The Magnitude and its Rate of Diminution in the Semi-Closed Fishing Ground.※

By

Takerow SATOW

Introduction

Considerations on a fishery of one species in a specified fishing ground may be classified into three cases as follows: (i), the case of a species behaving only in that area and having no connection with ones living outside —— it contains, for example, the case of some landlocked species or of some species covering its whole habitat; (ii), the case of a species coming from and going to its outer area freely —— most worker may treat of this case; and (iii), the case of a species having a one-side movement between the fishing ground and its exterior —— of course, actually it contains cases of only immigration and of only emigration within a limited period.

Of these cases, (i) or the case of so-called "closed" fishing ground may be theoretically simple though its practical treatments may be difficult or complicated as it has its meagre instances or covers an extensive scope. Though the second case is more general its considerations tend often to be difficult because of many unavoidable factors. In contrast to them the case of "semi-closed" ground contains fewer assumptions and gives several actual examples in reality, so the author wishes to consider on the last case as an approach to the case of "open" fishing ground.

In addition he wishes to report his works on the "closed" case if occassion offers and is at present working on the case of "open" fishing ground by a way different from the method in this report.

The autor wishes to report a method for estimation of the magnitude of fish recruitment and its rate of diminution in a fishing ground considered as almost semi-closed during a certain period. Such trial as this method is, of course, accustomed to presuppose some conditions, examinations on which should be carried out from all angles. However, such examinations should be often originated from biological aspects and, nevertheless, for the brevity of procedure it can not but neglect the biological details. In treating some difficulties in this method the author resorted to biologists' advices as far as circumstances permitted.

※ Contribution from the Shimonoseki College of Fisheries, No. 174.

Assumptions

A fishing ground is deemed as almost semi-closed ——— in other words, there is a fish recruitment to and no departure from this area ——— during a certain period. Such restriction is nearly acceptable in case of a newly born fish shoal or a spawning fish shoal within a limited period.

When fish groups successively enter this area as catchable objects, the amount of an immigrating group at time t may be considered as a continous variable. But in this report, for convenience' sake, we set up an assumption that N_t come in there at the beginning of the t-th unit-period.

It may be permitted to consider that the increment of average body length of a fish group per unit-period follows a mode proper to the species. Moreover, there are often some cases in which the mode of increment of body length can be considered as nearly linear.

The lowest average body length of each immigrating group ——— or, the average body length of a group just at the time of entrance as a portion of catchable stock into this area ——— is assumed as constant.

At last, an assumption that the short-term rate of decrease is constant irrespective of unit-period, is set up. And, if the length of unit-period is considerably short enough to set the natural mortality of fish as almost-negligible against the fishing mortality and there is no decrease resulting from some extraordinary causes, the short-term rate of decrease mentioned above may be considered as synonymous with the corresponding rate of fishing mortality.

Amount of recruitment and of available fishes, and the general average body length in each unit-period.

Let us denote the amount of catchable fish group entering a fishing ground, the short-term fishing rate in the t-th unit-period and the average body length of a fish group passing through (t−1) unit-periods after its entrance as N_t, f and l_t respectively (Fig. 1).

Now, if there is no fishing, the general average body length covering all fish groups in the i-th period should result as follows ;

$$\bar{l}_i = \sum_{t=1}^{i} N_t \cdot l_{i-t+1} \Big/ \sum_{t=1}^{i} N_t . \qquad (1)$$

Then if f per cent. of each group per unit-period is consistently removed, the survival of each group is $(1-f)^{i-t} \cdot N_t$ at the beginning of the i-th period. And, the earlier a fish group enters this area, the fewer the member of a fish group survives. So the general average body length obtained

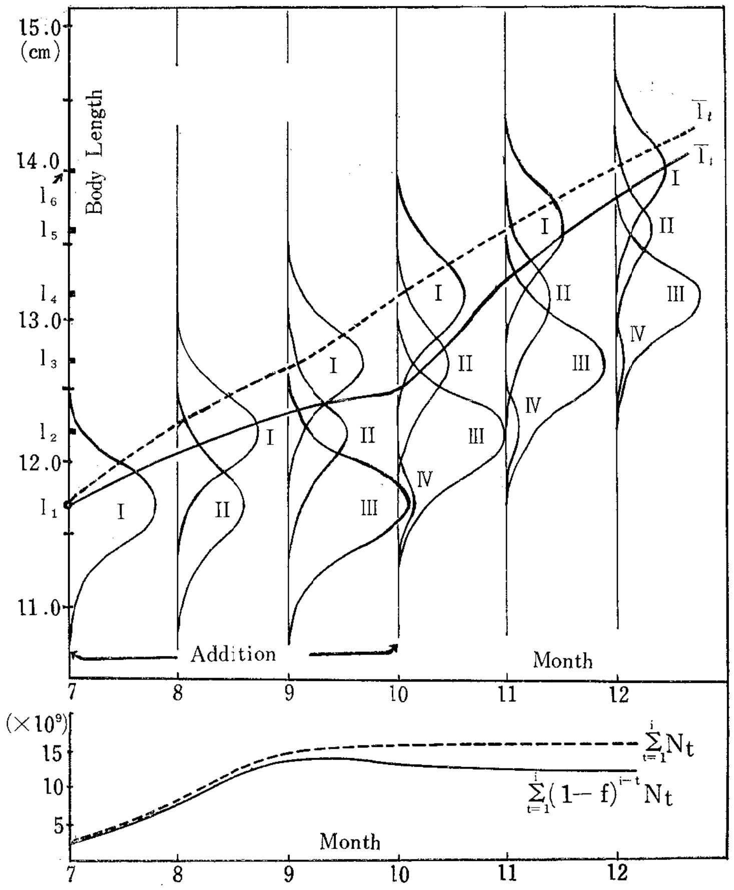

Fig. 1. Showing the mode of entrance, the mode of growth of body length of each group, the general average body length and the general average body length without fishing schematically.

actually should become smaller against the case of no fishing as follows;

$$\bar{l}_i^* = \sum_{t=1}^{i} (1-f)^{i-t} \cdot N_t \cdot l_{i-t+1} \Big/ \sum_{t=1}^{i} (1-f)^{i-t} \cdot N_t \,. \qquad (2)$$

When i is equal to 1,

$$\bar{l}_1^* = N_1 \cdot l_1 / N_1 = l_1 \equiv \bar{l}_1 \,,$$

and l_1 is just the lowest average body length at the time of entrance.

Next, if the fishing operation affects every group equally*, the amount of fishes caught during the i-th unit-period is expressed as follows;

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* It is assumed that the efficiency of gear affects fishes of all sizes equally. Later in this text the reader will find a consideration on this assumption.

$$C_i = f \cdot \sum_{t=1}^{i} (1-f)^{i-t} \cdot N_t \, . \qquad (3)$$

Meanwhile, the increment of average body length of a group passing through t unit-periods after its entrance, $\boldsymbol{\Delta}_t$, is a function of t and the average body length of the corresponding fish group can be rewritten as follows;

$$\bar{l}_t = \bar{l}_1 + \boldsymbol{\Delta}_{t-1} \, , \qquad (4)$$

where $\triangle_0 = 0$.

Therefore, from (2) and (4),

$$\bar{l}_i^* = [\, l_i \sum_{t=1}^{i} (1-f)^{i-t} \cdot N_t + \sum_{t=1}^{i} (1-f)^{i-t} \cdot \cdot {}_t \cdot \triangle_{i-t}] / \sum_{t=1}^{i} (1-f)^{i-t} \cdot N_t$$

$$= \bar{l}_i + \sum_{t=1}^{i} (1-f)^{i-t} \cdot N_t \cdot \triangle_{i-t} \, / \sum_{t=1}^{i} (1-f)^{i-t} \cdot N_t \, , \qquad (5)$$

and by substituting (3) into (5) we obtain

$$C_i (\bar{l}_i^* - \bar{l}_1) / f = \sum_{t=1}^{i} (1-f)^{i-t} \cdot N_t \cdot \triangle_{i-t} \, , \qquad (6)$$

In the last equation its right side can be rewritten as follows;

$$(1-f) \cdot N_{i-1} \cdot \triangle_1 + (1-f)^2 \cdot N_{i-2} \cdot \triangle_2 + \cdots\cdots\cdots\cdots$$

$$\cdots\cdots\cdots\cdots + (1-f)^{i-1} \cdot N_1 \cdot \boldsymbol{\Delta}_{i-1} \, , \qquad (6')$$

and, if the number of terms is not so great, the actual calculation of (6′) may not be so difficult or tedious, provided that N_t can be known.

Now, if we set up as $N_t = \lambda_t \cdot N$, then (6′) can be rewritten as $N \cdot \sum_{t=1}^{i} (1-f)^{i-t} \cdot \lambda_t \cdot \triangle_{i-t}$, and, therefore, (6) may be turned out as follows;

$$C_i (\bar{l}_i^* - \bar{l}_1) / f \cdot N = \sum_{t=1}^{i} (1-f)^{i-t} \cdot \lambda_t \cdot \triangle_{i-t} \, , \qquad (7)$$

The right side of (7) may be again rearranged according to the order of f as follows;

$$N_{i-1} \cdot \boldsymbol{\Delta}_1 + N_{i-2} \cdot \boldsymbol{\Delta}_2 + \cdots\cdots + N_1 \cdot \boldsymbol{\Delta}_{i-1} - (N_{i-1} \cdot \triangle_1 + 2N_{i-2} \cdot \boldsymbol{\Delta}_2$$

$$+ \cdots\cdots + (i-1) \cdot N_1 \cdot \boldsymbol{\Delta}_{i-1}) \times f + (\qquad N_{i-2} \cdot \boldsymbol{\Delta}_2 +$$

$$\cdots\cdots) \times f^2 + \cdots\cdots\cdots\cdots + N_1 \cdot \boldsymbol{\Delta}_{i-1} \cdot f^{i-1} .$$

And, if the mode of growth and the type of immigration are known, the coefficients of f^{i-t} can be easily calculated separately. Then,we denote these coefficients as κ_0, κ_1, κ_2, ………, κ_{i-1} respectively, so (7) may be rewritten as follows;

$$C_i(\bar{l}^*_i - \bar{l}_1)/f \cdot N = \kappa_0 + \kappa_1 \cdot f + \kappa_2 \cdot f^2 + \cdots\cdots + \kappa_{i-1} \cdot f^{i-1}. \quad (8)$$

When t is equal to (i+1), we can formulate an analogous equation to (8) as follows;

$$C_{i+1}(\bar{l}^*_{i+1} - \bar{l}_1)/f \cdot N = \kappa'_0 + \kappa'_1 \cdot f + \kappa'_2 \cdot f^2 + \cdots\cdots + k'_i \cdot f^i. \quad (9)$$

From (8) and (9) we obtain the next equation,

$$\frac{C_i(\bar{l}^*_i - \bar{l}_1)}{C_{i+1}(\bar{l}^*_{i+1} - \bar{l}_1)} = \frac{\kappa_0 + \kappa_1 \cdot f + k_2 \cdot f^2 + \cdots\cdots + \kappa_{i-1} \cdot f^{i-1}}{\kappa'_0 + \kappa'_1 \cdot f + \kappa_2 \cdot f^2 + \cdots\cdots + \kappa'_i \cdot f^i}. \quad (10)$$

In the left side of (10) C_i, C_{i+1}, $\bar{l}^*_1$, l^*_{i+1} and l_1 are known from the actual data, and therefore, we may denote as $C_i(\bar{l}^*_i - l_1)/C_{i+1}(\bar{l}^*_{i+1} - \bar{l}_1) = \theta_{i,i+1}$. Then we may obtain an i-th order equation of f as follows;

$$\theta_{i,i+1} \cdot \kappa'_i \cdot f^i + (\theta_{i,i+1} \cdot \kappa'_{i-1} - \kappa_{i-1}) f^{i-1} + \cdots\cdots$$

$$\cdots\cdots + (\theta_{i,i+1} \cdot \kappa'_0 - \kappa_0) = 0. \quad (11)$$

From (11) we can deduce the value of f and by substituting this value of f into eqs. (8) or (9) we can obtain an equation for calculation of N, or,

$$N = \frac{C_i(\bar{l}^*_i - \bar{l}_i)}{f(\kappa_0 + \kappa_1 \cdot f + \kappa_2 \cdot f^2 + \cdots\cdots + \kappa_{i-1} \cdot f^{i-1})}$$

$$= \frac{C_{i+1}(l^*_{i+1} - \bar{l}_i)}{f(\kappa'_0 + \kappa'_1 \cdot f + \cdots\cdots + \kappa'_i \cdot f^i)}. \quad (12)$$

Thus we can estimate the rate of total decrease over all periods as follows;

$$\varphi = C/N.$$

Special case in which f is considerably small and $\triangle_t$ is constant

If we can consider that f is considerably small, in the development of $(1-f)^{i-t}$ no serious difference may be thrown into the result from the neglect of terms of comparatively higher order of f. Then, if we neglest terms of the third order and higher we obtain the next approximate equation

$$(1-f)^{i-t} \fallingdotseq 1-(i-t)\cdot f+\frac{(i-t-1)(i-t)}{2}f^{2} .$$

And

$$\triangle_{i-1}=\triangle_{i-2}=\blacktriangle_{i-3}=\cdots\cdots\cdots\cdots=\triangle_{2}=\triangle_{1}\equiv\blacktriangle=\text{const.}$$

So,

$$\sum_{t=1}^{i}(1-f)^{i-t}\cdot N_{t}\cdot l_{i-t+1}=\sum_{t=1}^{i}(1-f)^{i-t}\cdot N_{t}\,[\,\bar{l}_{1}+(i-t)\triangle\,]$$

$$=\bar{l}_{1}\cdot\sum_{t=1}^{i}(1-f)^{i-t}\cdot N_{t}+\blacktriangle\cdot\sum_{t=1}^{i}(1-f)^{i-t}\cdot N_{t}\,(i-t) .$$

Then from (2),

$$(\bar{l}_{i}^{*}-\bar{l}_{i})\cdot\sum_{t=1}^{i}(1-f)^{i-t}\cdot N_{t}=\triangle\cdot\sum_{t=1}^{i}(1-f)^{i-t}\cdot N_{t}\cdot(i-t), \qquad (13)$$

or,

$$\frac{C_{i}(\bar{l}_{i}^{*}-\bar{l}_{i})}{\triangle f}=\sum_{t=1}^{i}(1-f)^{i-t}\cdot N_{t}(i-t)$$

$$=(1-f)^{i-1}\cdot N_{1}\cdot(i-1)+(1-f)^{i-2}\cdot N_{2}(i-2)+$$

$$\cdots\cdots\cdots\cdots+(1-f)\cdot N_{i-1}$$

$$=N_{1}(i-1)\,[\,1-(i-1)\cdot f+\frac{(i-2)(i-1)}{2}f^{2}\,]$$

$$+N_{2}(i-2)\,[\,1-(i-2)f+\frac{(i-3)(i-2)}{2}f^{2}\,]$$

$$+\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$+N_{i-1}(1-f)$$

or,

$$\frac{C_{i}(\bar{l}_{i}^{*}-\bar{l}_{1})}{\triangle\cdot f}=\sum_{t=1}^{i}(i-t)\cdot N_{t}-f\cdot\sum_{t=1}^{i}(i-t)^{2}\cdot N_{t}$$

$$+f^{2}\sum_{t=1}^{i}\frac{(i-t-1)(i-t)^{2}}{2}N_{t} . \qquad (14)$$

Now if we denote that $N_{t}=\lambda_{t}\cdot N$,

$$\frac{C_{i}(\bar{l}_{i}^{*}-\bar{l}_{1})}{\blacktriangle f}=N\,[\,\sum_{t=1}^{i}(i-t)\cdot\lambda_{t}-f\cdot\sum_{t=1}^{i}(i-t)^{2}\cdot\lambda_{t}$$

$$+f_{2}\cdot\sum_{t=1}^{i}\frac{(i-t-1)(i-t)}{2}\lambda_{t}\,] . \qquad (14')$$

All terms of Σ 's in the right side of (14') can be calculated from the actual data. Let us denote as

$$\sum_{t=1}^{i}(i-t)\cdot\lambda_t=\tau_1\,,\quad \sum_{t=1}^{i}(i-t)^2\cdot\lambda_t=\tau_2\ \text{and}\ \sum_{t=1}^{i}\frac{(i-t-1)(i-t)\cdot\lambda_t}{2}=\tau_3\,,$$

then we may obtain an equation as follows;

$$\frac{C_i(\bar{I}_i^*-\bar{I}_1)}{\Delta f}=\tau_1-f\cdot\tau_2+f^2\cdot\tau_3\,. \tag{15}$$

Similarly, we may obtain an analogous equation for t = i + 1 as follows;

$$\frac{C_{i+1}(\bar{I}_{i+1}^*-\bar{I}_1)}{\Delta f}=\tau'_1-f\cdot\tau'_2+f^2\cdot\tau'_3\,. \tag{15'}$$

Therefore,from (15) and (15') the next equation can be deduced as follows;

$$\frac{C_{i+1}(\bar{I}_{j+1}^*-\bar{I}_1)}{C_i(\bar{I}_i^*-\bar{I}_1)}=\frac{\tau'_1-f\cdot\tau'_2+f^2\cdot\tau'_3}{\tau_1-f\cdot\tau_2+f^2\cdot\tau_3}\,. \tag{16}$$

The left side of (16) can be calculated from the actual data, so, if we denote it as k,then we can obtain an equation of the second order of f, or

$$f^2(k\cdot\tau_3-\tau'_3)-f(k\cdot\tau_2-\tau'_2)+(k\cdot\tau_1-\tau'_1)=0\,. \tag{17}$$

By solving (17) we may gain an appropriate value of f which satisfies the condition as follows; f is a positive and considerably small value.

Actual Example

We wish to apply this method to the yearlings of sardine (*Sardinia melanosticta*) being catchable in the area including the Gotō Nada and its southern neighbourhood (off the west Coast of Kyushu) from July to December 1953. It is deemed that these yearlings can be traced back to the eggs spawned in the same area during the period January to April in the same year. And these yearlings form a catchable stock from July* to December. In January of the next year and hereafter it seems to vanish from this area. Moreover, it seems that these yearlings don't emigrate gradually from this area but conceal themselves abruptly, perhaps, at the middle or end of December.

If we can consider that each group follows the same specified mode of growth irrespective of time of spawning, it may be permitted that the length of duration in which the immigration is executed is equivalent to that of the spawning period.

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* Though in 1953 there was a fishing with some catches on 10 June, it was since July that there were continuous fishing operatinos.

Though it is desirable that the length of a unit-period is specified as small as possible, we adopt one month for it from the restrictions of actual data.

Average body length and number of caught fishes can be calculated on the basis of the data furnished in "Surveys of 'Iwashi' Resources" by the Seikai Regional Laboratory of Fisheries (Nagasaki), using together with the catch statistics from the Service of Agricultural Statistics.

In our case it may be considered that the addition of fish groups has completed by i = 4. The mode of growth of body length is not likely to be linear, so $\triangle_{i-t}$ should be reckoned from its growth curve* already established. Then

$$i=2 \cdots\cdots\cdots\cdots \frac{C_2(\bar{l}_2^* - \bar{l}_1)}{f} = N \cdot \lambda_1 \triangle_1 \cdot (1-f),$$

$$i=3 \cdots\cdots\cdots\cdots \frac{C_3(\bar{l}_3^* - \bar{l}_1)}{f} = N\,[\lambda_2 \cdot \blacktriangle_1 + (1-f) \cdot \lambda_1 \cdot \blacktriangle_2]\,(1-f),$$

$$i=4 \cdots\cdots\cdots\cdots \frac{C_4(\bar{l}_4^* - \bar{l}_1)}{f} = N\,[\lambda_3 \cdot \triangle_1 + (1-f)\lambda_2 \cdot \triangle_2 + (1-f)^2 \cdot \lambda_1 \cdot \blacktriangle_3] \cdot (1-f),$$

$$i=5 \cdots\cdots\cdots\cdots \frac{C_5(\bar{l}_5^* - \bar{l}_1)}{f} = N\,[\lambda_4 \cdot \triangle_1 + (1-f) \cdot \lambda_3 \cdot \blacktriangle_2 + (1-f)^2 \cdot \lambda_2 \cdot \blacktriangle_3 + (1-f)^3 \cdot \lambda_1 \cdot \blacktriangle_4]\,(1-f),$$

$$i=6 \cdots\cdots\cdots\cdots \frac{C_6(\bar{l}_6^* - \bar{l}_1)}{f} = N\,[\lambda_4 \cdot \blacktriangle_2 + (1-f) \cdot \lambda_3 \cdot \blacktriangle_3 + (1-f)^2 \cdot \lambda_2 \cdot \blacktriangle_4 + (1-f)^3 \cdot \lambda_1 \cdot \blacktriangle_5]\,(1-f)^2,$$

If we denote as

$$\frac{C_3(\bar{l}_3^* - \bar{l}_1)}{C_2(\bar{l}_2^* - \bar{l}_1)} = k_1, \quad \frac{C_4(\bar{l}_4^* - \bar{l}_1)}{C_3(\bar{l}_3^* - \bar{l}_1)} = k_2,$$

$$\frac{C_5(\bar{l}_5^* - \bar{l}_1)}{C_4(\bar{l}_4^* - \bar{l}_1)} = k_3, \quad \frac{C_6(\bar{l}_6^* - \bar{l}_1)}{C_5(\bar{l}_5^* - \bar{l}_1)} = k_4,$$

then we may obtain next equations showing the relation between λ_j and λ_i, or

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* This formula was drawn from 5) in literatures mentioned below.

$$\lambda_2 = \lambda_1 \left[k_1 - (1-f)\frac{\triangle_2}{\triangle_1} \right],$$

$$\lambda_3 = \lambda_1 \left[k_1 k_2 - k_1 \frac{\triangle_2}{\triangle_1}(1-f) + (1-f)^2 \left(\frac{\triangle_2^2}{\triangle_1^2} - \frac{\triangle_3}{\triangle_1} \right) \right],$$

$$\lambda_4 = \lambda_1 \left[k_1 k_2 k_3 - (1-f)\frac{\triangle_2}{\triangle_1}(k_1 k_2 + k_1 k_3 + k_2 k_3 - k_2 k_3^2) \right.$$
$$+ (1-f)^2 \frac{\triangle_2^2}{\triangle_1^2}(k_1 + k_2 + k_3 - k_2 k_3) - (1-f)^2 k_3^2 \frac{\triangle_3}{\triangle_1}$$
$$\left. - (1-f)^3 \frac{\triangle_2}{\triangle_1}\left(\frac{\triangle_2^2}{\triangle_1^2} - k_3 \frac{\triangle_3}{\triangle_1} \right) \right],$$

and

$$\lambda_4 (\triangle_2 - k_4 \triangle_1) + (1-f)\lambda_3 (\triangle_3 - k_4 \triangle_2) + (1-f)^2 \lambda_2 (\triangle_4 - k_4 \triangle_3)$$
$$+ (1-f)^3 \lambda_1 (\triangle_5 - k_4 \triangle_4) = 0 .$$

From these equations an equation of third order of f can be deduced as follows;

$$\tau_1 (1-f)^3 + \tau_2 (1-f)^2 + \tau_3 (1-f) + \tau_4 = 0 ,$$

where

$$\tau_1 = (\triangle_5 - k_4 \triangle_4) - \frac{\triangle_2}{\triangle_1}(\triangle_4 - k_4 \triangle_3) + \left(\frac{\triangle_2^2}{\triangle_1^2} - \frac{\triangle_3}{\triangle_1} \right)(\triangle_3 - k_4 \triangle_2)$$
$$- \frac{\triangle_2}{\triangle_1}\left(\frac{\triangle_2^2}{\triangle_1^2} - k_3 \frac{\triangle_3}{\triangle_1} \right)(\triangle_2 - k_4 \triangle_1),$$

$$\tau_2 = k_1 (\triangle_4 - k_4 \triangle_3) - k_1 \frac{\triangle_2}{\triangle_1}(\triangle_3 - k_4 \triangle_2) + \frac{\triangle_2^2}{\triangle_1^2}(k_1 + k_2 + k_3 - k_2 k_3)$$
$$\times (\triangle_2 - k_4 \triangle_1) - k_3^2 \frac{\triangle_3}{\triangle_1}(\triangle_2 - k_4 \triangle_1),$$

$$\tau_3 = k_1 k_2 (\triangle_3 - k_4 \triangle_2) - \frac{\triangle_2}{\triangle_1}(k_1 k_2 + k_1 k_3 + k_2 k_3 - k_2 k_3^2)$$

and

$$\tau_4 = k_1 k_2 k_3 (\triangle_2 - k_4 \triangle_1).$$

As each τ_j consists of only known values, we can obtain value of f by solving this equation.

Using this value of f, ratio λ_j / λ_1 can be calculated and, moreover, values λ_j can be gained from the fact that $\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 1$.

In our case, we obtain next values from the actual data.

Month	C_t	$\bar{l}^*_t$(cm)	$\triangle_t$(cm)
7	280.9×10^6	$11.702 (= \bar{l}_1)$	
8	657.6 〃	12.038	0.552
9	941.4 〃	12.321	1.005
10	820.1 〃	12.497	1.455
11	415.9 〃	13.246	1.890
12	402.4 〃	13.828	2.314

From these values

$$k_1 = 2.177, \ k_2 = 1.164, \ k_3 = 0.532 \text{ and } k_4 = 1.743$$

and

$$\tau_1 = -0.4071, \ \tau_2 = 0.9109, \ \tau_3 = -0.4328 \text{ and } \tau_4 = 0.0068.$$

So, by solving the equation

$$(1-f)^3 - 2.2375 \ (1-f)^2 + 1.0632 \ (1-f) - 0.0168 = 0,$$

we can obtain three roots of $(1-f)$, and we adopt only a value 0.945 which seems the most appropriate value to the actual condition. Then

$$\lambda_1 = 0.320, \ \lambda_2 = 0\ 240, \ \lambda_3 = 0.435 \text{ and } \lambda_4 = 0.005 \text{ and } N = 15.111 \times 10^9.$$

So

$$N_1 = 4.836 \times 10^9, \ N_2 = 3.627 \times 10^9, \ N_3 = 6.573 \times 10^9 \text{ and } N_4 = 0.075 \times 10^9,$$

Thus we obtain

$$\varphi = 0.233.$$

Considerations

In constructing such method as shown above it is apt to give rise to serious discussions as to whether assumptions are adequate or not. Examinations of those assumptions come, of course, to be inevitable always in case of the adaptation of this method and should be executed mainly from the biologist's aspect. The author wishes to discuss somewhat on assumptions, aiming at the adaptability of this method to actual conditions.

At first, there may be two cases in the meaning of the restriction ″semi-closed″. One is a case treating an adult shoal and the other an newly born fish shoal. In the former cases, though we draw a rough interpretation from the catch conditions in the neighbouring areas of a fishing ground in question, ″no catch″ is not always synonymous with no-existence of fish. It is possible to obtain some degree of proof by means of echo-sounder. In case of the newly born fish shoal, wherever the spawning may be performed, only groups entering this area come to be qualified for the catchable object. In case of the yearlings the presence of departure of fish from this area ought to be ascertained in the same manner as in the case of the adults. Generally, the area, covering the terminal point of migration route, appears to be semi-closed during a certain period. For example, in the area covering the Gotō Nada and its southern neighbourhood the entrance of adults for spawning commences during January and they constitute a catchable stock from January to June every year. They come already to hide themselves from this area at the beginning of July, and in a period from January to July it seems that there is no emigration during some months. And in the same area the yearlings expose themselves to fishing by the purse-seiners from the last decade of July or a little earlier to mid-December. Toward the end of December they seem to vanish suddenly to a fish. In this case it is deemed that no departure is noticed.* It is dangerous to conclude from this reason that there is no emigration from this area through this period. But from another fact that number of caught fishes per unit-effort in November is nearly identical with that of December from the data of the catch statistics,** the above-mentioned inference may be considered as almost appropriate.

Next, there are many studies on the growth of body length of different species and those general modes are already shown on the basis of data extending over several years. Nevertheless, there is still a possibility that the base time may change with the variation of the spawning period owing to annual fluctuations in the environmental conditions and others. In our case, there is no discriminating difference between the year in question and years from which the base formula of growth was deduced.

Thirdly, there is a question in the assumption that the average body length of each entering group is constant irrespectively of the time of entrance. $\bar{l}_1$ may vary in accordance with various combinations of the mode of growth, the time of entrance and the efficiency (for example, mesh size) of gear used. If the efficiency of gear is constant throughout all the periods in question, each group persists a common mode of growth and the sequence of entrance is not disturbed, it is hardly possible that $\bar{l}_1$ may not be constant. But there is little hope that actual examinations can be carried out from point of this problem, and from the body length composition of

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* It seems that this inference is nearly appropriate from the review of the results of tag experiments performed by the Seikai Regional Laboratory of Fisheries in recent years 1), 2), 3).

** Both values are 0.1185 and 0.1195 respectively.

fish caught we can obtain the lowest catchable body length alone. Particularly, it is possible to treat reasonably and perform some examinations on the basis of data only in case that all fishes are adults and immigrate in order of age.

Fourthly, it is comparatively facile to find out the duration of immigration in case of the yearlings. In spite of increase of ($\bar{l}_t - \bar{l}_{t-1}$), which is an increment of average body length of each group, with t, the increment of general average body length of a unit-period, ($\bar{l}^*_t - \bar{l}^*_{t-1}$), may be apparently smaller than in case of no fishing, being caused by the combined effects from the addition of a group of the smallest body length and the decrease of number of larger groups, in the duration of immigration. On the contrary, the amount of each group decreases at the same rate and concurrently the average body length of each group increases also after the completion of immigration, therefore ($\bar{l}^*_{i+1} - \bar{l}^*_i$) may be generally larger than ($\bar{l}^*_i - \bar{l}^*_{i-1}$), provided that the addition completes by the i−th period, and later this increment may gradually become smaller again. So there must be a unit-period showing the minimum of ($\bar{l}^*_t - \bar{l}^*_{t-1}$) and this period corresponds to the time of completion of immigration as in Fig. 2. Apart from this expedient, there is a way to estimate the duration of addition from the data of spawning, based on the hypothesis the former's length comes to nearly equal to that of the spawning period in case which all groups persist in the same mode of growth. In our cases, from the reults of surveys on the spawning by the Seikai Regional Laboratory of Fisheries we deduce the next conclusion : the eggs of sardine were found there from a cruise 9~19 Jan. (in northern part) to a cruise 20~23 April (in southern part) and there was no larva during December and the larvae were, for the first time, sampled from a cruise of 9~19 Jan., and the peaks of appearence of eggs lay in the period 9~19 Jan. (in northern part) and in the period 21 Feb. ~ 8 March (in southern part), and that of larvae in the periods 9~14 Feb. (in northern part) and 27 Feb. ~8 March (in southern part) respectively. From this conclusion*,

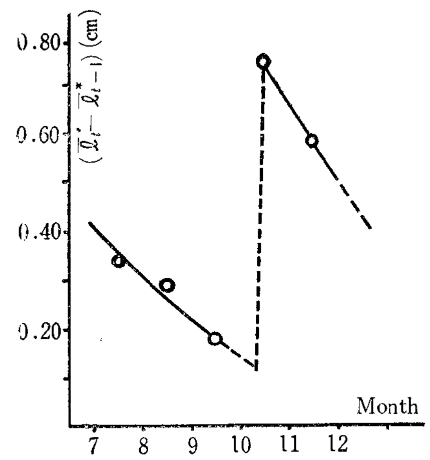

Fig. 2. Showing the change of the difference of the general average body length, ($\bar{l}^*_t - \bar{l}^*_{t-1}$), with t, in case of the yearlings (The reader is referred to the text for full account of this figure).

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* These results are quoted in an approximate meaning, because these surveys were not designed statistically and quantitatively.

it may be permitted that the length of duration of immigration is considered to cover four months, from the consideration that there was a spawning from the beginning of January to the end of April. we should inspect in detail whether an immigrating shoal commenced to be fished after the completion of entrance or not, for example if fishing operations commence for the first time during November in our case, then we must treat the problem in another mode.

Next, though we always anticipate a criticism on the assumption f = const., it is nothing but an expedient method as an approximation for the purpose of simplyfing the procedure. It is natural that f may have actually different values according to the period, and though it is desirable to set f as a function of t, such procedure is extremely difficult in reality. So, if it seems that the variation of f is not so great, there may be brought about no unreasonable deviation due to this assumption. There is a trial to judge, beforehand, the goodness of application of this method by testing the value C_t / e_t, presupposing that C_t / e_t is directly proportional to the amount of available fishes at the beginning of the t-th period (Fig. 3).

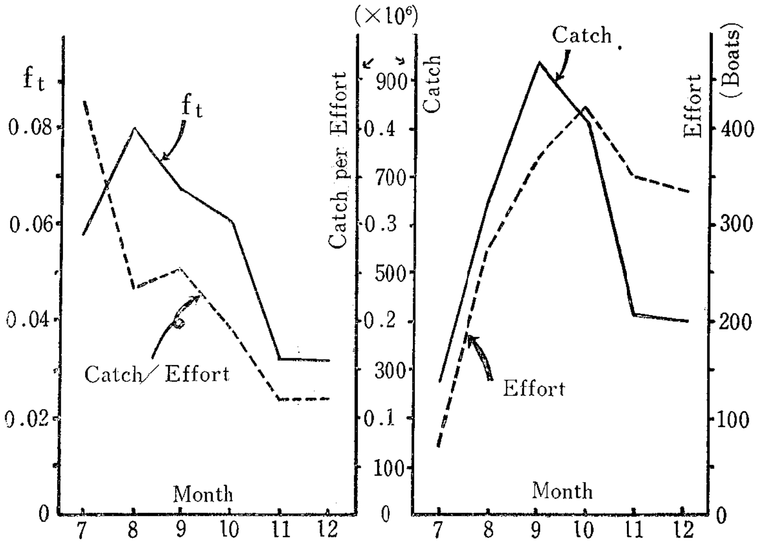

Fig. 3. Showing the catch, the effort, the catch per unit effort and f_t in the area covering the Goto Nada and its southern neighbourhood during a period from July to December 1953.
right ; catch and its corresponding fishing effort.
left ; catch per unit effort and f_t.

Though we did not refer to thus far, another assumption that there is no difference of efficiency in gear, or, for example no selection due to the mesh-size, is tacitly set up. Actually, when the body of fishes are comparatively small and a net is used as a gear to fish, the smaller the body length of a fish group is, the greater the selection perhaps affects, with the exception of the gill net. Even if other conditions were identical, the decrease of a group that has just entered a fishing ground may show a lower rate than that of other groups that already passed through some unit-periods there, owing to the selection of a net. But there is not so unique studies on selection of gear as to be applicable to the actual cases,* so we don't refer to this point further.

As the result of application to our case, we obtain $f = 0.055$ and $\varphi = 0.233$. And we can deduce a mode of immigration, and the addition during each unit-period has a minimum in August, a maximum in September and is extremely small in Ocotber. Therefore, the rate of decrease during each unit-period is maximum in August and has the same value 0.032 in November and December after the completion of addition. It is desirable that the appropriateness of result obtained should be examined by reviewing the assumptions and comparing with the results gained from other ways, for example, from the tag experiment.

In addition, there are shown the entrance, the survival, the fishing rate, $\bar{l}_t^*$ and $\bar{l}_t$ (the general average body length when there is no fishing) in the following table.

Table

Month	Catch ($\times 10^6$)	Effort (Boat)	Catch per Unit Effort ($\times 10^6$)	Recruitment ($\times 10^9$)	Survival ($\times 10^9$)	f_t	$\bar{l}_t^*$ (cm)	$\bar{l}_t$ (cm)
7	280.9	660	0.4256	4.836	4.836	0.058	11.702	11.702
8	657.6	2785	.2361	3.627	8.182	.080	12.038	12.500
9	941.4	3688	.2553	6.573	14.098	.067	12.321	12.651
10	820.1	4222	.1942	.075	13.352	.061	12.497	13.136
11	415.9	3509	.1185	—	12.937	.032	13.246	13.596
12	402.4	3367	.1195	—	12.534	.032	13.828	14.034
Total	3518.3			15.111	$\bar{f} = 0.055$			

Litteratures

1) ANON : 1954. The Intermediate Report from the Suryeys on the Sardine Resources, Seikai Regional Laboratory of Fisheries.

2) 〃 : 1954. The Report from the Surveys on the Sardine Resources (I), Seikai Regional Laboratory of Fisheries.

3) 〃 : 〃 . 〃 (II), 〃 .

4) 〃 : 〃 . 〃 (III), 〃 .

5) SATOW, Takerow : 1953. Studies on the growth of the Sardine, *Sardinia melanosticta*, ——I. Bull. Jap. Soc. Sci. Fish., **18** (10).

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* The author himself is now studying on this problem.