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APPLICATION OF MAHALANOBIS DISTANCE FUNCTION FOR THE MORPHOMETRIC SEPARATION OF SPOTTED FLOUNDER (*CITHARUS LINGUATULA* LINNAEUS, 1758) STOCKS IN THE GULF OF MERSIN

DURSUN AVSAR*
Institute of Marine Sciences, Middle East Technical University, P.O. Box 28, 33731 Erdemli, Içel, Turkey

ABSTRACT

Stock differentiation studies were carried out applying the Generalized Distance of Mahalanobis (D^2) for spotted flounder *(Citharus linguatula)* collected from four different localities in Mersin Bay. The relative evaluation of D^2 values obtained from the spotted flounder samples indicated that great separation exists between the adjacent stocks of Tuzla-Goksu, Tirtar, and Seyhan. A calculated D^2 value of 2.571 between Seyhan and Goksu stocks demonstrated strict separation, while Tuzla and Goksu samples showed weak similarity. The cluster analysis also indicated a high degree of heterogeneity between the samples from the sampling stations, while similarity was observed between the stocks of Tuzla and Goksu characterized by three horizontal nodes.

INTRODUCTION

The spotted flounder *(Citharus linguatula)* is common off the west coast of Africa, along the eastern Atlantic from Portugal to Angola (Tortonese, 1975), and in the Adriatic, Black, Marmara, and Mediterranean seas (Nielsen, 1973).

This fish feeds on living invertebrates, mainly Decapoda, Euphasiacea, Mollusca, Nematoda, Polychaeta, Natantia, Gastropoda, Mysidacea, Amphipoda, and on small fishes, and is common in shallow coastal waters (Nielsen, 1973). Its bathymetric range extends to a depth of 300 m (Tortonese, 1975).

Spotted flounder has some economic importance as a food fish, but in the region studied it is not commonly consumed. During 1980–1982, 2.9% of the total catch of this species was from Tirtar, 0.3% from Goksu, 0.06% from Tuzla, and 0.06% from Seyhan (Bingel, 1987). Length frequency data of this species indicate that this fish spawns in Mersin Bay, probably in early summer and in autumn (Bingel, 1987).

On the Mediterranean coast of the Anatolia region, knowledge of fish populations is mainly based on species lists or location records (Aksiray, 1954; Ben-Tuvia, 1973; Geldiay, 1976). Recent investigations have shown that different demersal fish species

*Present address: Fisheries Faculty, The University of Cukurova, P.O. Box 173, 01330 Balcali, Adana, Turkey.
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are undergoing overfishing in Iskenderun and Mersin bays (Bingel, 1981, 1987). In Turkey, for the regulation of such overfished stocks along the Mediterranean coast, different methods such as mesh size limitation, minimum fish size, and banning of fishing activity have been applied.

However, such applications are only suitable if one unit stock is exploited, and to achieve optimum management of the fisheries along the Anatolian coast, much information is needed on the geographical distribution of fish stocks. The only study was that carried out by Mengi (1971) along the coasts of Turkey, which aimed to identify existing populations of spotted flounder in Marmara, middle Aegean, southern Aegean, and in northeastern Mediterranean regions. No other comprehensive studies on stock differentiation of the spotted flounder inhabiting the Turkish coast exist. To fill this gap, a study on the differentiation of the existing unit stocks of spotted flounder inhabiting the northern Cilician Basin (Mersin Bay) was performed.

MATERIAL AND METHODS

The sampling sites in Mersin Bay are shown in Fig. 1. Seyhan, Tirtar, and Goksu stations were directly influenced by important fresh water input from the Tarsus and Seyhan, the Lamas, and the Goksu rivers, respectively.

Material collections were carried out using two similar trawler boats. Samples were obtained by bottom trawl towed for approximately 1.5 to 4.5 km. The mesh size of the nets was 28 mm in stretched form. Random sampling was performed at monthly intervals between 19.3.1985 and 20.12.1985. Fish were transferred into 10-liter plastic containers and preserved in 10% formalin solution immediately after separation of the catch.

Samples collected at each station were assumed to be from the same stock. Morphometrics and sexes of 734 fish were recorded, and 552 fish specimens were used for the discriminant analysis. In general, the two sexes of any fish species show different growth characteristics (Holden and Raitt, 1974). Therefore, it was assumed that the results of discriminant analysis would be radically affected by differences in male-to-female ratios. In order to prevent posssible errors arising from this, the numbers of males and females were equalized.

Subsampling was carried out according to the procedure described by Holden and Raitt (1974). The measured morphometric characters are presented in Fig. 2. Length measurements were made as a straight line.

It is well known that weight is a power of length (Ricker, 1975). Additionally, according to Blackith and Reyment (1971), the weight unit can be used for the standardization of raw data. On the other hand, a few length measurements would not give any discriminative clues (Panhorst and Becker, 1976) even for very dissimilar body sizes. Therefore, other measurements have to be made (Blackith and Reyment, 1971). Notwithstanding, Ehrich and Rempe (1980) used 15 length characters and successfully separated hake populations. For this reason, the discriminating power in the present study was extended to three dimensions by adding as many characters as possible in

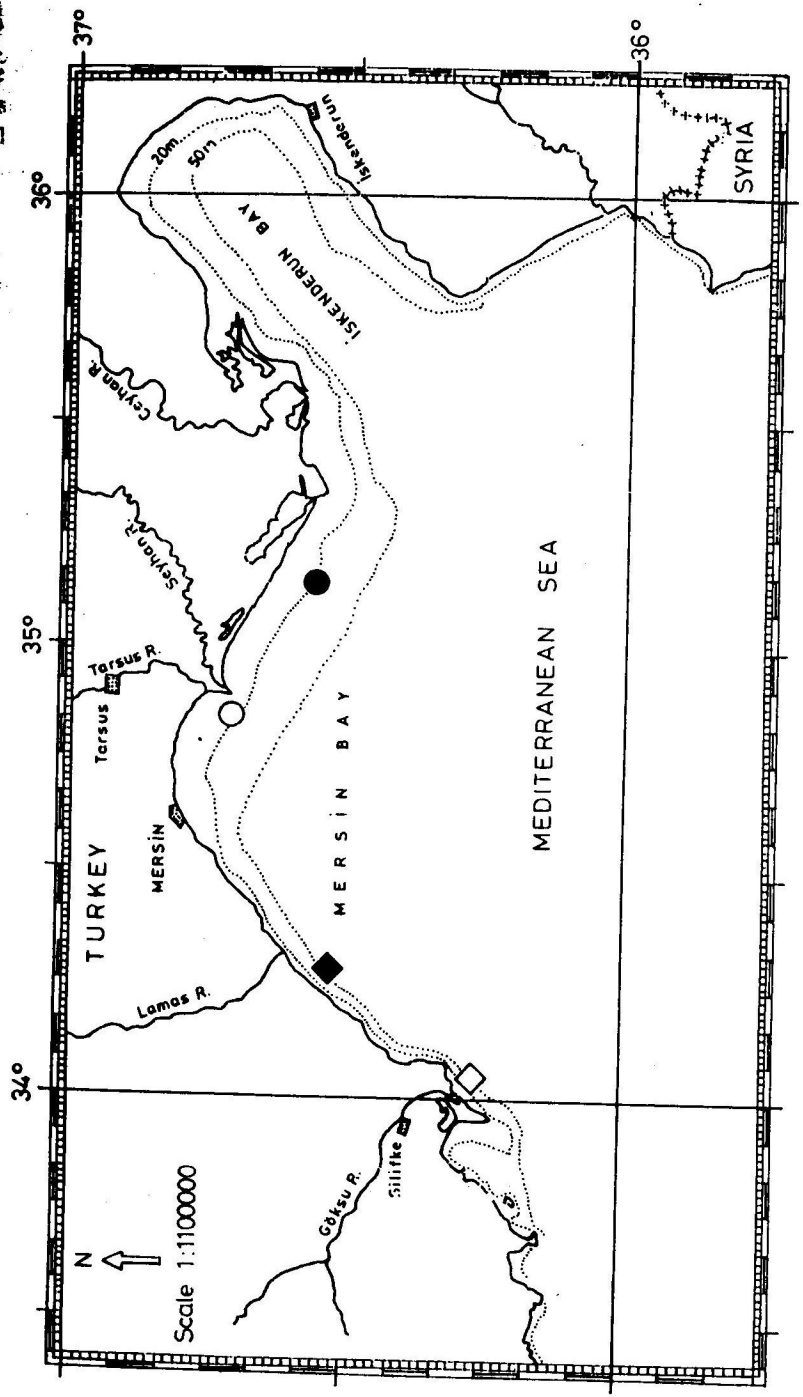

Fig. 1. Sampling locations in Mersin Bay (Solid circle: Tuzla; Empty circle: Seyhan; Solid square: Tirtar; Empty square: Goksu).

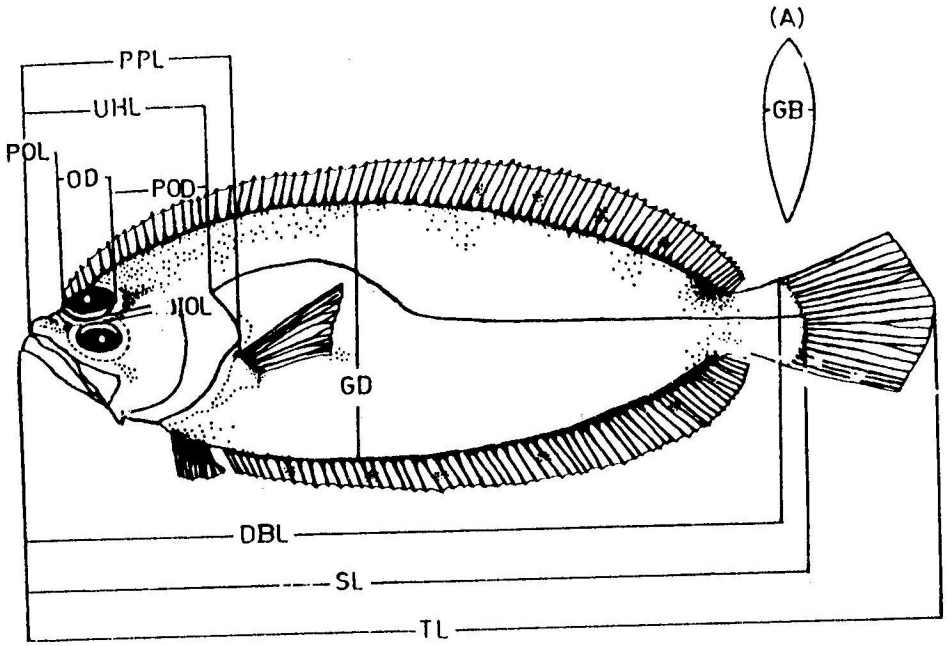

Fig. 2. Measured morphometric characteristics of *Citharus linguatula*. TL = total length, SL = standard length, DBL = dorsal body length, UHL = upper head length, PPL = prepectoral length, POL = snout length, OD = orbital diameter, POD = postorbital distance, IOL = interorbital length, GD = greatest depth, GB = greatest breadth. (A): The maximum breadth of the cross section. (Redrawn from Tortonese, 1975).

order to have optimal discriminating conditions. Based on this idea, the weight unit was used in this study for standardization of the raw data. Each morphometric measurement was divided by the individual gutted weight directly. Weighing was done using an electronic balance (accuracy 0.01 g).

Generalized distance of Mahalanobis (Mahalanobis et al., 1949 cited in Weber, 1972) was used for the quantitative separation of the spotted flounder stocks:

$$D^2 = (b_1d_1 + b_2d_2 + b_3d_3 + \ldots + b_md_m)/m$$

where m is the number of measured characters, D^2 is the generalized distance of Mahalanobis, b_i represents the discriminant functions of the *i*-th measurement, and d_i is the mean difference of the *i*-th measurement.

The results of this analysis were used in conjunction with the unweighted-pair group method of Davis (1973) to obtain a qualitative relationship among stocks. The calculated D^2 value between samples collected from two localities was used to quantify the separation of related stocks. The *F*-test as described by Overall and Klett (1972) and Sneath and Sokal (1973) was used to determine any significant differences between groups.

RESULTS

The number of individuals sampled in the four localities, their total length ranges, and those used for further statistical analysis are given in Table 1.

There were no considerable differences between the mean lengths of raw and equalized data (Table 1). The differences in percentage ratios of males and females showed a wide range of fluctuation, from 0 to 32. However, the variances, standard deviations, and mean lengths of the equalized data for different stations were closer than for raw data values. In addition, differences between maximum and minimum values were reduced due to the equalizaton of males and females in the Tirtar and Goksu samples. This is already seen in the diagram of length frequency distribution for the four sampling stations (Fig. 3).

Results of significance testing and D^2 values obtained from possible combinations of the sampling stations are given in Table 2. A decreasing trend was observed in the D^2 values from Tuzla to Goksu (Table 2). The hypothesis that "there is no difference between the groups" was accepted for the Tuzla–Goksu pair but was rejected for all other sample pairs. Consequently, it can be proposed that stocks of Seyhan and Tirtar differ greatly from one another, as well as from the Tuzla and Goksu populations.

The cluster analyss also supports the existence of three different stocks, namely: Tuzla–Goksu, Tirtar, and Seyhan (Fig. 4).

Table 1
Minimum and maximum total length values and related statistics of specimens treated in four sampling stations

	Stations			
	Tuzla	Seyhan	Tirtar	Goksu
	Raw Data			
Total length (cm) (minimum–maximum)	9.2 – 20.0	9.1 – 20.9	8.1 – 23.1	12.5 – 21.9
Total # of specimens	161	54	498	21
Total # of males	72	27	169	8
The differences in percentage ratios of males and females	11	0	32	24
Variance	3.37	5.35	6.23	4.49
Standard deviation	1.84	2.31	2.50	2.12
Mean length	13.41	13.82	13.24	14.13
	Equalized Data			
Total length (cm) (minimum–maximum)	9.2 – 20.0	9.1 – 20.9	8.1 – 20.1	12.5 – 16.0
# of specimens	144	54	338	16
Variance	2.04	5.35	3.83	1.20
Standard deviation	1.43	2.31	1.96	1.10
Mean length	13.00	13.82	12.53	13.50

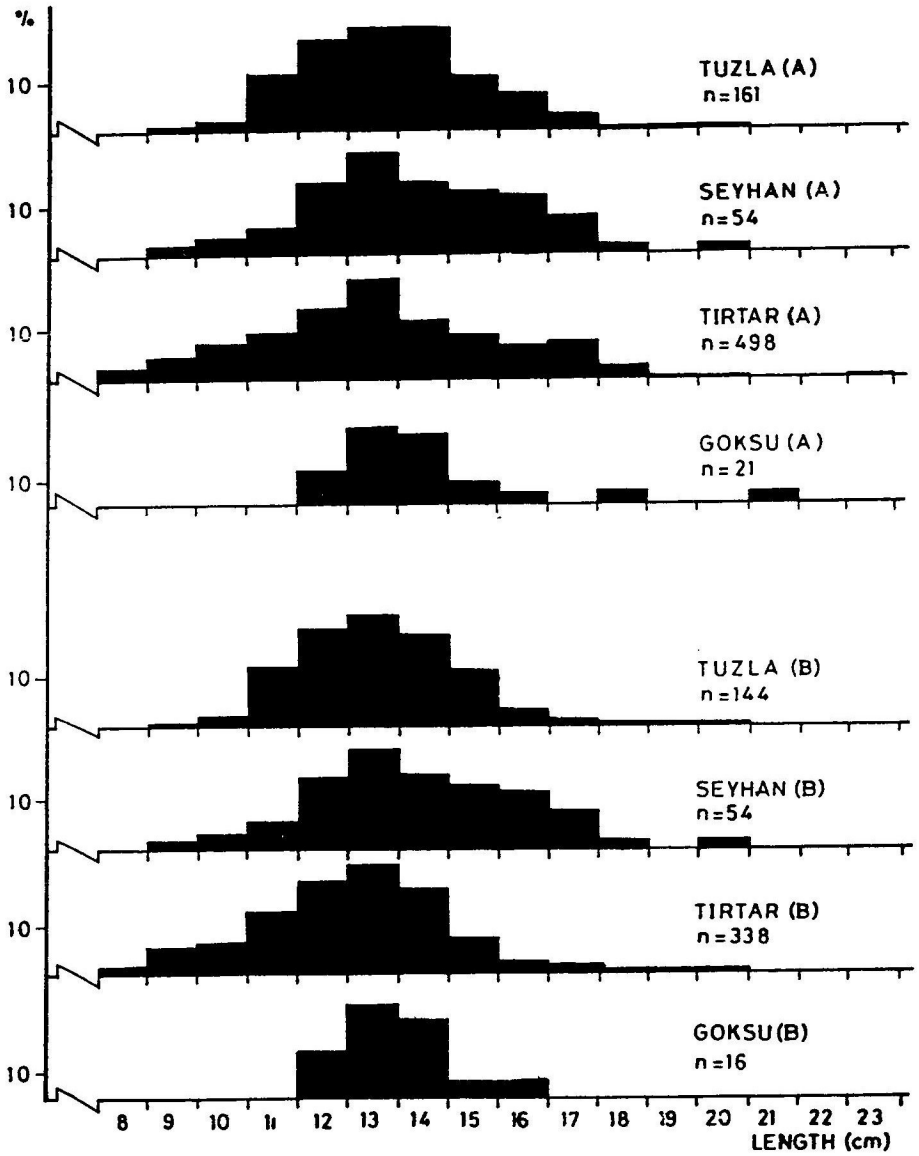

Fig. 3. Length frequency distribution of the raw (A) and the equalized (B) data.

DISCUSSION

The noticeably small sample size of Goksu (Table 1) may have played a role in the similarity observed between Tuzla and Goksu samples. In the calculation of the generalized distance of Mahalanobis, the inverse of variance–covariance matrix and the vector

Table 2
Generalized distance of Mahalanobis (D^2) above the diagonal and results of the significance test below the diagonal

Station	Tuzla	Seyhan	Tirtar	Goksu
Tuzla		1.109	0.712	0.239
Seyhan	(+)		1.308	2.571
Tirtar	(+)	(+)		1.348
Goksu	(−)	(+)	(+)	

(+) = $p < 0.05$.
(−) = $p > 0.05$.

of the difference of means were multiplied together. With decreasing sample size the product of the multiplication may be inflated. This variation causes the higher variabilities in the generalized distance of Mahalanobis of the two stations. Therefore, a D^2 value of 0.239 may not be a sufficient representation for the two stations. Nevertheless, Mais (1972) used a sample of 15 specimens for Pacific sardines, Sharp et al. (1978) used 20 individuals of capelin, and Ehrich and Rempe (1980) worked with a sample size of 13 for hake.

Unluata et al. (1980) and Ozsoy and Unluata (1983) have mentioned the existence of a cyclonic circulation in the sampling area, where the current flow is bifurcated in the northeastern corner of the Levantine Basin. One of the components flows directly from Tuzla to Goksu; therefore, the transportation of larvae and hence an exchange of genetic material is possible between the spotted flounder samples of Tuzla and Goksu. Thus, a decrease in the differentiation of morphometric characters between the two stations is expected.

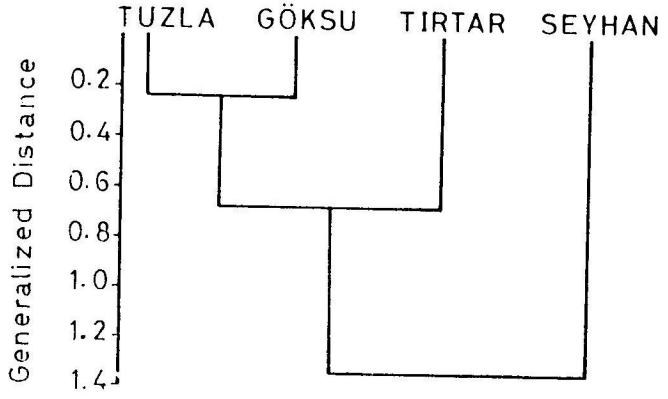

Fig. 4. Dendogram of generalized distance of Mahalanobis matrix of *Citharus linguatula*.

The stronger dissimilarities obtained between the samples of Seyhan–Tuzla, Seyhan–Tirtar, and Seyhan–Goksu stations may be explained not only by the effects of local circulation, but also by the inshore–offshore migration of spotted flounder for reproduction and feeding purposes. According to Aksiray (1954), mature individuals of citharids migrate during the breeding season (February–September) from near shore to depths of approximately 50 m where they spawn. The pelagic eggs spawned in the Tuzla region may be carried westwards with the previously mentioned current system. This current mixes the eggs and larvae of the Tuzla and Goksu regions more efficiently than those of Tuzla and Tirtar. This may cause more similarities between specimens from Tuzla and Goksu than those of Tuzla and Tirtar. However, the eggs and larvae of the specimens collected from the Seyhan station positioned in the interior part of Mersin Bay (Fig. 1) may not be directly affected by the current system referred to. Thus, specimens collected from the Seyhan station are isolated from the spotted flounder of Tuzla, Tirtar, and Goksu, yielding higher dissimilarities between the samples of Seyhan and other stations.

The spawning ground of specimens from Seyhan may not extend to the areas of Tirtar and Goksu. The organisms may be affected by the cyclonic circulation, and hence, this situation may cause a phenotypic difference between the stocks of Seyhan and those of Tirtar and Tuzla. However, there are no data available concerning the boundary of the spawning grounds of spotted flounder for Seyhan station. On the other hand, the D^2 values obtained between Tuzla–Tirtar, Tuzla–Goksu, and Tirtar–Goksu are smaller than those obtained for the samples of Seyhan, while the value of D^2 decreased from Tuzla to Goksu. This finding was supported by the abovementioned theory, i.e., passive transportation of eggs or larvae of *Citharus linguatula* by the currents.

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