	33	-0.11	0.0003	0.06	30	-0.05	0.53	23
	15	42	-0.55	0.0032	4.24	18	0.05	0.63	16
	17	38	-0.26	0.0014	0.56	30	-0.03	0.52	21
	19	58	-0.60	0.0026	0.76	34	-0.07	0.96	15
	21	29	-0.06	0.0000	0.00	28	-0.06	0.33	16
	23	-69	1.78	-0.0085	7.33*	25	-0.07	0.34	16
Aug.	1	-66	1.89	-0.0100	6.56*	18	-0.01	0.02	19
	3	-20	0.66	-0.0026	1.45	4	0.14	3.80	16
	5	39	-0.32	0.0014	0.22	28	-0.06	0.64	20
	7	48	-0.43	0.0016	0.12	37	-0.15	3.16	21
	9	72	-1.16	0.0069	2.26	26	0.01	0.00	21
	11	3	0.43	-0.0022	0.21	21	0.02	0.03	16
	13	56	-0.77	0.0043	2.00	28	-0.05	0.39	23
	15	41	-0.32	0.0018	1.61	25	0.04	0.59	16
	17	-20	1.00	-0.0056	3.36	16	0.05	0.33	23
	19	-25	0.96	-0.0051	0.78	20	-0.02	0.02	19
	21	18	0.01	-0.0002	0.00	19	-0.03	0.12	20
	23	26	-0.15	0.0006	0.07	20	-0.02	0.07	16

Table 1. – (cont'd)

	Hour	a_0	a_1	a_2	F_2	b_0	b_1	F_1	n
Sept.	1	-28	0.94	-0.0045	2.46	10	0.09	0.93	22
	3	94	-1.33	0.0056	0.24	35	-0.17	1.48	18
	5	48	-0.51	0.0032	0.10	28	0.01	0.00	15
	7	37	-0.25	0.0008	0.01	32	-0.12	0.47	19
	9	19	0.28	-0.0021	0.61	31	-0.06	0.63	26
	11	30	-0.11	0.0004	0.01	28	-0.05	0.29	21
	13	-50	1.59	-0.0081	2.62	4	0.23	3.59	24
	15	26	-0.02	-0.0001	0.00	26	-0.03	0.11	22
	17	56	-0.83	0.0044	0.87	26	-0.07	0.36	22
	19	10	-0.07	0.0009	0.05	-1	0.13	2.61	16
	21	26	-0.13	0.0003	0.00	24	-0.09	0.42	13
	23	-70	1.88	-0.0094	4.02	17	0.02	0.03	17
Oct.	1	-97	2.30	-0.0112	2.54	14	0.04	0.19	19
	3	-34	0.71	-0.0022	0.41	-10	0.24	6.44*	16
	5	-29	0.76	-0.0028	0.34	6	0.12	1.39	17
	7	49	-1.11	0.0083	0.86	-9	0.30	4.18	15
	9	46	-0.46	0.0020	0.16	31	-0.10	0.84	24
	11	-23	1.13	-0.0069	4.48	18	0.03	0.07	18
	13	-5	0.73	-0.0043	2.18	26	-0.03	0.07	16
	15	-52	1.59	-0.0084	1.12	31	-0.10	0.71	20
	17	-162	3.43	-0.0160	1.46	0	0.17	1.35	17
	19	51	-0.72	0.0038	0.12	11	0.08	0.23	13
	21	125	-2.40	0.0132	1.75	-1	0.21	2.64	17
	23	-16	0.72	-0.0034	1.70	15	0.03	0.18	17
Nov.	1	195	-3.33	0.0156	0.59	20	0.01	0.00	11
	3	116	-2.47	0.0141	3.69	-5	0.22	2.13	14
	5	-56	1.70	-0.0092	1.46	6	0.13	0.60	8
	7	-37	1.31	-0.0068	1.86	13	0.11	1.13	18
	9	161	-3.12	0.0170	4.78	15	0.11	0.42	13
	11	258	-3.92	0.0158	12.16**	50	-0.25	3.96	18
	13	4	0.17	-0.0004	0.06	9	0.07	0.78	12
	15	-12	0.32	-0.0006	0.03	-7	0.20	4.59	11
	17	-408	7.94	-0.0363	4.78	28	-0.09	0.18	10
	19	114	-1.93	0.0093	0.32	16	0.01	0.00	7
	21	-54	1.37	-0.0063	1.10	-4	0.21	1.36	11
	23	407	-6.41	0.0262	2.86	-4	0.21	0.46	5
Jan. '70	1	103	-2.11	0.0119	0.54	-15	0.29	3.35	11
	3	-103	2.09	-0.0088	1.77	-13	0.28	4.07	11
	5	-23	0.44	-0.0011	0.06	-11	0.21	5.44*	12
	7	52	-0.91	0.0054	1.99	20	-0.04	0.14	17
	9	40	-0.26	0.0004	0.02	39	-0.20	5.12*	19
	11	27	0.05	-0.0012	0.06	34	-0.14	1.38	16
	13	22	0.00	0.0009	0.02	18	0.13	0.90	11
	15	39	-0.41	0.0022	0.18	27	-0.05	0.12	14
	17	359	-6.07	0.0260	5.66*	35	-0.17	0.97	11
	19	-52	1.27	-0.0062	0.99	8	0.02	0.05	11
	21	-292	4.90	-0.0193	2.30	10	0.05	0.04	15
	23	34	-0.30	0.0013	0.04	22	-0.05	0.17	10

Table 1. – (cont'd)

	Hour	a_0	a_1	a_2	F_2	b_0	b_1	F_1	n
Feb.	1	18	-0.03	0.0005	0.18	14	0.07	1.57	13
	3	-28	0.74	-0.0025	0.44	-8	0.27	6.45*	10
	5	73	-0.84	0.0034	3.66	33	-0.07	1.06	17
	7	11	0.08	0.0002	0.01	10	0.12	1.95	13
	9	98	-1.48	0.0073	1.35	32	-0.08	0.25	17
	11	75	-1.33	0.0073	1.31	15	0.04	0.07	12
	13	-51	1.59	-0.0077	2.01	17	0.09	0.48	15
	15	79	-1.02	0.0048	2.96	43	-0.16	2.50	13
	17	-38	1.04	-0.0045	1.93	9	0.10	0.93	17
	19	-48	0.99	-0.0032	1.06	-7	0.25	7.84**	10
	21	-60	1.06	-0.0032	1.10	-6	0.21	5.48*	12
	23	664	-9.94	0.0381	2.26	-5	0.20	1.22	12
March	1	-19	0.85	-0.0041	0.35	15	0.07	0.28	10
	3	43	-0.43	0.0024	1.30	28	-0.01	0.00	10
	5	3	0.72	-0.0042	3.20	29	0.02	0.09	20
	7	33	-0.24	0.0020	0.74	23	0.07	1.06	22
	9	7	0.80	-0.0065	2.37	33	-0.06	0.51	24
	11	29	-0.05	0.0007	0.10	26	0.06	0.71	21
	13	43	-0.44	0.0039	3.28	29	0.05	0.83	26
	15	28	0.01	0.0004	0.03	26	0.07	1.12	21
	17	-1	0.65	-0.0037	3.66	19	0.06	0.46	18
	19	-4	0.30	-0.0004	0.00	2	0.21	1.93	9
	21	-70	1.73	-0.0079	0.76	-4	0.25	2.22	12
	23	-5	0.69	-0.0037	0.15	23	0.02	0.02	9
April	1	41	-0.60	0.0027	0.07	7	0.01	0.01	9
	3	232	-4.60	0.0236	3.41	11	0.04	0.03	11
	5	57	-0.72	0.0036	1.09	34	-0.12	1.24	22
	7	-13	1.05	-0.0073	3.38	35	-0.17	2.42	24
	9	68	-0.97	0.0046	0.98	38	-0.19	3.72	24
	11	25	-0.04	0.0003	0.00	23	0.01	0.01	18
	13	46	-0.40	0.0018	1.64	31	-0.06	0.98	19
	15	22	-0.02	0.0006	0.06	17	0.08	0.98	19
	17	20	-0.03	0.0001	0.00	19	-0.01	0.06	21
	19	23	-0.24	0.0009	0.13	8	0.01	0.00	13
	21	36	-0.85	0.0050	0.23	-27	0.29	2.43	8
	23	-9	0.27	-0.0012	0.11	6	0.00	0.00	12

Note:

x ..... The length of towing time (in minutes)

y ..... The amount of catch by a towing (in tons)

$y = a_0 + a_1x + a_2x^2$ $\qquad$ $y = b_0 + b_1x$

n ..... The number of the records in the stratum

F_i ..... The Snedecor's F-value for the i-th order regression coefficient in the i-th order regression equation with 1 and $(n - i - 1)$ degrees of freedom

* Significant at 0.05 level ** significant at 0.01 level

The length of towing time at the minimum of catch

Concave

- Longer than the longest limit of the applicable time range..... A
- Between the median and the longest limit
  - The difference of the catch at the longest limit from the minimum catch being less than 10% of the latter ..... A′
  - The difference being more than 10% ..... B
- Between the shortest limit and the median
  - The difference of the catch at the shortest limit from the minimum catch being more than 10% of the latter C
  - The difference being less than 10% ..... D′
- Shorter than the shortest limit ..... D
- The difference of the catch at either of the limits of the applicable range from the minimum of catch being less than 10% of the latter ..... F

The length of towing time at the maximum of catch

Convex

- Shorter than the shortest limit ..... a
- Between the shortest limit and the median
  - The difference of the catch at the shortest limit from the maximum catch being less than 10% of the latter ..... a′
  - The difference being more than 10% ..... b
- Between the median and the longest limit
  - The difference of the catch at the longest limit from the maximum catch being more than 10% of the latter c
- The difference being less than 10% ..... d′
- Longer than the longest limit ..... d
- The difference of the catch at either of the limits of the applicable range from the maximum catch being less than 10% of the latter ... f

$a_1 < 0$ $\quad 0 < a_2 < 0.00005$ ..... (A)

$a_1 > 0$ $\quad 0 > a_2 > -0.00005$ ..... (D)

The amount of catch by a towing in the types A,A′,a,a′, and (A) shows the general decreasing trend, and that in the types B and b shows mainly the decreasing trend and partly the increasing one. That in the types D,D′,d,d′, and (D) shows the general increasing trend, and that in the types C and c shows mainly the increasing trend and partly the decreasing one.

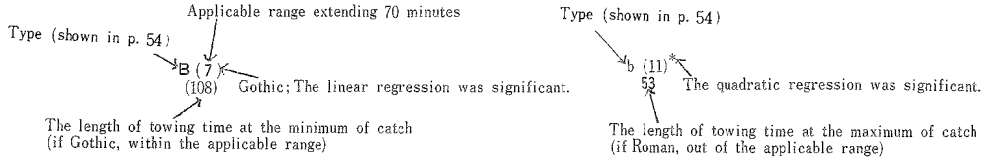
As shown in Table 2, the present analysis revealed that the insignificance of the quadratic regression in the 80 hour-month groups of the records was due to the strong

Table 2. The seasonal and daily rhythmic change of the catch-time relation within the applicable range.

Season	The hour shooting the net 1	3	5	7	9	11	13	15	17	19	21	23	AA′ aa′ (A)	B	b	C	c	DD′ dd′ (D)	F
Jan. '69	A′(9) (112)	A′(9) (103)	B(8) (58)	A′(9) (91)	D′(7) (38)	a′(5) 23	a (6) 1	b (11)* 53	d (9) 122	B(6) (102)	b (5) 75	d′(7) 100	5	2	2			3	
Fed.	b (10) 66	c (9) 88	B(3) (75)	d (5) 95	b (6) 28	D′(7) (18)	a′(5) 25	A′(11) (96)	A′(10) (98)	A (5) (128)	C (5) (94)	b (9)* 105	4	1	3	1	1	2	
March	A′(10) (114)	D′(17) (50)	b (9)* 39	C (10) (45)	C (9) (44)	b (7) 39	C (9) (41)	A (11) (250)	B (10) (82)	B (9) (82)	(D)	(12)	D′(8) (61)	2	2	2	3		3	
April (A)			c (7)* 68	c (7) 58	a (5) 8	B (4)* (41)	c (6) 55	B (6) (51)	a (7) −150					2	2			3		
April (B)	a (6) −94	A (8) (195)	C (3) (74)	B (6) (60)	c (5) 74	b (6) 66	D (8) (20)	d (3) 136	b (3) 102	a (3) 45	B (8) (94)	a′(4) 63	4	2	2	1	1	2	
May	A (4) (275)	c (8) 88	A (5) (271)	B (7) (108)	a′(8) 66	d′(7) 101	A (6) (191)	C (4) (68)	C (4)* (107)	b (4) 108	a′(6) 75	B (6) (93)	5	2	1	2	1	1	
July	b (7) 109	c (13) 139	D (13) (−500)	C (18) (83)	A′(11) (106)	B (13) (114)	A′(16) (183)	C (13) (86)	B (11) (93)	B (10) (115)	(A)	(8)	b (9)* 105	3	3	2	2	1	1	
Aug.	b (8)* 95	d′(10) 127	A′(9) (114)	A (7) (134)	C (7) (84)	d′(7) 98	B (8) (90)	C (11) (89)	c (9) 89	b (7) 94	a (9) 25	A′(10) (125)	4	1	2	2	1	2	
Sept.	c (10) 104	A′(5) (110)	C (6) (80)	A (6) (156)	a′(9) 67	A (9) (138)	c (7) 98	a (9) −100	B (8) (94)	D (7) (39)	A (8) (217)	c (8) 100	6	1		1	3	1	
Oct.	C (5) 103	d (8) 161	d′(8) 136	D′(5) (67)	A′(7) (115)	c (9) 82	b (9) 85	b (6) 95	C (4) 107	D′(5) (95)	C (5) (91)	c (10) 106	1		2	1	4	4	
Nov.	C (4) (107)	C (6) (88)	c (7) 92	c (7) 96	B (6) (92)	B (6)* (124)	d (13) 213	d (9) 267	b (4) 109	C (5) (104)	c (8) 109	C (5) (122)		2	1	4	3	2	
Jan. '70	D′(4) (89)	c (7) 119	d (7) 200	B (9) (84)	A (10) (325)	a (7) 21	D (8) (0)	A′(9) (93)	B (5)* (117)	c (6) 102	c (5) 127	A′(7) (115)	4	2			3	3	
Feb.	D (13) (30)	d (9) 148	B (12) (124)	D (13) (−200)	B (7) (101)	C (7) (91)	c (8) 103	B (10) (106)	c (9) 116	d (7) 155	d′(9) 166	C (3) (130)		3		2	2	5	
March	c (7) 104	C (12) (90)	c (10) 86	D′(9) (60)	b (7) 62	D′(10) (36)	C (10) (56)	D (9) (−13)	c (12) 88	d (6) 375	d′(6) 109	d′(6) 93			1	2	3	6	
April	C (5) (111)	B (5) (97)	B (10) (100)	c (8) 72	A′(7) (105)	D′(9) (67)	B (12) (111)	D (11) (17)	A′(16) (150)	C (9) (133)	D (5) (85)	b (7) 113	2	3	1	2	1	3	

Jan. to Sept. in 1969	1) AA′ aa′ (A)	4	3	2	3	4	2	4	3	2	2	4	2
	2) B			2	2		2	1	1	3	3	1	1
	3) b	3		1		1	2		1	1	2	1	2
	1)+2)+3)	7	3	5	5	5	6	5	5	6	7	6	5
	4) C			2	2	2		1	3	1		1	
	5) c	1	3	1	1	1		2		1			1
	6) DD′ dd′ (D)		2	1	1	1	3	1	1	1	1	1	2
	4)+5)+6)	1	5	4	4	4	3	4	4	3	1	2	3
Oct. '69 to April '70	7) AA′ aa′ (A)					3	1		1	1			1
	8) B		1	2	1	2	1	1	1	1			
	9) b					1		1	1	1			1
	7)+8)+9)		1	2	1	6	2	2	3	3			2
	10) C	2	2				1	1			2	1	2
	11) c	2	1	2	2		1	1		3	1	2	1
	12) DD′ dd′ (D)	2	2	2	3		2	2	3		3	3	1
	10)+11)+12)	6	5	4	5		4	4	3	3	6	6	4

Legend



bias of the length of towing time at the maximum or the minimum of catch; however, it was hard to find the reason of making the quadratic regression coefficient in the other groups insignificant. The results making the interpretation complicated was that the 20 concave curves showed the general increasing trend and the 28 concave ones showed the decreasing trend and the 18 convex ones showed the increasing trend and the 14 convex ones showed the decreasing trend. However, the distribution of the groups showing the increasing (or the decreasing) trend showed the seasonal and daily rhythmic change.

The examination on the linear regression coefficient showed the similar results: namely, about a half of the hour-month groups took the positive linear regression coefficient and the other half took the negative one, and most of the coefficients were insignificant (significantly positive in the five groups, insignificantly positive in the 85 groups, insignificantly negative in the 80 groups, and significantly negative in the five groups). However, the distribution of the groups showing the increasing trend (or the decreasing one) showed the seasonal and daily rhythmic change.

And the results of these examinations on the quadratic and linear regressions of the amount of catch by a towing on the length of towing time were summarized as follows:

1. The amount of catch by a towing in the 155 hour-month groups of the records out of the 175 ones showed neither the significant quadratic regression nor the significant linear one on the length of towing time.
2. The trends found in the hour-month groups showing significant regression were
   - Linear decrease ..... 5 groups
   - Concave (the applicable range covering mainly the decreasing half) ..... 3 groups
   - Convex (covering mainly the decreasing half) ..... 5 groups
   - Linear increase ..... 5 groups
   - Concave (covering mainly the increasing half) ..... 1 group
   - Convex (covering mainly the increasing half) ..... 1 group
3. When whether the regression coefficient was significant or not was left out of consideration, the groups showing the decreasing trend were found mainly in the daytime before September in 1969 and those showing the increasing one were mainly at night after October in 1969.

2. The bi-hourly change of the catch-time relation

As mentioned above, the catch by a towing in most of the hour-month groups of the records showed neither the significant quadratic regression nor the significant linear one on the length of towing time. However, the distribution of the groups showing either the positive linear regression or the negative one suggested the seasonal and hourly change of the catch-time relation. The amount of catch by a towing varies not only the regression coefficient and the applicable range but also the constant of the regression equation. However, the examinations in the preceding section did not touch the influence of the constant of the equation. For the purpose of finding out the hourly change of the

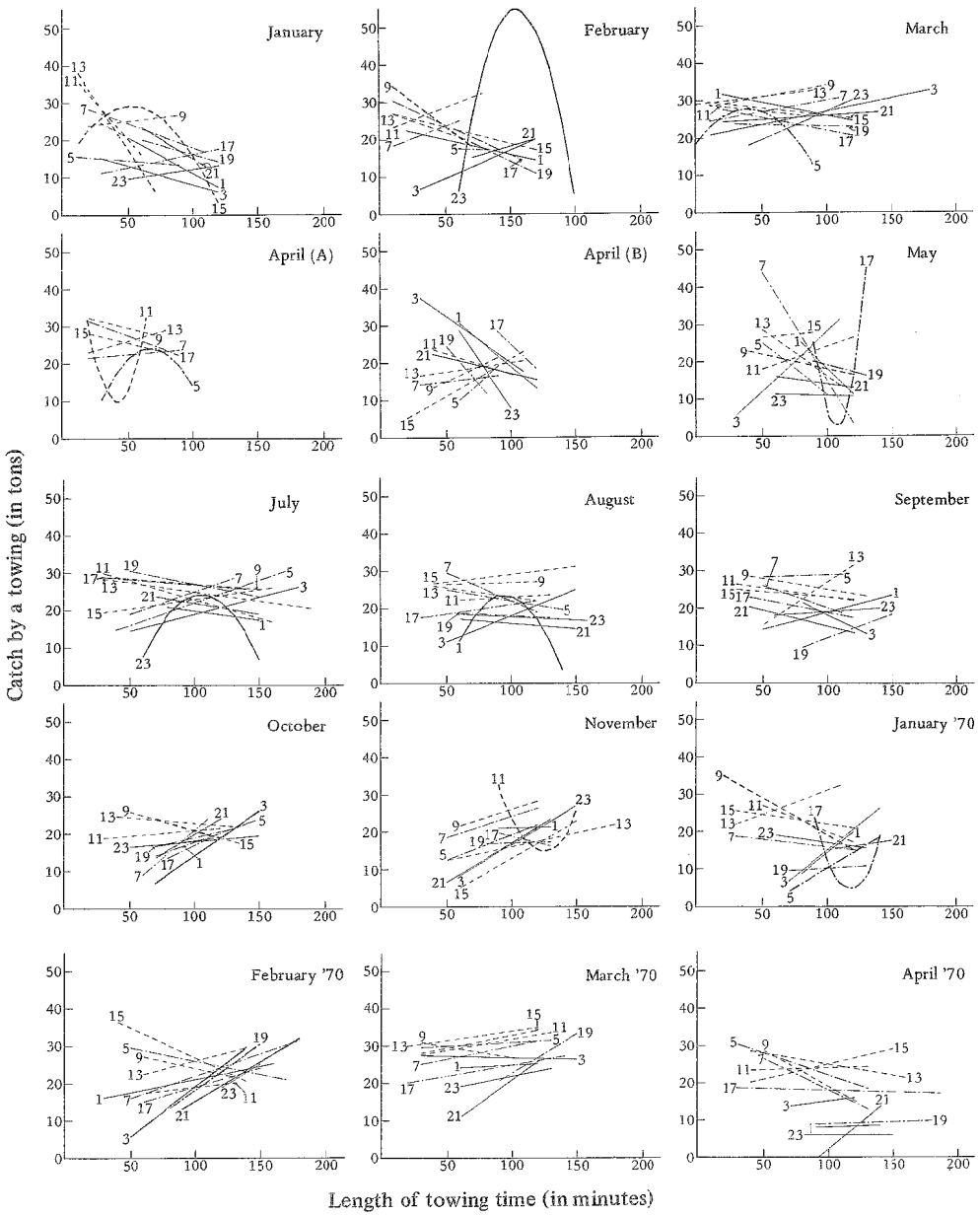


Fig. 1. The bi-hourly change of the catch-time relation.

Note: Curve . . . . . The stratum showing the significant quadratic regression
Thick line . . . . . That showing the insignificant quadratic regression but the significant linear one
Thin line . . . . . That showing neither the significant quadratic regression nor the significant linear one
The numerals attached the lines are the hour of shooting the net.

catch-time relation, accordingly, the estimated regression lines for the different hour groups in the same months were compared one another with the assistance of Fig. 1, and the following trends were found out: the first trip covered from January to May in 1969. In January and February in 1969, the towing time in the daytime was short and showed a small variation. The catch by a towing was very good, but the catch by a towing decreased sharply in accordance with the increase of towing time. At night, the towing time was elongated and showed a wide variation. The catch by a towing at night was poorer than that in the daytime and showed a slight decrease in accordance with the increase of towing time. Thus, the decreasing trend of catch in accordance with the increase of towing time found in the preceding report[2] was observable even after the stratification of the records according to the hour of shooting the gear. And the different work pattern according to the hour was suggested. In March, the short towing in the daytime did not supply very abundant fish, and the extended range of the towing time offset the decreasing trend of catch in accordance with the increase of towing time. The similar change occurred at night, too. In consequence, the range of the towing time was extended, and the amount of catch by a towing was equalized; and the probable difference of the density of the population in the fishable state (near the sea floor) was shown by the variation of the length of towing time. In April (Ground A) the boat yielded a good catch by a short towing. This fact made the boat repeat frequent towings. And she could yield sufficient fish during the daytime, and there was no need to tow the net at night expending many efforts for yielding a poor catch. The ground B was in a very shallow water. And the trend roughly contrary to that found in January and February was observable. However, it was hard to find its reason. May was the month of the longest daytime (the boat did not fish in June). The clearest trends in this month were the difference of catch roughly suggesting the daily rhythmic change and the lack of the records of the short towings.

The second trip covered from July to November in 1969. In July, the towing time showed a large variation, but the catch by a towing showed neither clear regression on the length of towing time nor clear daily rhythmic change except that the catch by a short towing in the daytime was better than that at night. In accordance with the passing of the season from July to October, the following trends were observable: the variation of the towing time became smaller, because of the lack of the short towings. The amount of catch did not show any clear regression on the length of towing time; however, the diversity of the regression lines suggestive of the daily rhythmic change of the work pattern became clearer. The catch by a towing became poorer. The number of the hour-month groups showing the positive regression increased; this trend was clearer at night than in the daytime, although most of the regression coefficients were insignificant. And in November, the amount of catch by a towing in most of the hour groups showed the insignificantly positive regression on the length of towing time.

The third trip covered from January to April in 1970. In January, a large daily rhythmic change of the probable density of the population in the fishable state was suggested by the shift of the regression lines on the graph — not only in the constant but also in the

applicable range. During the daytime the regression coefficient inclined to be negative and that at night inclined to be positive. In February, the catch by a long towing yielded a similar amount of catch regardless of the hour; however, the variation of catch by a short towing loosely relating to the hour caused the diversity of the regression lines, although the coefficients in most of the hour groups were insignificantly positive. In March, the difference of the catch-time relation according to the hour was mainly due to the different constant — large in the daytime and small at night. In April, the probable daily rhythmic change of the density of the population in the fishable state, especially the decline of catch at night, was suggested by the constants and the shortest limits of the applicable range of the towing time.

Thus, it may be said that the catch by a towing of the same time length was better in the daytime than at night; however, the pattern of the daily rhythmic change of the catch-time relation differed according to the month — either in the applicable range (short in the daytime and long at night), or in the coefficient (negative in the daytime and positive at night), or in the constant (large in the daytime and small at night). And in accordance with the passing of the season, the change similar to that from the daytime to the night was observable.

3. The seasonal change of the catch-time relation

The third report[3] revealed the clear daily rhythmic change of the length of towing time and the amount of catch. And the examinations in the preceding sections revealed many facts suggestive of the daily rhythmic change of the catch-time relation. For the purpose of clarifying the seasonal change of the catch and the work pattern, accordingly, the regression lines observable in the records of the same hour should be compared with one another. In the present case, however, the following facts made the analysis complicated: the fishing ground was in the high latitudinal waters, and the length of daytime showed a large seasonal change. The lines in the hour classes 1 : 00 and 23 : 00 showed the relations at night and those in the hour classes 11 : 00 and 13 : 00 showed the relations in the daytime throughout the seasons. In the other hour classes, some of the lines showed the relations in the daytime and the others showed those at night or dawn or dusk according to the season. The other fact making the analysis complicated was as follows: the records used in the present series were those just after entering a new fishery into the probably unexploited population. And the length of towing time was elongated in accordance with the passing of season. The records covered more than a year, but the catch and the work pattern in the same months of the succeeding years differed completely. This fact aroused a doubt if the results would show the seasonal change. These facts were taken into account, and the following trends common to all the hour groups in a month or common to some consecutive hour groups were found out: the short towing and the clear decreasing trend of catch in accordance with the increase of towing time were the characteristics of the hour groups in January and February in 1969. These trends were clearer in the daytime and less clear at night. The good

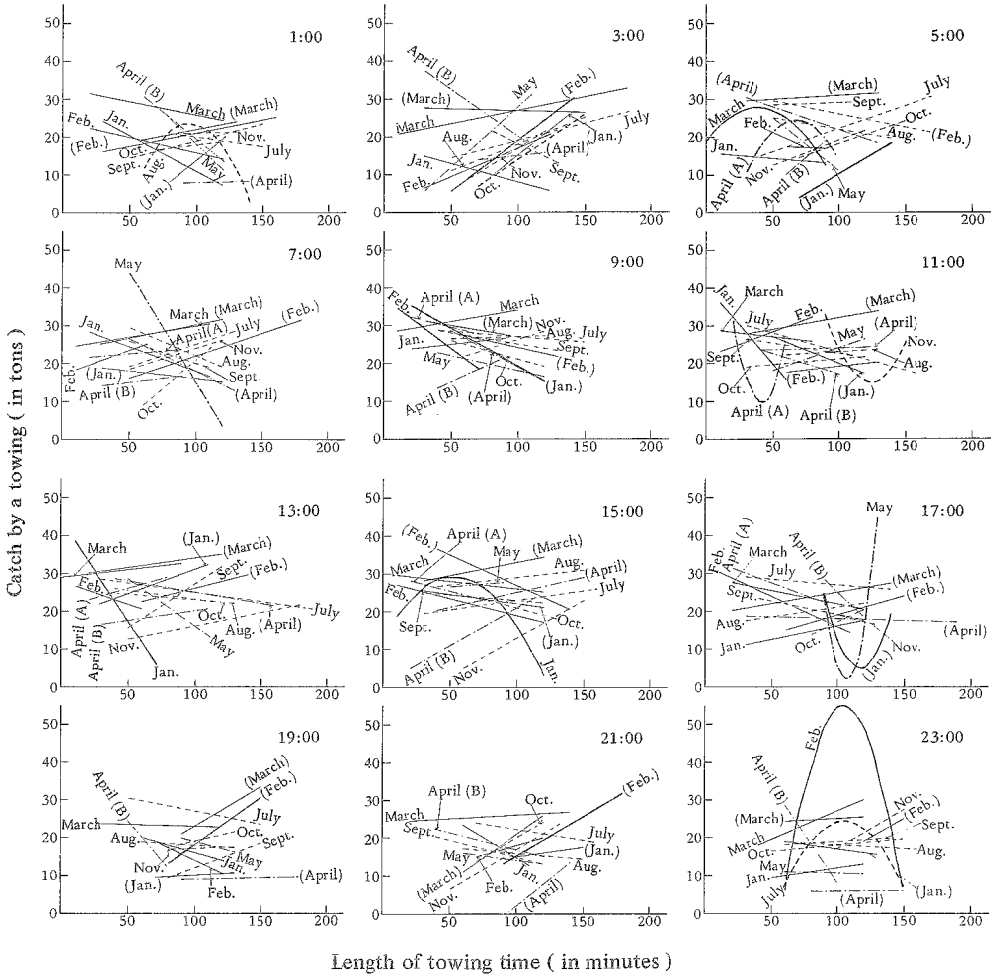


Fig. 2. The seasonal change of the catch-time relation.

Note: The month in parentheses is in 1970.

daily catch in these months was partly due to better catch by a towing of the same time length than that in the other months but mainly due to the frequent towings as the results of the short towing in the daytime. The catch by a towing in March was better than that of the other months throughout the hour groups. In April in 1969, the short towing made it possible to repeat the frequent towings. This resulted in a good daily catch. The towing time in May showed a small variation, because of the lack of both the short towings and the long ones. When the catch by the towing of the same time length were compared with one another, it may be said that the catch in this month was poorer than that in the other months throughout the hour groups. The length of

towing time showed the widest variation in July. It was found out, when the catch by the towings of the same time length in the different months were compared with one another, that the catch by a towing in the evening (17 : 00 to 21 : 00) in this month inclined to be better than that in the other months. In most of the hour groups, the regression lines for August, September, and October showed the similar trend to one another. It could also be known by the same comparison that a towing in these months yielded neither remarkably poorer catch nor remarkably better catch than that in the other months. In January in 1970, the catch by a towing of the same time length at night was poorer than that in the other months, although that in the daytime did not show any clear difference from that in the other months. In February in 1970, catch by a towing showed an increasing trend in accordance with the increase of towing time in most of the hour classes. The catch by a towing in March in 1970 was better than that in the other months. In April in 1970, the catch by a towing of the same time length in this month was poorer than that in the other months.

Thus, the daily catch in the earlier months was better than that in the other months, partly because of a good catch by a towing of the same time length but mainly because of the frequent towings as the results of the short towings. In accordance with the passing of the season, first the long towings were added; in consequence, the variation of the length of towing time was widened. Second, the short towings disappeared; this resulted in less frequent towings. And last, the catch at night became conspicuously poorer than that in the earlier months, although that in the daytime showed a slight decrease.

Discussion

The clearest results found in the present report were that the amount of catch by a towing did not show any significant quadratic and linear regressions on the length of towing time in the 155 hour-month-ground strata of the records out of the 175 ones and that about a half of the strata took the insignificantly positive linear regression coefficient and the other half took the insignificantly negative one. In most of the fishing methods, it is hard to estimate the catch during the fishing work or hard (or of no use) to change the length of fishing hour for the purpose of adjusting the amount of catch by a haul. In these fishing methods, the variation of the time for completing a haul is small or depends on the length of the time for brailing work. And it is rare that the time for completing a haul shows a large variation independently of the amount of catch. In the present case, however, it was possible to estimate roughly the catch in the net during the towing, and it was possible to change the length of towing time for the purpose of adjusting the amount of catch by a towing. When abundant fish entered in the net during the towing, the boat cut down the towing time and hauled up her net for the purpose of mainly making it possible to repeat frequent towings over the ground of high density and partly preventing the net from lowering efficiency on account of over-packing the

catch. And when it was hard to expect a good catch by a short towing, she towed her net over many hours till yielding a certain level of catch. In these cases, the variation of the density of the fish in the fishable state should be understood in the form of the regressive relation of the amount of catch on the length of towing time. And the present results may indicate the following fact: the variation of the density of the population in the fishable state in the same hour in the same month on the same ground was large but within the range of yielding the similar amount of catch by adjusting the length of towing time, and that the boat adequately adjusted the length of towing time according to the density and yielded the similar amount of catch by a towing. And the different density within the same hour-month-ground strata of the records was found in the variation of the length of towing time. Accordingly, the daily rhythmic and seasonal change of the bathymetric distribution of the density of the population in the fishable state will be examined in the succeeding report by using the length of towing time in stead of either the amount of catch by a towing or that per unit hour of towing.

As mentioned above, the catch by a towing showed the insignificant quadratic and linear regressions on the length of towing time in most of the hour-month-ground strata of the records. However, it may be better to give some significance on the linear regression, because the distribution of the groups showing positive (or negative) linear regression showed a seasonal and daily rhythmic change. The decreasing trend of catch in accordance with the increase of towing time does never mean the escape of fish in the net during the towing but shows the pattern found in the following case: the density variation is severe, and the difference of catch due to it is hardly filled up by adjusting the length of towing time or it is possible to find a dense school by a short scouting and the increase of the catch from the newly detected dense school may easily fill up the probable decrease of catch due to the inefficient towing over the ground of low density and due to the loss of towing time for hauling up the net, scouting the school, and shooting the net again. The preceding reports[1) 3)] revealed that the boat fished over the dense schools in the earlier season and in the daytime. However, there remained a doubt in these findings, because either the influence of the daily rhythmic change of the work pattern or the different length of towing time according to the haul was not taken into account in these reports. The present report swept out the doubt, and revealed that the decreasing trend was found mainly throughout the hours in the earlier months or in the daytime throughout the seasons, namely in the hour-month groups of attacking the dense population in the fishable state.

The increasing trend of catch in accordance with the increase of towing time (positive coefficient and small constant) is the type expected to be observable when the variation of the density is small, because the amount of catch per unit hour of towing shows either only a slight decrease (positive constant) or a slight increase (negative one) in accordance with the increase of towing time. In most of the cases, the amount of catch per hour of towing is very small. Namely, this type is found during the work on the ground of low density of the population in the fishable state. The second report[2)] revealed that this type was least frequently observable (only in the shallow zones in October and

November in 1969), as if the well-equipped boat did not fish on the grounds of low profitability. On the other hand, the first report[1] showed that the towing time was elongated in accordance with the passing of the season, although the amount of catch by a towing did not show any clear change. And the third report[3] showed that the length of towing time and the amount of catch showed clear daily rhythmic change (the towing time was long and the catch was poor at night). These findings aroused a doubt whether the boat would not commit the inefficient work even at night in the latter half of the season. The present report revealed that the increasing trend of catch in accordance with the increase of towing time was found at night after October in 1969. Namely, the boat was well equipped but she was obliged to fish over the ground of low profitability during the hours and months difficult to find out the dense schools in the fishable zone (near the sea floor).

In about a half of the months, the linear regression coefficient in most of the hour groups was small (either positive or negative) and the constant varied as if it represented the daily rhythmic change of the density of the population in the fishable state. However, this impression was wrong. The hourly change of the constant of the lines with the small coefficient does never mean that of the density but means that of the work pattern mainly indebted to the administrative reason. The hourly difference of the density is found in the different catch by the towing of the same time length; while the variation of the density within the same hour was found in the variation of the length of towing time. The latter was far larger than the former. However, the following facts made it hard to deny the daily rhythmic change of the density: in general, the constant of the catch-time line in the hour groups of the daytime was larger and the applicable range covered the classes of shorter towings than those at night. These facts meant that the probable daily rhythmic change of both the density of the population in the fishable state and the catch per hour may be far clearer than those shown by the daily rhythmic change of either the constant or the catch by a towing.

In the examination of the seasonal or the hourly change of the catch-time relation, some trends characteristics of some of the months were found out; however, it was hard to find those characteristics of the hour groups. This fact may be due to the following reasons: the former ones are the trends observable in the records of the consecutive works under the same conditions except in respect of the hour, but the latter ones are observable in the comparison of the records in the different months working under the different conditions. The meaning of the same hour differs according to the season because of the large seasonal change of the length of daytime in the high latitudinal waters.

The other point of the seasonal change to be discussed was as follows: the trends changed in accordance with the passing of the season, and it was hard to find the cyclic change relating to the season in spite of the fact that the records covered the 16 consecutive months. In consequence, the trends of the same months in the succeeding years showed a large difference. This may be due to the fact that the records covered the seasons from just after entering of a new fishery into the probably unexploited population to the state before the new equilibrium of the population to the fishing

effort.

Conclusion

All the results of the examinations and the discussions were summarized, and it may be concluded as follows:

The variation of the density of the population in the fishable state was still large after stratification of the records of the same months into the classes of 2-hour intervals according to the hour of shooting the net, as shown in the variation of the catch per unit hour of towing. For the purpose of equalizing the amount of catch by a towing, the boat adequately adjusted the length of towing time according to the variation of the density observable within the same hour of the same months, as shown by the insignificant linear regression of the amount of catch by a towing on the length of towing time and the variation of the latter. And the probable daily rhythmic and seasonal change of the density made the adjustment different according to the hour and season: the groups of the records taking the negative linear regression coefficient, which was the pattern suggestive of the work for the dense schools, were found mainly throughout the hours in the earlier months or throughout the months in the daytime, and those taking the positive one, which was the pattern suggestive of the work for less dense population, were found mainly at night after October in 1969, although the coefficient was insignificant in most of the groups. The seasonal and hourly difference of the catch-time relation showed that of the adjustment; and that of the density of the population in the fishable state may be far larger than that shown by either the constant of the regression line (the coefficient in most of the hour groups was small) or the amount of catch by a towing.

Summary

The preceding reports revealed that (1) the minced fish factory trawler sometimes towed her net over many hours and yielded a poor catch and that (2) the catch by a towing and the length of towing time showed clear daily rhythmic change. For the purpose of finding out whether the above-mentioned inefficient work pattern was observable throughout day and night or only in the limited hours, accordingly, the catch records by a stern ramp factory trawler of about 4,000 gross tons during the season from Dec. '68 to April '70 along the outer edge of the continental shelf of the Eastern Bering Sea were stratified according to the hour of shooting the net, the month, and the ground; and the quadratic and linear regressions of the amount of catch by a towing on the length of towing time were examined, and the following results were obtained:

1. The amount of catch by a towing in the 155 hour-month-ground groups of the records

out of the 175 ones showed neither the significant quadratic regression nor the significant linear one on the length of towing time.

2. When whether the regression coefficient was significant or not was left out of consideration, the groups showing the decreasing trend of catch in accordance with the increase of towing time were found mainly in the daytime before September in 1969 and those showing the increasing one were mainly at night after October in 1969.

3. The catch by a towing in the daytime was better than that at night; however, the pattern of the daily rhythmic change of the catch-time relation differed according to the month — either in the applicable range, the coefficient, or in the constant.

4. In accordance with the passing of the season, first, the long towings were added; second, the short towings disappeared; and last, the catch at night became poorer than that in the earlier months, although that in the daytime showed a slight decrease.

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2) MAÉDA, H., 1974: *ibid.*, 22, 147-165.
3) MAÉDA, H., 1974: *ibid.*, 22, 167-176.