A Proposal Giving Some Significances upon Micro-distribution of Fishes for the Comparison of the Fishing Efficiencies of Serial Gears Variously Constructed※

By

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Mesh size, colour or dye used, material and thickness of netting cord and many other elements of structure are thought to be important factors affecting fishing efficiency of gears. And considerably many and valuable reports were published in which the influences of these factors were studied technologically, field and laboratorial experimental ecologically or physiologically. But when we wish to, field experimentally, compare the fishing efficiencies of nets variously constructed with one another——especially when the length covered by each kind of net is not so long enough——, another factor, micro-distribution of fish individuals, becomes as much as or more influential and adequate attention should be paid to it.

And this report is written for the purpose of calling attention to its significance adopting the results of salmon drift-nets test operations which are thought to be one of the typical examples emphasizing this fact.

Before entering the subject, I must express my sincere thanks to Prof. Dr. D. MIYADI and Dr. T. TOKIOKA of the Kyoto University for their kind guidance and criticisms given on the present work. And I must also record here my hearty thanks to former Prof. M. TOYOTA of the Shimonoseki College of Fisheries and Mr. T. TAKAGI of the Nippon Suisan Co. Ltd. by whom I was so kindly given the records used in this study.

Data used in this study

Daily reports of salmon drift-nets test operations pursued during the period from April to August in 1955 by four research boats belonging to the Nippon Suisan Co. Ltd., Matsu-maru, Suzu-maru, Yoko-maru and Nikko-maru, were used in this study. These boats operated in the waters near the Aleutians (48°—52° N, 155°—180° E) cruising from east to west and catching five species of salmons (*Oncorhynchus nerka*,

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O. keta, O. gorbuscha, O. kisutch and *O. tschawytscha*) using 250 sections of nets or a little less sections being constituted of following 18 kinds of nets of variable numbers of sections.

Net No.	material of cord	mesh size (sun=3.3 cm)	colour or dye used
1		4.3	Brown stained by Nichimō type
2		4.2	〃
3		〃	Brown stained by Nitto type
4	Ramie	〃	Deutrex*
5		〃	N. G.*
6		〃	Cutch fixed by $CuSO_4$
7		4.1	Brown stained by Nichimō type
8		4.4	Cutch colour
9		4.3	〃
10		4.2	〃
11		〃	Deep cutch colour
12		〃	Light blue
13	Amilan	〃	Blue
14	(Nylon)	4.1	Cutch colour
15		4.0	〃
16		3.9	〃
17		4.3 and 4.0 mixed	〃
18		4.2 and 4.0 mixed	〃

Note : * indicates the nets the details of staining of which are not clear.

And besides the section numbers of respective kinds of nets used in respective operations, catches by respective kinds of nets in a little more than a half number of operations are shown being partitioned into respective species, while in the rests, sums of catches of five species of salmons by respective kinds of nets and total catches of respective species by a row are described. And there is no record in which the frequency distribution of respectively occupied sections is described. Therefore, against

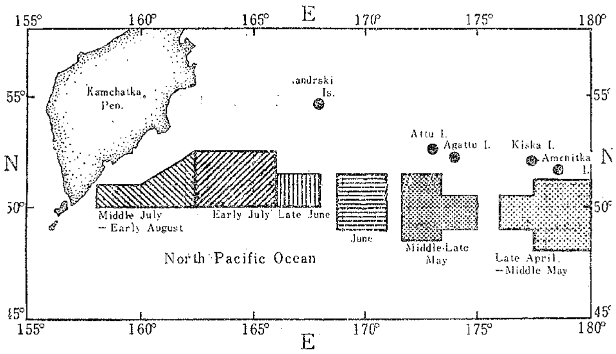

Fig. 1. Sketch chart of fishing ground, showing the migration of it due to passing of season.

the fact that it is more desirable to treat the data separating into each species, I can not help adopting the total catch (sums of catch of five species) for the purpose of increasing the number of operations avairable. And averages of them per section by respective kinds of nets in respective operations (this is hereafter called simply as catch rate) deviate from less than 1 individual to atmost 20 per section, mostly from 2 to 7.

Results

1. Preliminary consideration and transformation of catch rates

In order to compare the catch rates by various kinds of nets with one another, I must, at first, examine the frequency distribution of respectively occupied sections, then each variate should be transformed following the adequate method into the type of frequency distribution fit for observed ones, because the frequency distribution of such example of low catch rate as these is hardly expected to fit for the normal one. But in spite of this fact, I can not presume the actual frequency distribution from the original records. Accordingly, there are only two ways treating the original records ——either to use simply mathematical mean or to treat the data setting hypothetical distribution of which is as POISSON'S one which is only one theoretical distribution presumable from the original records. While, I reported that the frequency distribution of respectively occupied sections of salmon drift-net in the same waters near the end of the fishing season in 1952 follows THOMAS' or PÓLYA-EGGENBERGER'S distribution but to see roughly it is not so far from POISSON'S (MAÉDA, 1953 A). Therefore, I was obliged to treat the data setting as POISSON'S one. And in order to treat statistically POISSON'S or slightly contagious distribution, each variate should be transformed into square root value for the purpose of normalizing the distribution. Therefore, hypothetical frequency distribution of respectively occupied sections of each kind of net in each day by each boat setting to follow POISSON'S one is computed from the following formula: $N_x = Nm^x e^{-m}/x!$ ·············· (1) (Here, N_x is number of sections expected to be occupied by x individuals when N sections of drift-nets are used. m is mathematical mean of catch per section). Then, average of transformed catch, x', is computed using the following formula:

$$x' = \frac{\sum_{x=0}^{xi} \sqrt{x} \cdot N \cdot m^x e^{-m}/x!}{N} = \sum_{x=0}^{xi} \sqrt{x}\, m^x e^{-m}/x! \quad \cdots\cdots\cdots (2)$$

Symbols are the same as in Formula (1). Practically, x is limited from 0 to the smallest x_i, where x_i is defined by $\sum_{x=0}^{x_i} m^x e^{-m}/x!$ which becomes as equal as or a little more than 0.99.

2. Variation of relative catch rates depending on difference of season and locality

It is easily assumable that, when density of individuals is high, catch rates of all kinds of nets may increase while *vice versa*. Accordingly, when we wish to compare the efficiencies of nets with one another, it seems to be better to adopt the ratios of them, because this makes it possible to eliminate the deviation due to daily deviation of density of fishes. And for convenience's sake of comparison, the words "relative catch rate" is used hereafter representing the ratio of catch rate of a certain nets to

Table 1. Frequency distribution of section numbers of respective kinds of nets used by Matsu-maru in 85 operations.

Net No.	Section number						
	0	1—5	6—10	11—20	21—30	31—40	41<
1	4	20	61	0	0	0	0
2	2	1	1	28	11	9	33
3	49	6	30	0	0	0	0
4	15	70	0	0	0	0	0
7	34	20	31	0	0	0	0
8	2	0	3	3	77	0	0
9	4	1	80	0	0	0	0
10	6	78	1	0	0	0	0
11	9	76	0	0	0	0	0
12	5	80	0	0	0	0	0
13	7	78	0	0	0	0	0
14	25	0	60	0	0	0	0
15	39	0	46	0	0	0	0
16	54	0	31	0	0	0	0
17	73	0	12	0	0	0	0
18	0	0	0	1	0	3	81

Note : Frequencies of net Nos. 5 and 6 are omitted because of less frequencies used.

that of net No. 2 (Ramie, 4.2 sun mesh and brown stained by Nichimo type) for net Nos. 1~7 or net No. 18 (Amilan, 4.2 and 4.0 sun mesh mixed and cutch colour) for net Nos. 8~18 because the number of sections of these kinds of nets used in each operation is the largest of all consequently the deviation of catch rate due to accidental error is expected to be the smallest.

Before entering the principal subjects, whether or not the relative catch rates vary depending on the difference of season and localities should be examined because fishing season of off shore salmon drift-net fishery is rather long and fishing ground of it covers considerably wide area consequently it is highly probable that efficiency of even the same kind of net may not be the same throughout the fishing season and all over the fishing ground but may change depending on growth and changes of physiological (during the season, gonads are matured) or oceanographical conditions. But practically, fishing ground was limited in the range from 48° to 52° N and moved from east to west covering from 155° to 180° E, from the beginning to the end of fishing season. Accordingly, the difference of latitude is able to be negligible and the differences of longitude and season are unable to treat separately. Thus, these factors are representable simply by the difference of longitude. So, the relation between longitude and relative catch rates is examined. And several examples of the results are illustrated in Figs. 2(1)—(3), which tell us that the relative catch

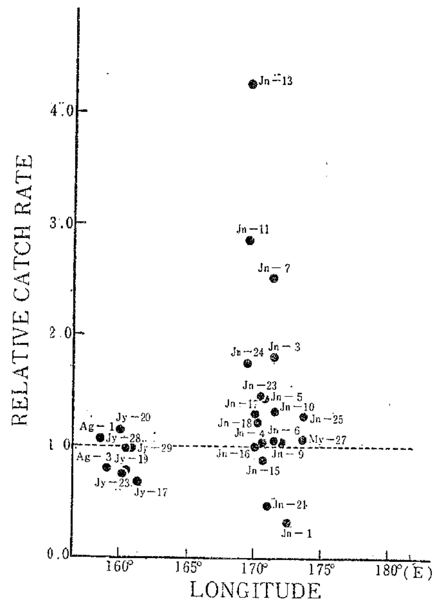

Fig. 2(1). Longitude—relative catch rate relation graph.
(Amilan, 4.2 sun mesh, deep cutch colour: By Suzu-maru).
Abbreviations
Ap : April My : May Jn : June Jy : July
Number illustrated in figure indicates the date of operation.

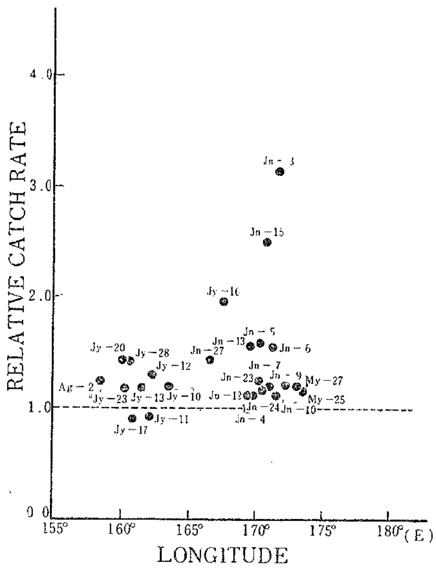

Fig. 2(2). Longitude—Relative catch rate relation graph.
(Amilan, 4.2 sun mesh, blue: By Nikko-maru).

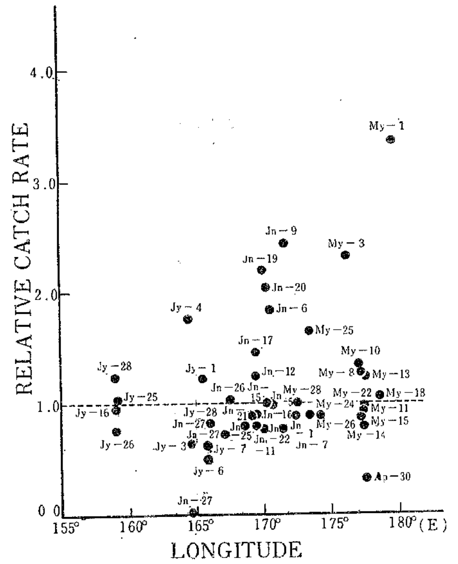

Fig. 2(3). Longitude—Relative catch rate relation graph. (Amilan, 4.2 sun mesh, light blue: By Matsu-maru).

rates do not vary depending on longitude, while some relations between deviation of them and longitude are alluded which will be discussed in "consideration".

3. Comparison of fishing efficiencies of nets constructed variously

(Consideration upon the frequency distribution of relative catch rates).

It is deducible from the facts mentioned in the preceding paragraph that there is

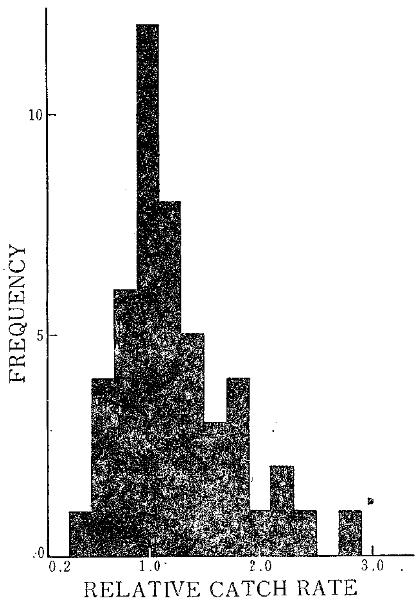

Fig. 3 (1). Frequency distribution of relative catch rate. (Ramie, 4.3 sun mesh, Nichimo-zome: By Matsu-maru).

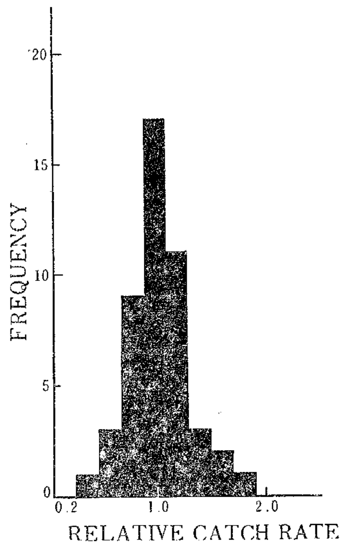

Fig. 3 (2). Frequency distribution of relative catch rate. (Amilan, 4.3 sun mesh, cutch colour : By Matsu-maru).

Fig. 3 (3). Frequency distribution of relative catch rate.
(Amilan, 4.2 sun mesh, cutch colour : By Nikko-maru).

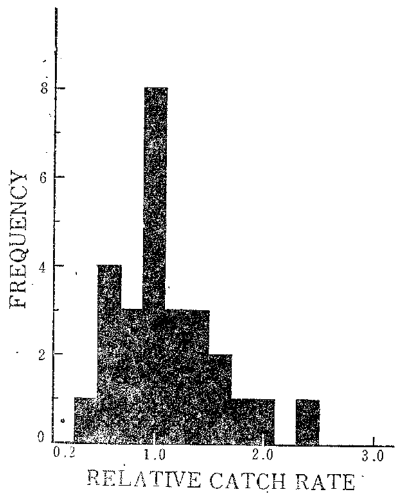

Fig. 3 (4). Frequency distribution of relative catch rate.
(Amilan, 4.2 sun mesh, blue: By Suzu-maru).

no need to treat the data stratifying into several longitude groups. So, frequency distributions of relative catch rates regardless of longitude are examined and several examples of the results are shown in Figs. 3 (1)—(4), which tell us that most of modes are observable at 1 or thereabout and that, considering together with less frequencies, it seems to be difficult giving any significance upon the difference of frequencies between lower and higher than 1. Accordingly, I cannot help considering, so far as the present study has concerned, no significant difference of catch rates can be admitted to be caused by such small differences of mesh size and colour as used in these operations.

Consideration

As mentioned in the last section of the 2nd paragraph in the results, we will find easily from Figs. 2(1)—(3) that the station showing large deviation of relative catch rates from 1 towards larger or towards smaller is frequently observable in the waters east parts of the fishing ground, while this deviation becomes smaller and smaller in company with the migration of stations towards west and relative catch rates are apparently converged into 1 —— although the convergence of relative catch rate is represented here as if simply due to the migration of fishing station, difference of operation date may also contribute as significantly as difference of locality. And, in any case, adequate attentions should be paid to this apparent convergence. Figure 4 represents an example of the relation between catch rate and longitude. And this

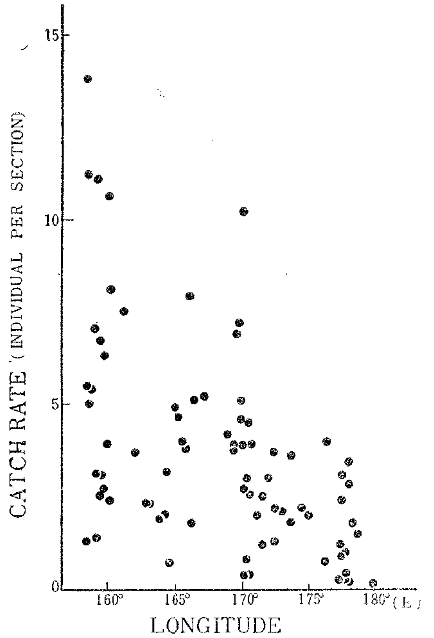

Fig. 4. An example of catch rate—longitude relation graph. (Net No. 2, by Matsu-maru)

figure suggests that, as commonly recognized, the catch rate in the beginning of fishing season is low but increases with passing the season. Accordingly, it is probable that when catch rate is low, the relative catch rate may be heavily suffered from the influence of accidental error and fluctuate severely, while when catch rate is high, accidental error becomes less influential and relative catch rate may fluctuate not so severely. And when the size of sample is the larger, the larger deviation of relative catch rate is observable. Of course, these facts may more or less contribute to cause the apparent convergence. While this figure also suggests that even the daily catch rates in the water near the west limit fluctuate severely, against the fact that those in the waters near the east end seem to fluctuate not so severely. Accordingly, deducing from the apparent convergence of relative catch rates and fluctuation of daily catch rates, it may be one of the ways of thinking to regard that, in the waters near the east limit, not so much individuals are aggregated showing strong dishomogeneity observable within a row, while with approach to the west limit, dishomogeneity observable within a row becomes weaker and weaker but that between days,——consequently this may well be thought that between rows——, is still as influential as or becomes a little more influential than in the waters near the east limit. Therefore it is probable that the length of each kind of net used in the water near the west limit may be adequate being able to obtain accurate relative catch rates because if longer some influences of distribution of large scale may be introduced while if shorter scarcity of total catch by each kind of net or short length is afraid to introduce the influence of accidental error. But the length of each kind of net is not suitable in the waters near the east limit —— perhaps too short to get accurate catch rate overcoming the dishomogeneity of distribution of fish individuals within the waters covered by a row, although the length itself is rather invariable.

Conclusion

Summarizing the facts mentioned in the chapters of results and consideration, I wish to conclude as follows: These test operations were planned for the purpose of finding out the difference among the fishing efficiencies of nets variously constructed, but no clear conclusion fit for this purpose can be obtained because length covered by each kind of net is not long enough comparing with the scale of micro-distribution of fish individuals, especially in the east waters, and this makes unable to obtain the accurate and less deviating catch rate. And if we wish to obtain accurate conclusion fit for the purpose I propose to pursue far well designed test operations of far large scale in such fishing ground as the waters near the west limit where individuals are expected to be distributed densely and rather uniformly within the waters covered by a row——decreasing kinds of nets used (consequently length of each kind of net is elongated for the purpose of overcoming the dishomogeneity of distribution of individuals within short range), using many boats (because large deviation of catch rate or relative catch rate is expected, statistical size of samples should be far increased, against the fact that fishing season, especially suitable season for the test operation, is limited and it is unable to increase the number of operations capable to be pursued by each boat), and moreover recording the frequency distribution of respectively occupied sections by respective species although it may have much obstacles to make this plan into practice due to technological conditions, limitation of commercial system *etc.*

Summary

1. This report is written for the purpose of calling attention to the significance of micro-distribution of fish individuals for comparison of fishing efficiencies of serial gears variously constructed with one another.
2. As typical examples, daily reports of salmon drift-net test operations pursued by 4 research boats of the Nippon Suisan Co. Ltd. in the waters near the Aleutians during the fishing season in 1955 are adopted.
3. It is one of the foci of this report that, first, hypothetical frequency distribution of respectively occupied sections assuming as POISSON'S one is estimated, next, each variate is transformed into square root value and then averages of transformed values are used in the consideration, because the frequency distribution in such examples of low catch rate as these is hardly expected to be normal and no frequency distribution except POISSON'S is presumable from the original records moreover POISSON'S is expected to be not so far from the actually observed one.
4. The relation between longitude and relative catch rate (average of transformed catch rates of respective nets divided by that of Net No. 2 or No. 18) is examined

for the purpose of finding out whether or not relative catch rates vary depending on difference of season or locality of fishing stations. And several examples showing this relation are represented in Figs. 2(1)—(3). While no clear relation, excepting that between longitude and deviation of relative catch rate, is observable.

5. Examining the frequency distribution of relative catch rates regardless of season and locality [Figs. 3(1)—(4)], we can not find out any significant difference among fishing efficiencies caused by such small differences of mesh size and colour as adopted in these test operations.
6. Relative catch rates in the east parts seem to deviate largely but they are converged into a certain value with approach of fishing station to the west limit. While even the daily catch rate in the waters near the east limit seems to fluctuate severely.
7. The above-mentioned facts are thought to be due to the fact that length covered by each kind of nets used in each operation is too short, consequently, it is highly expected that relative catch rate is strongly affected by the micro-distribution of fish individuals.
8. Deducing from the apparent convergence of relative catch rates and the fluctuation of daily catch rate, it may be one of the ways of thinking to consider that, in the waters near the east limit, not so much individuals are aggregated showing strong dishomogeneity observable within a row, while with approach to the west limit, dishomogeneity observable within a row becomes weaker and weaker but that between days, which may well be thought to be that between rows, is still as influential as or become a little more influential than in the waters near the east limit.
9. If we wish to obtain the adequate conclusion for the aim of this test operation, I recommend to pursue the test operations in the waters near the west limit decreasing kinds of nets used while using many boats, and moreover, frequency distribution of respectively occupied sections by respective species should be recorded.

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