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THE STOCK DISCRIMINATION AND RECRUITMENTAL AGE OF SPOTTED MACKEREL, *SCOMBER AUSTRALASICUS* IN TAIWAN*

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ABSTRACT

Kun-hsiung Chang and Chang-po Chen (1976) *The Stock Discrimination and Recruitmental Age of Spotted Mackerel,* Scomber australasicus *in Taiwan.* Bull. Inst. Zool., Academia Sinica 15(2): 57-64 The spotted mackerel, *Scomber australasicus* Cuvier, is one of the commercially important fish in Taiwan fisheries. Forty-one samples, totaling 2106 individuals caught by hand liners from Nanfangao, Penchiahsu, the Fishing Islets, Kaohsiung, Tungkang, Hengchun and Kyushu (Japan) from 1969 to 1971 were used for stock discrimination by multiple-discriminant analysis (MDA) and Mahalanobis' generalized distance. Samples were clustered into three year groups, each consisting of fish caught from late summer to next summer. There was a trend of geographical cline within each group. The results showed that the spotted mackerel around the waters of Taiwan may belong to different stocks. Based on composition of each yearly group and the comparison between the body size of the catch and the estimated recruitmental body size, it is suggested that the recruitment entering the fishing ground (off northern Taiwan) of hand liners in late summer is 1^+ years old.

The spotted mackerel, *Scomber australasicus* Cuvier, is one of the most commercially important fish in Taiwan's fish catch. Studies on its resources were undertaken from 1969 to 1973 and a series of reports about them were published by the Laboratory of Fishries Biology of this institute[3-14].

Many approaches were carried out for the stock discrimination of the spotted mackerel. For example, morphometrically, the significant difference in body portions between the fish off northern and southern Taiwan suggested that there might be two groups of spotted mackerel around the waters of Taiwan[4,8,9]. A geographical cline based on some meristic characters was revealed by the Reduced Coefficient of Racial Likeness (R.C.R.L.)[14]. The results from the study of the reproductive ecology of the spotted mackerel also suggested that the waters off southern Taiwan and the waters around the Fishing Islets (off northern Taiwan) might be the spawning ground of the fish. Although the spotted mackerel off both southern and northern Taiwan spawn in the same season, the range of fecundity of the fish off southern Taiwan was shown to be slightly larger than that of the fish off northern Taiwan[11,12].

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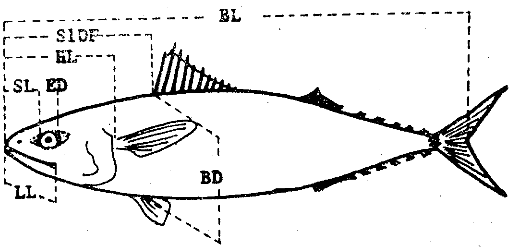
Strangely, those fish that had been tagged and then released in the waters off northern Taiwan were almost all recaptured from the waters off northern Taiwan and Japan, with only one of them was recaptured from the waters off southern Taiwan[4]. This result indicates that the spotted mackerel around the waters of Taiwan might be of two different stocks but with some degree of overlapping.

In this paper, we try to employ some non-meristic characters in applying multiple-discriminant analysis (MDA)[20] and Mahalanobis' generalized distance[18] on stock analysis. Some fishery biological problems such as recruitmental period, age composition and monthly CPUE were also discussed.

MATERIALS AND METHODS

The materials used in this study were chosen from the samples used by Chang and Fong (1971)[5]. Under two criteria: (1) whether the sample size is large enough, i. e., nearly 40 individuals or more, and (2) whether the seven characters were measured (Fig. 1), forty-one samples, including 2106 individuals, were chosen. They were caught by hand liners from Nanfangao, Penchiahsu, the Fishing Islets, Kaohsiung, Tungkang, Hengchun and Kyushu (Japan) from 1969 to 1971. The fishing areas and the details of each sample were shown in Fig. 2 and Table 1, respectively.

For eliminating the effect from body size



BL: Fork Length
HL: Head Length
SL: Snout Length
LL: Lacrimal Length
ED: Eye Diameter
BD: Body Depth
S1DF: Snout to 1st Dorsal Fin

Fig. 1. *Scomber australasicus* CUVIER, illustrating parts of measuring.

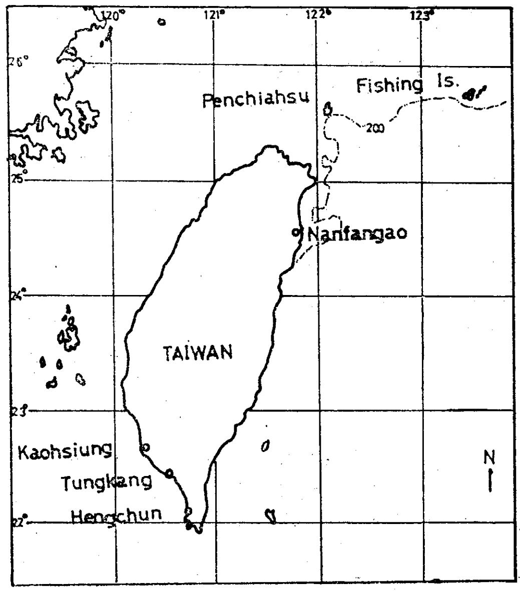


Fig. 2. Map showing fishing ground of spotted mackerel.

and unequal weight of each characters, a natural log transformation of ratio was calculated from the formula:[19]

$$\hat{X}_i = \ln\ (X_1/X_i) \qquad (1)$$

where, X_1 is the body length and X_i represent the other six non-meristic characters.

Once the MDA based on $\hat{X}_i$ is obtained, the generalized distance (D^2_{ij}) can easily be calculated from the canonical variates of MDA and a few larger discriminant axes will evaluate most of the value[18].

$$D^2_{ij} = \sum_{r=1}^{r} (\bar{X}_{ir} - \bar{X}_{jr})^2 \qquad (2)$$

where, $\bar{X}_{ir}$ is the canonical variate of the i sample on r discriminant axes, and r is the number of roots.

Additionary, the Ward's hierarchical clustering method was performed on generized distance between sample means[2].

The MDA program was contributed by Mr. C. Liu, department of Agronomy, National Taiwan University (NTU) and the Anderverg's (1973) clustering program was modified by C. P.

TABLE 1
Materials used in the study

No.	Sampling date	Sampling area	Sample size	Body Length (mm)	
				range	mean
1	Jan. 14, 1969	N	50	258-299	276.7
2	Feb. 14, 1969	N	49	326-362	340.9
3	Feb. 14, 1969	P	70	245-294	267.9
4	Apr. 12, 1969	P	48	241-276	255.5
5	May. 17, 1969	F	47	302-379	333.7
6	Jun. 14, 1969	N	48	283-341	305.9
7	Jun. 18, 1969	F	50	266-320	294.1
8	Jul. 16, 1969	F	48	278-327	299.2
9	Aug. 15, 1969	N	47	289-325	307.1
10	Aug. 16, 1969	F	48	288-315	298.6
11	Sep. 18, 1969	N	38	296-333	310.0
12	Oct. 16, 1969	F	50	284-325	309.3
13	Oct. 18, 1969	N	46	282-331	294.9
14	Nov. 15, 1969	F	52	278-312	297.8
15	Nov. 19, 1969	N	48	292-340	316.5
16	Dec. 10, 1969	N	50	319-361	342.8
17	Dec. 13, 1969	P	50	239-264	253.0
18	Jan. 14, 1970	F	52	282-317	298.8
19	Jan. 17, 1970	N	51	285-330	313.2
20	Feb. 18, 1970	N	57	275-322	295.7
21	Mar. 4, 1970	K	40	311-354	334.3
22	Mar. 18, 1970	N	55	290-345	312.0
23	Mar. 19, 1970	I	58	264-347	292.5
24	Apr. 4, 1970	K	48	291-398	318.9
25	Apr. 18, 1970	N	49	280-345	311.2
26	Jul. 15, 1970	I	50	295-336	310.5
27	Jul. , 1970	T	85	272-369	310.7
28	Aug. 27, 1970	I	51	291-339	308.7
29	Sep. 25, 1970	I	46	299-348	317.0
30	Sep. 29, 1970	N	49	326-360	342.4
31	Sep. , 1970	H	58	288-346	323.6
32	Oct. 10, 1970	N	54	315-367	343.2
33	Nov. 6, 1970	N	47	323-356	340.4
34	Nov. 27, 1970	J	50	243-350	280.9
35	Dec. 16, 1970	I	48	280-330	298.7
36	Dec. 23, 1970	N	46	303-359	339.9
37	Dec. , 1970	H	44	324-391	354.8
38	Jan. 16, 1971	I	49	289-319	302.7
39	Jan. 21, 1971	N	45	305-351	325.6
40	Feb. 16, 1971	N	52	292-325	305.5
41	Mar. 22, 1971	K	83	307-340	322.6

N: Nanfangao P: Penchiahsu F: Fishing Is. K: Kaohsiung T: Tungkang
H: Hengchun I: Fishing Is. or Penchiahsu J: Japan

CHEN.

All calculations were computed by CDC 3150 at NTU.

RESULTS

Since the number of samples were larger than the number of characters (41>6) in this study, the maximum number of discriminating axes in MDA was equal to the number of characters[20]. All 6 roots were significant and the first two discriminating axes accounted for 80.3% significant variation (Table 2). The relationships

TABLE 2
The character roots (λ_j), aggregated variability and its chi-square value in MDA with transformed data.

j	λ_j	Chi-square*	df	Aggregated variability (%)
1	3.4645	8493.07**	240	44.30
2	2.8128	5378.83**	195	80.26
3	0.7952	2593.25**	152	90.43
4	0.3381	1375.29**	111	94.75
5	0.2802	769.06**	72	98.33
6	0.1303	254.90**	35	100.00

* Bartletl's ** singnificant at 0.01 level

among forty-one samples on the basis of the first two discriminant functions are shown in Fig. 3. Three distinguished spheroids were obtained and each group consisted of the fish caught from late summer to the following summer, regardless of where they collected.

The same result was also obtained by the clustering analysis of generalized distance which

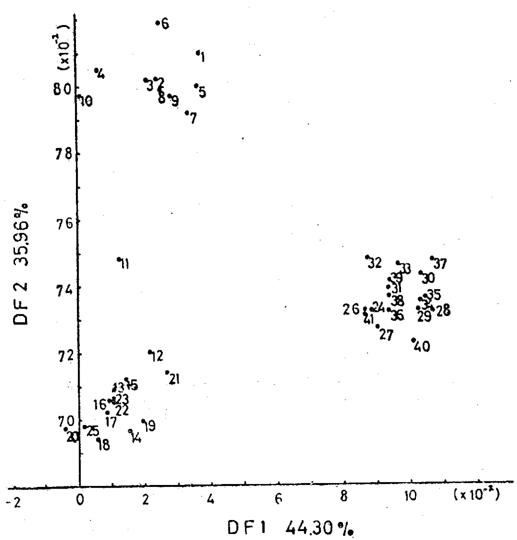


Fig. 3. Associations among 41 spotted mackerel samples on the basis of the first two discriminant function (DF). Abbreviations showing in Table 1.

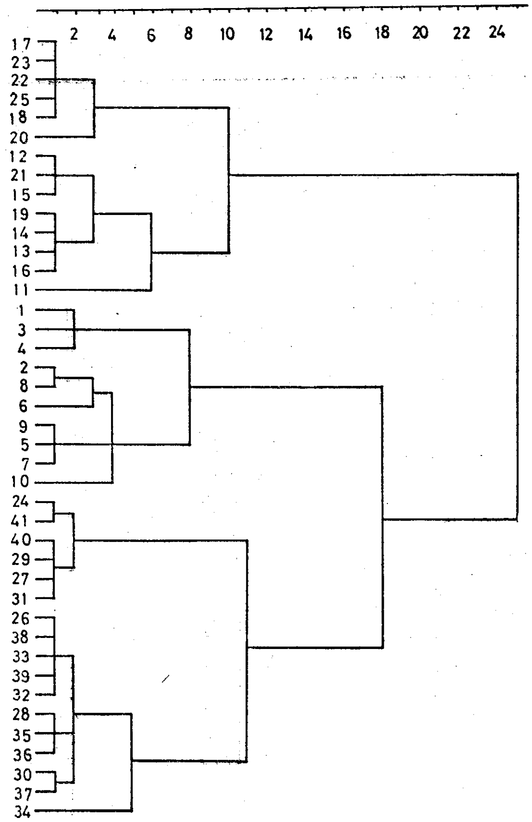


Fig. 4. Dendrogram of 41 spotted mackerel samples derived from distances based upon the first three discriminant function axes using Ward's clustering method. Abbreviation showing in Table 1.

calculated from the first three canonical variates (Fig. 4).

While significant variations from morphometric characters were observed among years, as differences among areas might still exist[21], *a postiriori*, an MDA was made on each of the three above-mentioned spheroides, respectively. The results of the MDA from the third group which had more different fishing areas than the others, revealed a trend of geographical cline extending from southern Taiwan to Japan, and the fish caught from northern Taiwan were clustered together. Besides, one of the southern samples was very close to the northern samples (Fig. 5).

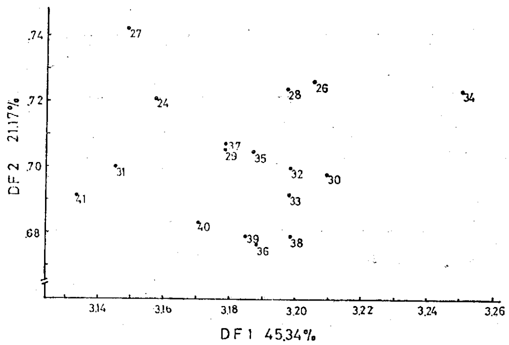


Fig. 5. Association among '71 yearly group (17 samples) on the basis of the first two discriminant function (DF). Abbreviations showing in Table 1.

DISCUSSION

According to Chang and Wang (1971), the biological minimum size of the spotted mackerel is between 200 mm to 250 mm in the Taiwan area[13]. While most of the materials used in this study were larger than 250 mm, it is reasonable to eliminate the effect from body size by ratio. Besides, an MDA based on seven original data was made to check whether the effect from body size really existed. Three groups equal to the above-mentioned spheroids were obtained with the element of each group scattering along three parallel lines (not shown). It implies that the ratio correction not only eliminates the effect from body size but also emphasizes its relationship while the body size is larger than its biological minimum size.

The results of this multivariate morphometric analysis reveal that a geographical cline was present on the spotted mackerel around the waters of Taiwan, regardless of the significant variation occuring in different years.

From the results mentioned above, it is suggested that the spotted mackerel around the waters of Taiwan may belong to different stocks. This study and many other approaches as previously mentioned support the evidence that there seem to be two groups of spotted macke-

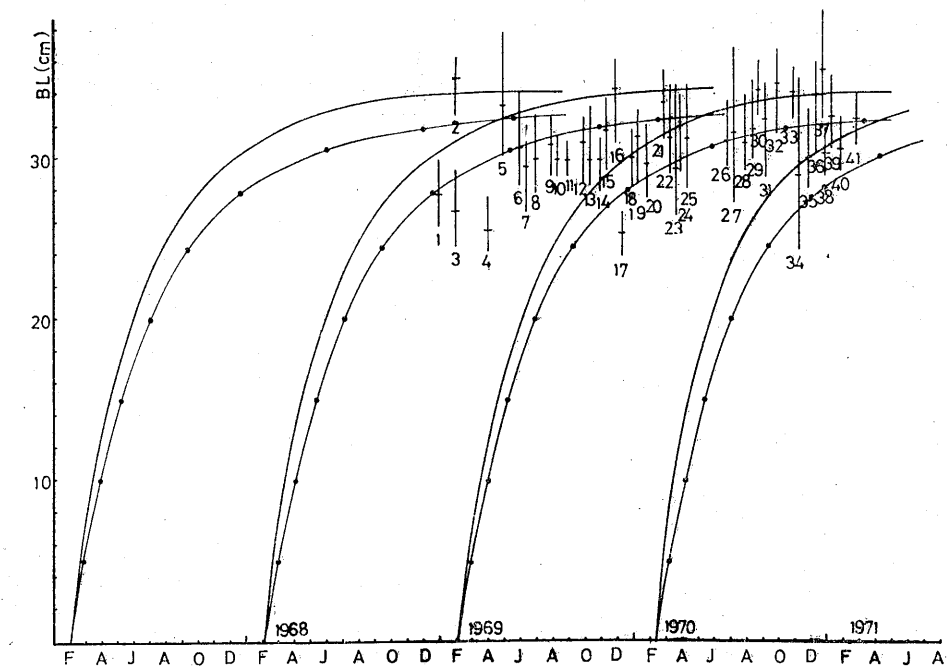


Fig. 6. The relationship between the body size of catch (range and mean) and two estimated growth curve (—— after Hanado, *et al*, 1968; -•-•- after Chang and Woo, 1970).

rel: southern-origin and northern-origin groups, overlapping in Taiwan. The present of juvenile fish off both southern and northern Taiwan also support this suggestion[6,7]. Juvenile fish about 36–92 mm in body size off Kaohsiung and 47–155 mm off Nanfangao were captured during March and April in 1969. Unfortunately, we have no information about whether the mature fish interchange thir spawning grounds or not.

The compositions of each year-group clustered by the MDA indicated that the spotted mackerel were recruited in late summer and stayed in the fishing ground around the waters of Taiwan not beyond the following summer. This hypothesis could be supported by the evidence mentioned below. Hanado, *et al.*[16] and Chang[8] reported respectively that the monthly CPUE of the spotted mackerel caught from Nangfangao and the Fishing Islets showed two peaks, one in spring the other in early fall. Clearly, the time of 2nd peak in CPUE coincides with the supposed recruitmental period. The spawning aggregation behavior might cause the spring peak on the spawning ground during the spawning season.

The growth of spotted mackerel is rapid. Hanado, *et al.*[16] estimated that the fish reached approximately 31 cm in body length during the first year and 34 cm by its 2nd year, and that the middle-size specimens caught in the late summer would have been hatched in the beginning of that same year. But Chang and Woo[10] reported that the newly-born grew to 27.5 cm at the end of the first year and 32 cm at the end of the second year in Nanfangao. Because the spawning season was estimated to be from February to April, but primarily in February[11], two growth curves revealed from Hanado, *et al*[16] and Chang and Woo[10], respectively, were plotted from the begining of February to estimate the recruitmental age of the fish. As shown in Fig. 6, if the fish recruited to fishing ground were at 0^+ age as estimated by Hanado, *et al*, then the body size of the year group would be larger than the estimated recruitmental body size by both of the above-mentioned growth curves. The growth curve estimated by Chang and Woo[10] seems to be in better agreement with this study as the recruitmental age is 1^+ age. In other words, the group consisting of samples from numbers 1 to 10 was born in 1967, the group consisting of samples 11 to 25, except sample 24, was born in 1968, etc.

Significant variation of morphometric between years has been more frequently been reported on meristic[1,15,17], but rarely on non-meristic characters[21]. The study of systematics of fish should be more careful to avoid this kind of variation[1]. It has been reported that many environmental factors could induce the yearly variation of meristic characters[1,15,17]. Among these factors, the water temperature during the spawning season seems to be one of the important factor. The fluctuation of gonad index of the spotted mackerel showed a highly negative correlation with that of water temperature[11]. As the monthly mean water temperature of both southern and northern Taiwan changed synchronously as shown on Fig. 7; therefore, the yearly morphometric variation of the spotted mackerel may be induced by the fluctuation of water temperature during spawning season.

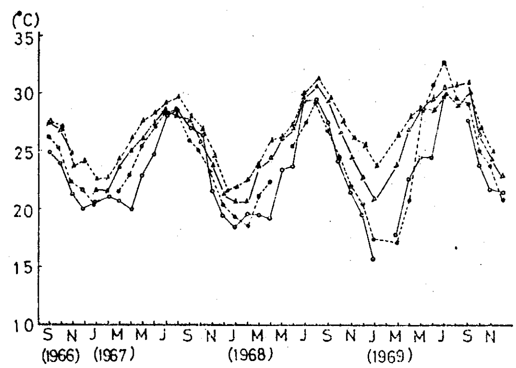


Fig. 7. Monthly variation of the water temperature at southern (●) and northern (▲) Taiwan. (After J.C.B.R.)

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臺灣花腹鯖的族群判別及其補充群之年齡

張 崑 雄 陳 章 波

花腹鯖 (*Scomber australasicus* Cuvier) 爲臺灣重要近海產經濟魚種之一。本文以 1969 至 1971年間在南方澳、彭加嶼、魚釣島、高雄、東港、恒春及日本九州等地用手釣漁獲的 41 個樣品，計 2106 尾魚爲材料，量取 7 個外部形質，以自然對數轉換體長及其它 6 個形質的比值，做多變值判別分析法 (Multiple discriminant analysis) 及泛距離 D^2 的形態測定學的分析。結果發現所有樣品不分採集地區，完全依採集時間而劃分爲三個年羣 (Yearly groups)，而同一年羣有地理傾斜 (Geographical cline) 的現象，顯示臺灣產花腹鯖爲不同的族羣。由年羣的劃分起迄及生長曲線的比較推測得臺灣北方手釣鯖魚的補充群是生長到 1 歲左右而於夏末秋初進入手釣漁場。