Theoretical Estimation of Albacore-shoals Dimensions in Accordance with the Characteristic of Fishing-rates

by Toshiro KUROKI

釣獲率よりするビンナガ魚群態の算定理論

黒　木　敏　郎

I. Introduction

In the present day, we can only confirm shoals in the range of few meters, at most few hundreds meters, by some optical apparatus or by sounding (fish finder); of course those in the range of several kilometers, for example in the long-line fishing of albacore, are beyond our capacity. Therefore, though many studies about the virtical distribution of this fish have been done by making some investigations on the length of branch-ropes and the slackness of main-ropes in the long-line fishing[1], we can hardly ever expect to find the study about the horizontal distributions of albacore shoals measured by kilometer unit.

In this paper, the author describes a new method by which the conditions of the horizontal distribution of albacore shoals in the ocean will be ascertained through considering the characteristic of the histograms on the fishing-rates* of the long-line. Although there may remain a few uncertainties in the results of the calculations, the author may venture to say that this method contains some what original idea to resolve the problems offered by the invisible phenomena under water.

Fundamental considerations: Here, let us consider the histogram of the fishing rate about the frequency of long-line fishing during a definite season on a certain fishing ground.

If albacores in the shoals on the fishing ground are assumed to be very sparsely populated and uniformly distributed, and if many long-lines are set optionally over very wide ground, the curve of the histogram should be as given in Fig. 1–a.

Usually, however, experiences enable long-lines to be set in a "good season" on a "good fishing ground". Therefore, when the dimensions of the fishing ground are appropriate the length of a long-line, and when the time of fishing matches with the "season" and the distribution of fishes is uniform and no rich, then the histogram of the frequency of the fishing rates should show a normal curve whose maximum mode lies on a rate not zero as given in Fig. 1–b.

Now, if the distribution of albacores should not be uniform and the group of fish should be formed one rich shoal in some extent (with a range of few kitometers, about a tenth of the length of long-line), the low frequencies should be found at the high rate side and the higher mode of ones should be appeared at low rate side. Especially, because it may be happened very often that the long-line does not be encountered the rich shoal, the peak of frequency may be appeared at very low fishing rate as in Fig. 1–c.

* "Fishing rate (%)" means catches per 100 hooks.

Fig. 1. Fundamental types in histograms of the frequency of fishing-rate.

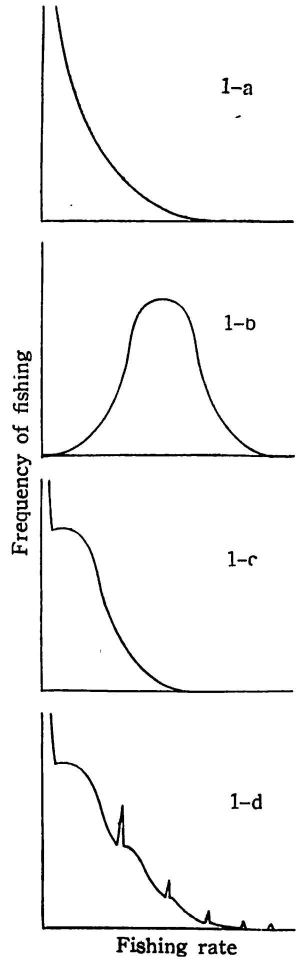


Fig. 2. Example of the histogram of frequency.

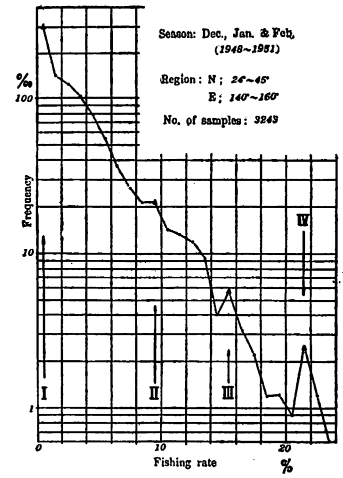
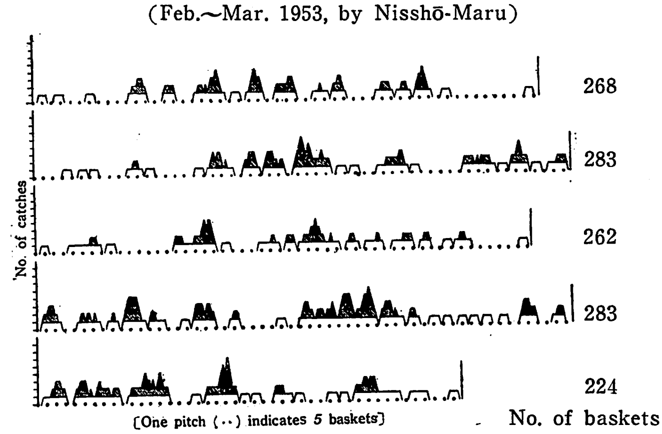


Fig. 3. The total numbers of albacore by the long-line in five baskets adjoined each other. (Feb.~Mar. 1953, by Nisshō-Maru)



And, if there should be not only one shoal but several shoals in the fishing ground, naturally the long-line is to be intersected with the several shoals. Then the histogram of frequency should be appeared to have several peaks as Fig. 1–d; i.e. the same modes as Fig. 1–c should be superposed at high rate side in low frequencies. Thus, we may be able to estimate the dimensions of albacore shoals by making use of such characteristics of the histogram. This idea shall be developed into a estimating theory.

Data treated: We selected data of fishing rate from the Working-Reports, Supplementary-Reports No. 1 and its Appendix Diagram (1952)[2] of NANKAI Regional Fisheries Research Laboratory, and arranged them in order (every month 1949–1951, every region of A·B·C): C.f. supplemental tables.

For an example, the histogram of 3243 samples in Dec., Jan. & Feb. 1948–1951 on a region (N: 24°~45°, E: 140°~160°) is shown in Fig. 2.

Now, it is evident that as described above the actual phenomena are similar to the last case (Fig. 1–d).

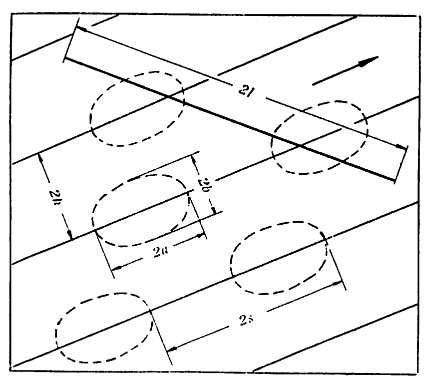
It may be said that another data[3] (Fig. 3) have the same meaning. In Fig. 3, one pitch of dots indicated five baskets of long-lines and the total numbers of albacores caught in five baskets adjoined each other are shown as height on a center basket which is slided from one end (excepting two baskets) to the other end (leaving two baskets) of the long-line. As we see, the groups of catches are shown periodically and similarly.

Then, our consideration is led to the presumption that there may be several rich shoals of albacore in the fishing ground and that these shoals are set in array at a distance. And, the efforts to resolve the dimensions of the albacore shoals on the presumption begin.

II. Theoretical estimation

The theory is going to be expanded on the following several assumptions. (C. f. Fig. 4.)

Fig. 4. Illustration on the assumptions.



◎ Shoals are shifting on the lines which are in parallel with each other at $2h$ (kilometer) intervals, and the distance between one shoal and the next is $2s$ (kilometer) on one line.

When a long-line, $2l$ (kilometer) in length, is set, it may be intersected with one or more of these parallel lines.

◎ The shape of shoal is a ellipsoid; but as the dimensions may be several kilometers while the thickness of shoal (the range of depths in where albacores are migrating) is one hundred meter at most, it may be regarded as a kind of elliptic plate.

The lengths of major and minor axises are fixed to be $2a$ and $2b$ (kilometer) long respectively.

◎ The direction of the shifting of shoals, or the direction of the parallel lines, may be not always in accord with the major axis of the ellipse. But, here, let it be confessed that the author regarded them to be in accord with each other, as this assumption has no essential influence on the calculation.

The probability of the intersecting of a long-line with albacore shoals is calculated according to the resolving method of the "Buffon's Needle Problem"[4]. In the following chapters, the needle is considered to be equivalent to a long-line and the parallel lines are to be parallel bands on which the shoals shift.

II. 0. Non-encountering probability

When a long-line ($2l$ in length) is laid discretionally on the parallel lines (at $2h$ intervals), dP_{0x} the probability of that M (the middle point of $2l$) lies between

* 2), 3): The author thanks to Dr. NAKAMURA and Mr. UEYANAGI for their co-operation in collecting these data.

Fig. 5. Illustration about the consideration to obtain the probability.

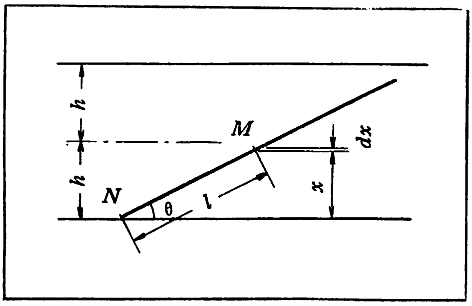
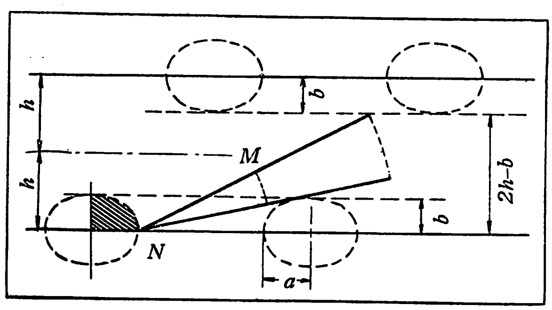


Fig. 6. The case of non-encountering.



x and dx should be written as (C.f. Fig. 5)

$$dP_{0x}=dx/h \qquad (1)$$

(in the range $0<x\leqq h$).

In Fig. 5, because the end of $2l$ is laid on the point N ($x\fallingdotseq 0$),

$$x=l\cdot \mathrm{Sin}\theta$$

$$\therefore \quad dx=l\cdot \mathrm{Cos}\theta\cdot d\theta \qquad (2).$$

On the other hand, $dP_{0\theta}$ the probability of a long-line's inclining between 0 and θ, also between $\pi-\theta$ and π, is given as

$$dP_{0\theta}=2\,\theta/\pi \qquad (3).$$

Therefore, the probability of the long-line's lying under these two conditions should be written as

$$dP_0=dP_{0x}\times dP_{0\theta}$$

or

$$dP_0=(2\,l/\pi h)\cdot\theta\cdot \mathrm{Cos}\theta\cdot d\theta \qquad (4).$$

Here, let us consider of the probability of non-encountering (i. e. of the long-line's non-intersecting with any parallel lines).

As we see in Fig. 6, the range of x should be given as

$$l\times b/\sqrt{(2s-a)^2-a^2+b^2}<x\leqq h-b/2 \qquad (5).$$

And instead of h in Eq. (4), we have to take the value;

$$h-(b/2)-(l\times b/\sqrt{(2s-a)^2-a^2+b^2}).$$

Furthermore, we must take the modification about the end position N into the equation. The modifying factor should be given as

$$(2\cdot s\cdot b-\pi a\cdot b/4)/2sb \qquad \text{or} \qquad 1-(\pi a/8s).$$

Fig. 7. The case of one-encounterering.

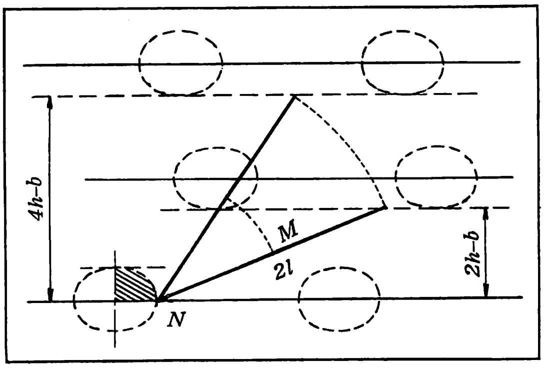
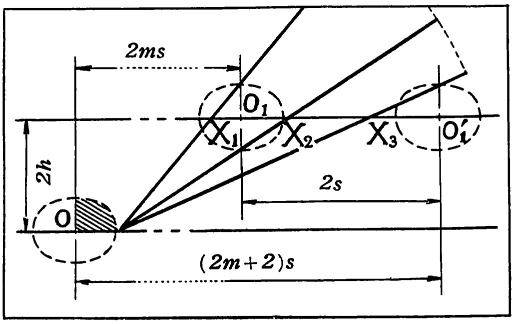


Fig. 8. Illustration about the consideration to obtain α_1 approximately.



Thus, we obtain the non-encountering probability P_0 as follows;

$$P_0=\int dP_0=\frac{2l\,(1-\pi a/8s)}{\pi\,[h-b(1/2+l/\sqrt{(2s-a)^2-a^2+b^2})]}\int_0^{\mathrm{Sin}^{-1}(2h-b)/2l}\theta\cdot\mathrm{Cos}\theta\cdot d\theta$$

or

$$P_0=\frac{l\,(8\pi-\pi a)}{4\pi s\,[h-b\,(1/2+l/\sqrt{(2s-a)^2-a^2+b^2})]}\times\Big[\theta\cdot\mathrm{Sin}\theta+\mathrm{Cos}\theta\Big]_0^{\mathrm{Sin}^{-1}(2h-b)/2l} \qquad (6).$$

II. 1. One-encountering probability

In this case (C.f. Fig. 7), the range of x is simply given as

$$(2h-b)/2<x\leqq(4h-b)/2\ ,$$

and the value of h in Eq. (4) should be as follow

$$(4h-b)/2-(2h-b)/2,\quad \text{i.e. } h \text{ remains itself.}$$

The range of θ should be written as

$$\mathrm{Sin}^{-1}(\overline{2h-b}/2l)<\theta\leqq\mathrm{Sin}^{-1}(\overline{4h-b}/2l).$$

It is necessary to take the factor $(1-\pi a/8s)$ in like wise the previous case. Simultaneously, the modifying factor α_1 of the probability of the long-line's *having* to be encountered once with an ellipse of shoal, has to be taken into the equation.

It may be thought that the value of α_1 should be equal or proximate to 1.00. When the end of the long-line lies upon N in Fig. 8, the value of α_1 is given approximately as follow;

$$\alpha_1=(\overline{X_1O_1}+\overline{O_1X_2})/(\overline{X_1O_1}+2s-\overline{X_3O'})$$

and, from geometrical calculations, we get

$$\alpha_1 = b(2ms-a)/s(2h-b),$$

where $m \doteqdot 0,\ 1/2,\ 1,\ 1\frac{1}{2},\ \cdots\cdots.$

Thus, P_1 the probability of one-encountering is given as

$$P_1 = \frac{2l(1-\pi a/8s)}{\pi h}\cdot\alpha_1\cdot\int_{\mathrm{Sin}^{-1}(2h-b)/2l}^{\mathrm{Sin}^{-1}(4h-b)/2l}\theta\cdot\mathrm{Cos}\theta\cdot d\theta$$

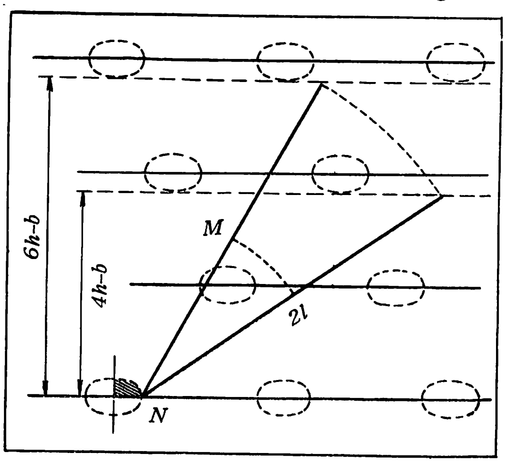
or

$$P_1 = \frac{l(8s-\pi a)}{4\pi hs}\cdot\frac{b(2ms-a)}{s(2h-b)}\cdot\Big[\theta\cdot\mathrm{Sin}\theta+\mathrm{Cos}\theta\Big]_{\mathrm{Sin}^{-1}(2h-b)/2l}^{\mathrm{Sin}^{-1}(4h-b)/2l} \qquad (7).$$

II. 2. Two-encountering probability

Let us treat, in this section, the case that "the long-line encounters with the 1st shoal upon one line of parallels and further it does the 2nd shoal upon the other line of them". C. f. Fig. 9.

Fig. 9. The case of tow-encountering.



Under the same consideration as in the previous case,

the range of x : $\left(\frac{4h-b}{2}\right) < x \leqq \left(\frac{6h-b}{2}\right)$

the range of θ : $\mathrm{Sin}^{-1}\left(\frac{4h-b}{2l}\right) < \theta \leqq \mathrm{Sin}^{-1}\left(\frac{6h-b}{2l}\right)$

the modification about the end : $\left(1-\frac{\pi a}{8s}\right)$

the modifying factor α_2 : $\left(\frac{b(2ms-a)}{s(4h-b)}\right)^2.$

Thus, P_2 the probability of two-encountering is written as follow

$$P_2 = \frac{l(8s-\pi a)}{4\pi hs}\times\left(\frac{b(2ms-a)}{s(4h-b)}\right)^2\times\Big[\theta\cdot\mathrm{Sin}\theta+\mathrm{Cos}\theta\Big]_{\mathrm{Sin}^{-1}(4h-b)/2l}^{\mathrm{Sin}^{-1}(6h-b)/2l} \qquad (8).$$

II. 3. Generally, n-encountering probability

Likewise with the previous cases,

$$\left(\frac{2nh-b}{2}\right)<x\leqq\left(\frac{2(n+1)h-b}{2}\right)$$

$$\mathrm{Sin}^{-1}\left(\frac{2nh-b}{2l}\right)<\theta\leqq\mathrm{Sin}^{-1}\left(\frac{2(n+1)h-b}{2l}\right)$$

$$\alpha_n=\left[\frac{b(2ms-a)}{s(2nh-b)}\right]^n.$$

Then, the probability of n-encountering should be given as

$$P_n=\frac{l(8s-\pi a)}{4\pi hs}\times\left[\frac{b(2ms-a)}{s(2nh-b)}\right]^n\times\Big[\theta\cdot\mathrm{Sin}\theta+\mathrm{Cos}\theta\Big]_{\mathrm{Sin}^{-1}(2nh-b)/2l}^{\mathrm{Sin}^{-1}(2\overline{n+1}h-b)/2l}, \qquad (9),$$

where $(\overline{2ms}^2+\overline{2nh}^2)<(2l)^2<(\overline{2(m+1)s}^2+\overline{2(n+1)h}^2)$

and $0\leqq 2m<n.$

II. 4. Notices in other cases

Now, in the actual phenomena, if the long-line may be intersected with n lines of parallels, it does not always follow that the long-line should be encountered with n shoals which are shifting respectively on n lines. Because, it may be happened that the long-line encounters two or more shoals upon one line and that it does not any shoals on several lines.

In the case that the long-line encounters y shoals while it intersects n lines, this probability may be written as follows

$$P_{ny}=\frac{l(8s-\pi a)}{4\pi hs}\times\left[\frac{b(2ms-a)}{s(2yh-b)}\right]^n\times\Big[\theta\cdot\mathrm{Sin}\theta+\mathrm{Cos}\theta\Big]_{\mathrm{Sin}^{-1}(2yh-b)/2l}^{\mathrm{Sin}^{-1}(2\overline{y+1}h-b)/2l} \qquad (9'),$$

and at $y<n;\quad P_y>P_{ny}>P_n$,

at $y>n;\quad P_y<P_{ny}<P_n$.

III. Example of solution

As it is too complicated to obtain the solutions of P_{ny}, we cannot but resolve only P_n in this paper. From Eq. (9), we obtain

$$P_n=\left(\frac{8s-\pi a}{8\pi hs}\right)\left(\frac{b(2ms-a)}{s(2nh-b)}\right)^n\times\Big[\{2(n+1)h-b\}\mathrm{Sin}^{-1}\left(\frac{2(n+1)h-b}{2l}\right)$$
$$+\sqrt{(2l)^2-\{2(n+1)h-b\}^2}-(2nh-b)\,\mathrm{Sin}^{-1}\left(\frac{2nh-b}{2l}\right)$$
$$-\sqrt{(2l)^2-\{2nh-b\}^2}\Big] \qquad (10).$$

This equation is simplified by next denotations.

$$\left(\frac{8s-\pi a}{8\pi hs}\right)=C,\quad \left(\frac{2ms-a}{s}\right)=D,$$

$$\left[(2nh-b)\,\mathrm{Sin}^{-1}\left(\frac{2nh-b}{2l}\right)+\sqrt{(2l)^2-(2nh-b)^2}\right]=E_n,$$

i. e. $$P_n=C\cdot D^n\cdot b^n\cdot[E_{n+1}-E_n]/(2nh-b)^n \qquad (11).$$

Then,

$$\left.\begin{aligned}
&\text{at } n=1; && P_1=C\cdot D\cdot b\cdot(E_2-E_1)/(2h-b)\\
&\text{at } n=2; && P_2=C\cdot D^2\cdot b^2\cdot(E_3-E_2)/(4h-b)^2\\
&\text{at } n=3; && P_3=C\cdot D^3\cdot b^3\cdot(E_4-E_3)/(6h-b)^3\\
&\text{at } n=4; && P_4=C\cdot D^4\cdot b^4\cdot(E_5-E_4)/(8h-b)^4
\end{aligned}\right\} \qquad (12).$$

From Eqs. (12),

$$\left.\begin{aligned}\frac{P_1}{P_2}&=\frac{(4h-b)^2}{D\cdot b\cdot(2h-b)}\cdot\frac{(E_2-E_1)}{(E_3-E_2)}\\ \frac{P_2}{P_3}&=\frac{(6h-b)^3}{D\cdot b\cdot(4h-b)^2}\cdot\frac{(E_3-E_2)}{(E_4-E_3)}\\ \frac{P_3}{P_4}&=\frac{(8h-b)^4}{D\cdot b\cdot(6h-b)^3}\cdot\frac{(E_4-E_3)}{(E_5-E_4)}\end{aligned}\right\} \quad (13).$$

From Eqs. (13),

$$\left.\begin{aligned}\frac{P_1\cdot P_3}{P_2^2}&=\frac{(4h-b)^4}{(2h-b)(6h-b)^3}\cdot\frac{(E_2-E_1)(E_4-E_3)}{(E_3-E_2)^2}\\ \frac{P_2\cdot P_4}{P_3^2}&=\frac{(6h-b)^6}{(4h-b)^2(8h-b)^4}\cdot\frac{(E_3-E_2)(E_5-E_4)}{(E_4-E_3)^2}\end{aligned}\right\} \quad (14).$$

If $P_1, P_2, \cdots, P_5$ should be known, we may be able to obtain the values of h and b, because $E_1, E_2, \cdots, E_5$ are functions of h, b and l (l is already known from data).

Although the values of $P_1, P_2, \cdots, P_5$ are obtained from the supplemental tables, they are too rough to be used in these calculations. Then they shall be modified in the diagram (for example, of a semi-log. paper) under the consideration about which we described already in a previous chapter.

Now, let us show one example of the result obtained through those ways, as follows:

Data: Jan. 1949, A-Region (277 samples)

Modified probabilities of each encountering: $\begin{cases} P_1=0.105 \\ P_2=0.041 \\ P_3=0.008 \\ P_4=0.001 \end{cases}$

Mean length of long-lines used : $2l=24$ km

The values obtained [solutions by diagrammatic method from Eq. (14)]:

$2h=4.5_2$ km

$2b=1.0_0$ km

From C, D and Eq. (6): $2s=9.8_4$ km, $2a=1.6_2$ km

In another example (Mar. 1949, A-region), the both axes of shoal-shape and the distances between two shoals are calculated as 2.9 km, 0.8km; 4.4 km, 3.7 km respectively.

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Summing up those considerations we get the result that the dimensions of albacore shoals are 1~2 km, and that the shoals are distributed at 4~10 km distance in the fishing ground.

IV. Discussion

We may be allowed to believe the fact; we got the theoretical results that in the fishing grounds of West Pacific Ocean albacore shoals are distributed at several kilometers distance, and that the dimensions of one shoal are 1～2 km. Of course, by any optical apparatus, it is impossible to observe the shoals or their distributions in this length order (km). And, even by using a horizontal fish finder (echo-sounder), it may be very difficult to record those shoals and their distributions.

After all, for the purpose of resolving the migrating manners of shoals in ocean, it is the best method to treat the data of fishing-rates by the theoretical and statistical means under the considerations described above.

By performing another theoretical calculations, in the previous example, it may be estimated that the velocity of migrating shoals should be about 6 km per hour and the number of fishes in one shoals should be about 13000.

These theoretical methods* to resolve the next questions shall be published by the author in another paper:

⦿ How many fish does one shoal contain?
⦿ With what speed are shoals migrating?
⦿ How to set a long-line for good catching?

V. Summary

1. The histogram of the frequency of fishing rates in long-line albacore fishing on the Pacific Ocean (N: 24°～45°, E: 130°～180°) shows some what significant modes.
2. The author interpreted the meaning of this modes by surmising that it may be caused by a long-line encountering with several albacore shoals. And he paid some efforts to resolve the dimensions of shoals and its distributions under the consideration of the probability in the "Buffon's needle problem".
3. By assuming that the shape of shoal is ellips (axes $2a$, $2b$) and the shoals are shifting on the parallel lines (intervals $2h$) at the distances $2s$, the probability of n-encounterings is given as Eq. (9).
4. In an example of the result of calculations (Jan. 1949, A-region), the values of $2a$, $2b$, $2s$ and $2h$ are obtained as 1.6 km, 1.0 km, 9.8 km and 4.5 km respectively.

   It is impossible or very difficult to resolve the under-water phenomena with such a large scope as these dimensions by optical or sounding apparatus. After all it is to be the best method to use the idea discrived in this paper.
5. About the theoretical methods to resolve the problems —the number of fish in one shoal (for example, 13000), the speed of shifting in the migration (for example, about 6 km/hr), how to set a long-line to secure good catches— another paper shall be published.

VI. References

1). For example, T. YOSHIHARA: Journal of the Tokyo Univ. of Fisheries, Vol 41, No. 1 (1954).
2). These publications were sent to the author through the good office of Dr. NAKAMURA.
3). These raw data were sent by Mr. UEYANAGI and treated by the author.
4). This problem was resolved by Buffon (George Louis, 1707～1788).

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* These theoretical methods and calculated results had been announced orally by the author on the annual meetings of the Japanese Society of Scientific Fisheries (1952 and 1953).

Supplemental table I. Nos. of the operations of albacore long-line in various fishing rate.

Region A (N: 24°~45°, E: 130°~150°)

Fishing rate %	'48	1949												1950												1951		
	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
0~1	11	49	46	**87**	9	**11**	**58**	1	2	13	19	**53**	**146**	**117**	**176**	**184**	**74**	122	104	9	14	11	**15**	**82**	**130**	**177**	**206**	**150**
~2	3	39	34	30	*12*		1					13	26	35	73	47	6						7	36	43	52	60	48
~3	1	*40*	32	22	9	1						**13**	29	*62*	**61**	44	**6**						4	**26**	27	29	38	51
~4	*4*	26	22	17	8							2	*32*	54	30	41	3							12	20	20	**22**	*60*
~5	1	23	13	*22*	7							*8*	19	40	*34*	16	2							12	13	18	11	37
~6	**3**	14	*25*	17	3							**5**	**11**	34	32	14								8	10	6	*13*	27
~7	1	**17**	15	17	*5*								4	27	18	*18*	2							**5**	**10**	4	7	26
~8	1	8	13	10								1	3	15	*22*	2							1	1	4	5	**11**	12
~9	1	**11**	9	6								1		*22*	9	**4**	2						*3*	**3**	1	**7**	4	*17*
~10	1	4	*11*	4									2	15	**12**	1	2								2	2	4	11
~11		*9*	8	*6*									1	8	6	*2*	1								**3**	2	*7*	8
~12		6	5											2	*8*	2								1		3	5	6
~13		*8*	2	2										1	1		1									1	1	5
~14		6	1											1	**3**									1	*3*	3	2	3
~15		4	1												1	2										2		2
~16		3	1												*3*										1		1	2
~17	1	2													2		1									1		2
~18		**3**															1									1		1
~19	1	1	1																								1	1
~20	1																							1				
more		4	3										1		3								1					
Total	30	277	242	240	53	12	59	1	2	13	19	96	274	433	494	377	101	122	104	9	14	11	31	188	267	333	466	469

〔Remarks〕 *Italics* : Statistically excellent nos.
Gothics: Very more excellent nos. than next ones.

Supplemental table II. Nos. of the operations of albacore long-line in various fishing rate.

Region B (N: 24°~45°, E: 150°~165°)

Fishing rate %	'48	1949												1950												1951		
	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
0~1	26	8	7	20	5		2	10	98	**217**	**183**	68	18	7	20	39	**198**	**85**	35	3	29	40	**138**	**193**	**56**	1	9	5
~2	*43*	*30*	18	*21*	3					2	24	**46**	12	*26*	*30*	23	1	2					4	**39**	15	7	10	1
~3	46	28	*35*	13	2						7	22	12	**26**	25	17		1					2	15	*19*	8	*20*	2
~4	*49*	*37*	27	**16**	2						6	14	12	12	18	10							1	**9**	4	**18**	11	2
~5	**43**	33	20	7							2	**13**	8	4	16	10								2	4	7	10	**4**
~6	15	23	**12**	*9*							2	3	2	1	8	5								1	4	5	**11**	1
~7	14	17	5	8	2							4		1	2	1								*3*	3	*10*	4	1
~8	13	11	**10**	2								2		1	1										*4*	*11*		
~9	6	8	3	*4*										1										1		6		
~10	5	6	*4*	2																				1	1	6	2	
~11	2		3	1																					1	6		
~12	2	2	*4*											1												5		
~13		1	3									1												1				
~14			2										1												1			
~15		1																								1	1	
~16			1									1																
~17			1																									
~18																										1		
~19																												
~20																												
more																												
Total	264	205	148	103	14	0	2	10	98	219	224	174	65	80	120	105	199	88	35	3	29	40	145	265	112	92	78	16

[Remark] *Italics*: Statistically excellent nos.
Gothics: Very more exellent nos. than next ones.

Supplemental table III. Nos. of the operations of albacore long-line in various fishing rate.

Region C (N: 24°~45°, E: 165°~180°)

Fishing rate %	1949				1950												1951	
	Apr.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
0~1	1	45	10	20	23	11	43	**68**	22	3			4	22	19	1		
~2		41	*35*	*83*	46	37	33	1					1	12	**18**	8	11	1
~3		**26**	35	76	*86*	*46*	29	1						5	9	**14**	*17*	*4*
~4		8	**29**	**60**	80	25	29	1						6	1	5	**14**	2
~5		**9**	11	29	68	**47**	21								3	4	9	2
~6		4	9	**20**	**45**	22	13								2	4	**11**	5
~7		1	9	**10**	17	6	8								**4**	2	7	**6**
~8		1	7	5	13	*12*	7								1		*8*	2
~9		1	**5**	1	8	8	6									2	**6**	*7*
~10			2	1	4	4	1								1		2	4
~11		1	1	1	2	4											*3*	1
~12		1	*3*	1	2	2											2	
~13			1			**5**											1	
~14			1	1		2												
~15																		
~16		1																
~17						1												1
~18																		
~19																		
~20																		
more																		
Total	1	139	158	308	394	232	190	71	22	3	0	0	5	45	58	40	91	35

[Remark] *Italics*: Statistically excellent nos.

Gothics: Very more excellent nos. than next ones.

要　　約

◎ 太平洋（N: *24°～45°*, E: *130°～180°*）におけるビンナガ延縄漁の釣獲率のヒストグラムを画いてみると意味あり気な山が出て来る．

◎ 筆者は，この山が延縄とビンナガ魚群との交截によつて生ずるものと見た．そして「ブッフォンの針の問題」の確率解法に準じて之を解き魚群の大きさやその分布様態を解こうと努力した．

◎ 魚群を長軸 $2a$，短軸 $2b$ なる楕円とし之が距離 $2s$ づつ離れて間隔 $2h$ なる平行線群上を移動しつつあるものとすれば，延縄が n 魚群と遭う確率は (9) 式で与えられる．

◎ 計算結果の例（1949年1月，A海区）では，$2a\cdot 2b\cdot 2s\cdot 2h$ の値として夫々 *1.6* km・*1.0* km・*9.8* km・*4.5* km が得られる．

この程度の大きさの水面下現象は視力による方法でも音響探測装置による方法でさえも之を解明する事が不可能又は極めて困難であつて，結局本文に説く考え方を活用するのが最もよいと信ぜられる．

◎ 一群中の尾数（例解では *13,000* 尾），洄游における移動速度（例解では毎時約 **6** km），好漁を得るための縄の延え方などの諸問題を解く理論的方法については別報として他日発表するつもりである．　　（以上）