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

By

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The hand-angling is one of the most widely spreading fishing methods and has the longest history. Its gear construction is simplest, although it varies according to the objective species and the preference of the individual fishermen. The line (or the lines) with baited hooks is (are) handled by the human hand directly or through a very simple device like a pole or a non-powered reel. During the fishing work, the gear is handled with great care, and adjusted very fine and unintermittently according to the minute change of the conditions. And the fishermen yield a catch waiting for a very few change of the visit of fish over many hours. The psychological condition of the fishermen differs according to the frequency of the visit of fish and the lapse of fishing work. In consequence, whether a fisherman yields a good catch or not depends deeply on his skill and his techniques including his temperament. These facts kept the hand-angling from the mechanization.

There are some anglings of exceptionally large scale, the representatives being the skipjack pole fishing, the dory fishing for cod, and the mackerel angling of the type so-called Hanezuri. Although they are really in large scale, they are nothing but the non-powered angling conducted by a group of unorganized individual fishermen on board a boat. And they are not the exception in many of the respects—for examples, the systematization of crew member, the division of labor, and the mechanization of handling the gear. Today, the squid angling with the automatic powered reel is the sole method of the angling developed into the stage capable of being included in the category of the modern techniques. Till about two decades ago, no basic change occurred in this fishing method, and this had been conducted by the same system as that employed by the other anglings of large scale. Then, the non-powered reel was introduced into it, but it was hard to consider that this caused a basic change. The introduction of the automatic powered reel makes it possible to handle all the sets of the gears installed on

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a boat by a master fisherman and caused a basic change in the work pattern of the crew members. The man-to-hook correspondency, which is the basic rule of the hand-angling succeeded since the invention of the hand-angling, has vanished from this method. And all the lines are swung by the same and simple pattern. And there is no space of entering the skill or the temperament of the individual fishermen. The change in the work pattern like this makes it possible not only to save the human hands and their labor but also to substitute the device for the very skillful fishermen.

Because of the above-mentioned change in the work pattern, the catch records are free from the influence of the unintermittent adjustment by the fishermen. And the change in the catch per unit of effort shows that of the behavior pattern of the objectives. The present report dealt with the catch pattern observable in the records collected from July to August of 1971 around the Yamatotai bank in the Japan Sea, for the purpose of describing exactly the catch pattern and finding out the reason of making it possible to substitute the device for the human's technique.

Material and Method

The boat chosen for the present work (57 gross tons) had the 10 lamps of 3000 W each hung at about 3 m high from the sea surface along the center line running between the forecastle and the wheelhause and the same number of lamps hung over the engine casing and the accomodation on the quarter along the center line of the same hight. She was equipped with the 11 sets of the automatic powered reels, the five being installed along the starboard bulkwark and the six along the port one. A set of the powered reel had a pair of drums. The reels were connected by the belt with the rodes running along both sides of the boat and driven by the hydraulic power. The amplitude and the periodicity of swings were controlled by changing the rotating speed of the rod. In consequence, all the drums on a side worked at the same amplitude and periodicity, although their phases differed according to the set. The gear wound on a drum consisted of the two parts, a No. 100 nylon line of about 50 m long and a leader. The leader differentiated into the four parts—the No. 80 nylon 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), and 20 jigs of various color were attached to the leader at one-meter intervals.

The catch records used in the present report were collected during the fishing work around the Yamatotai bank from July 15 to August 12 of 1971. The boat in the fishing ground started the scouting work with the assistance of the echo-sounder a little before the sunset. When she fortunately found a large school, she waited for the sunset, and started the fishing work. When she could not find any suitable school till the sunset, she continued the scouting work till about 20:00. Preceding the angling work, the boat was fixed with the sea-anchor and the spanker, for the purpose of minimizing the wind drift of the boat and making her drift according to the current, i.e. according to the drift of the objective school. A few minutes after putting the light, the drums were clutched on.

The amplitude of the swing was adjusted according to the depth of the schools estimated with the echo-sounder. As soon as the sinker reached the assigned depth, the line was wound up automatically, and the jigs repeated the up-and-down movement. In the

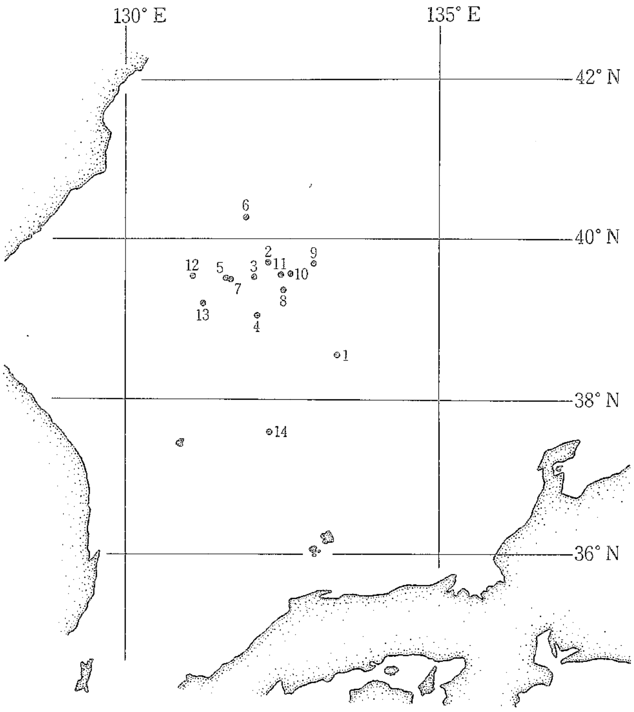


Fig. 1. A sketch chart of the position fished.

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

present case, the jigs were swung at 35-m amplitude and 50- to 60-second periodicity. The jigs were numbered from the shallowest end. The jug number and the swing number of each of the individuals caught by the jigs on the third drum on the starboard side throughout the angling work were recorded and used as the material of the present work.

Results

1. The frequency distribution of catch by a swing

The rate of the jigs occupied by the squid (mainly *Ommastrephes sloani pacificus*) was very low, being 0.005 to 0.05. As the first step of the examination, the observed frequency distributions of the swings in respect of the number of occupied jigs were compared with the binomial series, for the purpose of finding out whether the jigs were occupied by

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

	No. 1 (July 16−17)			No. 2 (July 17−18)			No. 3 (July 19−20)		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a swing 0	549	522.13	557.27	302	227.91	302.50	178	128.29	164.94
1	68	108.47	56.59	132	215.87	142.90	46	106.33	67.62
2	18	10.70	17.19	84	97.12	67.88	29	41.86	30.25
3	6	0.67	6.38	33	27.60	32.30	23	10.41	13.91
4		0.03	2.59	13	5.55	15.39	10	1.83	6.49
5			1.10	7	0.84	7.33	2	0.24	3.05
6			0.48	2	0.10	3.50		0.03	1.44
7		0.00	0.22		0.01	1.67	1	0.00	0.68
8			0.10			0.80		0.01	0.32
9			0.05		0.00	0.38			0.15
10	1		0.02	1		0.18			0.07
11≦			0.01	1		0.17			0.08
M	642			575			289		
N	132			520			230		
p		0.0103			0.0452			0.0398	
p'			1.0248			0.9144			0.9413
n			0.2006			0.9890			0.8455
χ_0^2			5.273		106.6	6.150		101.5	17.18
df			2		2	4		1	3
Pr.			0.10−0.05		<0.001	0.20−0.10		<0.001	<0.001

	No. 8 (July 29−30)			No. 9 (July 30−31)			No. 10 (July 31−Aug. 1)		
	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
Catch by a swing 0	487	375.34	498.44	338	307.76	336.85	373	308.76	388.27
1	136	257.58	124.37	53	94.95	53.49	122	191.10	99.40
2	61	83.97	54.32	15	13.91	17.01	43	56.18	41.23
3	23	17.29	27.11	6	1.29	6.31	16	10.43	19.28
4	16	2.52	14.38	4	0.08	2.51	4	1.37	9.53
5	6	0.28	7.89	2	0.00	1.04	3	0.14	4.86
6	4	0.02	4.43			0.44	1	0.01	2.53
7		0.00	2.53			0.19	2	0.00	1.34
8			1.46		0.01	0.08	3		0.71
9		0.00	0.85			0.04		0.01	0.38
10	1		0.50			0.02	1		0.21
11≦	3		0.72			0.02			0.26
M	737			418			568		
N	489			127			341		
p		0.0332			0.0152			0.0300	
p'			1.6591			0.9133			1.3451
n			0.3999			0.3327			0.4463
χ_0^2		150.7	4.172			0.8961		68.65	10.75
df		1	5			2		1	4
Pr.		<0.001	0.70−0.50			0.70−0.50		<0.001	0.50−0.20

Note: Ob ..... Observed series B ..... Binomial series $(p+q)^{20}$ Nb ..... Negative binomial series $(q'-p')^{-n}$
M ..... Number of swings N ..... Number of squids caught by the M consecutive swings

chance or not. And it was found out that the observed distributions in all the 14 examples were not agreeable to this series, because the observed frequency of the swings with one occupied jig was too low and that with no occupied jig and that with more than two occupied jigs were too high. Then, as the second step, the observed distirbutions were compared with the negative binomial series. And it was found out that the observed

No.4 (July 22—23)			No.5 (July 23—24)			No.6 (July 24—25)			No.7 (July 25—26)		
Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
277	266.65	275.94	357	265.14	371.23	437	355.12	446.60	353	315.44	348.25
36	53.03	37.93	204	282.24	187.61	170	255.48	152.90	81	136.50	90.84
8	5.01	8.33	96	142.71	94.31	60	87.31	64.93	33	28.06	29.30
4	0.30	2.06	50	45.57	47.32	30	18.84	29.36	12	3.64	10.05
	0.01	0.54	24	10.31	23.72	10	2.88	13.68	3	0.33	3.55
	0.00	0.14	9	1.76	11.89	6	0.33	6.48	2	0.02	1.28
		0.04	1	0.23	5.95	3	0.03	3.11		0.00	0.46
	0.00	0.01	2	0.02	2.98	2	0.00	1.50			0.17
		0.00	2	0.00	1.49	1		0.73		0.01	0.06
					0.75		0.01	0.36			0.02
		0.01	1	0.02	0.37	1		0.18			0.01
			2		0.38			0.17			0.01
325			748			720			484		
64			756			500			205		
	0.0098			0.0505			0.0347			0.0212	
		0.4325			0.9999			1.0284			0.6237
		0.4553			1.0108			0.6753			0.6791
				135.8	7.161		99.27	3.682		70.16	2.033
				2	5		1	4		1	2
				<0.001	0.30—0.20		<0.001	0.50—0.30		<0.001	0.50—0.30

No.11 (Aug. 1—2)			No.12 (Aug. 7—8)			No.13 (Aug. 8—9)			No.14 (Aug. 10—11)		
Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.	Ob.	B.	Nb.
225	199.07	226.11	492	437.64	487.12	206	196.94	204.64	505	428.51	528.48
62	96.89	61.08	102	180.98	112.71	5	19.15	7.82	167	251.98	133.71
24	22.40	21.43	42	35.55	37.21	4	0.88	2.51	58	70.38	54.16
6	3.27	8.09	17	4.41	13.51	1	0.03	1.05	15	12.42	24.68
2	0.34	3.17	1	0.39	5.13		0.00	0.49	8	1.55	11.87
1	0.03	1.26	4	0.03	2.00	1		0.24	8	0.15	5.89
2	0.00	0.51	1	0.00	0.79			0.12	1	0.01	2.98
		0.21			0.32			0.06	1	0.00	1.53
	0.00	0.09		0.00	0.13		0.00	0.03			0.80
		0.04			0.05			0.02		0.00	0.42
		0.01			0.02			0.01			0.22
		0.00			0.01			0.01	2		0.26
322			659			217			765		
153			267			21			437		
	0.0238			0.0203			0.0048			0.0286	
		0.7591			0.7511			1.5340			1.2578
		0.6260			0.5395			0.0631			0.4542
	30.94	0.8834		110.7	3.295					75.32	16.20
	1	2		1	2					1	4
	<0.001	0.70—0.50		<0.001	0.20—0.10					<0.001	0.01—0.001

p .... Occupied rate of jig, i.e. $N/20M$

p' and n ..... Estimated parameters of the negative binomial series, i.e.

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

distributions in the 11 examples fit this theoretical series, suggesting a weakly contagious pattern.

2. The vertical distribution of catch along the serial jigs

The examination in the preceding section revealed the weakly contagious pattern of catch. However, this was not sufficient to conclude that the squids were caught in the pattern suggestive of the school formation. One of the most probable possibilities of causing a false schooling pattern is the vertical dishomogeneity of the occupied rate of the jigs. To examine this possibility, the regressive relation of the number of catch on the jig number counted from the shallowest end was examined. As shown in Table 2 and Fig. 2, the regression coefficient of the highest order in the cubic equation was positive

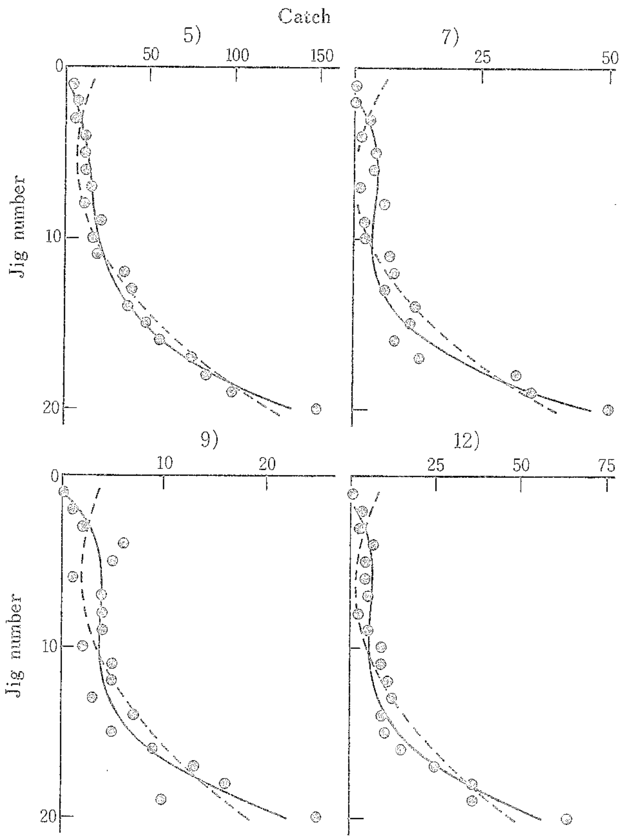


Fig. 2. The change of the number of catch in accordance with the jig number counted from the shallowest end.

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

in all the 14 examples, although that in the five examples was insignificant; the quadratic one in all the examples was negative, and the linear one in all the examples was positive. And the equations in the 10 examples showed a sharp and continuous increase of catch from the jig No. 1 to No. 20, showing neither maximum nor minimum in this range. The regression coefficient of the highest order in the quadratic equation was positive and the linear one was negative in all the examples, although the former in one of the examples

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

Example No.	a_0	a_1	a_2	a_3	F_3	b_0	b_1	b_2	F_2	c_0	c_1	F_1
1	−2.5	2.57	−0.385	0.0169	26.30**	6.5	−2.00	0.147	31.97**	−4.8	1.09	24.35**
2	−2.0	3.11	−0.404	0.0242	6.94*	10.9	−3.44	0.357	44.66**	−16.6	4.06	63.78**
3	−5.5	4.04	−0.497	0.0209	17.14**	5.5	−1.61	0.159	20.43**	−6.7	1.74	44.20**
4	0.7	0.19	−0.048	0.0034	0.89	2.5	−0.73	0.059	10.59**	−2.0	0.50	18.95**
5	−5.0	7.03	−0.919	0.0457	22.41**	19.3	−5.37	0.522	51.32**	−20.8	5.58	58.67**
6	−4.2	4.94	−0.620	0.0300	9.03**	11.8	−3.20	0.326	28.75**	−13.3	3.65	53.68**
7	−6.2	4.58	−0.632	0.0268	23.25**	8.0	−2.68	0.211	24.99**	−8.2	1.76	28.19**
8	−3.5	5.36	−0.607	0.0267	3.88	10.6	−1.87	0.233	10.10**	−7.3	3.02	42.81**
9	−1.9	2.30	−0.291	0.0118	9.20**	4.3	−0.89	0.079	11.18**	−1.8	0.78	25.97**
10	−1.7	4.67	−0.514	0.0197	3.85	8.8	−0.68	0.107	3.87	0.6	1.57	27.10**
11	−1.4	1.52	−0.177	0.0084	4.01	3.1	−0.75	0.087	14.51**	−3.6	1.07	47.87**
12	−6.4	5.40	−0.737	0.0312	25.86**	10.2	−3.06	0.246	26.01**	−8.8	2.11	30.27**
13	−1.3	0.84	−0.109	0.0041	7.73*	0.9	−0.28	0.021	5.95*	−0.8	0.17	11.36**
14	0.3	0.64	−0.031	0.0087	2.05	4.9	−1.73	0.245	60.00**	−13.9	3.41	103.02**

Note: Cubic regression equation $y = a_0 + a_1 x + a_2 x^2 + a_3 x^3$
Quadratic regression equation $y = b_0 + b_1 x + b_2 x^2$
Regression line $y = c_0 + c_1 x$
where x is the jig number counted from the shallowest end; 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

was insignificant. And the minimum of catch was found at the jig No. 3 to No. 7. The coefficient of the regression line was significantly positive in all the examples. These facts meant that the catch showed a very sharp increase in accordance with the jig number.

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

The results of the preceding section threw a doubt whether the weakly contagious pattern is due to the increasing trend of catch in accordance with the jig number or whether abundant squids are caught within limited hours. For the purpose of examining the former possibility, the frequency distribution of catch by a swing was examined again through the following method: The records throughout a continuous work were stratified into the 20 groups according to the jig number, and the catch in the lot of 10 consecutive swings was counted. When the squids were jiged showing an increasing trend in accordance with the jig number and the catch by a jig was distributed by chance throughout the consecutive swings, the frequency distribution of the lot with j squids caught by the jig No. i was illustrated by the following formula (tentatively named the stratified binomial distribution) :

$$f(i.j) = m \; {}_{10}C_j \; p_i^{\,j} \; q_i^{10-j}$$

where $q_i = 1 - p_i$

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

m is the number of lots, being a positive integer between $(\frac{M}{10} - 1)$ and $\frac{M}{10}$; and the numerator of p_i is the regression equation of catch by M consecutive swings on the jig number (shown in Table 2).

When we set that the occupied rate of the jigs increases in accordance with the jig number following the estimated regression equation, it was possible to explain that, as shown in Table 3, the weakly contagious pattern in the eight examples of poor catch was the false one due to the increasing trend of catch in accordance with the jig number but the pattern in the six examples of good catch was more strongly contagious than expected from the regressive relation of catch on the jig number. This fact was suggestive of the good catch being due to the staying of schooling squids under the lamp.

Table 3-1. The comparison of the observed frequencies with the estimated ones of "the stratified binomial series (a tentative name)" (Example No.1).

Jig number (i)	Observed Catch by 10 consecutive swings (j)						Estimated (Cubic regression equation)					Estimated (Quadratic regression equation)				
	0	1	2	3	4	5	0	1	2	3	4	0	1	2	3	4
1	64						64.00					59.50	4.35	0.15		
2	63	1					62.78	1.21	0.01			60.98	2.96	0.06		
3	61	3					61.83	2.14	0.03			62.20	1.78	0.02		
4	59	5					61.35	2.60	0.05			63.15	0.84	0.01		
5	63	1					61.22	2.73	0.05			63.83	0.17			
6	64						61.34	2.61	0.05			64.00				
7	64						61.62	2.34	0.04			64.00				
8	61	3					61.96	2.01	0.03			64.00				
9	59	5					62.26	1.72	0.02			63.59	0.41			
10	62	2					62.42	1.56	0.02			62.81	1.18	0.01		
11	62	2					62.34	1.64	0.02			61.75	2.21	0.04		
12	61	3					61.93	2.04	0.03			60.43	3.48	0.09		
13	62	2					61.09	2.85	0.06			58.85	4.95	0.19		
14	60	3		1			59.74	4.13	0.13			57.05	6.60	0.34	0.01	
15	58	5	1				57.82	5.90	0.27	0.01		55.05	8.36	0.57	0.02	
16	53	11					55.30	8.14	0.54	0.02		52.85	10.21	0.89	0.05	
17	54	10					52.16	10.78	1.00	0.06		50.50	12.11	1.31	0.08	
18	51	10	2	1			48.44	13.68	1.74	0.13	0.01	48.02	14.00	1.83	0.14	0.01
19	48	13	2	1			44.20	16.67	2.83	0.28	0.02	45.43	15.84	2.49	0.23	0.01
20	41	17	3	2		1	39.54	19.51	4.33	0.57	0.05	42.76	17.60	3.26	0.36	0.02
Sum	1170	96	8	5		1	1163.34	104.26	11.25	1.07	0.08	1160.75	107.05	11.26	0.89	0.04

Cubic regression equation: $\chi_0^2 = 11.6968$, df $= 33 - 7 = 26$, $0.995 > P_r\{\chi^2 > \chi_0^2\} > 0.990$

Quadratic regression equation: $\chi_0^2 = 46.6276$, df $= 32 - 6 = 26$, $0.010 > P_r\{\chi^2 > \chi_0^2\} > 0.005$

Note: To the chi-squre test, the frequencies in a frame were aggregated.

Table 3-2. (Example No.2)

Observed Catch by 10 consecutive swings (j)

Jig number (i)	0	1	2	3	4	5
1	56	1				
2	54	3				
3	53	4				
4	51	6				
5	49	8				
6	50	5	2			
7	49	8				
8	54	3				
9	49	6	2			
10	50	6	1			
11	46	7	4			
12	36	18	3			
13	33	20	4			
14	26	21	10			
15	34	18	4	1		
16	24	22	10	1		
17	31	12	11	3		
18	21	19	9	7	1	
19	16	20	14	7		
20	14	11	16	6	9	1
Sum	796	218	90	25	10	1

Estimated (Cubic regression equation)

Jig number (i)	0	1	2	3	4	5	6	7
1	56.27	0.72	0.01					
2	54.26	2.68	0.06					
3	52.80	4.06	0.14					
4	51.71	5.06	0.22	0.01				
5	50.85	5.84	0.30	0.01				
6	50.07	6.53	0.38	0.01				
7	49.25	7.25	0.48	0.02				
8	48.26	8.10	0.61	0.03				
9	46.99	9.17	0.80	0.04				
10	45.34	10.50	1.09	0.07				
11	43.24	12.12	1.53	0.11	0.01			
12	40.64	13.98	2.17	0.20	0.01			
13	37.54	16.01	3.07	0.35	0.03			
14	33.96	18.05	4·32	0.61	0.06			
15	30.01	19.88	5.93	1.05	0.12	0.01		
16	25.79	21.29	7.91	1.74	0.25	0.02		
17	21.48	22.02	10.16	2.78	0.50	0.06		
18	17.25	21.90	12.51	4.24	0.94	0.14	0.02	
19	13.29	20.84	14.69	6.14	1.68	0.32	0.04	
20	9.76	18.84	16.36	8.42	2.84	0.66	0.11	0.01
Sum	778.76	244.84	82.74	25.83	6.44	1.21	0.17	0.01

$\chi_0^2 = 48.0350$

df = 51 − 7 = 44

$0.500 > P_r\{\chi^2 > \chi_0^2\} > 0.250$

Estimated (Quadratic regression equation)

Jig number (i)	0	1	2	3	4	5	6	7
1	49.65	6.90	0.43	0.02				
2	51.78	5.00	0.22					
3	53.32	3.57	0.11					
4	54.21	2.73	0·06					
5	54.43	2.52	0.05					
6	53.96	2.96	0.08					
7	52.83	4.03	0.14					
8	51.07	5.64	0.28	0.01				
9	48.74	7.69	0.55	0.02				
10	45.91	10.04	0.99	0.06				
11	42.68	12.53	1.66	0.13				
12	39.14	14.99	2.59	0.26	0.02			
13	35.40	17.27	3.79	0.50	0.04			
14	31.56	19.22	5.27	0.85	0.09	0.01		
15	27.73	20.72	6.97	1.39	0.18	0.01		
16	23.99	21.69	8.82	2.13	0.34	0.03		
17	20.43	22.08	10.74	3.09	0.58	0.08		
18	17.10	21.88	12.60	4.30	0.96	0.15	0.01	
19	14.07	21.13	14.28	5.72	1.50	0.27	0.03	
20	11.36	19.88	15.66	7.31	2.24	0.47	0.07	0.01
Sum	779.36	242.47	85.29	25.79	5.95	1.02	0.11	0.01

$\chi_0^2 = 65.3439$

df = 50 − 6 = 44

$P_r\{\chi^2 > \chi_0^2\} \fallingdotseq 0.025$

Table 3-3. (Example No. 3)

Observed Catch by 10 consecutive swings (j)

Jig number (i)	0	1	2	3	4	5	6
1	28						
2	28						
3	25	3					
4	25	3					
5	24	4					
6	27	1					
7	23	4	1				
8	22	6					
9	22	4	2				
10	22	4	2				
11	22	6					
12	21	5	1		1		
13	22	5	1				
14	18	5	5				
15	21	6	1				
16	16	7	3	2			
17	16	6	4	2			
18	17	4	4	3			
19	12	6	5	1	1	1	2
20	14	1	5	2	4	1	1
Sum	425	80	34	10	6	2	3

Estimated (Cubic regression equation)

Jig number (i)	0	1	2	3	4	6	7
1	28.00						
2	27.25	0·74	0.01				
3	25.40	2.48	0.11	0.01			
4	24.21	3.55	0.23	0.01			
5	23.48	4.17	0.33	0.02			
6	23.08	4.50	0.40	0.02			
7	22.88	4.67	0.43	0.02			
8	22.78	4.75	0.44	0.03			
9	22.68	4.83	0.46	0.03			
10	22.47	5.00	0.50	0.03			
11	22.04	5.34	0.58	0.04			
12	21.32	5.89	0.73	0.06			
13	20.24	6.68	0.99	0.08	0.01		
14	18.76	7.67	1.41	0.15	0.01		
15	16.88	8.76	2.05	0.28	0.03		
16	14.68	9.79	2.94	0.52	0.06	0.01	
17	12.24	10.56	4.10	0.94	0.14	0.02	
18	9.73	10.85	5.44	1.62	0.32	0.04	
19	7.31	10.51	6.80	2.61	0.65	0.11	0.01
20	5.13	9.49	7.90	3.89	1.26	0.28	0.05
Sum	390.56	120.23	35.85	10.36	2.48	0.46	0.06

$\chi_0^2 = 59.0205$

df = 42 − 7 = 35

$0.010 > P_r\{\chi^2 > \chi_0^2\} > 0.005$

Estimated (Quadratic regression equation)

Jig number (i)	0	1	2	3	4	5	6
1	24.21	3.55	0.23	0.01			
2	25.22	2.65	0.13				
3	25.97	1.96	0.07				
4	26.44	1.52	0.04				
5	26.61	1.36	0.03				
6	26.47	1.49	0.04				
7	26.05	1.89	0.06				
8	25.33	2.55	0.12				
9	24.34	3.43	0.22	0.01			
10	23.13	4.46	0.39	0.02			
11	21.72	5.59	0.65	0.04			
12	20.14	6.75	1.02	0.09			
13	18.45	7.86	1.51	0.17	0.01		
14	16.69	8.86	2.12	0.30	0.03		
15	14.90	9.70	2.85	0.49	0.06		
16	13.12	10.33	3.66	0.77	0.11	0.01	
17	11.39	10.72	4.54	1.14	0.19	0.02	
18	9.75	10.85	5.43	1.61	0.31	0.04	(0.01)
19	8.21	10.72	6.29	2.19	0.50	0.08	0.01
20	6.81	10.34	7.07	2.86	0.76	0.14	0.02
Sum	394.95	116.58	36.47	9.70	1.97	0.29	0.04

$\chi_0^2 = 74.1412$

df = 42 − 6 = 36

$0.005 > P_r\{\chi^2 > \chi_0^2\}$

Table 3-4. (Example No.4)

Jig number (i)	Observed: Catch by 10 consecutive swings (j) 0	1	2	3	Estimated (Cubic regression equation) 0	1	2	3	4	Estimated (Quadratic regression equation) 0	1	2	3	4
1	32				31.16	0.83	0.01			30.22	1.74	0.04		
2	32				31.10	0.89	0.01			30.75	1.23	0.02		
3	31	1			31.08	0.91	0.01			31.17	0.82	0.01		
4	29	3			31.10	0.89	0.01			31.48	0.52			
5	30	2			31.14	0.85	0.01			31.68	0.32			
6	32				31.16	0.83	0.01			31.76	0.24			
7	31	1			31.17	0.82	0.01			31.72	0.28			
8	30	2			31.12	0.87	0.01			31.57	0.43			
9	31	1			31.01	0.97	0.02			31.30	0.69	0.01		
10	32				30.82	1.16	0.02			30.92	1.06	0.02		
11	31	1			30.53	1.44	0.03			30.43	1.54	0.03		
12	32				30.11	1.84	0.05			29.83	2.10	0.07		
13	31	1			29.56	2.35	0.09			29.14	2.74	0.12		
14	31	1			28.87	2.99	0.14			28.36	3.45	0.19		
15	27	5			28.02	3.75	0.22	0.01		27.49	4.21	0.29	0.01	
16	25	5	1	1	27.01	4.62	0.35	0.02		26.55	5.01	0.42	0.02	
17	29	3			25.85	5.58	0.54	0.03		25.54	5.83	0.60	0.03	
18	22	7	3		24.53	6.61	0.80	0.06		24.47	6.66	0.81	0.06	
19	23	7	2		23.07	7.67	1.15	0.10	0.01	23.35	7.48	1.08	0.09	
20	25	6		1	21.48	8.73	1.60	0.18	0.01	22.19	8.27	1.39	0.14	0.01
Sum	586	46	6	2	579.89	54.60	5.09	0.40	0.02	579.92	54.62	5.10	0.35	0.01

Cubic regression equation: $\chi_0^2=9.5471$, df $=29-7=22$, $P_r\{\chi^2>\chi_0^2\}\fallingdotseq 0.99$

Quadratic regression equation: $\chi_0^2=9.7340$, df $=30-6=24$, $P_r\{\chi^2>\chi_0^2\}>0.995$

Table 3-5. (Example No.5)

Jig number (i)	Observed: Catch by 10 consecutive swings (j) 0	1	2	3	4	5	6	7
1	70	4						
2	67	7						
3	69	5						
4	63	10	1					
5	64	8	2					
6	65	6	3					
7	59	15						
8	64	9	1					
9	58	12	3	1				
10	61	10	2	1				
11	55	18	1					
12	50	17	4	2	1			
13	48	15	9	1	1			
14	46	19	9					
15	40	25	6	2		1		
16	37	25	8	2	1	1		
17	31	20	15	7	1			
18	33	18	11	6	6			
19	25	21	17	5	4	1		1
20	19	10	16	17	8	2	2	
Sum	1024	274	108	44	22	5	2	1

Jig number (i)	Estimated (Cubic regression equation) 0	1	2	3	4	6	7	8
1	72.85	1.14	0.01					
2	68.45	5.36	0.19					
3	65.43	8.10	0.45	0.02				
4	63.41	9.87	0.69	0.03				
5	62.08	11.00	0.88	0.04				
6	61.16	11.77	1.02	0.05				
7	60.42	12.38	1.14	0.06				
8	59.62	13.03	1.28	0.07				
9	58.54	13.89	1.48	0.09				
10	56.97	15.09	1.80	0.13	0.01			
11	54.75	16.74	2.31	0.19	0.01			
12	51.75	18.84	3.09	0.30	0.02			
13	47.91	21.29	4.26	0.50	0.04			
14	43.25	23.86	5.93	0.87	0.08	0.01		
15	37.89	26.23	8.17	1.51	0.18	0.02		
16	32.05	27.97	10.99	2.56	0.39	0.04		
17	26.02	28.67	14.21	4.18	0.80	0.11	0.01	
18	20.14	27.99	17.51	6.49	1.58	0.26	0.03	
19	14.74	25.81	20.34	9.49	2.91	0.61	0.09	0.01
20	10.11	22.26	22.07	12.97	5.00	1.32	0.24	0.03
Sum	967.54	341.29	117.82	39.55	11.02	2.37	0.37	0.04

$\chi_0^2=94.8771$, df $=56-7=49$, $0.005>P_r\{\chi^2>\chi_0^2\}$

Jig number (i)	Estimated (Quadratic regression equation) 0	1	2	3	4	5	6	7
1	60.75	12.10	1.09	0.06				
2	64.02	9.35	0.61	0.02				
3	66.48	7.16	0.35	0.01				
4	68.06	5.72	0.22					
5	68.68	5.14	0.18					
6	68.33	5.47	0.20					
7	67.02	6.67	0.30	0.01				
8	64.81	8.65	0.52	0.02				
9	61.77	11.26	0.92	0.05				
10	58.01	14.30	1.59	0.10				
11	53.67	17.52	2.57	0.23	0.01			
12	48.90	20.68	3.94	0.45	0.03			
13	43.86	23.55	5.69	0.82	0.08			
14	38.71	25.92	7.81	1.39	0.16	0.01		
15	33.59	27.61	10.21	2.24	0.32	0.03		
16	28.64	28.52	12.78	3.39	0.59	0.07	0.01	
17	23.98	28.60	15.35	4.89	1.02	0.15	0.01	
18	19.69	27.87	17.76	6.71	1.66	0.28	0.03	
19	15.84	26.40	19.80	8.80	2.57	0.51	0.07	0.01
20	12.47	24.31	21.32	11.08	3.78	0.88	0.14	0.02
Sum	967.28	336.80	123.21	40.27	10.22	1.93	0.26	0.03

$\chi_0^2=121.1256$, df $=57-6=51$, $0.005>P_r\{\chi^2>\chi_0^2\}$

Table 3-6. (Example No.6)

Jig number (i)	Observed Catch by 10 consecutive swings (j)						Estimated (Cubic regression equation)							Estimated (Quadratic regression equation)						
	0	1	2	3	4	5	0	1	2	3	4	5	6	0	1	2	3	4	5	6
1	69	3					71.85	0.15						63.56	7.98	0.45	0.01			
2	68	4					68.63	3.30	0.07					65.57	6.16	0.26	0.01			
3	67	5					66.36	5.44	0.20					67.03	4.81	0.16				
4	67	4	1				64.79	6.87	0.33	0.01				67.89	4.00	0.11				
5	65	7					63.71	7.84	0.43	0.02				68.15	3.76	0.09				
6	66	5	1				62.95	8.51	0.52	0.02				67.78	4.11	0.11				
7	64	7	1				62.35	9.04	0.59	0.02				66.80	5.03	0.17				
8	63	7	1	1			61.72	9.58	0.67	0.03				65.24	6.46	0.29	0.01			
9	62	8	2				60.94	10.25	0.78	0.03				63.13	8.35	0.50	0.02			
10	62	10					59.84	11.17	0.94	0.05				60.52	10.60	0.84	0.04			
11	60	9	2	1			58.29	12.44	1.20	0.07				57.47	13.10	1.35	0.08			
12	53	14	5				56.18	14.11	1.60	0.11				54.06	15.72	2.05	0.16	0.01		
13	49	18	4		1		53.44	16.17	2.20	0.18	0.01			50.35	18.33	3.01	0.29	0.02		
14	48	20	3		1		50.01	18.56	3.10	0.31	0.02			46.44	20.82	4.20	0.50	0.04		
15	50	18	4				45.93	21.12	4.37	0.54	0.04			42.39	23.06	5.65	0.82	0.08		
16	38	23	9	1	1		41.25	23.63	6.09	0.93	0.09	0.01		38.29	24.96	7.32	1.27	0.15	0.01	
17	52	11	5	3	1		36.12	25.79	8.29	1.58	0.20	0.02		34.22	26.43	9.18	1.89	0.26	0.02	
18	39	20	11	2			30.72	27.31	10.93	2.59	0.41	0.04		30.24	27.40	11.18	2.70	0.43	0.05	
19	29	22	16	2	3		25.26	27.89	13.86	4.08	0.79	0.11	0.01	26.42	27.86	13.22	3.72	0.68	0.09	0.01
20	27	15	15	10	3	2	19.99	27.33	16.81	6.13	1.47	0.24	0.03	22.80	27.79	15.23	4.95	1.06	0.15	0.02
Sum	1098	230	80	20	10	2	1060.32	286.50	72.98	16.70	3.03	0.42	0.04	1058.35	286.73	75.37	16.47	2.73	0.32	0.03

Cubic: $\chi_0^2 = 56.0097$, df $= 49 - 7 = 42$, $\Pr\{\chi^2 > \chi_0^2\} \fallingdotseq 0.050$

Quadratic: $\chi_0^2 = 69.3519$, df $= 49 - 6 = 43$, $0.005 > \Pr\{\chi^2 > \chi_0^2\}$

Table 3-7 (Example No.7)

Jig number (i)	Observed Catch by 10 consecutive swings (j)						Estimated (Cubic regression equation)							Estimated (Quadratic regression equation)					
	0	1	2	3	4	5	0	1	2	3	4	5	6	0	1	2	3	4	5
1	48						48.00							42.75	4.98	0.26	0.01		
2	48						47.36	0.64						44.63	3.26	0.11			
3	45	3					45.49	2.45	0.06					46.17	1.80	0.03			
4	47	1					44.41	3.47	0.12					47.35	0.65				
5	44	4					43.92	3.92	0.16					48.00					
6	44	4					43.86	3.98	0.16					48.00					
7	47	1					44.07	3.78	0.15					48.00					
8	42	6					44.42	3.46	0.12					47.94	0.06				
9	46	2					44.74	3.16	0.10					47.04	0.95	0.01			
10	46	2					44.90	3.01	0.09					45.75	2.20	0.05			
11	42	5	1				44.73	3.17	0.10					44.10	3.75	0.15			
12	41	6	1				44.09	3.76	0.15					42.13	5.53	0.33	0.01		
13	44	2	2				42.85	4.89	0.25	0.01				39.88	7.46	0.63	0.03		
14	40	4	4				40.93	6.57	0.48	0.02				37.40	9.45	1.08	0.07		
15	39	8		1			38.27	8.77	0.90	0.06				34.73	11.42	1.69	0.15	0.01	
16	41	6	1				34.90	11.30	1.65	0.14	0.01			31.96	13.27	2.48	0.27	0.02	
17	37	9	2				30.90	13.91	2.82	0.34	0.03			29.11	14.93	3.45	0.47	0.04	
18	29	11	4	3	1		26.45	16.24	4.49	0.73	0.08	0.01		26.24	16.33	4.58	0.76	0.08	0.01
19	25	12	10	1			21.77	17.91	6.63	1.46	0.21	0.02		23.41	17.43	5.84	1.16	0.15	0.01
20	22	11	10	2	2	1	17.13	18.59	9.08	2.63	0.50	0.06	0.01	20.66	18.17	7.19	1.69	0.26	0.03
Sum	817	97	35	7	3	1	793.19	132.98	27.51	5.39	0.83	0.09	0.01	795.25	131.64	27.88	4.62	0.56	0.05

Cubic: $\chi_0^2 = 30.3938$, df $= 38 - 7 = 31$, $0.500 > \Pr\{\chi^2 > \chi_0^2\} > 0.250$

Quadratic: $\chi_0^2 = 76.7716$, df $= 37 - 6 = 31$, $0.005 > \Pr\{\chi^2 > \chi_0^2\}$

Table 3-8. (Example No.8)

Jig number (i)	Observed Catch by 10 consecutive swings (j) 0	1	2	3	4	5	Estimated (Cubic regression equation) 0	1	2	3	4	5	6	Estimated (Quadratic regression equation) 0	1	2	3	4	5	6
1	70	3					71.73	1.26	0.01					64.52	8.20	0.45	0.01			
2	73						68.15	4.70	0.15					65.57	7.08	0.34	0.01			
3	66	5	2				65.53	7.11	0.35	0.01				66.21	6.49	0.29	0.01			
4	63	9	1				63.65	8.78	0.55	0.02				66.43	6.29	0.27	0.01			
5	58	11	4				62.32	9.94	0.71	0.03				66.23	6.48	0.28	0.01			
6	62	11					61.36	10.75	0.85	0.04				65.59	7.06	0.34	0.01			
7	62	10	1				60.62	11.37	0.96	0.05				64.55	7.99	0.45	0.01			
8	66	6	1				59.98	11.90	1.06	0.06				63.11	9.26	0.61	0.02			
9	65	7	1				59.28	12.47	1.18	0.07				61.30	10.80	0.86	0.04			
10	60	10	3				58.41	13.17	1.34	0.08				59.15	12.58	1.20	0.07			
11	51	18	3	1			57·23	14.10	1.56	0.10	0.01			56.69	14.52	1.67	0.11	0.01		
12	57	12	4				55.64	15.31	1.90	0.14	0.01			53.97	16.55	2.28	0.19	0.01		
13	60	11	1	1			53.56	16.85	2.38	0.20	0.01			51.03	18.60	3.05	0.30	0.02		
14	45	22	4	2			50.92	18.68	3.08	0.30	0.02			47.92	20.60	3.99	0.46	0.03		
15	52	17	2	2			47.68	20.75	4.06	0.47	0.04			44.68	22.48	5.09	0.69	0.06		
16	47	16	9	1			43.88	22.91	5.39	0.75	0.07			41.36	24.18	6.36	0.99	0.10	0.01	
17	44	21	5	3			39.56	24.99	7.11	1.20	0.13	0.01		37.99	25.64	7.79	1.40	0.17	0.01	
18	33	23	13	3		1	34.85	26.75	9.24	1.89	0.25	0.02		34.64	26.81	9.34	1.93	0.26	0.02	
19	46	19	5	3			29.90	27.92	11.73	2.92	0.48	0.05		31.34	27.65	10.98	2.59	0.40	0.04	
20	24	23	15	10	1		24.88	28.28	14.46	4.38	0.87	0.12	0.01	28.13	28.15	12.67	3.38	0.59	0.07	0.01
Sum	1104	254	74	26	1	1	1069.13	307.99	68.07	12.71	1.89	0.20	0.01	1070.41	307.23	68.31	12.24	1.65	0.15	0.01

Cubic: $\chi_0^2 = 62.1220$, df = 49 − 7 = 42, $0.025 > P_r\{\chi^2 > \chi_0^2\} > 0.010$

Quadratic: $\chi_0^2 = 85.6993$, df = 50 − 6 = 44, $0.005 > P_r\{\chi^2 > \chi_0^2\}$

Table 3-9. (Example No.9)

Jig number (i)	Observed Catch by 10 consecutive swings (j) 0	1	2	3	Estimated (Cubic regression equation) 0	1	2	3	4	Estimated (Quadratic regression equation) 0	1	2	3	4
1	41				40.88	0.12				37.64	3.23	0.13		
2	40	1			39.40	1.57	0.03			38.25	2.67	0.08		
3	39	2			38.38	2.54	0.08			38.72	2.22	0.06		
4	36	4	1		37.73	3.15	0.12			39.04	1.92	0.04		
5	37	3	1		37.36	3.49	0.15			39.21	1.75	0.04		
6	40	1			37.20	3.64	0.16			39.23	1.73	0.04		
7	37	4			37.18	3.65	0.16	0.01		39.10	1.86	0.04		
8	37	4			37.25	3.59	0.16			38.82	2.13	0.05		
9	38	2	1		37.33	3.52	0.15			38.39	2.53	0.08		
10	39	2			37.36	3.49	0.15			37.82	3.07	0.11		
11	36	5			37.27	3.57	0.16			37.11	3.72	0.17		
12	36	5			37.00	3.82	0.18			36.27	4.47	0.25	0.01	
13	39	1	1		36.49	4.27	0.23	0.01		35.31	5.32	0.36	0.01	
14	35	5	1		35.70	4.98	0.31	0.01		34.24	6.23	0.51	0.02	
15	38	2		1	34.56	5.96	0.46	0.02		33.07	7.19	0.70	0.04	
16	32	9			33.06	7.20	0.70	0.04		31.80	8.18	0.95	0.07	
17	31	8	1	1	31.18	8.66	1.08	0.08		30.46	9.18	1.25	0.10	0.01
18	27	12	2		28.94	10.26	1.64	0.15	0.01	29.06	10.18	1.60	0.15	0.01
19	33	6	2		26.38	11.89	2.42	0.29	0.02	27.60	11.14	2.02	0.22	0.02
20	23	12	5	1	23.56	13.42	3.44	0.53	0.05	26.10	12.06	2.51	0.31	0.02
Sum	714	88	15	3	704.21	102.79	11.78	1.14	0.08	707.24	100.78	10.99	0.93	0.06

Cubic: $\chi_0^2 = 16.6439$, df = 34 − 7 = 27, $0.95 > P_r\{\chi^2 > \chi_0^2\} > 0.90$

Quadratic: $\chi_0^2 = 25.6867$, df = 35 − 6 = 29, $0.750 > P_r\{\chi^2 > \chi_0^2\} > 0.500$

Table 3-10. (Example No.10)

Jig number (i)	Observed Catch by 10 consecutive swings (j) 0	1	2	3	4	5	Estimated (Cubic regression equation) 0	1	2	3	4	5	Estimated (Quadratic regression equation) 0	1	2	3	4	5
1	51	4	1				53.57	2.38	0.05				48.30	7.20	0.48	0.02		
2	52	4					50.52	5.23	0.24	0.01			48.61	6.93	0.44	0.02		
3	47	8	1				48.31	7.19	0.48	0.02			48.74	6.81	0.43	0.02		
4	48	6	2				46.75	8.52	0.70	0.03			48.68	6.87	0.43	0.02		
5	48	7	1				45.70	9.38	0.87	0.05			48.43	7.09	0.46	0.02		
6	52	4					45.04	9.92	0.98	0.06			48.00	7.46	0.52	0.02		
7	47	9					44.63	10.24	1.06	0.07			47.38	7.99	0.60	0.03		
8	45	9	1	1			44.40	10.43	1.10	0.07			46.59	8.65	0.72	0.04		
9	40	15		1			44.23	10.56	1.14	0.07			45.63	9.44	0.88	0.05		
10	44	9	3				44.04	10.71	1·17	0.08			44.52	10.33	1.08	0.07		
11	43	11	1	1			43.72	10.96	1.24	0.08			43.26	11.31	1.33	0.09		
12	39	13	4				43.18	11.37	1.35	0.10			41.87	12.35	1.64	0.13	0.01	
13	43	6	6	1			42.35	12.00	1.53	0.11	0.01		40.36	13.44	2.01	0.18	0.01	
14	43	11	1	1			41.15	12.88	1.81	0.15	0.01		38.74	14.54	2.45	0.25	0.02	
15	44	7	4	1			39.52	14.02	2.24	0.21	0.01		37.04	15.63	2.97	0.34	0.02	
16	40	11	5				37.42	15.40	2.85	0.31	0.02		35.26	16.69	3.56	0.45	0.04	
17	39	15	1	1			34.86	16.92	3.70	0.48	0.04		33.43	17.70	4.22	0.60	0.05	
18	34	14	5	2	1		31.85	18.49	4.82	0.75	0.08	0.01	31.55	18.63	4.95	0.78	0.08	0.01
19	40	12	4				28.49	19.92	6.27	1.17	0.14	0.01	29.65	19.47	5.75	1.01	0.11	0.01
20	24	18	7	4	2	1	24.85	21.03	8.01	1.81	0.27	0.03	27.74	20.19	6.61	1.29	0.16	0.01
Sum	863	193	47	13	3	1	834.58	237.55	41.61	5.63	0.58	0.05	833.78	238.72	41.53	5.43	0.50	0.03

Cubic regression equation: $\chi_0^2 = 55.8336$, df = 47 − 7 = 40, $Pr\{\chi^2 > \chi_0^2\} \doteqdot 0.050$

Quadratic regression equation: $\chi_0^2 = 64.3146$, df = 48 − 6 = 42, $Pr\{\chi^2 > \chi_0^2\} \doteqdot 0.010$

Table 3-11. (Example No.11)

Jig number (i)	Observed Catch by 10 consecutive swings (j) 0	1	2	3	Estimated (Cubic regression equation) 0	1	2	3	4	5	Estimated (Quadratic regression equation) 0	1	2	3	4	5
1	30	2			32.00						29.64	2.28	0.08			
2	32				31.02	0.97	0.01				30.11	1.84	0.05			
3	31	1			30.25	1.71	0.04				30.40	1.56	0.04			
4	30	2			29.69	2.23	0.08				30.54	1.43	0.03			
5	32				29.28	2.61	0.11				30.51	1.46	0.03			
6	29	2	1		28.98	2.89	0.13				30.31	1.65	0.04			
7	27	5			28.72	3.13	0.15				29.95	1.99	0.06			
8	29	2	1		28.46	3.36	0.18				29.43	2.48	0.09			
9	28	3	1		28.16	3.62	0.21	0.01			28.76	3.09	0.15			
11	27	3	1	1	27.78	3.96	0.25	0.01			27.95	3.81	0 23	0.11		
12	29	3			27.27	4.40	0.32	0.01			27.01	4.62	0.35	0.02		
13	29	3			26.59	4.97	0.42	0.02			25.96	5.49	0.52	0.03		
14	27	4	1		25.73	5.67	0.56	0.04			24.80	6.40	0.75	0.05		
15	26	3	2	1	24.65	6.51	0.78	0.06			23.56	7.33	1.03	0.08		
15	23	8		1	23.35	7.47	1.08	0.09	0.01		22.24	8.24	1.37	0.14	0.01	
16	22	9		1	21.83	8.51	1.49	0.16	0.01		20.88	9.11	1.79	0.21	0.01	
17	22	6	2	2	20.09	9.58	2.05	0.26	0.02		19.48	9.91	2.27	0.31	0.03	
18	21	6	4	1	18.18	10.58	2.77	0.43	0.04		18.06	10.63	2.82	0.44	0.05	
19	22	7	2	1	16.12	11.44	3.65	0.69	0.09	0.01	16.64	11.25	3.42	0.62	0.07	
20	11	14	5	2	13.99	12.07	4.68	1.08	0.16	0.02	15.23	11.74	4.07	0.84	0.11	0.01
Sum	527	83	20	10	512.14	105.68	18.96	2.86	0.33	0.03	511.46	106.31	19.19	2.75	0.28	0.01

Cubic regression equation: $\chi_0^2 = 23.2298$, df = 38 − 7 = 31, $0.900 > Pr\{\chi^2 > \chi_0^2\} > 0.750$

Quadratic regression equation: $\chi_0^2 = 23.9065$, df = 37 − 6 = 31, $0.900 > Pr\{\chi^2 > \chi_0^2\} > 0.750$

Table 3-12. (Example No.12)

Jig number (i)	Observed: Catch by 10 consecutive swings (j) 0	1	2	3	4	Estimated (Cubic regression equation) 0	1	2	3	4	5	Estimated (Quadratic regression equation) 0	1	2	3	4	5
1	65					65.00						57.98	6.66	0.35	0.01		
2	62	3				63.32	1.66	0.02				60.11	4.72	0.17			
3	63	2				61.10	3.79	0.11				61.84	3.09	0.07			
4	59	6				59.79	5.01	0.19	0.01			63.13	1.85	0.02			
5	61	4				59.17	5.58	0.24	0.01			63.96	1.03	0.01			
6	61	4				59.05	5.69	0.25	0.01			64.31	0.69				
7	61	3	1			59.25	5.51	0.23	0.01			64.17	0.82	0.01			
8	63	2				59.61	5.19	0.20				63.55	1.44	0.01			
9	60	5				59.94	4.88	0.18				62.46	2.50	0.04			
10	56	9				60.08	4.75	0.17				60.92	3.96	0.12			
11	57	7	1			59.84	4.97	0.19				58.96	5.78	0.25	0.01		
12	55	9	1			59.07	5.68	0.24	0.01			56.63	7.86	0.49	0.02		
13	53	12				57.62	6.99	0.38	0.01			53.96	10.14	0.86	0.04		
14	58	6		1		55.35	8.97	0.65	0.03			51.00	12.52	1.38	0.09	0.01	
15	55	10				52.22	11.56	1.15	0.07			47.82	14.91	2.09	0.17	0.01	
16	54	8	3			48.22	14.62	1.99	0.16	0.01		44.46	17.21	3.00	0.31	0.02	
17	47	14	4			43.43	17.87	3.31	0.36	0.03		41.00	19.34	4.10	0.52	0.04	
18	38	20	6	1		38.00	20.96	5.20	0.76	0.07	0.01	37.48	21.21	5.40	0.82	0.08	0.01
19	40	18	5	2		32.17	23.44	7.69	1.49	0.19	0.02	33.96	22.78	6.88	1.23	0.14	0.01
20	30	18	9	7	1	26.23	24.92	10.65	2.70	0.45	0.05	30.48	23.98	8.49	1.78	0.25	0.02
Sum	1098	160	30	11	1	1078.46	182.04	33.04	5.63	0.75	0.08	1078.18	182.49	33.74	5.00	0.55	0.04

Cubic regression equation: $\chi_0^2 = 34.0412$, $df = 43 - 7 = 36$, $0.750 > P_r\{\chi^2 > \chi_0^2\} > 0.500$

Quadratic regression equation: $\chi_0^2 = 78.6778$, $df = 40 - 6 = 34$, $0.005 > P_r\{\chi^2 > \chi_0^2\}$

Table 3-13. (Example No.13)

Jig number (i)	Observed: Catch by 10 consecutive swings (j) 0	1	2	3	Estimated (Cubic regression equation) 0	1	2	3	Estimated (Quadratic regression equation) 0	1	2	3
1	21				21				20.37	0.62	0.01	
2	21				21				20.58	0.42		
3	21				20.65	0.35			20.75	0.25		
4	21				20.43	0.56	0.01		20.88	0.12		
5	20	1			20.32	0.67	0.01		20.98	0.02		
6	21				20.31	0.68	0.01		21.00			
7	20	1			20.36	0.63	0.01		21.00			
8	21				20.46	0.53	0.01		21.00			
9	20	1			20.59	0.41			20.92	0.08		
10	20	1			20.70	0.30			20.80	0.20		
11	21				20.79	0.21			20.64	0.36		
12	20	1			20.83	0.17			20.44	0.55	0.01	
13	20	1			20.79	0.21			20.21	0.78	0.01	
14	21				20.66	0.34			19.93	1.05	0.02	
15	21				20.39	0.60	0.01		19.62	1.34	0.04	
16	18	3			19.99	0.99	0.02		19.27	1.66	0.07	
17	20	1			19.43	1.51	0.06		18.89	2.01	0.10	
18	19	2			18.71	2.18	0.11		18.48	2.38	0.14	
19	19	2			17.81	2.96	0.22	0.01	18.04	2.76	0.19	0.01
20	18	1		2	16.75	3.83	0.40	0.02	17.58	3.15	0.26	0.01
Sum	403	15	0	2	401.97	17.13	0.87	0.03	401.38	17.75	0.85	0.02

Cubic regression equation: $\chi_0^2 = 1.5973$, $df = 23 - 7 = 16$, $P_r\{\chi^2 > \chi_0^2\} > 0.995$

Quadratic regression equation: $\chi_0^2 = 0.9148$, $df = 23 - 6 = 17$, $P_r\{\chi^2 > \chi_0^2\} > 0.995$

Table 3-14 (Example No.14)

Jig number (i)	Observed Catch by 10 consecutive swings (j)						Estimated (Cubic regression equation)							Estimated (Quadratic regression equation)						
	0	1	2	3	4	5	0	1	2	3	4	5	6	0	1	2	3	4	5	6
1	74	2					75.09	0.91						72.65	3.28	0.07				
2	74	2					74.49	1.50	0.01					73.62	2.35	0.03				
3	74	2					73.85	2.12	0.03					74.11	1.87	0.02				
4	74	2					73.13	2.82	0.05					74.12	1.86	0.02				
5	73	3					72.27	3.65	0.08					73.66	2.31	0.03				
6	71	4	1				71.24	4.63	0.13					72.73	3.21	0.06				
7	74	2					69.98	5.80	0.22					71.34	4.53	0.13				
8	73	3					68.47	7.18	0.34	0.01				69.52	6.22	0.25	0.01			
9	66	8	2				66.67	8.79	0.52	0.02				67.31	8.23	0.45	0.01			
10	59	16		1			64.56	10.62	0.79	0.03				64.73	10.48	0.76	0.03			
11	65	8	2	1			62.13	12.65	1.16	0.06				61.83	12.89	1.21	0.07			
12	60	11	5				59.36	14.85	1.67	0.11	0.01			58.67	15.38	1.82	0.13			
13	56	13	7				56.28	17.16	2.36	0.19	0.01			55.28	17.88	2.60	0.23	0.01		
14	56	16	4				52.89	19.53	3.24	0.32	0.02			51.72	20.30	3.58	0.37	0.03		
15	56	13	6	1			49.24	21.84	4.36	0.52	0.04			48.04	22.55	4.76	0.60	0.05		
16	43	22	10	1			45.35	24.03	5.73	0.81	0.08			44.30	24.57	6.13	0.91	0.09		
17	48	18	10				41.30	25.97	7.35	1.23	0.14	0.01		40.54	26.29	7.68	1.33	0.15	0.01	
18	38	29	6	3			37.14	27.57	9.21	1.82	0.24	0.02		36.81	27.68	9.36	1.88	0.25	0.02	
19	38	25	8	1	2	2	32.95	28.72	11.27	2.62	0.40	0.04		33.17	28.67	11.16	2.57	0.39	0.04	
20	38	15	13	8	2		28.79	29.35	13.46	3.66	0.65	0.08	0.01	29.64	29.27	13.00	3.42	0.59	0.07	0.01
Sum	1210	214	74	16	4	2	1175.18	269.69	61.98	11.40	1.59	0.15	0.01	1173.79	269.82	63.12	11.56	1.56	0.14	0.01

Cubic regression equation: $\chi_0^2 = 58.3186$, df $= 46 - 7 = 39$, $0.050 > \Pr\{\chi^2 > \chi_0^2\} > 0.025$

Quadratic regression equation: $\chi_0^2 = 59.3762$, df $= 45 - 6 = 39$, $\Pr\{\chi^2 > \chi_0^2\} \doteqdot 0.025$

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

The above-mentioned suggestion and the following fact necessitated the examination on the change of catch in accordance with the lapse of working time: The examination of the agreeable type of frequency distribution does never concern with the sequence of the swings, in spite of its decisive importance in the present case. For the purpose of confirming the chance distribution, therefore, the fact that the observed distribution is agreeable to the stratified binomial series is not sufficient, but it is necessary to verify the randomness of the catch in accordance with the lapse of working time. If the squids are caught collectively within some time sections, it is necessary to examine the relation between the time sections of good catch and the environmental conditions including the astronomical ones, for the purpose of finding out whether the fishermen's sayings of the dusk catch and the dawn one are true or whether they are nothing but the wrong impression caused by the psychological condition of the fishermen during the long and monotoneous work.

4. 1 General trend

For the purpose of finding out the general trend of the change of catch in accordance with the lapse of working time, the cubic or quadratic or linear regressive relation of the number of catch by a swing on the swing number was examined after the $\log(y+\frac{n}{2})$ transformation, because the frequency distribution of catch by a swing was agreeable to

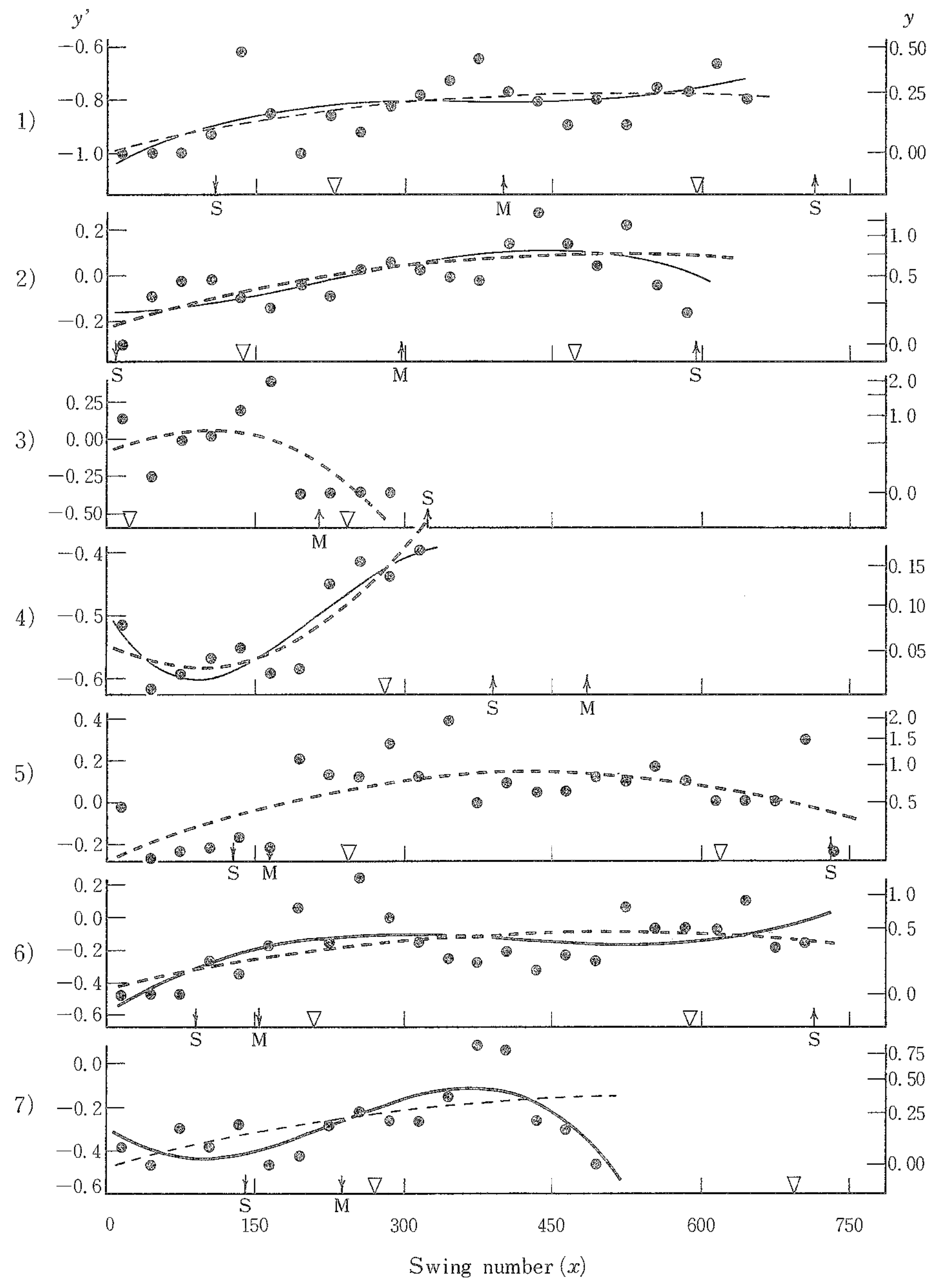
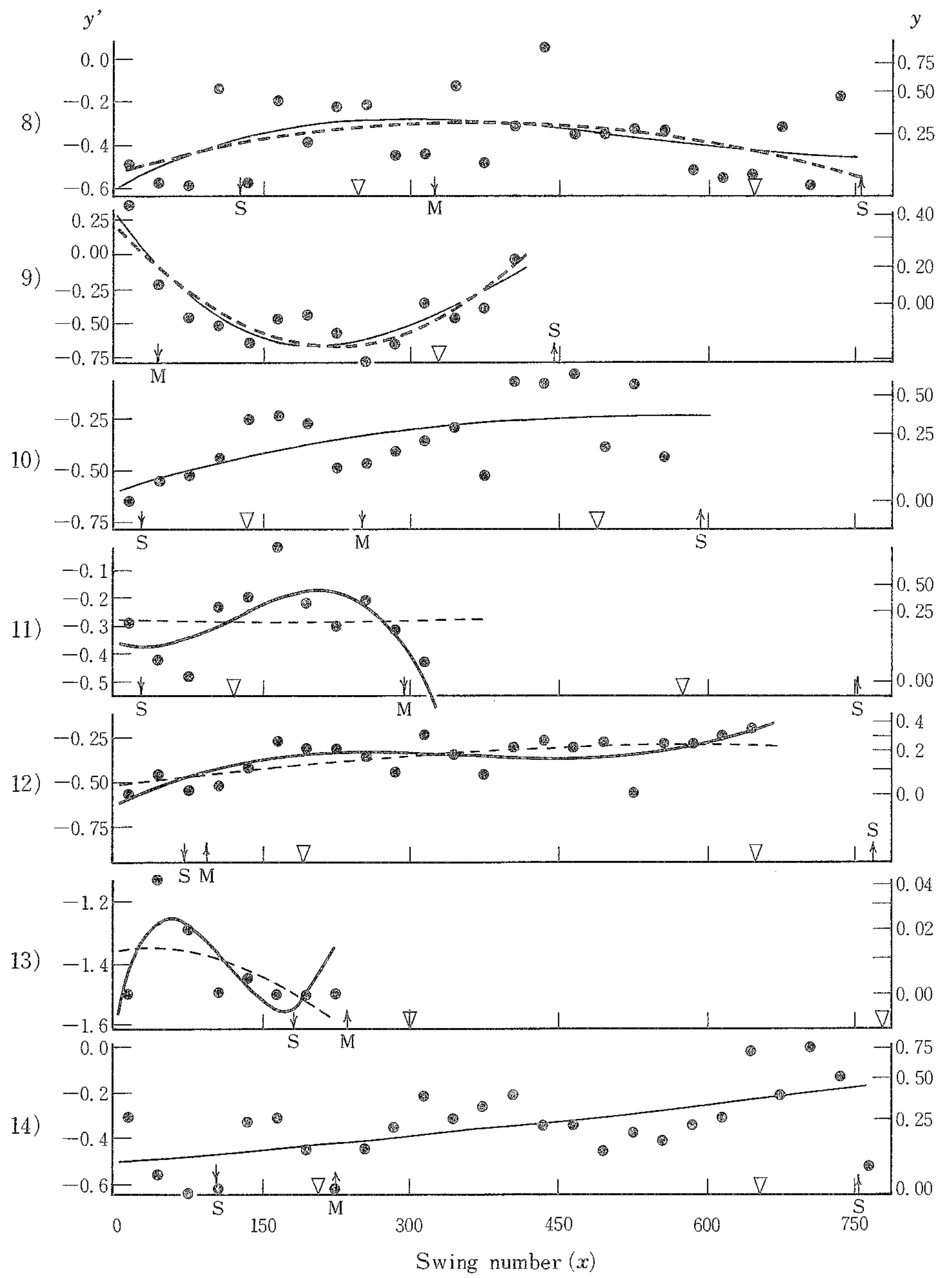


Fig. 3-1. The change of catch by a swing in accordance with the swing number (showing the regression lines estimated from the records of all the consecutive swings).

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 30 consecutive swings.



Solid line ..... Estimated cubic regression equation
Broken line ..... Estimated quadratic equation
Thick line ..... Significant equation
Thin line ..... Insignificant equation
s↓ sunset s↑ sunrise m↓ moonset m↑ moonrise
Open triangle ..... Limit of the astronomical twilight (the sun being 18° below the horizon)

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

Example number	Applicable range (x)	Cubic equations						
		a_0	$a_1 \times 10^3$	$a_2 \times 10^6$	$a_3 \times 10^9$	F_3	Max. x	Max. y'
1	1−642	−1.0501	1.9089	−4.9731	4.3435	1.84	—	
	1−330	−1.1256	4.9373	−29.2935	53.9385	3.48	133.5	−0.8602
	151−480	0.8023	−20.3363	75.5688	−85.5441	6.16*	380.9	−0.7073
	331−642	1.1714	−8.6374	10.1780	−1.8666	0.002	3144.6	16.6128
2	1−575	−0.1627	0.0359	3.9438	−5.9684	2.31	445.0	0.1083
	1−300	−0.3811	7.8240	−56.1685	120.9367	9.56**	105.8	−0.0388
	151−450	−2.4219	25.6587	−89.4576	102.6751	6.83**	258.1	0.0067
	301−575	6.5508	−52.0865	134.5924	−111.8741	4.13*	476.0	0.1874
3	1−289	−0.0806	2.3820	−8.4092	−20.5886	0.20	102.8	0.0530
4	1−325	−0.4973	−2.5160	17.3230	−26.4149	1.05	345.2	−0.3881
5	1−748	−0.2781	1.9895	−2.4250	0.1973	0.02	433.1	0.1447
	1−360	0.0038	−6.1799	46.0470	−74.8450	15.61**	325.6	0.2898
	181−540	−1.1448	12.6020	−37.3617	34.1256	2.65	264.5	0.2061
	361−748	0.7266	−5.8046	14.7351	−11.3077	0.51	566.9	0.1113
6	1−720	−0.5948	3.9535	−10.3211	8.2953	17.88**	300.1	−0.1137
	1−360	−0.4257	−3.1166	45.5801	−102.5810	27.63**	256.8	0.0426
	181−540	−2.6661	28.3736	−94.1851	95.0148	17.22**	232.2	0.0336
	361−720	6.2196	−41.3676	85.0579	−55.7300	5.20*	615.5	−0.0137
7	1−484	−0.2896	−3.3452	21.9003	−31.2839	21.63**	370.5	−0.1138
	1−240	−0.5036	4.9741	−48.5344	133.1636	4.25*	73.4	−0.3473
	121−360	1.3078	−23.1905	99.5196	−130.3428	2.60	328.5	−0.1914
	241−484	10.6540	−102.2743	311.8381	−307.0151	11.24**	398.5	−0.0105
8	1−737	−0.6139	2.5987	−6.1606	3.9723	2.97	295.2	−0.2814
	1−360	−0.6392	3.8748	−16.7253	25.2410	0.73	—	
	181−540	0.9081	−12.0234	36.8587	−35.2784	1.31	435.9	−0.2514
	361−737	−15.2641	86.9054	−163.6785	99.7062	16.95**	452.9	−0.2129
9	1−418	−0.2165	−5.6919	19.0851	−16.2851	1.40	580.6	−0.2750
	1−210	−0.0300	−13.6602	89.9555	−180.1330	1.02	215.8	−0.5990
	91−330	−1.7965	19.5558	−104.1737	172.2506	4.18*	148.7	−0.6256
	211−418	0.3395	−9.1579	22.7363	−11.9530	0.01	1017.0	1.9688
10	1−568	−0.6060	1.5890	−2.2253	0.9710	0.03	568.8	−0.2434
	1−270	−0.6886	1.7569	19.9734	−95.4531	1.95	174.6	−0.2810
	121−420	−0.3563	4.1737	−31.4894	55.1713	1.06	85.5	−0.1952
	271−568	5.7878	−52.0726	141.3309	−121.8900	4.91**	470.0	−0.1213
11	1−322	−0.3568	−1.4448	26.6790	−74.7381	5.49*	206.8	−0.1756
12	1−659	−0.6303	2.6728	−7.8794	7.3182	8.12**	274.8	−0.3390
	1−330	−0.5900	1.4787	−0.4247	−5.0663	0.04	285.2	−0.3203
	151−510	0.2175	−4.5678	11.1368	−7.9397	0.11	631.4	−0.2253
	331−659	−5.6015	33.9818	−72.2017	50.4671	2.24	422.3	−0.3265
13	1−217	−1.6196	13.8156	−155.4090	448.1458	9.53**	60.0	−1.2533
14	1−765	−0.5003	0.3446	0.0533	0.0688	0.001	—	
	1−390	−0.3677	−3.0328	17.3485	−22.8146	1.63	394.7	−0.2649
	181−600	−2.2546	13.9458	−31.9593	23.2015	2.65	356.9	−0.2935
	391−765	18.5312	−101.6132	177.7676	−100.9770	18.32**	681.3	−0.1164

Note: Cubic regression equation $y' = a_0 + a_1 x + a_2 x^2 + a_3 x^3$

Quadratic one $y' = b_0 + b_1 x + b_2 x^2$

Regression line $y' = c_0 + c_1 x$

Min.		Quadratic equations						Regression line		
x	y'	b_0	$b_1 \times 10^3$	$b_2 \times 10^6$	F_2	Max. (or Min.) x	y'	c_0	$c_1 \times 10^3$	F_1
——		−0.9930	0.8285	−0.7826	2.29	529.3	−0.7737	−0.9390	0.3253	14.51**
228.6	−0.8834	−1.0241	1.3693	−2.5130	1.16	272.4	−0.8376	−0.9778	0.5375	7.53**
208.1	−0.9280	−1.4519	3.8385	−5.3987	3.73	355.5	−0.7696	−0.9631	0.4319	3.37
490.5	−0.8368	0.9644	−7.3173	7.4317	4.21*	(492.3)	(−0.8368)	−0.7352	−0.0853	0.09
− 4.5	−0.1628	−0.2206	1.2275	−1.2139	4.59*	505.6	0.0897	−0.1532	0.5282	39.61**
203.8	−0.0958	−0.2088	1.2008	−1.5655	0.30	383.5	0.0215	−0.1850	0.7296	11.17**
322.7	−0.0072	−0.0425	−0.8024	3.1040	1.16	(129.3)	(−0.0944)	−0.2998	1.0631	23.68**
326.0	−0.0014	−2.3243	11.1396	−12.4959	11.47**	445.7	0.1583	−0.0044	0.1921	0.54
−375.1	−1.0707	−0.1072	3.4363	−17.3927	29.02**	98.8	0.0625	−0.1391	−1.6106	42.24**
92.0	−0.6027	−0.5450	−0.8156	4.3884	4.56*	(92.9)	(−0.5829)	−0.6234	0.6154	12.99**
7760.9	−38.6712	−0.2739	1.9229	−2.2033	57.88**	436.4	0.1456	−0.0674	0.2726	22.22**
84.5	−0.2348	−0.1780	−0.2959	5.5184	10.44**	(26.8)	(−0.1820)	−0.2986	1.6962	114.38**
465.4	0.0677	0.2187	−0.0502	−0.4549	0.06	(−55.2)	(0.2201)	0.2729	−0.3782	4.96*
301.8	0.0061	−1.0624	4.3766	−4.0778	7.19**	536.6	0.1119	0.1406	−0.1458	0.92
529.4	−0.1637	−0.4378	1.3618	−1.3498	14.10**	504.4	−0.0943	−0.3206	0.3886	33.44**
39.4	−0.4840	−0.6748	4.9479	−9.9675	31.08**	248.2	−0.0608	−0.4570	1.3496	62.57**
428.6	−0.3260	1.1303	−6.8537	8.5735	17.17**	(399.7)	(−0.2394)	0.1080	−0.6722	12.02**
402.0	−0.2850	−2.0042	6.4095	−5.3083	5.97*	603.7	−0.0694	−0.5104	0.6712	11.21**
96.2	−0.4366	−0.4717	1.0872	−0.8650	1.09	628.4	−0.1301	−0.4377	0.6677	42.09**
169.5	−0.4064	−0.4041	0.2820	−0.3957	0.01	356.3	−0.3539	−0.4003	0.1866	0.72
180.6	−0.4022	−0.2443	−1.6588	5.4781	1.43	(151.4)	(−0.3699)	−0.5353	0.9762	12.60**
278.7	−0.2744	−3.0411	16.2852	−22.2882	16.73**	365.3	−0.0663	−0.2205	0.1243	0.13
738.7	−0.4547	−0.5332	1.2979	−1.7623	16.94**	368.2	−0.2942	−0.3728	−0.0028	0.001
——		−0.5779	1.8905	−3.0574	1.38	309.2	−0.2857	−0.5111	0.7868	10.84**
260.6	−0.3464	0.5015	−1.0562	−1.2949	0.23	(407.8)	(−0.2861)	−0.3471	0.1226	0.24
641.5	−0.5473	0.1100	−1.2446	0.6222	0.07	(1000.2)	(−0.5124)	−0.0703	−0.5614	6.37*
200.6	−0.7218	−0.2780	−3.9681	8.8468	38.48**	(224.3)	(−0.7230)	−0.5382	−0.2611	2.69
117.2	−0.6853	−0.1218	−8.7810	32.9471	14.81**	(133.3)	(−0.7069)	−0.3699	−1.8292	15.86**
254.5	−0.7275	−0.4917	−1.9077	4.6026	0.92	(207.2)	(−0.6894)	−0.6739	0.0300	0.01
251.1	−0.7157	−0.0084	−5.6893	11.4654	2.01	(248.1)	(−0.7142)	−1.1023	1.5236	13.31**
959.1	−0.2723	−0.5970	1.3999	−1.3964	3.51	501.3	−0.2461	−0.5214	0.6053	30.83**
− 35.1	−0.7215	−0.7887	6.0008	−18.8283	18.16**	159.4	−0.3106	−0.5560	0.8984	8.41**
295.0	−0.4490	0.5389	−7.2095	13.2821	11.65**	(271.4)	(−0.4394)	−0.3344	−0.0239	0.01
303.0	−0.4055	−2.5522	10.7274	−12.1106	9.14**	442.9	−0.1767	−0.5095	0.5660	3.42
31.2	−0.3782	−0.2785	−0.0360	0.0628	0.001	(286.6)	(−0.2837)	−0.2791	−0.0182	0.01
442.9	−0.3563	−0.5239	0.7562	−0.6341	2.20	596.3	−0.2984	−0.4777	0.3376	21.68**
−341.1	−0.9427	−0.5995	1.8138	−2.9401	1.87	308.5	−0.3198	−0.5455	0.8406	21.69**
303.7	−0.3650	−0.0189	−2.1178	3.2645	2.47	(324.4)	(−0.3624)	−0.3405	0.0400	0.04
531.4	−0.3592	0.1236	−2.3193	2.7498	1.02	(421.7)	(−0.3654)	−0.5256	0.4030	3.15
171.1	−1.5606	−1.3644	0.7225	−8.1330	1.13	44.4	−1.3484	−1.2989	−1.0520	6.47*
——		−0.4987	0.3203	0.1324	0.15	−1209.6	−0.6924	−0.5117	0.4217	38.27**
112.3	−0.5218	−0.4378	−0.9302	3.9677	5.33*	(117.2)	(−0.4923)	−0.5395	0.6211	13·05**
561.5	−0.3928	−1.1098	3.9384	−4.7787	10.34**	412.1	−0.2983	−0.4510	0.2062	1.64
492.3	−0.4573	0.2192	−2.4106	2.5872	1.33	(465.9)	(−0.3423)	−0.6152	0.5805	7.29**

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

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

The Gothic numerals in the columns max. or min. show those estimated from the significant regression equation.

* significant at 0.05 level ** significant at 0.01 level

the negative binomial series in most of the examples (where y was the number of catch by a swing, and n was one of the parameters of the negative binomial series shown in Table 1).

Among the 14 examples, the working time of the four examples was short, and the records of these examples consisted of less than 350 consecutive swings. The results of these examples were shown for reference. As shown in Table 4 and Fig. 3, an increasing trend of catch with the lapse of working time (the significantly positive linear regression)

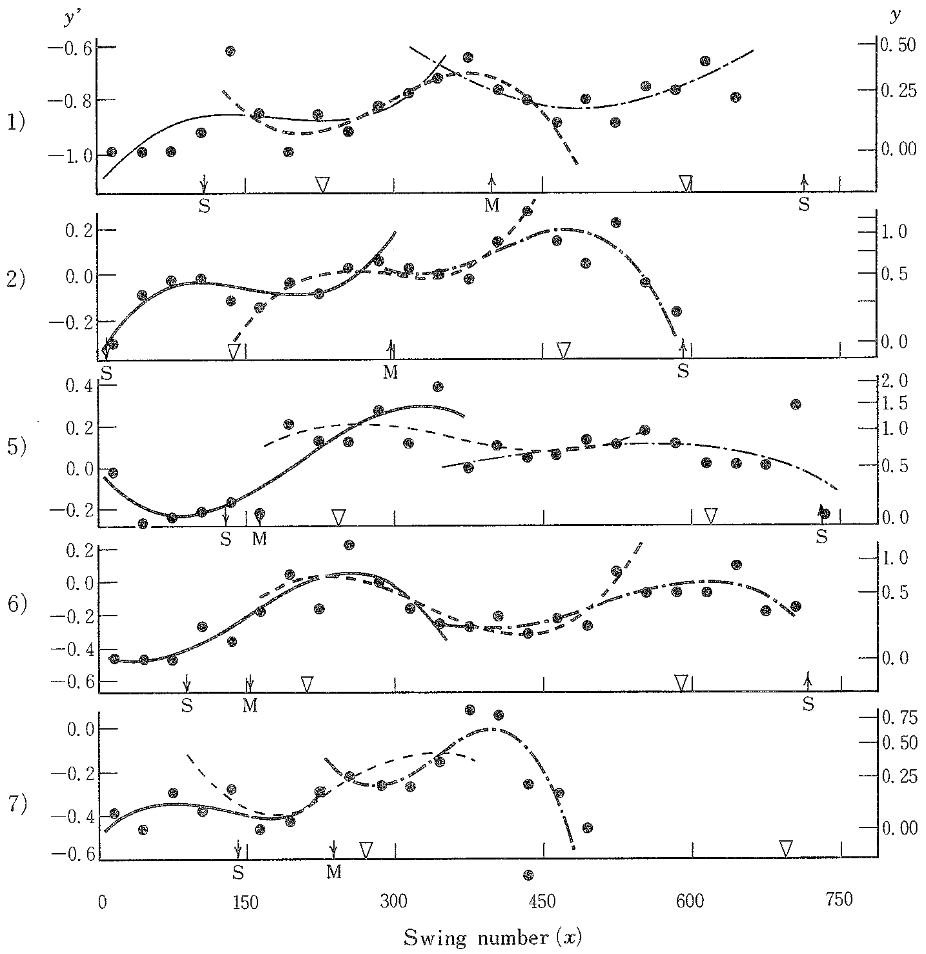
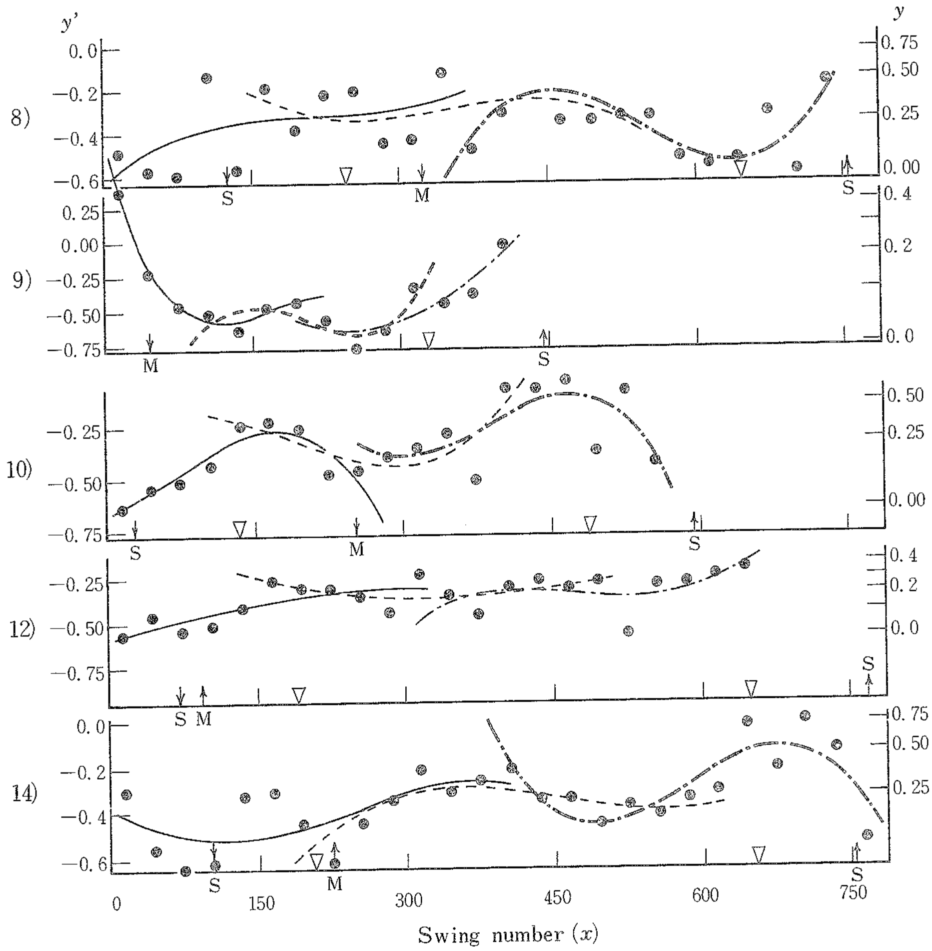


Fig. 3-2. The change of catch by a swing in accordance with the swing number (showing the cubic regression equations estimated from the records in the two successive quarters of all the consecutive swings).

Note: All the consecutive swings are sectioned into the four parts of the same time length; and the regression equations are estimated from the records in the two successive parts.
Solid curve ..... The relation estimated from the records in the first and the second quarters

was found in the nine examples out of the 10 ones. The quadratic regression equations suggested the concentration of catch in the latter half of working time in the examples Nos. 2, 4, 5, and 6, at the middle in the examples Nos. 3 and 8, and both of the earlier and the latter parts in the example No. 9. But the concentration of catch was not found out in the other examples. The cubic regression equations suggested the concentrated catch in the earlier half and the last part of the working time in the examples Nos. 6, 12, and 13, that in the earliest part and the last one in the example No. 7, and that in the



Broken curve.... The relation estimated from the records in the second and the third quarters
Chain curve ..... The relation estimated from the records in the third and the last quarters
Thick curve .... Significant cubic coefficient
Thin curve....... Insignificant cubic coefficient

latter half in the example No. 11.

To summarize, it may be said as follows: There were the six examples showing more contagious pattern than that expected from the increasing trend of catch according to the jig number. Among them, the contagiousness in the examples Nos. 3 and 8 was due to the concentrated catch in the middle of the working time (the quadratic regression), and that in the examples Nos. 5, 6, 10, and 14 was due to the increasing trend of catch in accordance with the lapse of working time (the linear regression). It was possible to explain the contagiousness in the eight examples through the increasing trend of catch in accordance with the jig number. However, the examinations in the present section showed that either the increasing trend of catch with the lapse of working time or the concentra-

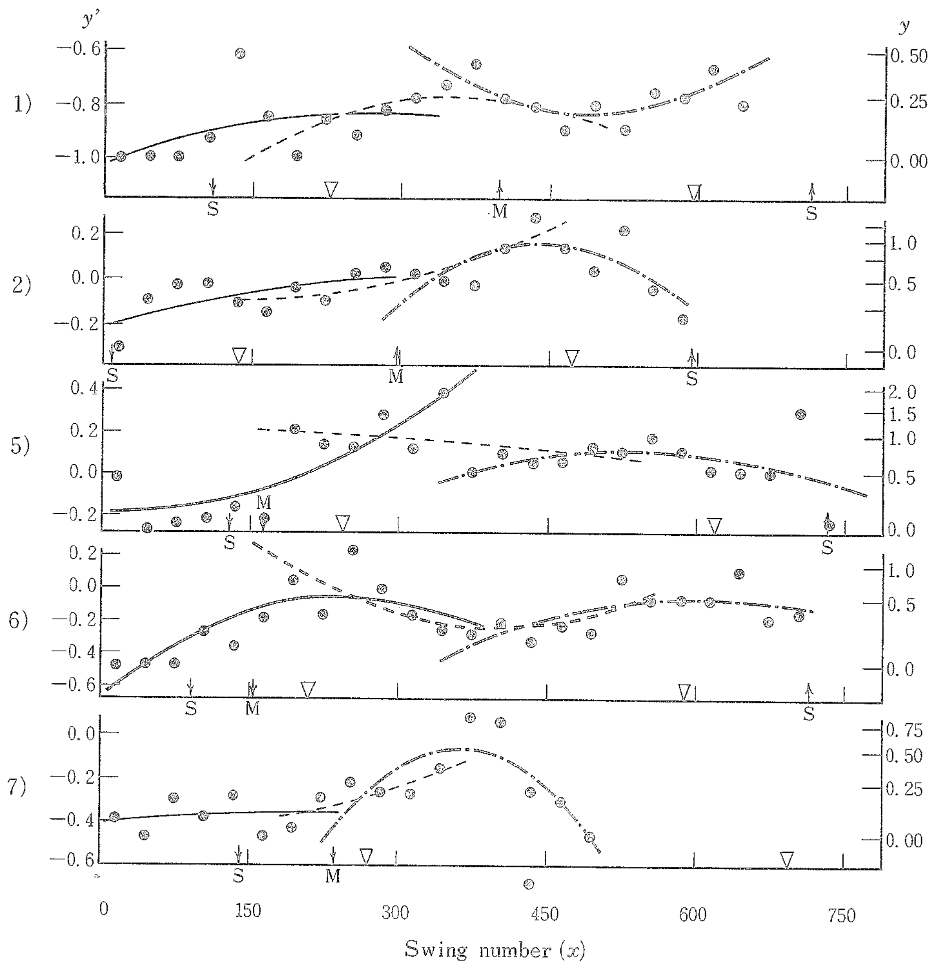


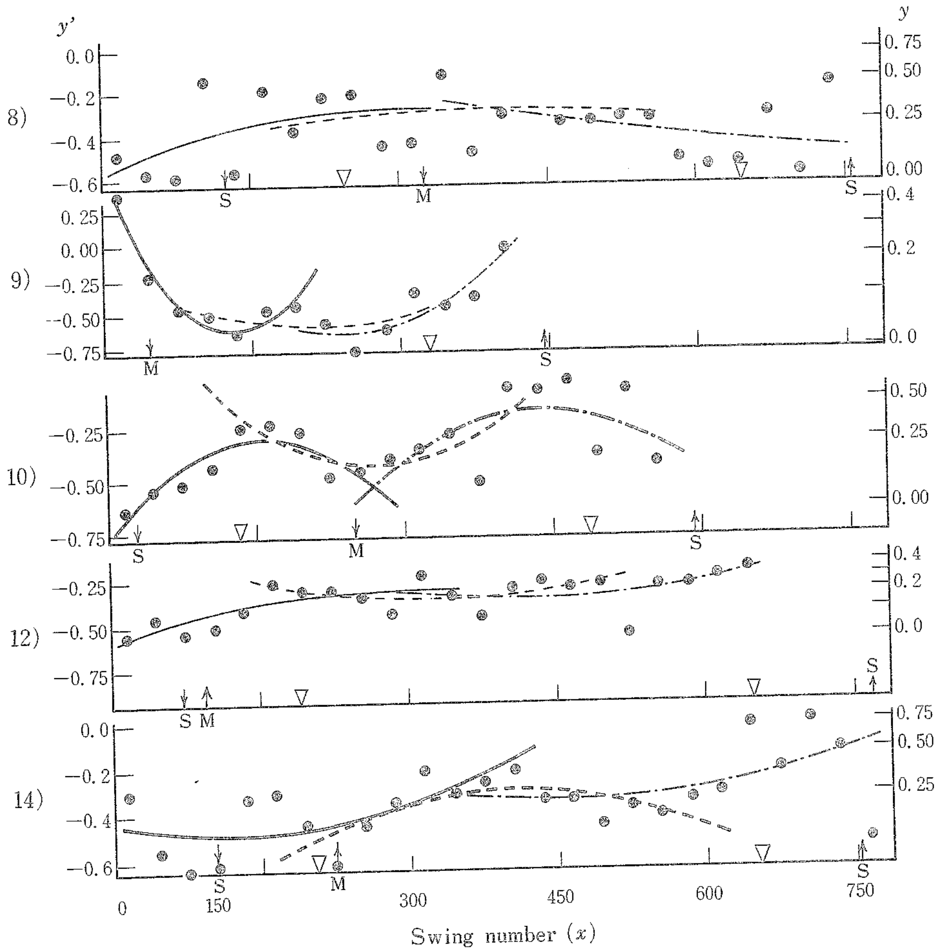
Fig. 3-3. The change of catch by a swing in accordance with the swing number (showing the quadratic regression equations estimated from the records in the two successive quarters of all the consecutive swings).

tion of catch was found even in these examples. Namely, even in these examples, it was hard to consider that the swings with various number of catch were arranged by chance.

4. 2 The trend in the earlier half of the night

The working time was very long, being about 17:30 to 5:30. Accordingly, it is necessary to examine the same problem in detail. The series of consecutive swings in the examples of more than 350 swings were sectioned into the three parts overlapping each other, i.e. the earlier two quarters, the middle ones, and the latter ones. And the regressive relation of the number of catch by a swing on the swing number was examined.

The linear regression equations in the earlier half revealed the following facts: The



increase in the catch in accordance with the lapse of working time was found in the eight examples out of the 10 ones (except the examples Nos. 7 and 9). In one of the examples (No. 9), the decreasing trend was found out, but the working time of this example differed from that of the others (after 22:10). In the other example (No. 7), the boat started the work a little before the sunset and shifted about midnight; in consequence, the earlier half ended before the end of the astronomical twilight, and the catch showed neither any significant increase nor any significant decrease in accordance with the lapse of working time.

The catch in this half showed the significant quadratic regression on the swing number in the five examples, but the maximum of catch in the three of them was out of the applicable range of the equations (except Nos. 6 and 10). The maximum of catch was found near the end of the astronomical twilight. The catch in this half showed a significant cubic regression on the swing number in the four examples. The maximum of catch was found before the sunset in the example No. 7, during the astronomical twilight in the example No. 2, and after the end of the astronomical twilight in the examples Nos. 5 and 6.

The results of these examinations meant that few evidence in support of the so-called dusk catch was found in the present examples.

4. 3 The trend about midnight

The linear regression equations revealed the continuous increase of catch till the beginning of the astronomical twilight before the sunrise in the example No. 2, the increase from the sunset to midnight in the example No. 7, and the decrease after the end of the astronomical twilight (the maximum of catch being at the end of the astronomical twilight) in the examples Nos. 5 and 6. The quadratic regression equations revealed the minimum of catch at midnight (i.e. the maximum of catch at the end of the astronomical twilight) in the examples Nos. 6 and 10, and the maximum of catch at midnight in the example No. 14. The catch in the four examples showed the significant cubic regression on the swing number. However, it was hard to find any common conclusion of the trend in the position of the maximum and the minimum of catch and their relation to the astronomical twilight.

4. 4 The trend in the latter half

The linear regression equations showed the increasing trend of catch in the examples Nos. 6, 9, and 14, and the decreasing one in the example No. 8. The quadratic regression equations revealed the increase of catch in the astronomical twilight before the sunrise in the example No. 1 (in this example, the boat ended the work still in dark) and the maximum of catch near the beginning of the astronomical twilight in the examples Nos. 2, 5, 6, and 10 (it was still dark in the earlier half of the twilight). The cubic regression equations revealed the maximum of catch near the astronomical twilight in the examples Nos. 2, 6, 10, and 12 and the increase of catch during the twilight in the example No. 8.

The results of these examinations meant that the fact in support of the so-called dawn catch was found in the three examples, but the facts contrary to this saying was found in the five examples.

4.5 The relation between the hour of concentrated catch and either the moonrise or the moonset

The relations of the hours of concentrated catch to the sunset, the sunrise, and the twilight were shown in the preceding subsections. This is the night fishing using the lamps, and the examples were distributed over the nights of the different moon ages. The seven examples covered the hour of the moonset (the examples No. 5 to No. 10), and the same number of examples covered the hour of the moonrise (the examples No. 1 to No. 4 and No. 12 to No. 14). For the purpose of finding out the relation between the hour of good catch and either the hour of the moonset or the moonrise, the hours of the local maxima of catch were estimated from the significant regression equations shown in Table 4, and they were plotted against the hour (Fig. 4). Here as shown in Table 4 and Fig. 3, some discrepancies were found between the number and the hours of the local maxima of catch according as the equations were cubic or quadratic and according as they were applicable to throughout the working time or applicable to the consecutive two quarters of the working time. In the present case, however, the estimated maxima of catch through the cubic regression equations applicable to the range shorter than 400 consecutive swings were used, because these equations represented the trends of the points in Fig. 3 with accuracy. And those estimated through the cubic ones applicable to more than 400 consecutive swings and those through the quadratic ones were shown for reference.

As shown in Fig. 4, it was hard to find any clear relations between the hour of the moonset and the hour of good catch, especially between the former and the latter estimated through the quadratic equations. This result may be because of the fact that this is the night fishing with lamp and the records were collected from the nights of the crescent to the half moon after the new moon. The sole finding was that about a half or two-thirds of the maxima of catch estimated through the cubic regression equations were found from one to three hours after the moonset. The earliest hour of local maximum of catch was found about two hours before the moonset. But, at the hour of good catch, the half moon was within 30° above the horizon. And the influence of the moon light may be very weak in the swimming layer of the objective squids (about 30 m deep), and it was getting dark rapidly.

The records covering the moonrise consisted of the four series of the nights of the crescent just before the new moon and the three series of the nights just after the full moon. It was also hard to find any clear relations between the hour of the moonrise and the hour of good catch. Among the seven chances of good catch estimated through the cubic regression equations, the four were before the moonrise. One was three hours after the rise of the crescent. The two chances were found after the rise of nearly full moon. One was one hour before the sunrise. The other was two and a half hour

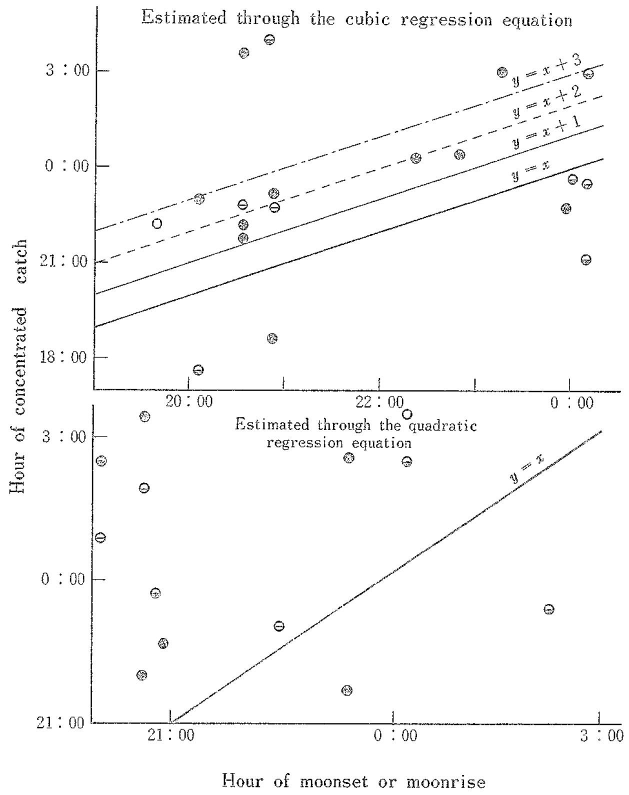


Fig. 4. The hour of the moonrise or moonset and the estimated hour of good catch.

Note: The hour of good catch is set to be the hour of the local maximum estimated from the regression equations with the significant coefficient.

Circle with the lower half filled ..... The hour of moonrise and the hour of good catch (estimated from the regression equation applicable to less than 400 consecutive swings)

Open circle..... That estimated from the equation applicable to more than 400 consecutive swings

Solid circle ..... The hour of moonset and the hour of good catch (estimated from the equation applicable to less than 400 consecutive swings)

Circle with horizontal bar ..... That estimated from the equation applicable to more than 400 consecutive swings.

after the moonrise, the moon being about 30° above the horizon. And it was hard to consider that the influence of the moon light at the swimming layer was negligible. However, the examination of the records threw a doubt as to the validity of this estimated chance of good catch: This was the local maximum of catch estimated through the cubic regression equation covering all the consecutive swings, but this was not clear in the distribution of the points in the example No. 12 of Fig. 3. And the corresponding local maximum was found neither in the quadratic equations nor the cubic ones covering any two quarters of the records.

These results were summarized, and it may be said that it was hard to find any clear relation between the hour of the moonset or the moonrise and the hour of good catch, except a slightly high possibility of occurrence of good catch from one to three hours after the moonset.

Discussion

1. The vertical distribution of catch

The most probable type of the vertical distribution of catch yielding a good result may be that the maximum of catch is by the jigs on the central parts of the leader and the jiged density decreases towards both shallower and deeper parts. But the results were contrary to the expectation, and the clearest trend found in the catch records was the sharp and continuous increase of catch in accordance with the jig number counted from the shallowest end. During the fishing work, the skipper adjusted the swinging depth of the jigs with the assistance of the echo-sounder. Accordingly, it was hard to consider that the results were due to the fact that the jigs did not reach the swimming depth of the objective schools under the lamp. Then, another probable reason of causing the observed pattern might be as follows: Even if all the jigs reached the swimming layer of the objective schools, the jigs in the deeper parts passed longer time in the layer of dense population than the jigs in the shallower parts. When the catch increases in accordance with the length of the passing time of the jigs through the densely populated layer, the catch may increase in accordance with the jig number counted from the shallowest end. The skipper was skillful enough. And it was also hard to consider that the results were due to the insufficient swinging down of the jigs. The other probable reason of causing the increase of catch in accordance with the jig number was the habit of the objective squids: During the recording, we observed frequently some individuals swimming up pursuing the jigs on the shallower parts, staying just beneath the surface, stalking the chance of catching the other jigs wound up one by one, and finally being hooked by the jigs in the deeper parts. If the increasing trend of catch in accordance with the jig number is due to this reason, it is hard to change the type of the vertical distribution of catch, by adjusting the swinging depth of the jiged leader. The sharp increase of catch was found in all the 14 examples without exception; and all the fishermen interviewed supported this trend and the above-mentioned mechanism. Accordingly, it may be concluded that the sharp increase of catch in accordance with the jig number was not due to the inadequate adjustment of the swinging depth of the jiged leader but due to the habit of the objective squids.

This mechanism of the sharp increase of catch provided us with the following suggestion: In the angling for most of the fishes, a very fine adjustment of the position and movement of the baited hooks is one of the key points of yielding a good catch, and it was hard to do so using a simple device. This prevented the other angling from the mechanization. In contrast with this, it is not necessary to adjust the position and movement of the jigs in the squid angling under the lamp, because the squids under the lamp pursue their prey actively. This makes it possible to catch the squids with the simple device. i.e. substitute the simple device for the human's technique.

The vertical distribution of catch suggested a possibility of long leader with dense jigs yielding a good catch. But there are many doubts as to the efficiency of long leader, although the reel capable of handling long leader with 30 to 40 jigs has been invented out. During the fishing work, the boat was fixed with the sea-anchor and the spanker. It was, however, rare that the boat was drifted exactly according to the current, and the leaders were swung vertically. Accordingly, the risk of a leader in water interlacing with the neighbouring ones increases in accordance with its length, and the risk of jigs wound on the drum catching the wound leader increases in accordance with the number and the density of jigs. In the type of fishery studied here, the crew was minimized and all the powered reels worked without watchmen. Accordingly, it is necessary to reduce the trouble during the fishing work; in consequence, it was hard to use long leaders with dense jigs, in spite of the sharp increase of catch in accordance with the jig number counted from the shallowest end.

2. Fluctuation of catch in accordance with the lapse of fishing work

The catch was scattering over at very low density throughout the fishing hour (i.e. throughout the night). And it was hard to find any clear symptom of concentrated catch within some limited hours. In the angling by the human hands, the behavior of fishermen differs according to the feeding activity of the objectives. During the time of low activity, the fishermen incline to swing the leaders slowly relaxing their attention. Some of them close the angling work and take rest or engage in the other work, for examples, preparing the other leaders and repairing the instruments and equipment. When they find a symptom of active feeding, they easily concentrate their attention and labor into handling the gears and work at their highest efficiency. And they easily change their work pattern according as the squids are jiged. They repeat swings within the densely populated layer till catching a squid; and when they find a symptom of catching a squid, they wind up all the parts of the leader and take inboard the catch. When the jigs are occupied by the squids during sinking step, the fishermen wind up the leader immediately. In contrast with this, the leaders on the automatic powered reels repeat simple up-and-down movement at regular periodicity and at regular amplitude regardless of the feeding activity of the objectives. Because of the above-mentioned work pattern, the fishing activity of the human hands differs according to the feeding activity of the objectives; in consequence, the influence of the different feeding activity is doubled. This makes the analysis of the catch records complicated. In contrast with this, the catch records of the automatic powered reel are free from the influence of the different feeding activity of the objectives, and are suitable for the analysis of the change of the behavior pattern of the objective schools.

Under low feeding activity, the loss of efficiency of the automatic powered reel due to useless winding up and useless sinking down may be small and made up by the constancy of the working pace. Today, the rise in the labor cost and the short labor supply are the most fatal necks in our fishing industry. And the importance of the substitution of a simple device for the human hand lies in this point, especially when the feeding activity of the objectives is low. The records of the present study are in the case like this. But it is doubtful as to the mechanized angling always having advantages over the angling with human hand. It is hard to substitute a simple device for the human hand in the angling requiring fine adjustment and fine techniques. In the squid angling, it may be hard to neglect the efficiency loss, when most of catch are concentrated in some short time sections. In the case like this, the mechanized angling has advantages over the angling with human hand, only when the labor supply is very hard or when low feeding activity continues over many hours and the rise of catch in these time sections fills up the low efficiency during the short time sections of high feeding activity. Namely, the advantage and disadvantage of the automatic powered reel depends on the condition of the labor supply or the labor charge and the pattern of feeding activity of the objective fish.

3. The relation between the catch and the astronomical conditions

The squid angling is the fishing using lamps at night. Many reports dealt with the relation between either the amount of catch or the behavior and the moon age[1),2)]. The records used in the present report were distributed over the nights of the different moon ages. But the present records were collected from the different point of view. And the unit of effort chosen was very minute, and the present records were not suitable for the examination of the daily difference of the catch. In regard to the change of catch with lapse of working time, Hokkaido Fishery Station[3)] reported that the squids fed actively around the sunset, the sunrise, and the midnight, and this trend was clearer in the moonlight night than in the dark night. The present records covered the moonlight nights—either the nights of the crescent to the half moon after the new moon and those just after the full moon. But the results were different, and it was hard to find any clear symptoms suggestive of the dusk catch, the dawn one, and the relation between the catch and either the moonset or the moonrise. In spite of the clear difference between the results, it was hard to find the reason of causing the difference, because all the backgrounds of these records were completely different: The light source became far intense, the fishing ground shifted far off-shore, and the gear construction and the supporting devices developed into the uncomparable level.

There remains a doubt as to the difficulty in finding out the relation between the catch and the astronomical conditions, because this is the fishing using lamps at night. The difficulty may be mainly due to such distribution pattern that the catch were scattering over at very low density throughout the fishing hours without showing any clear concentration into some limited time sections. The other reason was that, as suggestive of the following observations, it is doubtful that the light is indispensable and this fishing is exclusively at night: When an echogram probably from the densely schooling squids was found out during drifting or slow shifting in the daytime or in the evening, the squids were fished with the same gear as that used in the fishing at night. In the case like this, it was not dark and we did not use the lamp, but the squids fed very actively and a large number of squids were jiged up, although the active feeding lasted only several minutes. Sometimes, the powered reel was clutched on just after finding out the school, and a large number of squids were yielded before putting the lamp. An active feeding continued after the sunrise and many squids were caught after cutting off the lamp. These distribution pattern and the feeding behavior of the objective squids in the fishing grounds may make it difficult to find out the relation between the catch and the astronomical conditions during the fishing work.

Summary

The invention of the automatic powered reel caused a basic change in the hand-angling for the squid, by making it possible to substitute a simple device for the human's technique. The present report dealt with the catch records of the squids by the automatic powered reel collected from July to August of 1971 around the Yamatotai bank in the Japan Sea, for the purpose of describing exactly the catch pattern and finding out the reason of making it possible to substitute a simple device for the human's technique. And the results obtained were summarized as follows:

1. The occupied rate of the jigs by squid was very low, being 0.005 to 0.05. And the frequency distribution of catch by a swing in the 11 examples out of the 14 ones was agreeable to the negative binomial series.

2. The catch showed a very sharp and continuous increase in accordance with the jig number counted from the shallowest end to the sinker.

3. It was possible to explain that the weakly contagious pattern in the eight examples of poor catch was the false one due to the increasing trend of catch in accordance with the jig number, but the pattern in the six examples of good catch was more strongly contagious than expected from the regressive relation of catch on the jig number.

4. Some of the cubic and quadratic regression equations of catch by a swing on the swing number suggested the presence of the local maxima of catch; but most of them were not

firm but were so faint that the location and number differed according as the equations were cubic or quadratic and according as they were applicable to throughout the working time or applicable to the consecutive two quarters of the working time.

5. It was hard to find any clear relation between the hour of local maximum of catch and the hour of either the sunset, the sunrise, the moonset, or the moonrise. This may partly be due to the above-mentioned distribution pattern of catch and partly be due to the following possibility: It was doubtful that the light is indispensable and the fishing is exclusively at night.

6. It is possible to substitute a simple device for the human's technique, because the squids under the lamp pursue their prey actively. The mechanized angling has advantages over the angling with human hands, because of scattering of catch at very low density and because of the short labor supply.

References

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