相模湾沿岸定置網ブリ漁況の判別分析

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Discriminant Analysis of Yellowtail Fishing Conditions on the Sagami Bay Coasts

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Discriminant analyses were carried out on the fishing conditions of yellowtails caught in stationary fishing nets on the Sagami Bay coasts during the past five years. The salinity of the water in the layer at a depth of 50 m in Iwae (x_1), the sea surface temperature in Iwae (x_2), the north-south component and east-west component of wind direction and velocity in Ajiro, (x_3) and (x_4) respectively, were chosen and used as the explanatory variables.

It has been clarified that the effects of these variables on the results of discriminant analyses are x_2, x_4, x_1 and x_3 in the descending order of description. The variables x_4 and x_3 were both found to be contributing to good catches of yellowtails when the wind blows inshore. In the discriminating test with the discriminant, mean right discrimination rates of 93% were obtained. Thus the discriminant to discriminate between a good catch and no catch of yellowtails was acquired. We consider that this model is effective for the discriminant prediction of yellowtail fishing conditions.

In the fishing grounds on the Sagami Bay coasts (Fig. 1), yellowtails *Seriola quinqueradiata* are caught in stationary fishing nets during the period from February to May each year.[1] The temporal distribution of the yellowtail catch is so random (Fig. 2) that most of the aggregate annual catch of yellowtails is reportedly achieved in an extremely short period representing only several percent of the total number of days of fishing operations a year.[2] It is also reported that the total of days with no yellowtail catch is as high as 30% of the total number of days of fishing operations in a year.

Hence, an accurate prediction of fishing conditions is necessary for the fishery to imporve the efficiency of yellowtail fishing operations. Attempts were therefore made to process and analyze data covering the past five years on the basis of the results[3] of discriminant analyses of yellowtail fishing conditions using such factors as oceanographic and meteorological conditions on a trial basis.

Satisfactory results of the analyses are reported here.

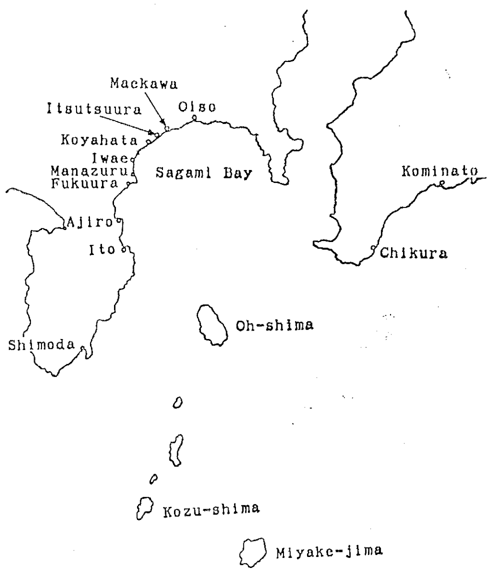

Fig. 1. Fishing grounds on the Sagami Bay Coasts and the related points.

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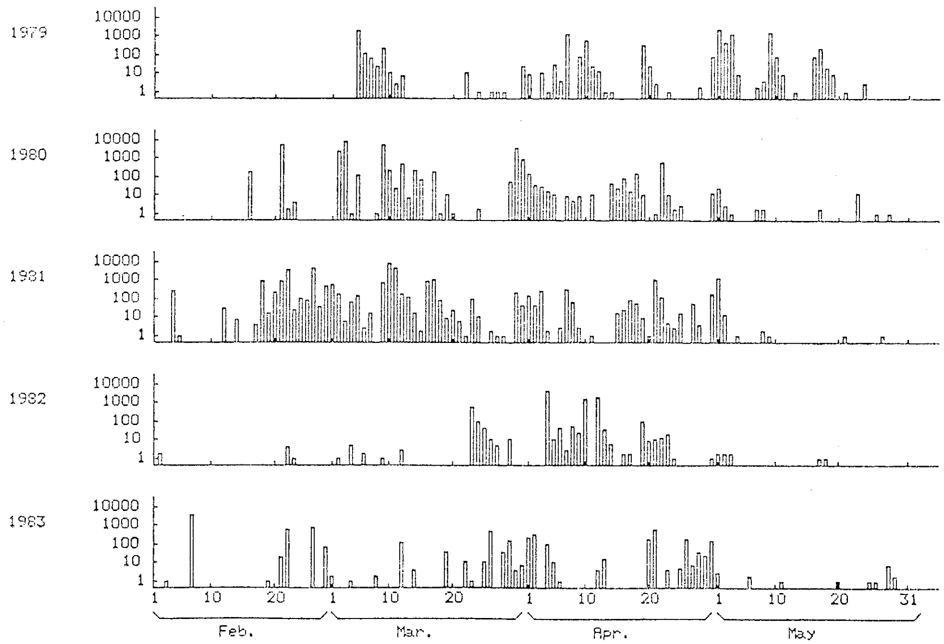

Fig. 2. The temporal distribution of the yellowtail catch for the period from 1979 to 1983. Vertical axis shows logarithm of catch in number.

Materials and Methods

The materials used are the survey table on the conditions of the stationary net fishery in Sagami Bay by the Kanagawa Prefectural Fishery Experimental Station and the monthly Meteorological Journal published by the Meteorological Agency, both for the period from 1979 to 1983. The yellowtail catch data in each coastal stationary fishing ground, the salinity data on water in the layer at a depth of 50 m and sea surface temperature data in Iwae in the period from February to May were obtained from the former. The wind direction and velocity data covering the same period furnished by the Ajiro Meteorological Observatory were obtained from the latter.

To discriminate fishing conditions, the catch of yellowtails was classified into two groups:

1) Group I: A group of days with good catches representing 100 or more yellowtails caught in a day (Good fishing condition group).
2) Group II: Another group of days in which no yellowtails were caught (Bad fishing condition group).

The number of data by group and year is given in the prime data column of Table 1. These two groups were then subjected to discriminant analysis[4] using the four explanatory variables given in Table 2.[4] The selection of these explanatory variables and the determination of groups were

Table 1. Numbers of data by year and group

Year	Number of prime data			Number of data for discriminant analysis		
	Group I	Group II	Total	Group I	Group II	Total
1979	9	16	25	7	16	23
1980	12	18	30	12	14	26
1981	22	22	44	17	17	34
1982	6	14	20	6	5	11
1983	10	15	25	10	10	20
Total	59	85	144	52	62	114

Table 2. Explanatory variables

Explanatory variable	Contents
x_1	Salinity (‰) of water layer at a depth of 50 m in Iwae for the fishing day.
x_2	Sea surface temperature (°C) in Iwae for the fishing day.
x_3	North-south component ($v\cos\theta$) of wind direction (θ) and wind velocity v for one day before fishing.
x_4	West-east component ($v\sin\theta$) of wind direction (θ) and wind velocity v for one day before fishing

made on the basis of the results of past analyses.[3)]

Discriminant, equation (1), can be obtained by discriminant analyses, which is to determine the discrimination coefficient l that maximizes the correlation ratio η in equation (4).

$$f=l_0+\sum_{i=1}^{4}l_ix_i \qquad (1)$$

where

f: composite variate

l_0: discrimination threshold

l_i: discrimination coefficient

x: explanatory variable

$$v=\frac{n_1}{n}(\bar{f}_1-\bar{f})^2+\frac{n_2}{n}(\bar{f}_2-\bar{f})^2 \qquad (2)$$

$$V=\frac{1}{n}\sum_{j=1}^{n}(f_j-\bar{f})^2 \qquad (3)$$

$$\eta^2=\frac{v}{V} \qquad (4)$$

where

v: variance of f between two groups

V: total variance of f for all samples

n_1, n_2: number of samples of Group I and Group II respectively

n: sum of n_1 and n_2

$\bar{f}$: mean value of f for all samples

$\bar{f}_1$,$\bar{f}_2$: mean value of f in Group I and Group II respectively

In the case of four variables, for instance, four-dimensional standard distributions are postulated for the respective populations of Group I and Group II to make the discriminant valid.[3)] It is further postulated that the respective variances and covariances of the populations are equal to each other.[3)] Accordingly, for the prime data given in Table 1, mean value μ and standard deviation σ of each variable were calculated by group (see the prime data column in Table 3). Then, a discriminant analysis was made with the data for which $\mu-2\sigma<x<\mu+2\sigma$ held (see the discriminant analysis data in Table 1). This is for the purpose of the homogenization of data to approach the above mentioned postulations.

When the sign of f obtained by substituting each variable with raw data is negative, equation (1) is identified to represent Group I, and when positive, Group II. However, the corresponding function or weight of the variables cannot be compared or examined from the sign and magnitude of the value of each discrimination coefficient. To clarify this the raw data were standardized by equation (5). The resultant discriminant is as-

Table 3. Mean value μ and standard deviation σ of each explanatory variable

a Prime data					b Data for discriminant analysis				
Exp. var.	μ / σ	Group I	Group II	Whole	Exp. var.	μ / σ	Group I	Group II	Whole
x_1	μ	34.50	34.51	34.51	x_1	μ	34.50	34.56	34.53
	σ	0.22	0.33	0.29		σ	0.22	0.31	0.28
x_2	μ	13.92	16.37	15.37	x_2	μ	13.67	16.31	15.10
	σ	1.30	2.23	2.26		σ	1.08	1.86	2.04
x_3	μ	0.13	−0.43	−0.20	x_3	μ	0.27	−0.65	−0.23
	σ	1.53	1.72	1.67		σ	1.89	1.40	1.71
x_4	μ	−0.90	−2.20	−1.66	x_4	μ	−0.90	−2.30	−1.66
	σ	2.25	2.71	2.61		σ	2.16	2.42	2.40

sumed to be equation (6) shown below.

$$X=\frac{x-\mu}{\sigma} \quad (5)$$

where

X : standardized data
x: raw data
μ: mean value of x
σ: standard deviation of x

$$F=\sum_{i=1}^{4} L_i \cdot X_i \quad (6)$$

where

F: composite variate by standardized data
L: discrimination coefficient by standardized data

Results

Discriminant

The discriminants incorporating raw data and standardized data respectively become as follows:

$$f=-29.67+0.68x_1+0.39x_2+0.07x_3-0.16x_4 \quad (7)$$

$$F=0.19X_1+0.90X_2+0.11X_3-0.39X_4 \quad (8)$$

The values of composite variates f and F are negative in Group I (Good catch) while they are positive in Group II (No catch). Since the correlation ratio that shows the discrimination accuracy is 0.64, discrimination tests were conducted for each group on the 114 items of data for discriminant analysis given in Table 1 using equation (7). As a result, the right discrimination rate signifying a rate of correct results to the total results in discriminating each group as high as 93% was obtained for both Group I and Group II.

Weights of explanatory variables

It can be seen from the discrimination coefficient of equation (8) that the weights of explanatory variables contributing to a good catch ($F<0$) are the water temperature in the surface layer in Iwae (X_2), west-east component of wind direction and velocity in Ajiro (X_4), salinity in the layer of water at a depth of 50 m in Iwae (X_1), and north-south component of wind direction and velocity in Ajiro (X_3) in the descending order of description. From the fact that the discrimination coefficient L_4 of X_4 is negative, it follows that when X_4 is positive, *i.e.* the wind is easterly, the composite variate F tends to assume a negative value. In the case of X_3, it assumes a negative value when the wind is southerly. Then, since $L_3>0$, the composite variate F also tends to assume a negative value.

In other words, the results of the above study suggest that a good catch of yellowtails can be anticipated when a strong wind blows inshore *i.e.* easterly to southerly in waters in the vicinity of Ajiro. In the comparison between the meteorological observatory data and the actual yellowtail catch, it is also shown that the wind direction at times of good catches is overwhelmingly easterly and its relative frequency is as high as 92.4%.

The water temperature in the surface layer (X_2) and the salinity in the layer of water at a depth of 50 m (X_1) in Iwae have positive discrimination coefficients. It therefore follows that the more the values of x_1 and x_2 increase beyond the mean values ($X_1>0$, $X_2>0$), the closer the fishing conditions, in terms of yellowtail catch, of a given day approach those of a poor catch or no catch ($F>0$).

Discussion

The mean values and standard deviations of discriminant analysis data, and the variance and covariance are given in Tables 3 and 4 respectively. The tabulated variance and covariance of Group I must be approximately equal to those of Group II, respectively, from the postulation stated in the

Table 4. Variance and covariance between variables

	Group	x_1	x_2	x_3	x_4
x_1	I	0.05	0.01	−0.02	−0.02
	II	0.10	−0.36	−0.20	−0.30
x_2	I		1.18	−0.20	−0.07
	II		3.45	1.38	2.76
x_3	I			3.57	3.32
	II			2.32	3.31
x_4	I				4.65
	II				6.95

Table 5. Examples of discriminant test for new data

No.	x_1	x_2	x_3	x_4	Catch	f value
1	34.60	12.2	1.109	0.459	1556	−1.380
2	34.40	12.3	4.065	1.648	3690	−1.466
3	34.40	14.3	−2.220	−5.358	122	0.001
4	34.49	15.3	−1.722	−4.157	0	0.295
5	34.26	17.6	−1.755	0.727	0	0.252
6	34.20	12.8	−1.110	−2.679	0	−1.071
7	34.40	12.7	−2.296	−5.543	1056	−0.599
8	34.20	12.4	0.000	−1.600	1153	−1.322
9	34.70	17.0	−0.990	−2.125	0	0.834
10	34.43	15.8	−0.497	−1.201	1	0.062

preceeding section. Inasmuch as Table 4 is concerned, however, a considerable differences are seen between Group I and Group II of the samples. Considering that the correlation ratio shows much larger value for the discriminant analysis data than for the prime data in Table 1, this is not so serious as to discuss the data construction.

A dramatic improvement in the discrimination accuracy would not be expected merely by increasing the number of samples and imporving their quality. Accordingly, studies were made on other explanatory variables.

When Kuroshio runs extremely close to the southeastern tip of the Boso Peninsula in the north-bound path, the south-bound migration of yellowtails is naturally blocked.[1] This is normally referred to as "the blockage phenomenon at the mouth of Boso." In order to quantify this phenomenon, the relationship between the yellowtail catch and the difference in water temperature between Kominato and Oh-shima or Miyake-shima (x_5) was examined with a cross-correlogram. However, no time lag with any significant correlation was observed.

The fluctuation of the running path of Kuroshio causes contractions and relaxations of the water in Sagami Bay due to the mass of warm water.[6] This phenomenon is also recognized as one of the contributory factors closely related to the yellowtail catch.[2,7] To verify this phenomenon, several sets of fixed points were chosen in and out of the waters of the bay (Fig. 1), through which the possible relationship between the yellowtail catch and the in-and-out temperature difference (*e.g.* between Oh-shima and Iwae or Oiso) (x_6) was assessed; however, no meaningful time lag was identified.

To dig deeper into the problem, two temperature difference variables x_5 and x_6 not involving a time lag were added to the discriminant analysis as the explanatory variables representitng the above two phenomena. Except for a slight increase in correlation ratio, however, they did not function as such with any appreciable effectiveness. Hence, it will be necessary to introduce some other approaches to these two phenomena for clarification in the future.

In either event, discriminants (7) and (8) could achieve a mean right discrimination rate of 93% in the discrimination tests. But it could not achieve only 86% as the result of our trial discrimination tests for Group I and Group II on the 21 entirely new samples conducted during the period from 1984 to 1986. As seen in examples No. 3 (x_4) and No. 6 (x_2) of Table 5, discriminations may fail when either x_2 or x_4 takes improperly abnormal value. Further study is necessary to establish the discrimination model for more effective use.

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