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The Distribution Pattern of Squids Caught by the Automatic Powered Reel-II*

Decline of Catch and Change of Jigged Pattern

By
Hiroshi MAÉDA

The squid angling by the automatic powered reel is one of the representatives of the fisheries newly developed as the results of the adaptation to the recent change in the social backgrounds of our fisheries. The rapid expansion of our industries brought the labor shortage and rise in wage. The fisheries could naturally not be free from its influence, and our fishing boats were obliged to modify the system capable of working with less hands mainly by mechanizing the work on deck and in processing plant. The introduction of new deck machines and processing system needs frequently the basic remodeling of the boat. It takes many days to remodel the fishing boat. To make it possible to continue the fishing work during remodeling too, the new boat is built during the last few trips of the boat which should be remodeled. This way of renewal of fishing boat can be done only when the new way of using the worn boat is exploited, for the worn boat loses not only her crew but also the fishing license and becomes unable to engage in the same kind of fishing, in spite of the fact that this boat was still serviceable if the social backgrounds were not changed abruptly. It is natural that the new way of use should need few unskillful hands with the license easy to be issued but need no basic remodeling for the purpose of saving the cost. The squid angling by the automatic powered reel is one of the ways most suitable to the above-mentioned conditions. This is the reason why a new type of fishing with large but worn boat using the simple device could develope and continue the work without economic and social difficulties.

The angling is one of the most widely spreading fishing methods having the longest history, and is conducted mainly by the individual fishermen using small boats. The squid angling with the automatic powered reel is basically nothing but one of the modifications of the angling, but should be included in one of the modern methods, for this is different from other anglings in many respects, for example, the origin of invention, the size of boat, the application of power and control system of handling the gear automatically, the system of handling the landing, the supporting system, and the size of enterprise adopting this method.

In the ordinary way of angling, the catch deeply depends on the skill and temperament of the individual fishermen. The psychological conditions of the fisherman fluctuate during a consecutive work depending on that of catch, which has the possibility of amplifying the latter: During a long lapse of poor catch, the fisherman inclines to be relaxed and is easy to miss

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the catch. On the other hand, during the hours of good catch the fisherman works exciting and earnestly for catching as much fish as possible. And it is hard to take the technical difference of individual fishermen into account the analysis of catch records; in addition, it is difficult to find the relation between the catch and the environmental conditions correcting the fluctuation due to that of the fishing activities according to the conditions through the above-mentioned reasons. The basic difference of this method from the other anglings in technical point of view is as follows: The man-to-man correspondency is the basic rule of the angling since long ago. In the method examined here, however, all the sets of the powered reels repeat swings automatically. The master fisherman checks its amplitude and periodicity, if necessary. All the hands engage in the work of packing and icing the catch gathered through the shooter cannal or arranging the tangled lines but do not handle the gear directly. This change in the work pattern of the man on board makes it possible to collect the catch records free from the difference of the skill and fluctuation of the fishing activity throughout the consecutive work.

In the preceding report[1] were examined the records collected from the Yamatotai Bank during the summer of 1971 for the purpose of showing the catch pattern as the bases of giving consideration on the reason why it is possible to substitute the simple device for the human's skill in the angling which is the method thought to be indispensable the human's fine techniques. Recently the catch showed a marked decline till the level difficult to sustain this fishery economically. In the present report were, accordingly, examined the records collected from the same area in the summer of 1975. And it was found out that the decline of catch brought the changes in the catch pattern in many points. The details were shown in the present report.

Before entering the subject, the author wishes to express his hearty thanks to Mr. T. Shimada for his assistance of collecting the records used in the present report.

Materials and Methods

The boat chosen for collecting the records of the present study was constructed originally as an off-shore tuna longliner but was converted into this fishery without any remodeling of hull and superstructure except installing the indispensable equipments. The 10 3000-w lamps were hung 3 m high from sea surface along the center line between the forecastle and wheelhause and the eight ones were about the same height along the center line over the engine casing and poop deck for concentrating the squids. The seven sets of automatic powered reels were installed along the starboard bulwark and the same number along the port one. A set of reel had a pair of drums. All the sets of lines were swung automatically at the same amplitude and periodicity, and were adjusted by the master fisherman if necessary. The jigs were in the present case swung at 35-m amplitude and 50 - to 60 - second periodicity. The gear on a drum was the same structure as that used in the first report[1], being consisted of the two parts, a nylon monofilament leader of about 50 m long and a snood. The latter differentiated into the four parts ——— the No. 80 nylon monofilament line, the No.60 one, the No. 40 one, and the No. 20 one, from the shallow end to the sinker (a 670 g lead drop). Only the difference was in the number of jigs: In the preceding case, 20 jigs were attached to the snood at 1-m intervals, but the jigs were increased into 23 although their intervals were the same. In spite of the marked decline of catch, the work pattern was the same: The boat started scouting just before the sunset. And as soon as the suitable school to be attacked was detected, the boat put the lamps and started angling. During the angling work, the spanker and sea anchor were used for minimizing the wind drift and making the boat drifted according to the current, i.e. according to the drift of the objective school. During the eight series of consecutive works (the nine examples) in the area shown in Fig. 1 on July 31 to Aug. 7 in 1975, the jig number and the swing number of each of the individuals caught by the quarter drum of the fourth reel on the starboard side were recorded and used in the present study.

Results

1. The frequency distribution of catch by a swing

The rate of the jigs occupied by the squids (mainly *Ommastrephes sloani pacificus*) was extremely low, being 0.0018 to 0.0202 . The examination of the agreeable type of the frequency distribution of the catch by a swing is the step necessary to analyse the fluctuation of catch in the fishing method like this. The simplest theoretical model of the frequency distribution is the binomial one, which is the model observable when the squids are jigged by chance. The observed series of frequency distributions were compared with this model, but they showed tailing in the direction of good catch, although low rate and the insufficient swings in a consecutive work made it hard to test through the chi-square.

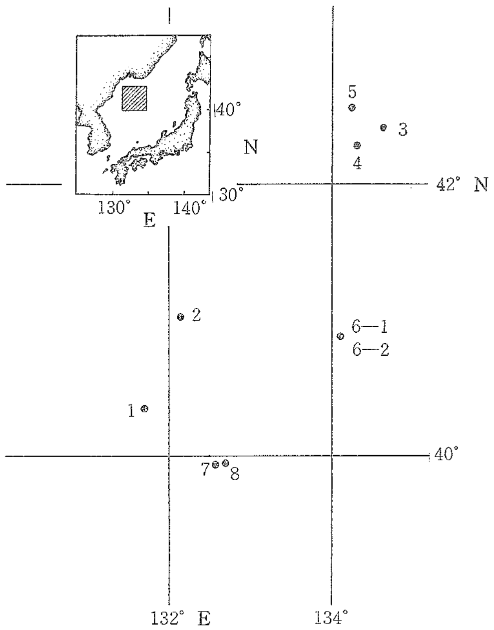

Fig. 1. A sketch chart of the position fished.

Note : The numeral attached to the mark shows the example number.

As the second step of the examination, accordingly, the observed series were compared with the negative binomial ones, and it was found out that the observed distribution showed a close approximation to the negative binomial series, but it was hard to find whether the former was agreeable to the latter or not because of insufficient catch classes with higher frequency than 5 due to low rate of catch and insufficient swings in a consecutive work. These facts suggested the possibility of the squids caught in a weakly contagious pattern.

2. The distribution of catch along the serial jigs

The examination in the preceding step showed the weak contagiousness of catch, and the preceding report revealed that the catch increased with the jig number counted from the shallowest end of the serial jigs. The jigs of very rich variety in coloration and luster are easily available from the ship chandler in the fishing port. This boat used however the redish ones and the greenish ones. But these two types of jigs were arranged at random hardly

Table 1. The frequency distribution of catch by a swing.

	Example 1 (July 31—Aug. 1)			Example 2 (Aug. 1—2)			Example 3 (Aug. 2—3)		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a swing 0	326	315.71	323.90	392	387.34	391.19	224	190.28	222.92
1	22	40.68	27.16	8	16.33	9.87	49	90.07	48.50
2	9	2.51	5.83	3	0.33	2.10	14	20.39	18.15
3	2	0.10	1.51	1	0.00	0.58	9	2.94	7.74
4		0.00	0.42		0.00	0.18	5	0.30	3.50
5		0.00	0.12		0.00	0.06	2	0.02	1.64
6		0.00	0.04		0.00	0.02	0	0.00	0.79
7		0.00	0.01		0.00	0.01	1	0.00	0.38
8		0.00	0.00		0.00	0.00		0.00	0.19
9		0.00	0.00		0.00	0.00		0.00	0.09
10≦		0.00	0.01		0.00	0.00		0.00	0.10
M	359			404			304		
N	46			17			141		
p		0.00557			0.00183			0.02017	
p'			1.52830			1.66793			2.13185
n			0.24254			0.06300			0.40979
χ_0^2									1.42092
df.									2
Pr.									0.50—0.25

	Example 4 (Aug. 3—4)			Example 5 (Aug. 4—5)			Example 6—1 (Aug. 5)		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a swing 0	351	331.90	347.60	304	282.73	301.86	151	149.49	150.73
1	29	60.52	36.14	46	79.58	50.89	9	12.04	9.79
2	12	5.28	9.56	17	10.71	14.31	2	0.46	1.25
3	5	0.29	3.04	5	0.92	4.56		0.01	0.19
4	1	0.01	1.05	1	0.06	1.54		0.00	0.03
5		0.00	0.38	1	0.00	0.54		0.00	0.00
6		0.00	0.14		0.00	0.19		0.00	0.00
7		0.00	0.05		0.00	0.07		0.00	0.00
8		0.00	0.02		0.00	0.03		0.00	0.00
9		0.00	0.01		0.00	0.01		0.00	0.00
10≦		0.00	0.01		0.00	0.00		0.00	0.01
M	398			374			162		
N	72			104			13		
p		0.00787			0.01209			0.00349	
p'			1.74013			1.64941			1.23507
n			0.24442			0.42819			0.34138
χ_0^2						0.99124			
df.						1			
Pr.						0.50—0.25			

showing any regularity in the arrangement. And when the damaged jigs were replaced, it was hard to say that they were by those of the same coloration. For finding out the reason why the catch by a swing shows a weak contagiousness, accordingly, the regression of catch on the jig number counted from the shallowest end was examined. As shown in Table 2 , the estimated cubic regression was significant (at 0.05 level) only in one of the examples out of the nine ones, but even this example practically showed a sharp increase of catch in the deepest few jigs. The quadratic regression coefficient was positive in all the nine examples, although that in the two examples was insignificant. These facts meant that the catch showed a con-

Table 1. (cont'd.)

		Example 6—2 (Aug. 5—6)			Example 7 (Aug. 6—7)			Example 8 (Aug. 7—8)		
		Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a swing	0	111	103.96	110.77	480	453.41	472.80	500	482.75	499.99
	1	31	41.20	31.14	66	115.39	84.76	55	83.89	56.10
	2	8	7.81	8.71	33	14.05	19.79	16	6.97	12.95
	3	3	0.94	2.43	5	1.09	4.98	1	0.37	3.50
	5	1	0.08	0.68		0.06	1.30	1	0.01	1.02
	5		0.01	0.19		0.00	0.34	1	0.00	0.31
	6		0.00	0.05		0.00	0.09		0.00	0.10
	7		0.00	0.01		0.00	0.03		0.00	0.03
	8		0.00	0.00		0.00	0.01		0.00	0.01
	9		0.00	0.00		0.00	0.00		0.00	0.00
	10≦		0.00	0.02		0.00	0.00		0.01	0.00
	M	154			584			574		
	N	60			147			99		
	p		0.01694			0.01094			0.00750	
	p'			1.38606			1.40375			1.53728
	n			1.00921			0.62343			0.32102
	χ_0^2						13.53640			
	df.						1			
	Pr.						0.005>			

Note : Ob.....Observed series
B .....Binomial series
Nb.....Negative binomial series
M......Number of swings
N.....Number of squids caught by the M consecutive swings
p......Occupied rate of jig, i.e. $N/23M$
p' and n.....Estimated parameters of the negative binomial series, i.e.

$$p' = \frac{s^2}{\bar{x}} - 1 , \quad n = \frac{\bar{x}}{p'} \quad \text{and} \quad \bar{x} = \frac{N}{M}$$

cave relation to the jig number, although no more than a negligible number of squids was caught by the jigs shallower than the estimated minimum. It may be, accordingly, said that the catch showed a sharp increase with the jig number. And naturally the linear regression coefficient was significantly positive in all the examples.

3. The elimination of the influence of vertical dishomogeneity of catch from the frequency distribution

As the preceding two sections threw a doubt as to the weak contagiousness of catch being derived from the increasing trend of catch with the jig number counted from the shallowest end, the frequency distribution of catch was examined again through the following methods: The records were stratified into the 23 groups according to the jig number, and were sectioned into the lots of 10-consecutive swings. When the squids are jigged by a swing or not has no relation to the fact that the other individuals are jigged by the succeeding one, the

Table 2. The estimated regression equations of the catch on the jig number.

1) Cubic regression

Example No.	a_0	a_1	a_2	a_3	F_3
1	0.3	−0.15	0.029	−0.0006	0.168
2	−0.6	0.40	−0.057	0.0022	7.545*
3	3.0	−1.60	0.185	−0.0038	1.056
4	0.6	0.27	−0.022	0.0014	0.819
5	1.2	−0.56	0.039	0.0009	0.054
6−1	−0.7	0.39	−0.042	0.0013	3.740
6−2	0.9	−0.37	0.041	−0.0005	0.135
7	4.1	−2.00	0.212	−0.0041	1.620
8	2.3	−1.20	0.129	−0.0024	1.543

2) Quadratic regression

Example No.	b_0	b_1	b_2	F_2	Min. x	Min. y
1	−0.2	0.05	0.009	1.207	−2.83	−0.251
2	1.1	−0.37	0.022	17.349**	8.46	−0.515
3	0.1	−0.27	0.049	5.414*	2.75	−0.264
4	0.5	−0.22	0.028	9.986**	3.93	0.050
5	1.8	−0.86	0.069	11.179**	6.21	−0.844
6−1	0.3	−0.08	0.006	2.213	6.11	0.070
6−2	0.5	−0.21	0.024	12.191**	4.31	0.084
7	0.9	−0.55	0.064	11.307**	4.26	−0.254
8	0.5	−0.37	0.044	15.721**	4.23	−0.295

3) Linear regression

Example No.	c_0	c_1	F_1
1	−1.0	0.25	30.060**
2	−1.1	0.16	14.007**
3	−4.8	0.91	43.750**
4	−2.3	0.46	52.123**
5	−5.1	0.80	28.805**
6−1	−0.3	0.07	8.282**
6−2	−1.9	0.38	53.753**
7	−5.5	0.99	51.906**
8	−3.9	0.68	63.753**

Note : Cubic regression equation $y = a_0 + a_1x + a_2x^2 + a_3x^3$
Quadratic regression equation $y = b_0 + b_1x + b_2x^2$
Regression line $y = c_0 + c_1x$
where x is the jig number counted from the shallowest end, and y is the number of catch by M consecutive swings.
F_i.....The Snedecor's F value for the i-th order coefficient in the i-th order regression equation.
* significant at 0.05 level ** significant at 0.01 level

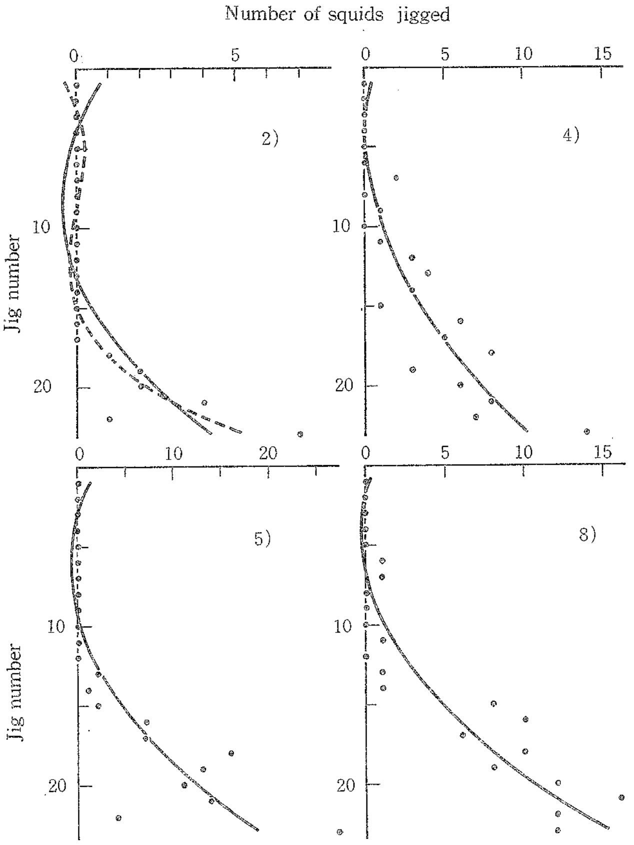

Fig. 2. The change of the number of catch in accordance with the jig number counted from the shallowest end.

Note : The numeral with parenthesis shows the example number. The solid curve shows the estimated quadratic regression equation, and the broken one the cubic one.

frequency distribution of the lot with j individuals caught by the i-th jig is illustrated by the following equations:

$$f_{(i \cdot j)} = m_{10}C_j p_i^j q_i^{10-j}$$

where $q_i = 1 - p_i$

and $p_i = \frac{a_0 + a_1 i + a_2 i^2 + a_3 i^3}{M}$, or $\frac{b_0 + b_1 i + b_2 i^2}{M}$, or $\frac{c_0 + c_1 i}{M}$

m is the number of lots, being a positive interger between ($M/10-1$) and $M/10$, the numerator of p_i is the regression equations shown in Table 2, and M is the number of consecutive swings.

The observed series of the frequency distribution and the estimated ones through the above-mentioned equations were shown in Table 3. This table revealed that the contagiousness of catch in all the examples could be explained by the above-mentioned mechanism.

4. The change of catch in accordance with the lapse of working hour

The examinations in the preceding section showed the possibility of the contagiousness of catch derived from the vertical dishomogeneity of catch. The above-mentioned examination was, however, insufficient, for this examination did not treat the sequence of respectively occupied swings (or lots) along the time flow in spite of its fundamental importance in the case like now in consideration. To fill up this insufficiency of the examination, the regression of catch on swing number was examined. Here, the number of squids caught by a swing (y) was transformed into $\log(y+n/2)$ for the frequency distribution showed a close approximation to the negative binomial series. The relation observable throughout the consecutive work could reveal the general trend but was not suitable to examine whether the squids would be jigged in the pattern suggesting the visits of schools or not, for a consecutive work continued 154 swings (in the Example 6-2) to 584 ones (in the Example 7). A series of records for a consecutive work was, accordingly, sectioned into the quarters, and the relations observable in the consecutive two quarters were examined. The results of these examinations were shown in Table 4 and Fig. 3.

In Example 1 , the quadratic regression throughout the work showed a maximum of catch

Table 3—1. The comparison of the observed frequencies with the estimated ones of "the stratified binomial series (a tentative name)". (Example 1)

Jig number (i)	Observed 0	1	2	3	Quadratic regression 0	1	2	3	Linear regression 0	1	2	3
j 1	35	0	0	0	34.77	0.23	0.00	0.00	35.00	0.00	0.00	0.00
2	35	0	0	0	34.70	0.30	0.00	0.00	35.00	0.00	0.00	0.00
3	35	0	0	0	34.61	0.39	0.00	0.00	35.00	0.00	0.00	0.00
4	34	1	0	0	34.50	0.49	0.00	0.00	35.00	0.00	0.00	0.00
5	35	0	0	0	34.38	0.61	0.00	0.00	34.78	0.22	0.00	0.00
6	35	0	0	0	34.25	0.75	0.01	0.00	34.53	0.46	0.00	0.00
7	34	1	0	0	34.10	0.89	0.01	0.00	34.29	0.70	0.01	0.00
8	35	0	0	0	33.93	1.06	0.01	0.00	34.05	0.94	0.01	0.00
9	35	0	0	0	33.74	1.23	0.02	0.00	33.81	1.17	0.02	0.00
10	34	1	0	0	33.55	1.43	0.03	0.00	33.57	1.40	0.03	0.00
11	33	2	0	0	33.33	1.63	0.04	0.00	33.33	1.63	0.04	0.00
12	34	1	0	0	33.11	1.85	0.05	0.00	33.10	1.85	0.05	0.00
13	35	0	0	0	32.86	2.08	0.06	0.00	32.86	2.08	0.06	0.00
14	32	3	0	0	32.61	2.32	0.07	0.00	32.63	2.29	0.07	0.00
15	31	3	1	0	32.34	2.57	0.09	0.00	32.40	2.51	0.09	0.00
16	32	3	0	0	32.06	2.83	0.11	0.00	32.17	2.72	0.10	0.00
17	31	4	0	0	31.76	3.10	0.14	0.00	31.94	2.93	0.12	0.00
18	29	6	0	0	31.45	3.38	0.16	0.00	31.72	3.14	0.14	0.00
19	34	1	0	0	31.13	3.67	0.19	0.01	31.49	3.34	0.16	0.00
20	33	2	0	0	30.80	3.96	0.23	0.01	31.27	3.54	0.18	0.01
21	29	6	0	0	30.45	4.27	0.27	0.01	31.05	3.74	0.20	0.01
22	33	1	1	0	30.10	4.57	0.31	0.01	30.83	3.94	0.23	0.01
23	30	4	0	1	29.73	4.89	0.36	0.02	30.61	4.13	0.25	0.01

Quadratic regression: $\chi_o^2 = 5.407$, df $= 30-6 = 24$, $\Pr\{\chi^2 > \chi_o^2\} > 0.995$

Linear regression: $\chi_o^2 = 2.488$, df $= 29-5 = 24$, $\Pr\{\chi^2 > \chi_o^2\} > 0.995$

Note : To the chi-square test, the frequencies in a fram were aggregated.

Table 3—2. (Example 2)

Jig number (i)	Observed			Cubic regression				Quadratic regression			Linear regression		
j	0	1	2	0	1	2	3	0	1	2	0	1	2
1	40	0	0	40.00	0.00	0.00	0.00	39.30	0.70	0.01	40.00	0.00	0.00
2	40	0	0	40.00	0.00	0.00	0.00	39.60	0.40	0.00	40.00	0.00	0.00
3	40	0	0	39.90	0.10	0.00	0.00	39.86	0.14	0.00	40.00	0.00	0.00
4	40	0	0	39.81	0.19	0.00	0.00	40.00	0.00	0.00	40.00	0.00	0.00
5	40	0	0	39.79	0.21	0.00	0.00	40.00	0.00	0.00	40.00	0.00	0.00
6	40	0	0	39.82	0.18	0.00	0.00	40.00	0.00	0.00	40.00	0.00	0.00
7	40	0	0	39.88	0.12	0.00	0.00	40.00	0.00	0.00	40.00	0.00	0.00
8	40	0	0	39.96	0.04	0.00	0.00	40.00	0.00	0.00	39.89	0.11	0.00
9	40	0	0	40.00	0.00	0.00	0.00	40.00	0.00	0.00	39.74	0.26	0.00
10	40	0	0	40.00	0.00	0.00	0.00	40.00	0.00	0.00	39.58	0.42	0.00
11	40	0	0	40.00	0.00	0.00	0.00	40.00	0.00	0.00	39.43	0.57	0.00
12	40	0	0	40.00	0.00	0.00	0.00	40.00	0.00	0.00	39.27	0.72	0.01
13	40	0	0	40.00	0.00	0.00	0.00	40.00	0.00	0.00	39.12	0.87	0.01
14	40	0	0	40.00	0.00	0.00	0.00	39.84	0.16	0.00	38.97	1.02	0.01
15	40	0	0	40.00	0.00	0.00	0.00	39.57	0.43	0.00	38.82	1.17	0.02
16	40	0	0	39.83	0.17	0.00	0.00	39.27	0.73	0.01	38.67	1.31	0.02
17	40	0	0	39.52	0.48	0.00	0.00	38.92	1.07	0.01	38.52	1.46	0.02
18	39	1	0	39.10	0.89	0.01	0.00	38.54	1.44	0.02	38.37	1.60	0.03
19	38	2	0	38.58	1.40	0.02	0.00	38.11	1.85	0.04	38.22	1.75	0.04
20	38	2	0	37.93	2.02	0.05	0.00	37.65	2.29	0.06	38.07	1.89	0.04
21	36	4	0	37.15	2.75	0.09	0.00	37.15	2.75	0.09	37.92	2.03	0.05
22	39	1	0	36.24	3.59	0.16	0.00	36.62	3.25	0.13	37.77	2.17	0.06
23	34	5	1	35.20	4.53	0.26	0.01	36.06	3.76	0.18	37.62	2.31	0.06

Cubic regression: $\chi_o^2 = 1.121$, df $= 26-7 = 19$, $\Pr\{\chi^2 > \chi_o^2\} > 0.995$

Quadratic regression: $\chi_o^2 = 2.817$, df $= 26-6 = 20$, $\Pr\{\chi^2 > \chi_o^2\} > 0.995$

Linear regression: $\chi_o^2 = 10.653$, df $= 27-5 = 22$, $0.99 > \Pr\{\chi^2 > \chi_o^2\} > 0.975$

Table 3—3. (Example 3)

Jig number (i)	Observed					Quadratic regression						Linear regression				
j	0	1	2	3	4	0	1	2	3	4	5	0	1	2	3	4
1	30	0	0	0	0	30.00	0.00	0.00	0.00	0.00	0.00	30.00	0.00	0.00	0.00	0.00
2	30	0	0	0	0	30.00	0.00	0.00	0.00	0.00	0.00	30.00	0.00	0.00	0.00	0.00
3	30	0	0	0	0	30.00	0.00	0.00	0.00	0.00	0.00	30.00	0.00	0.00	0.00	0.00
4	29	1	0	0	0	30.00	0.00	0.00	0.00	0.00	0.00	30.00	0.00	0.00	0.00	0.00
5	30	0	0	0	0	30.00	0.00	0.00	0.00	0.00	0.00	30.00	0.00	0.00	0.00	0.00
6	30	0	0	0	0	29.75	0.25	0.00	0.00	0.00	0.00	29.36	0.63	0.01	0.00	0.00
7	29	1	0	0	0	29.39	0.61	0.01	0.00	0.00	0.00	28.49	1.47	0.03	0.00	0.00
8	29	1	0	0	0	28.94	1.05	0.02	0.00	0.00	0.00	27.64	2.27	0.08	0.00	0.00
9	27	3	0	0	0	28.40	1.56	0.04	0.00	0.00	0.00	26.82	3.03	0.15	0.00	0.00
10	30	0	0	0	0	27.78	2.15	0.07	0.00	0.00	0.00	26.01	3.74	0.24	0.01	0.00
11	29	1	0	0	0	27.08	2.79	0.13	0.00	0.00	0.00	25.23	4.41	0.35	0.02	0.00
12	29	1	0	0	0	26.31	3.47	0.21	0.01	0.00	0.00	24.47	5.04	0.47	0.03	0.00
13	26	4	0	0	0	25.48	4.19	0.31	0.01	0.00	0.00	23.73	5.63	0.60	0.04	0.00
14	24	6	0	0	0	24.59	4.94	0.45	0.02	0.00	0.00	23.01	6.18	0.75	0.05	0.00
15	25	3	2	0	0	23.65	5.69	0.62	0.04	0.00	0.00	22.31	6.71	0.91	0.07	0.00
16	23	5	1	1	0	22.67	6.44	0.82	0.06	0.00	0.00	21.63	7.19	1.08	0.10	0.01
17	26	3	1	0	0	21.65	7.18	1.07	0.09	0.01	0.00	20.97	7.65	1.25	0.12	0.01
18	19	7	3	0	1	20.60	7.89	1.36	0.14	0.01	0.00	20.33	8.07	1.44	0.15	0.01
19	17	8	3	1	1	19.53	8.56	1.69	0.20	0.02	0.00	19.70	8.46	1.64	0.19	0.01
20	21	5	2	2	0	18.45	9.19	2.06	0.27	0.02	0.00	19.09	8.83	1.84	0.23	0.02
21	18	5	5	2	0	17.37	9.76	2.47	0.37	0.04	0.00	18.50	9.16	2.04	0.27	0.02
22	24	6	0	0	0	16.28	10.26	2.91	0.49	0.05	0.00	17.92	9.47	2.25	0.32	0.03
23	16	7	7	0	0	15.20	10.69	3.38	0.63	0.08	0.01	17.37	9.76	2.47	0.37	0.04

Quadratic regression: $\chi_o^2 = 37.471$, df $= 39-6 = 33$, $0.25 > \Pr\{\chi^2 > \chi_o^2\} > 0.10$

Linear regression: $\chi_o^2 = 48.545$, df $= 40-5 = 35$, $0.025 > \Pr\{\chi^2 > \chi_o^2\} > 0.010$

Table 3—4. (Example 4)

j	Observed 0	1	2	3	Quadratic regression 0	1	2	3	Linear regression 0	1	2	3
1	39	0	0	0	38.72	0.28	0.00	0.00	39.00	0.00	0.00	0.00
2	39	0	0	0	38.85	0.15	0.00	0.00	39.00	0.00	0.00	0.00
3	39	0	0	0	38.93	0.07	0.00	0.00	39.00	0.00	0.00	0.00
4	39	0	0	0	38.95	0.05	0.00	0.00	39.00	0.00	0.00	0.00
5	39	0	0	0	38.92	0.08	0.00	0.00	39.00	0.00	0.00	0.00
6	39	0	0	0	38.83	0.17	0.00	0.00	38.61	0.39	0.00	0.00
7	37	2	0	0	38.69	0.31	0.00	0.00	38.17	0.82	0.01	0.00
8	39	0	0	0	38.50	0.50	0.00	0.00	37.74	1.24	0.02	0.00
9	38	1	0	0	38.25	0.75	0.01	0.00	37.31	1.66	0.03	0.00
10	39	0	0	0	37.94	1.04	0.01	0.00	36.88	2.07	0.05	0.00
11	38	1	0	0	37.59	1.39	0.02	0.00	36.46	2.47	0.08	0.00
12	36	3	0	0	37.19	1.77	0.04	0.00	36.04	2.86	0.10	0.00
13	35	4	0	0	36.74	2.20	0.06	0.00	35.63	3.24	0.13	0.00
14	36	3	0	0	36.24	2.67	0.09	0.00	35.22	3.61	0.17	0.00
15	38	1	0	0	35.69	3.17	0.13	0.00	34.81	3.98	0.20	0.01
16	33	6	0	0	35.11	3.71	0.18	0.00	34.41	4.34	0.25	0.01
17	35	3	1	0	34.48	4.27	0.24	0.01	34.01	4.69	0.29	0.01
18	31	8	0	0	33.82	4.86	0.31	0.01	33.62	5.03	0.34	0.01
19	36	3	0	0	33.11	5.46	0.41	0.02	33.23	5.36	0.39	0.02
20	33	6	0	0	32.38	6.08	0.51	0.03	32.85	5.69	0.44	0.02
21	32	6	1	0	31.61	6.71	0.64	0.04	32.47	6.01	0.50	0.02
22	33	5	1	0	30.82	7.34	0.79	0.05	32.09	6.32	0.56	0.03
23	31	4	2	2	30.00	7.98	0.95	0.07	31.72	6.62	0.62	0.03

Jig number (i)

Quadratic regression: $\chi_0^2 = 6.438$, df $= 32-6 = 26$, $\Pr\{\chi^2 > \chi_0^2\} > 0.995$

Linear regression: $\chi_0^2 = 6.709$, df $= 34-5 = 29$, $\Pr\{\chi^2 > \chi_0^2\} > 0.995$

Table 3—5. (Example 5)

j	Observed 0	1	2	3	4	Quadratic regression 0	1	2	3	4	Linear regression 0	1	2	3	4
1	37	0	0	0	0	35.98	1.00	0.01	0.00	0.00	37.00	0.00	0.00	0.00	0.00
2	37	0	0	0	0	36.62	0.38	0.00	0.00	0.00	37.00	0.00	0.00	0.00	0.00
3	37	0	0	0	0	37.00	0.00	0.00	0.00	0.00	37.00	0.00	0.00	0.00	0.00
4	37	0	0	0	0	37.00	0.00	0.00	0.00	0.00	37.00	0.00	0.00	0.00	0.00
5	37	0	0	0	0	37.00	0.00	0.00	0.00	0.00	37.00	0.00	0.00	0.00	0.00
6	37	0	0	0	0	37.00	0.00	0.00	0.00	0.00	37.00	0.00	0.00	0.00	0.00
7	37	0	0	0	0	37.00	0.00	0.00	0.00	0.00	36.49	0.50	0.00	0.00	0.00
8	37	0	0	0	0	37.00	0.00	0.00	0.00	0.00	35.72	1.26	0.02	0.00	0.00
9	37	0	0	0	0	37.00	0.00	0.00	0.00	0.00	34.96	1.99	0.05	0.00	0.00
10	37	0	0	0	0	36.85	0.15	0.00	0.00	0.00	34.21	2.69	0.10	0.00	0.00
11	37	0	0	0	0	36.27	0.72	0.01	0.00	0.00	33.48	3.36	0.15	0.00	0.00
12	37	0	0	0	0	35.57	1.41	0.03	0.00	0.00	32.76	4.01	0.22	0.01	0.00
13	35	2	0	0	0	34.75	2.19	0.06	0.00	0.00	32.06	4.63	0.30	0.01	0.00
14	36	1	0	0	0	33.81	3.06	0.12	0.00	0.00	31.37	5.22	0.39	0.02	0.00
15	35	2	0	0	0	32.78	3.99	0.22	0.01	0.00	30.69	5.79	0.49	0.02	0.00
16	31	5	1	0	0	31.66	4.98	0.35	0.01	0.00	30.03	6.34	0.60	0.03	0.00
17	31	5	1	0	0	30.45	5.99	0.53	0.03	0.00	29.38	6.86	0.72	0.04	0.00
18	24	10	3	0	0	29.18	7.01	0.76	0.05	0.00	28.74	7.35	0.85	0.06	0.00
19	27	8	1	1	0	27.85	8.03	1.04	0.08	0.00	28.11	7.83	0.98	0.07	0.00
20	29	5	3	0	0	26.47	9.01	1.38	0.13	0.01	27.50	8.28	1.12	0.09	0.00
21	26	9	1	1	0	25.06	9.96	1.78	0.19	0.01	26.90	8.71	1.27	0.11	0.01
22	34	2	1	0	0	23.62	10.84	2.24	0.27	0.02	26.31	9.12	1.42	0.13	0.01
23	21	10	2	3	1	22.17	11.65	2.75	0.39	0.04	25.73	9.52	1.58	0.16	0.01

Jig number (i)

Quadratic regression: $\chi_0^2 = 26.135$, df $= 35-6 = 29$, $0.75 > \Pr\{\chi^2 > \chi_0^2\} > 0.50$

Linear regression: $\chi_0^2 = 43.844$, df $= 38-5 = 33$, $0.050 > \Pr\{\chi^2 > \chi_0^2\} > 0.025$

Table 3—6-1. (Example 6 - 1)

Jig number (i) *j*	Observed 0	1	2	Quadratic regression 0	1	2	Linear regression 0	1	2
1	16	0	0	15.77	0.23	0.00	16.00	0.00	0.00
2	16	0	0	15.83	0.17	0.00	16.00	0.00	0.00
3	16	0	0	15.87	0.13	0.00	16.00	0.00	0.00
4	16	0	0	15.90	0.10	0.00	16.00	0.00	0.00
5	16	0	0	15.92	0.08	0.00	15.95	0.05	0.00
6	16	0	0	15.93	0.07	0.00	15.88	0.12	0.00
7	15	1	0	15.93	0.07	0.00	15.81	0.19	0.00
8	16	0	0	15.91	0.09	0.00	15.74	0.26	0.00
9	16	0	0	15.88	0.12	0.00	15.66	0.33	0.00
10	16	0	0	15.84	0.16	0.00	15.59	0.40	0.00
11	15	0	1	15.78	0.22	0.00	15.52	0.47	0.01
12	16	0	0	15.72	0.28	0.00	15.45	0.54	0.01
13	16	0	0	15.64	0.36	0.00	15.38	0.61	0.01
14	15	1	0	15.55	0.45	0.01	15.31	0.68	0.01
15	16	0	0	15.45	0.54	0.01	15.24	0.74	0.02
16	15	1	0	15.33	0.65	0.01	15.17	0.81	0.02
17	16	0	0	15.21	0.77	0.02	15.10	0.88	0.02
18	15	1	0	15.08	0.90	0.02	15.03	0.94	0.03
19	15	1	0	14.93	1.04	0.03	14.96	1.01	0.03
20	16	0	0	14.77	1.18	0.04	14.89	1.07	0.03
21	16	0	0	14.61	1.33	0.05	14.82	1.14	0.04
22	14	1	1	14.43	1.50	0.07	14.76	1.20	0.04
23	13	3	0	14.25	1.66	0.09	14.69	1.26	0.05

Quadratic regression:

$\chi_o^2 = 0.748$

df $= 25-6 = 19$

$\Pr\{\chi^2 > \chi_o^2\} > 0.995$

Linear regression:

$\chi_o^2 = 0.951$

df $= 24-5 = 19$

$\Pr\{\chi^2 > \chi_o^2\} > 0.995$

Table 3—6-2. (Example 6 - 2)

Jig number (i) *j*	Observed 0	1	2	Quadratic regression 0	1	2	3	4	Linear regression 0	1	2	3	4
1	15	0	0	14.66	0.34	0.00	0.00	0.00	15.00	0.00	0.00	0.00	0.00
2	15	0	0	14.79	0.21	0.00	0.00	0.00	15.00	0.00	0.00	0.00	0.00
3	15	0	0	14.88	0.12	0.00	0.00	0.00	15.00	0.00	0.00	0.00	0.00
4	14	1	0	14.92	0.08	0.00	0.00	0.00	15.00	0.00	0.00	0.00	0.00
5	15	0	0	14.91	0.09	0.00	0.00	0.00	15.00	0.00	0.00	0.00	0.00
6	14	1	0	14.85	0.15	0.00	0.00	0.00	14.66	0.33	0.00	0.00	0.00
7	14	1	0	14.75	0.25	0.00	0.00	0.00	14.31	0.68	0.01	0.00	0.00
8	15	0	0	14.60	0.40	0.00	0.00	0.00	13.96	1.01	0.03	0.00	0.00
9	15	0	0	14.40	0.58	0.01	0.00	0.00	13.62	1.32	0.06	0.00	0.00
10	15	0	0	14.17	0.81	0.02	0.00	0.00	13.29	1.62	0.09	0.00	0.00
11	13	2	0	13.89	1.07	0.04	0.00	0.00	12.96	1.91	0.13	0.00	0.00
12	13	2	0	13.57	1.36	0.06	0.00	0.00	12.64	2.18	0.17	0.01	0.00
13	15	0	0	13.22	1.68	0.10	0.00	0.00	12.33	2.44	0.22	0.01	0.00
14	14	1	0	12.83	2.02	0.14	0.01	0.00	12.03	2.68	0.27	0.02	0.00
15	14	1	0	12.42	2.37	0.20	0.01	0.00	11.73	2.92	0.33	0.02	0.00
16	9	5	1	11.97	2.73	0.28	0.02	0.00	11.44	3.14	0.39	0.03	0.00
17	11	4	0	11.51	3.09	0.37	0.03	0.00	11.16	3.35	0.45	0.04	0.00
18	12	2	1	11.02	3.45	0.49	0.04	0.00	10.88	3.55	0.52	0.05	0.00
19	8	6	1	10.52	3.80	0.62	0.06	0.00	10.61	3.74	0.59	0.06	0.00
20	10	4	1	10.01	4.13	0.77	0.08	0.01	10.34	3.92	0.67	0.07	0.00
21	9	5	1	9.48	4.45	0.94	0.12	0.01	10.08	4.09	0.74	0.08	0.01
22	9	5	1	8.95	4.74	1.13	0.16	0.01	9.83	4.24	0.82	0.09	0.01
23	8	6	1	8.42	5.00	1.34	0.21	0.02	9.58	4.39	0.91	0.11	0.01

Quadratic regression:

$\chi_o^2 = 6.183$

df $= 31-6 = 25$

$\Pr\{\chi^2 > \chi_o^2\} > 0.995$

Linear regression:

$\chi_o^2 = 9.638$

df $= 31-5 = 26$

$\Pr\{\chi^2 > \chi_o^2\} > 0.995$

Table 3—7. (Example 7)

Jig number (i) j	Observed 0	1	2	3	Quadratic regression 0	1	2	3	4	Linear regression 0	1	2	3	4
1	58	0	0	0	57.58	0.42	0.00	0.00	0.00	58.00	0.00	0.00	0.00	0.00
2	58	0	0	0	57.93	0.07	0.00	0.00	0.00	58.00	0.00	0.00	0.00	0.00
3	58	0	0	0	58.00	0.00	0.00	0.00	0.00	58.00	0.00	0.00	0.00	0.00
4	57	1	0	0	58.00	0.00	0.00	0.00	0.00	58.00	0.00	0.00	0.00	0.00
5	57	1	0	0	58.00	0.00	0.00	0.00	0.00	58.00	0.00	0.00	0.00	0.00
6	58	0	0	0	58.00	0.00	0.00	0.00	0.00	57.55	0.44	0.00	0.00	0.00
7	55	3	0	0	57.78	0.22	0.00	0.00	0.00	56.58	1.40	0.02	0.00	0.00
8	58	0	0	0	57.37	0.63	0.00	0.00	0.00	55.63	2.33	0.04	0.00	0.00
9	58	0	0	0	56.84	1.15	0.01	0.00	0.00	54.69	3.22	0.09	0.00	0.00
10	57	1	0	0	56.19	1.79	0.03	0.00	0.00	53.77	4.09	0.14	0.00	0.00
11	57	1	0	0	55.42	2.53	0.05	0.00	0.00	52.85	4.93	0.21	0.01	0.00
12	57	1	0	0	54.54	3.36	0.09	0.00	0.00	51.96	5.75	0.29	0.01	0.00
13	58	0	0	0	53.56	4.28	0.15	0.00	0.00	51.07	6.54	0.38	0.01	0.00
14	53	5	0	0	52.48	5.28	0.24	0.01	0.00	50.20	7.30	0.48	0.02	0.00
15	55	3	0	0	51.30	6.33	0.35	0.01	0.00	49.35	8.04	0.59	0.03	0.00
16	50	8	0	0	50.04	7.44	0.50	0.02	0.00	48.50	8.75	0.71	0.03	0.00
17	43	15	0	0	48.69	8.59	0.68	0.03	0.00	47.67	9.44	0.84	0.04	0.00
18	40	14	3	1	47.27	9.77	0.91	0.05	0.00	46.85	10.11	0.98	0.06	0.00
19	45	11	1	1	45.79	10.95	1.18	0.08	0.00	46.05	10.75	1.13	0.07	0.00
20	46	10	1	1	44.25	12.14	1.50	0.11	0.01	45.26	11.37	1.29	0.09	0.00
21	43	11	3	1	42.66	13.31	1.87	0.16	0.01	44.47	11.97	1.45	0.10	0.00
22	45	11	2	0	41.02	14.46	2.29	0.22	0.01	43.71	12.54	1.62	0.12	0.01
23	40	17	1	0	39.36	15.56	2.77	0.29	0.02	42.95	13.10	1.80	0.15	0.01

Quadratic regression:
$\chi_o^2 = 22.359$
df $= 37-6 = 31$
$0.90 > \Pr\{\chi^2 > \chi_o^2\} > 0.75$

Linear regression:
$\chi_o^2 = 32.587$
df $= 39-5 = 34$
$0.50 > \Pr\{\chi^2 > \chi_o^2\} > 0.25$

Table 3—8. (Example 8)

Jig number (i) j	Observed 0	1	2	3	Quadratic regression 0	1	2	3	4	Linear regression 0	1	2	3
1	57	0	0	0	56.84	0.16	0.00	0.00	0.00	57.00	0.00	0.00	0.00
2	57	0	0	0	57.00	0.00	0.00	0.00	0.00	57.00	0.00	0.00	0.00
3	57	0	0	0	57.00	0.00	0.00	0.00	0.00	57.00	0.00	0.00	0.00
4	57	0	0	0	57.00	0.00	0.00	0.00	0.00	57.00	0.00	0.00	0.00
5	57	0	0	0	57.00	0.00	0.00	0.00	0.00	57.00	0.00	0.00	0.00
6	56	1	0	0	57.00	0.00	0.00	0.00	0.00	56.81	0.19	0.00	0.00
7	56	1	0	0	56.96	0.04	0.00	0.00	0.00	56.13	0.86	0.01	0.00
8	57	0	0	0	56.67	0.33	0.00	0.00	0.00	55.46	1.52	0.02	0.00
9	57	0	0	0	56.30	0.69	0.00	0.00	0.00	54.80	2.16	0.04	0.00
10	57	0	0	0	55.85	1.14	0.01	0.00	0.00	54.15	2.78	0.06	0.00
11	56	1	0	0	55.31	1.67	0.02	0.00	0.00	53.51	3.40	0.10	0.00
12	57	0	0	0	54.69	2.26	0.04	0.00	0.00	52.87	3.99	0.14	0.00
13	56	1	0	0	54.00	2.93	0.07	0.00	0.00	52.24	4.58	0.18	0.00
14	56	1	0	0	53.23	3.65	0.11	0.00	0.00	51.61	5.15	0.23	0.01
15	50	6	1	0	52.39	4.43	0.17	0.00	0.00	50.99	5.71	0.29	0.01
16	49	7	0	1	51.49	5.26	0.24	0.01	0.00	50.38	6.26	0.35	0.01
17	51	6	0	0	50.52	6.14	0.34	0.01	0.00	49.77	6.79	0.42	0.02
18	48	8	1	0	49.48	7.05	0.45	0.02	0.00	49.18	7.31	0.49	0.02
19	51	4	2	0	48.39	7.99	0.59	0.03	0.00	48.58	7.82	0.57	0.02
20	46	10	1	0	47.25	8.94	0.76	0.04	0.00	48.00	8.32	0.65	0.03
21	41	16	0	0	46.06	9.92	0.96	0.06	0.00	47.42	8.81	0.74	0.04
22	48	7	1	1	44.83	10.90	1.19	0.08	0.00	46.85	9.28	0.83	0.04
23	46	10	1	0	43.56	11.87	1.46	0.11	0.01	46.28	9.74	0.92	0.05

Quadratic regression:
$\chi_o^2 = 16.195$
df $= 35-6 = 29$
$0.975 > \Pr\{\chi^2 > \chi_o^2\} > 0.95$

Linear regression:
$\chi_o^2 = 29.584$
df $= 37-5 = 32$
$0.50 > \Pr\{\chi^2 > \chi_o^2\} > 0.25$

at about the 184-th swing. If this maximum of catch was conspicuous, the symptom supporting this should be found in the position of the maximum of catch in the cubic one for the same part, the cubic and quadratic ones for the second two quarters and the linear one for the first and the third two quarters. But all other regression equations were insignificant. These facts meant that it was hard to find any clear symptom suggesting the concentrated catch in a limited hour. The same was true to the Example 2, although in this example the maximum of catch shifted to the 168-th swing and the linear regression in the third two quarters showed a significant decrease of catch. In Example 3, the linear regression throughout the work, the cubic and the linear ones for the third two quarters were significant; but they showed a sharp decrease of catch near the end of the consecutive work, and did not indicate the presence of concentrated catch. The same was true to Example 4, although the cubic one for the third two quarters was insignificant. In Example 5, the presence of maximum of catch at the 175-th swing was shown by the quadratic regression throughout the work. This was supported by the linear one and the general trend of the cubic one for the first two quarters. The presence of another maximum of catch at about the 260-th swing was shown by the quadratic regression for the third two quarters. No clear symptom supporting this was, however, found in the other equations. In regard to Example 6-1, the significant regression was found in the linear one throughout the work, the quadratic one and linear one for the second two quarters. The latter two indicated the presence of concentrated catch at about the 120-th swing. This was supported by the quadratic one for the third two quarters, although this equation was insignificant. Example 6-2 was that of the shortest work being started angling at 23:30 and ended at 01:40. All the estimated regression equations were insignificant; in consequence, any symptom suggesting the presence of concentrated catch could not be found out. In Example 7, the quadratic regression throughout the work showed the presence of a concentrated catch at the 352-nd swing. The second and the third two quarters covered this part; but any symptom supporting this could not be found in the other equations. The quadratic regression for the second two quarters was significant and showed the concentrated catch at about the 250-th swing, but the estimated position of concentration through this equation was different from the above-mentioned one. The presence of a concentrated catch at the latter position was supported by all the estimated equations for the first two quarters and the cubic one for the second two ones. In Example 8, the concentrated catch was found at the position from the 350-th to the 400-th swings through the significant cubic and quadratic regression equations. The quadratic one for the second two quarters showed similar result, although this equation was insignificant. The significance of the linear regression could be explained through the relation between the position of the concentrated catch and the applicable range of them.

These descriptions were summarized, and it may be said that the symptom of the presence of concentrated catch could be found in the four examples out of the nine ones——Example 5 (at the 175 -th swing), Example 6-1 (at the 120-th one), Example 7(at the 250-th one), and Example 8 (from the 350-th to the 400 -th swing).

For the purpose of finding out the relation between the work pattern or the estimated parameters and the presence of concentrated catch, all the examples were plotted in Fig. 4 using the different marks according to the presence or absence of the concentrated catch. It was however hard to find any clear relation between them.

Table 4. The estimated regression equations of the catch on the swing number.

Example No.	Applicable range (x)	Cubic equation a_0	$a_1\times10^2$	$a_2\times10^4$	$a_3\times10^6$	F_3	Max. x	Max. y'	Min. x	Min. y'
1	1 359	−0.8659	−0.0034	0.0658	−0.0198	1.111	219.3799	−0.7653	2.5837	−0.8660
	1 180	−0.9400	0.4955	−0.6431	0.2517	1.448	58.8691	−0.8198	111.4551	−0.8381
	90 270	−0.7165	−0.0835	−0.0031	0.0136	0.003	−135.6063	−0.6428	150.5134	−0.8026
	180 359	−3.4462	2.8486	−0.9606	0.1009	0.219	236.0305	−0.7477	398.7467	−0.9650
2	1 404	−1.5500	0.2688	−0.1382	0.0185	2.836	132.6203	−1.3934	364.5914	−1.5091
	1 200	−1.5242	0.1292	0.0228	−0.0320	0.040	142.3410	−1.3862	−94.6832	−1.5989
	100 300	0.0423	−2.3161	1.1965	−0.2016	1.534	226.9078	−1.4079	168.7765	−1.4277
	200 404	−3.1695	1.9719	−0.7205	0.0833	1.007	223.5003	−1.4310	352.9760	−1.5214
3	1 304	−0.3279	−0.2929	0.2499	−0.0629	1.939	177.2878	−0.4122	87.5247	−0.4350
	1 150	−0.3484	−0.2263	0.3369	−0.2043	0.149				
	70 230	1.0238	−3.5899	2.7300	−0.6495	2.393	174.8277	−0.3789	105.3790	−0.4877
	150 304	15.7292	−21.5323	9.4237	−1.3591	8.617**	255.7777	−0.4366	206.4640	−0.5181
4	1 398	−0.7775	0.1554	−0.1080	0.0162	1.169	90.2492	−0.7133	355.4887	−0.8640
	1 200	−0.9140	0.9824	−1.1279	0.3456	3.561	60.2094	−0.6560	157.3848	−0.8146
	100 300	−1.2191	0.5545	−0.1785	0.0097	0.003	182.6780	−0.7423	1,038.8826	−3.7990
	200 398	1.3059	−1.7529	0.4645	−0.0403	0.074	437.3879	−0.8435	331.8875	−0.8671
5	1 374	−0.6253	0.2410	−0.0892	0.0064	0.127	163.5776	−0.4421	773.3253	−1.1619
	1 180	−0.8688	1.8932	−2.4625	0.9205	14.560**	56.0716	−0.4192	122.2621	−0.5526
	90 270	−1.2949	1.3843	−0.7336	0.1229	0.252	153.6531	−0.4541	244.4584	−0.5001
	180 374	0.6090	−1.6604	0.7693	−0.1126	0.510	279.7005	−0.4811	175.7179	−0.5444
6—1	1 162	−0.7241	−0.4491	0.9175	−0.3974	3.421	123.3715	−0.6280	30.5328	−0.7870
	1 80	−0.7450	−0.4054	1.4212	−1.1966	1.210	60.5222	−0.7351	18.6593	−0.7790
	40 120	−1.8887	5.1992	−7.6265	3.6302	1.992	58.6313	−0.7303	81.4259	−0.7518
	80 162	−4.0523	7.4569	−5.1747	1.1324	0.144	116.9451	−0.5976	187.6955	−0.7981
6—2	1 154	−0.1770	−0.1426	0.4106	−0.1980	0.429	117.9185	−0.0987	20.3586	−0.1907
	1 80	−0.2368	0.3497	−0.0500	−0.5677	0.044	42.4730	−0.1408	−48.3448	−0.3534
	40 120	1.6607	−7.5813	9.8436	−3.9923	1.891	102.7992	−0.0675	61.5756	−0.2074
	80 154	−0.2273	−0.4833	1.1600	−0.5403	0.017	117.8325	−0.0700	25.3058	−0.2840
7	1 584	−0.5770	0.2200	−0.0621	0.0053	2.985	269.8772	−0.3318	516.6881	−0.3713
	1 280	−0.5075	−0.0288	0.1066	−0.0217	0.345	312.8550	−0.2196	14.0999	−0.5095
	140 420	−1.9382	1.7903	−0.6121	0.0646	2.291	229.9820	−0.2725	401.6692	−0.4359
	280 584	3.4001	−2.8177	0.6805	−0.0532	2.961	498.9024	−0.3254	353.8671	−0.4065
8	1 574	−0.7978	−0.0333	0.0596	−0.0092	6.464*	402.4145	−0.5657	30.0474	−0.8027
	1 280	−0.7709	−0.0683	0.0555	−0.0059	0.050	560.6136	−0.4451	69.1422	−0.7936
	140 420	1.2814	−2.7361	1.1444	−0.1444	8.061**	345.6902	−0.4656	182.7302	−0.7780
	280 574	−5.9387	4.1449	−1.0219	0.0805	2.993	336.9746	−0.4950	509.3914	−0.7013

Note : Cubic regression equation $y' = a_0 + a_1x + a_2x^2 + a_3x^3$
Quadratic equation $y' = b_0 + b_1x + b_2x^2$
Linear equation $y' = c_0 + c_1x$

x......Swing number $y' = \log\left(y + \frac{n}{2}\right)$ y....Catch by a swing

F_i .....The Snedecor's F value for the i-th order coefficient in the i-th order regression equation

* significant at 0.05 level ** significant at 0.01 level

Table 4. (cont'd.)

Quadratic equation								Linear equation			
b_0	$b_1\times10^2$	$b_2\times10^4$	F_2	Max. x	Max. y'	Min. x	Min. y'	c_0	$c_1\times10^2$	F_1	N
−0.9124	0.1506	−0.0409	5.750*	183.8788	−0.7740			−0.8237	0.0032	0.039	359
−0.8641	−0.0007	0.0403	0.178			0.8557	−0.8641	−0.8863	0.0723	2.662	180
−0.6490	−0.2094	0.0706	0.395			148.2934	−0.8042	−0.8585	0.0448	0.730	181
−1.6033	0.6992	−0.1449	2.178	241.3060	−0.7598			−0.5903	−0.0817	3.185	180
−1.4880	0.0861	−0.0256	5.128*	168.2689	−1.4155			−1.4179	−0.0175	2.186	404
−1.5374	0.2068	−0.0735	0.828	140.7198	−1.3918			−1.4876	0.0591	2.009	200
−1.3262	−0.0191	−0.0131	0.025	−73.1240	−1.3192			−1.2783	−0.0714	2.755	201
−1.0329	−0.2555	0.0345	0.638			370.5481	−1.5064	−1.3353	−0.0473	4.290*	205
−0.4180	0.0589	−0.0379	1.183	77.6035	−0.3952			−0.3590	−0.0568	4.305*	304
−0.3843	0.0542	−0.1259	0.395	21.5102	−0.3784			−0.3361	−0.1360	3.081	150
−0.7896	0.5419	−0.1928	1.255	140.5072	−0.4089			−0.3974	−0.0366	0.262	161
0.9430	−1.0115	0.1680	0.812			301.0835	−0.5797	0.1110	−0.2489	11.143**	155
−0.7258	0.0009	−0.0113	0.561	4.1187	−0.7258			−0.6957	−0.0442	8.124**	398
−0.7716	0.1426	−0.0860	0.847	82.9070	−0.7125			−0.7134	−0.0303	0.394	200
−1.1530	0.4435	−0.1200	2.048	184.7846	−0.7432			−0.7133	−0.0365	0.701	201
0.3015	−0.6972	0.1034	1.919			337.1470	−0.8739	−0.5889	−0.0789	4.206*	199
−0.6084	0.1873	−0.0535	10.005**	175.0841	−0.4445			−0.4827	−0.0133	0.648	374
−0.5913	0.0787	0.0368	0.104			−106.8558	−0.6334	−0.6116	0.1454	7.539**	180
−0.6870	0.2505	−0.0702	0.393	178.4910	−0.4634			−0.4788	−0.0021	0.002	181
−1.6067	0.8677	−0.1666	4.581*	260.4551	−0.4767			−0.3814	−0.0551	1.944	195
−0.8117	0.1864	−0.0542	0.372	171.8197	−0.6516			−0.7876	0.0980	6.971**	162
−0.7780	0.0686	−0.0326	0.022	105.0551	−0.7420			−0.7744	0.0421	0.865	80
−0.3158	−1.4136	1.0859	4.180*			65.0842	−0.7757	−0.9514	0.3240	8.180**	81
−2.1877	2.6000	−1.0640	2.900	122.1796	−0.5994			−0.6910	0.0251	0.034	83
−0.2146	0.1437	−0.0497	0.178	144.7040	−0.1106			−0.1945	0.0667	2.044	154
−0.2525	0.5746	−0.7398	1.843	38.8354	−0.1409			−0.1706	−0.0246	0.047	80
−0.0691	−0.3088	0.2620	0.191			58.9419	−0.1601	−0.2225	0.1103	0.784	81
1.0393	−1.6899	−0.7363	0.905	114.7473	−0.0697			−0.0658	−0.0332	0.049	75
−0.5240	0.1119	−0.0159	12.344**	352.4575	−0.3269			−0.4333	0.0190	7.632**	584
−0.5319	0.0744	0.0150	0.325			−248.5638	−0.6244	−0.5517	0.1165	37.740**	280
−0.7342	0.3472	−0.0694	5.181*	250.2667	−0.2997			−0.2360	−0.0413	3.430	281
−0.5688	0.0871	−0.0091	0.143	480.9392	−0.3595			−0.4069	0.0088	0.218	305
−0.8855	0.1490	−0.0196	13.829**	379.5466	−0.6027			−0.7771	0.0361	20.794**	574
−0.7775	−0.0404	0.0307	2.710			65.8187	−0.7908	−0.8180	0.0458	11.503**	280
−1.4094	0.4890	−0.0685	3.483	357.0688	−0.5365			−0.9177	0.1055	15.582**	281
0.1201	−0.1533	0.0093	0.071			821.3290	−0.7495	−0.2836	−0.0735	7.668**	295

Discussion

The records for the preceding and the present reports were collected from the commercial boats. It is, accordingly, necessary to give a short consideration of their administrative backgrounds before entering the discussion of the results. The boat for collecting the records of the preceding report was the Danish seiner owned by a small private enterprise working in the Japan Sea. She engaged in the squid angling from the time far before the invention of the automatic powered reel only during the off season of Danish seining in summer. Her crew

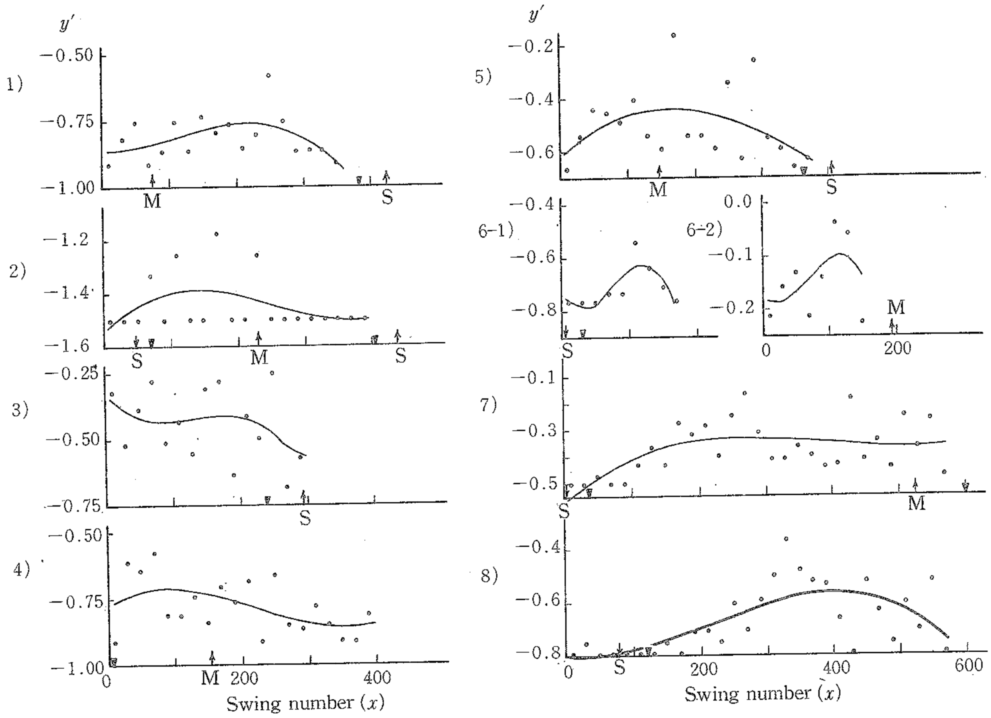

Fig. 3-1. The change of catch by a swing in accordance with the swing number (showing the cubic regression equation estimated from the records of all the consecutive swings).

Note : The numeral with parenthesis is the example number. The catch (y) was used after log $(y+\frac{n}{2})$ transformation. The solid circle shows the average of catch per swing estimated from the records of the 20 consecutive swings.

Thick curve..... significant at 0.05 level

Thin one.... insignificant at the same level

$\overset{\downarrow}{S}$ sunset $\overset{\uparrow}{S}$ sunrise $\overset{\downarrow}{M}$ moonset $\overset{\uparrow}{M}$ moonrise

Triangle.....Limit of the astronomical twilight (the sun being 18° below the horizon) members were the natives of fishing village at her home port or its vicinity. The boat for collecting the records of the present report was originally constructed as a tuna longliner, but she was converted into the squid angler few years ago, since then she had been engaged in this fishery throughout the year pursueing the migration of squids. This boat was owned by a small fishing company basing on a large fishing port, and her crew members were employed from this port although most of them were the fishing village origin. The proper boats for squid angling were introduced into this port after the popularization of the automatic powered reel. In spite of these differences in the experience and the backgrounds, there were no basic differences in the gear construction and in the work pattern between these two boats. This is because of the following reasons: These two boats were working in the same area basing on the same port, although this was only in summer season. All the boats on the same port or the same area exchange very frequently the informations one another not only during working but also during the stay in port. This fact makes the skippers having the common idea about the general recognition of the gear construction and interpretation of the fluctuation of catch and its relation to the oceanographic conditions. The decline of catch was common to all the boats, and the difference of the catch pattern between the preceding and the present reports was not due to the boat-by-boat difference. As this is a passive method and the crew members did not handle the gear directly, it is probable that the difference of catch pattern should be mainly derived from the biological reason.

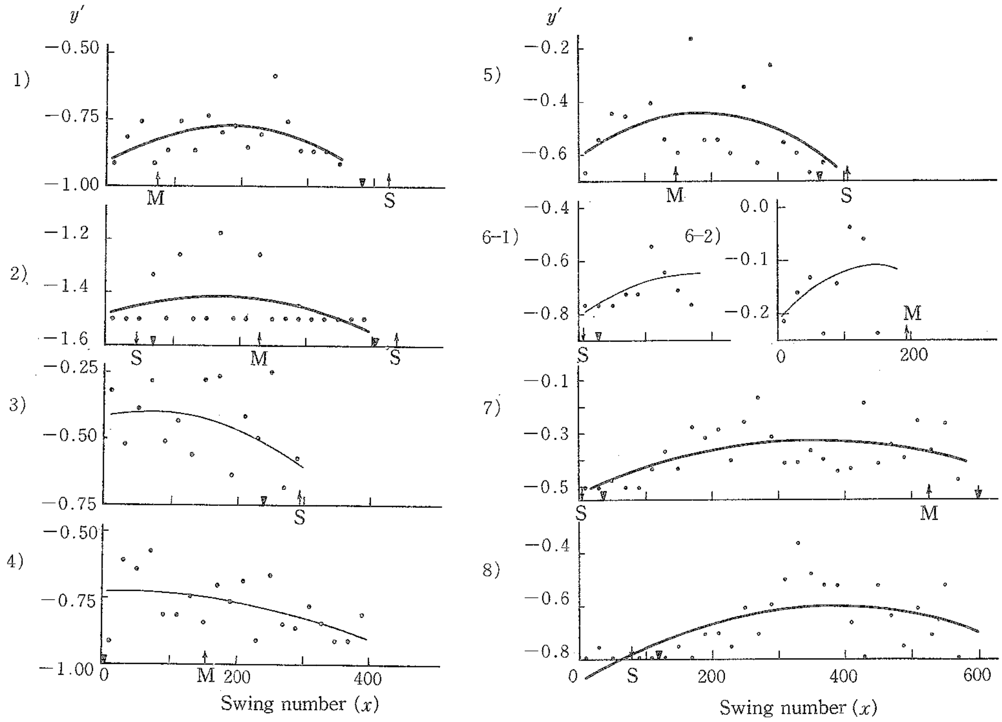

Fig. 3-2. The change of catch by a swing in accordance with the swing number(showing the quadratic regression equation estimated from the records of all the consecutive swings).

The decline of catch brought the difference in catch pattern in many points[2),3)]. The occupied rate of the jigs by squids was fallen down into a half: It was 0.005 to 0.05 in the summr of 1971, but was 0.0018 to 0.0202 in 1975. This was insufficient to show the decline of catch. The rate of the hours actually fished to the workable hours should be taken into account. In the summer of 1971, the boat could start angling before or at the sunset, and the shift during the fishable hours was observed only in one of the examples out of the 14 ones. In the summer of 1975, however, the difficulty in finding out the suitable school for catch sometimes made the boat unable to start angling about the sunset or made her scout again the other school after a short hour of fishing. The boat could work throughout the fishable hours without interruption only in the two examples out of the eight ones. In the other examples the boat was obliged to either scout the school till 22:00 or midnight or give up to continue fishing far before the sunrise.

The close approximation of the observed frequency distribution of catch by a swing to the negative binomial one was common to both the preceding and the present cases, although

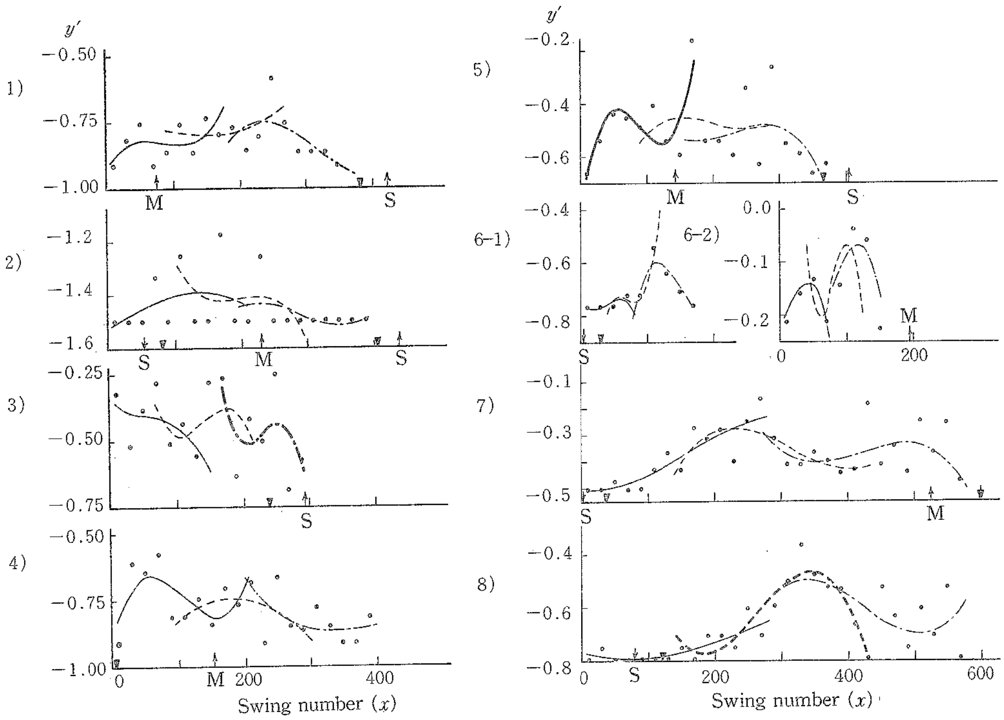

Fig. 3-3. The change of catch by a swing in accordance with the swing number (showing the cubic regression equations estimated from two successive quarters of all the consecutive swings).

Note : Solid curve....The equation estimated from the records in the first and the second quarters

Broken one.....The equation estimated from the records in the second and the third quarters

Chain one......The equation estimated from the third and the last quarters.

the squids were caught more strongly contagious pattern than the negative binomial distribution in the two examples of the preceding report out of the 14 ones.

The sharp increase of catch with the jig number counted from the shallowest end was common to the preceding and the present cases. In many fishings using the lamp, when it is difficult to guide the fish to the shallow zone, it is hard to get a good catch. In contrast with this, when the fish are strongly attracted to the lamp, they keep a stable behavior and are hardly scattered away but easily guided to the shallow zone. A good catch is frequently expected from the schools of this type. The figures showing the vertical distribution of jigged squids indicated the difficulty in guiding the squids to the shallow zone in the present case: The jigged squids showed a tailing to the shallow jigs in the preceding case, but they were only by the deeper ones in the present case. This tailing of jigged squids into shallow jigs made the cubic regression in the preceding case significant, but the difficulty in guiding into the shallow zone ended in the insignificant cubic regression in the present case. Although the present case was different from the preceding one in the significance of the cubic regression, the significant quadratic regression practically showing the sharp increase of catch with the jigs in the deep zone was the clearest trend observable common to the preceding and the present cases. As described in the preceding report, this was not due to the mis-adjustment of the amplitude of the swings but was due to the habit of squids pursueing the running jigs. Many

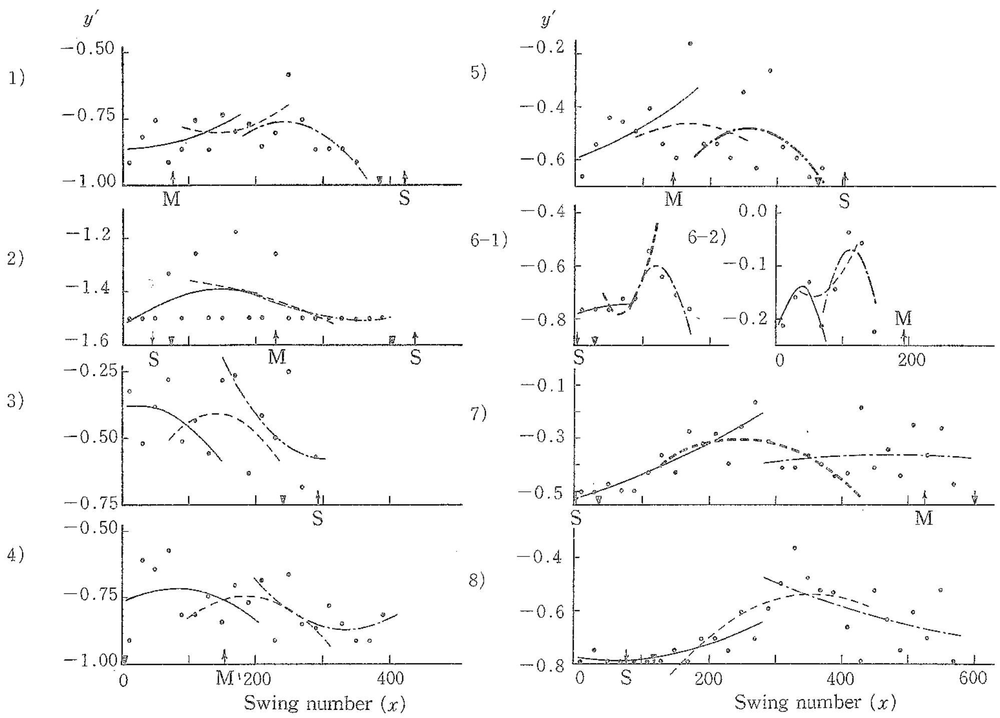

Fig. 3-4. The change of catch by a swing in accordance with the swing number (showing the quadratic regression equations estimated from two successive quarters of all the consecutive swings).

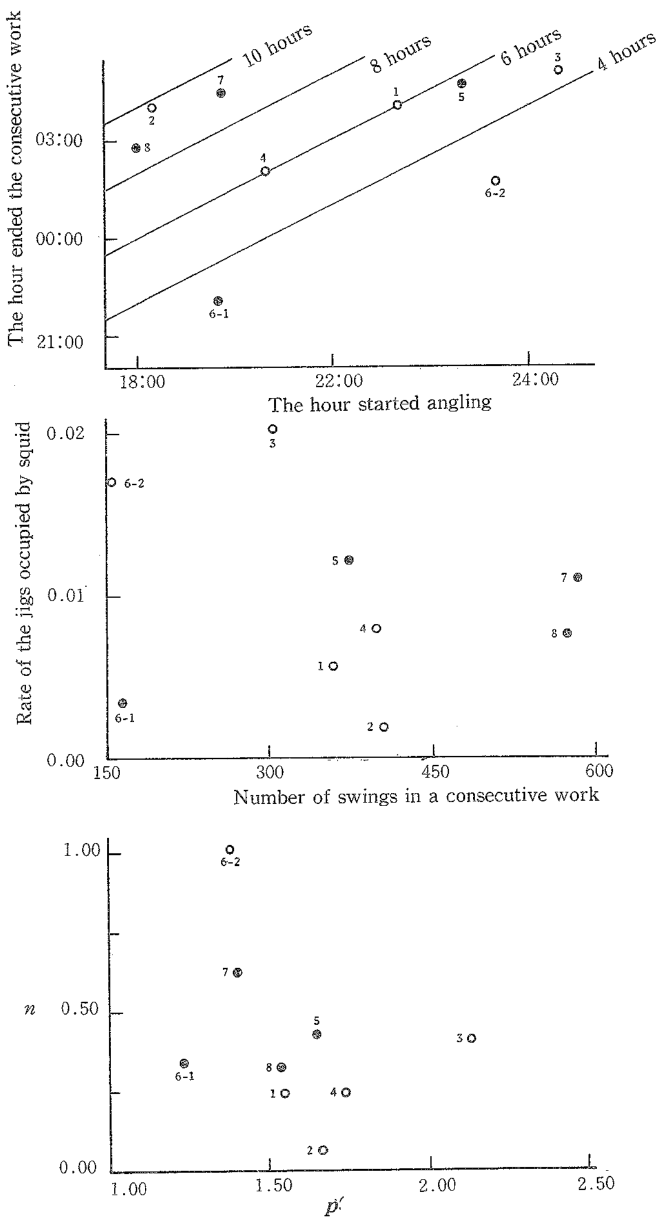

Fig. 4. Examples of the relation between the parameters of work pattern or catch pattern.

Note : Solid circle.......Example with the symptom of the hour of concentrated catch
Open one..........That without symptom

facts of the behavior of squids in support of this pattern could be found during the observation of the present case, too. And this sharp increase of catch with the deeper jigs gave the reason why it was possible to substitute the simple device for the fine human's techniques.

In the preceding report, the squids in the six examples of good catch were caught in more strongly contagious pattern than that due to the above-mentioned vertical dishomogeneity out of the 14 examples, although it was possible to explain the contagiousness in the eight examples of poor catch through this reason. In contrast with this, the contagiousness in all the examples in the present case could be explained through this reason. The above-mentioned change———the chance distribution in the case of poor catch but the contagious one in the case of good catch———is the trend found in the other fisheries too, for example in the salmon drift-netting[2] and in the between-fishermen difference of catch of squid angling with hand line[3].

In regard to the general pattern, the trend of increase of catch with lapse of fishing work was found in most of the examples in the preceding case especially in the examples extending more than 350 consecutive swings. And many symptoma suggesting the visits of schools could be found in the preceding case. In the present case, however, the visit of a single school was suggested only in a half of the examples. And the decline of catch either with passing of work or from a little before the twilight was found in most of the examples of the present case (the significant linear regression throughout the work in the two examples and the insignificant ones in the two examples; and the significant linear one for the third two quarters in the four examples, and the insignificant one in the three ones). This made the boat give up fishing, but it was near the morning and she had only insufficient time to scout again, in consequence, she was obliged to leave fishing far before the sunrise. The similar phenomena is frequently found in many other fisheries within the same season, for example, in the stick-held dip netting and in purse seining: In the case of good catch, abundant fish are attracted strongly to the lamp and they swin around the lamp intoxicatedly after the dawn. But the fish barely attracted to the lamp easily escape from it in twilight. And it is natural that the catch depends on the behavior pattern of the objective fish.

As above-mentioned, the decline of catch caused many changes in the catch pattern. And the similar changes to all of them were observable in the catch records of many other fisheries.

Conclusion

All the results and the discussion were summarized, and it may be concluded that the decline of catch caused many changes in the catch pattern common to that of poor catch in many other fisheries————not only the decline of the occupied rate of the jigs but also the shortening of the hours directly engaged in the angling work, lack of catch by the shallow jigs, weakening of contagiousness (approaching to the chance distribution), and low possibility of the hours of concentrated catch. The trend common to both the preceding and the present cases was the sharp increase of catch by the jigs near the lead end of the snood, which gave the reason why it is possible to substitute the simple device for the human's fine techniques.

Summary

The squid angling with the automatic powered reel is one of the representatives of the fishing methods invented out as one of the most suitable ways of making the fishery adapted to the recent changes in the social backgrounds. But the decline of catch made this fishery facing against the economic crisis. For the purpose of clarifying the changes in the catch pattern due to the decline of catch, the distribution of squids caught during the eight series of consecutive works (the nine examples) on the Yamatotai Bank from July 31 to Aug. 7 in 1975 was examined. And the following results were obtained:

1. The frequency distribution of catch by a swing showed a close approximation to the negative binomial series.
2. The catch increased sharply with the jig number counted from the shallowest end, keeping the significant quadratic regression in most of the examples. This fact practically meant the sharp increase of catch with the jig number near the lead end of the snood.
3. The comparison of the observed distribution with the stratified binomial one (shown in this report) revealed that it was possible to explain the weak contagiousness of catch through the above-mentioned increasing trend of catch with jig number.
4. The examination on the change of catch with time flow revealed the possibility of concentrated catch in a limited hour in the four examples out of the nine ones.
5. The trend of the decrease of catch with passing of fishing work could be found in most of the examples.
6. The above-mentioned results concerned with the change in the catch pattern during the consecutive work. In addition, the changes in the following points were observed: the hour of starting the consecutive work delayed, the possibility of shift after a short work during the fishable hours increased, and the decrease of catch near the twilight made the boat give up the fishing far before the sunrise. In consequence, the decline of catch was far more serious than that impressed from the decline of the occupied rate of the jigs by squids estimated from the records during the consecutive work.

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