

Research article

Stock Identification of Short Mackerel (*Rastrelliger brachysoma*) in the Upper and Middle Gulf of Thailand by Morphological Characters

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Abstract

Keywords

stock identification;
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Rastrelliger brachysoma, a short mackerel, is a significant pelagic fish that is common in the fisheries in the Gulf of Thailand. The management of fish stocks is a prerequisite for fish conservation strategies and profitable fisheries. Morphological character differences between stocks of species provide a method for identifying fish stocks. This study was aimed to identify stock population of short mackerel in the Upper and Middle Gulf of Thailand. The fish specimens were collected from four different locations: Chonburi and Prachuap Khiri Khan (central provinces of Thailand), Chumphon and Surat Thani (southern provinces of Thailand). Twelve morphometric characters of fish were assessed to determine the stock populations by stepwise discriminant analysis. The results showed that 12 morphometric characters were significantly different among the four populations. In the discriminant function analysis, the first function explained 61.30% of total variations, whereas the 2nd and 3rd functions were 26.50% and 12.20%, respectively. The characters included total length, standard length, fork length, head length, post – orbital length, pre – dorsal length, pre – pelvic length, 1st dorsal to 2nd dorsal length, pelvic to anal length, pre – anal length, head depth, and greatest depth, all of which can be used to differentiate these populations. According to the results of the discriminant analysis, the populations of short mackerel were predicted and subsequently classified with an accuracy rate of 54.88%.

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1. Introduction

Mackerel (*Rastrelliger* spp.) is a small pelagic fish that has important economic value in the local and regional market [1]. Mackerel is highly favored because its flesh is of soft texture with high omega-3 content and does not cause allergies [2]. It is also high in protein (18.5%) and low in fat (2.1%) [3]. The short mackerel (*R. brachysoma*) is a commercially important pelagic fish in Thailand, especially along the coast of the Gulf of Thailand [4] and Andaman Sea. Like other countries in Southeast Asia, fish is seen as a cheap protein source [2, 5-7].

Recently, catches of short mackerel have been dramatically decreasing as can be seen from the following figures: the catches of the fish in the years 2014, 2015, 2016, and 2017 were 145.3, 70.3, 31.1, and 25.3 tons, respectively [8]. The management of fish stocks is essential for the maintenance of a healthy and profitable fishery. One important variable of fish management is the stock structure of the target fish [1]. Marine fish stocks are an important part of the world food system and are particularly important for many of the poorest people of the world [9]. The management strategy for short mackerel in the entire Gulf of Thailand is based on the single-stock approach, which may not be efficient or effective [4]. To examine the impact of fishing on fish population, and to devise an appropriate management plan for large marine ecosystems such as the Gulf of Thailand, it is imperative to understand the stock of the target species, because each stock has its unique life history and response to intensity fishing [4, 10, 11].

Stock identification is useful for the management of fishery resources [1, 12] and sustainable fisheries [13]. Stock identification can be applied to understand the population dynamics clearly, biological characteristics, and productivity rates of a target species, all of which are undoubtedly important for sustainable fishery management [10].

Morphological characters such as body shape and meristic count have long been used to delineate stocks [14], and continue to be used successfully [15, 16]. Morphometric and meristic are the two types of morphologic characters that have been most frequently employed to delineate stocks of fish. Morphometric characters are continuous characters describing aspects of body shape [14]. Most protocols used for stock identification are morphometric measurements [17-19]; however, parasites as natural tags, genetic markers, and otoliths are also used [20].

The morphometric variations of the same species of fish are caused by genetic variation, the environment [19, 20] and genetic-environment interaction [19, 21, 22]. Morphometric approaches are very important tools in fishery management because they can be used to quantify traits of evolutionary implication, identify shape changes, and determine a certain developmental history and evolutionary relationship, and clarify the function of an individual organism [23].

Therefore, the aim of the present study was to identify the stock of *R. brachysoma* based on morphometric measurements with sampling done in the artisanal fisheries in Chonburi, Prachuap Khiri Khan, Chumphon and Surat Thani.

2. Materials and Methods

Short mackerels (*R. brachysoma*) were collected from artisanal fisheries in Chonburi and Prachuap Khiri Khan provinces (central of Thailand), Chumphon and Surat Thani provinces (southern of Thailand) over the period of June-November 2018 (Figure 1). Fish specimens in ice boxes were transported to the laboratory of King Mongkut's Institute of Technology Ladkrabang, Prince of Chumphon Campus. The morphometric measurements of the short mackerels; weight, total length, standard length, fork length, head length, post – orbital length, pre – dorsal length, pre – pelvic length, 1st dorsal to 2nd dorsal length, pelvic to anal length, pre – anal length, head depth, and greatest

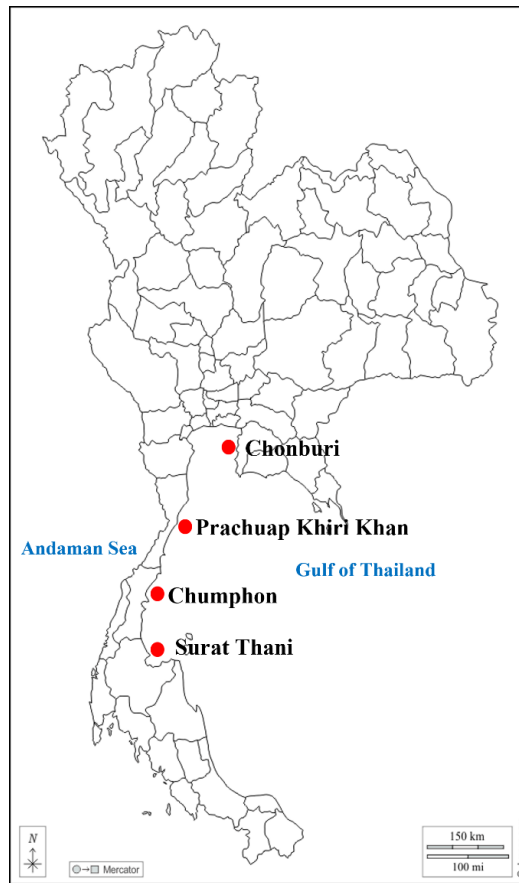


Figure 1. Map of the sample locations of *R. brachysoma*; Chonburi province, Prachuap Khiri Khan province, Chumphon province, and Surat Thani province

depth, were analyzed (Figure 2). These 12 morphometrics are common characteristics and have been the principal source of evidence for evolutionary and taxonomic investigations [24].

In the present research, an allometric formulation developed by Elliott *et al.* [25] was used to calculate the size-adjusted morphometrics:

$$M_{adj} = M(L_s/L_o)^b$$

where M is the primary morphometric measurement, M_{adj} is the size-adjusted morphometric determination, L_o is the standard length of the specimens, L_s is the total mean of standard length for all samples. The parameter b was assessment for each morphometric from the dataset as the coefficient of the regression of $\log M$ on $\log L_o$. All 12 morphometrics were estimated by stepwise discriminant analysis (DFA) for the pattern of morphological variation between samples used in order to visualize degree of differences and similarities and relationships among the individuals of groups. The results of DFA examination were evaluated in terms of the proportion of cases that were correctly classified by the model. A chi-square test of Wilk's lamda was used to compare the difference between the group centroids. Statistical analysis of morphometric records was achieved using SPSS software version 16.0.

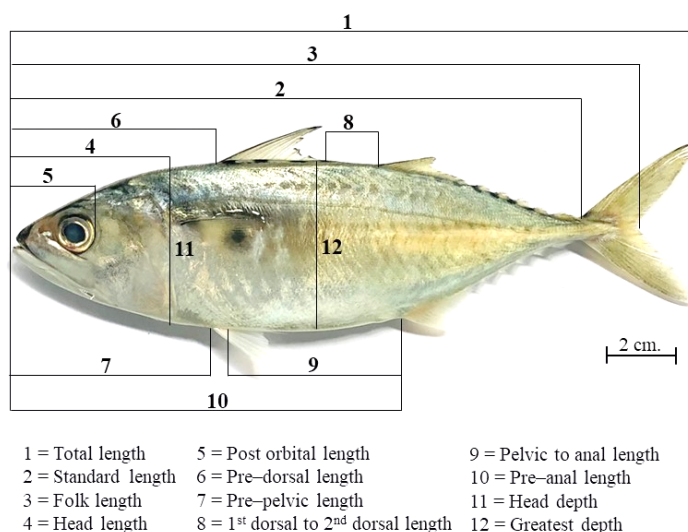


Figure 2. Morphometric characteristic measurements of *R. brachysoma*

The ethical base of this research was approved by the Animal Care and Use Committee, King Mongkut's Institute of Technology Ladkrabang (CC-KMITL/2022/001).

3. Results and Discussion

The entire 297 samples of short mackerel were assembled from the 4 sample sites. The total samples consisted of 119 individuals from Chumphon (mean weight 54.17 ± 21.62 g), 98 individuals from Prachuap Khiri Khan (mean weight 63.36 ± 13.56 g), 46 individuals from Surat Thani (mean weight 52.61 ± 15.04 g), and 34 individuals from Chonburi (mean weight 64.73 ± 13.77 g). The standard length of *R. brachysoma* was in the range of 131.97-142.32 mm, and the average standard length was 138.42 ± 12.43 mm across all sites (Table 1).

Table 1. Sampling amplification of *R. brachysoma* assembled from the Gulf of Thailand

Province	Sample Size	Weight (g)	Adjusted Total Length (mm)	Standard Length (mm)	Adjusted Folk Length (mm)
Chumphon	119	54.17 ± 21.62	176.04 ± 1.24	136.84 ± 14.65	154.88 ± 0.84
Prachuap Khiri Khan	98	63.36 ± 13.56	176.55 ± 1.49	142.03 ± 8.92	154.82 ± 0.74
Surat Thani	46	52.61 ± 15.04	176.92 ± 1.13	131.97 ± 11.69	154.97 ± 0.69
Chonburi	34	64.73 ± 13.77	175.54 ± 1.34	142.32 ± 8.76	154.46 ± 0.74
Total	297	58.16 ± 18.09	176.29 ± 1.38	138.42 ± 12.43	154.83 ± 0.78

A univariate ANOVA analysis showed significant differences ($P < 0.01$ and $P < 0.05$) for all morphometric traits for the short mackerel sampled from four locations in the Gulf of Thailand (Table 2).

Table 2. Univariate ANOVA for 12 morphometric characters of *R. brachysoma* collected from the Gulf of Thailand

Characters	Wilk's lambda	F	P
1	0.909	9.781	<0.001
2	0.913	9.358	<0.001
3	0.968	3.250	0.022
4	0.918	8.698	<0.001
5	0.965	3.512	0.016
6	0.964	3.651	0.013
7	0.922	8.207	<0.001
8	0.944	5.766	0.001
9	0.962	3.898	0.009
10	0.958	4.262	0.006
11	0.969	3.083	0.028
12	0.971	2.883	0.036

The discriminant function analysis (DFA) generated three equations (DF1, DF2, and DF3) which could be used as morphometrics for classifying the samples into their own groups. The first DF accounted for 61.30%, the second DF accounted for 26.50% and the third DF for 12.20% of overall variation of the populations. In summary, the discriminant function (DF) analysis revealed that the morphological multiformity described for the first DF and second DF (DF1, DF2) was 87.80%. The measurements of standard length, pre-pelvic length, head length, folk length, 1st dorsal to 2nd dorsal length and pelvic to anal length indicated a positive relation and contribution to the first discriminant equation. For the second discriminant equation, head length, pre-pelvic length, pelvic to anal length and folk length were also meaningfully in discrimination of morphological variation in *R. brachysoma* (Table 3).

Table 3. Parameters of discrimination analysis (DFA) of morphometric data including Eigenvalues, percentage of heterogeneity and cumulative, canonical correlation and standardized canonical coefficients in DFA of morphometric data.

Function	1	2	3
Eigenvalues	0.547	0.237	0.109
Percentage of heterogeneity	61.30	26.50	12.20
Percentage of cumulative	61.30	87.80	100.00
Canonical correlation	0.595	0.438	0.314
Standardized canonical coefficient in DFA of morphometric data			
Character 1	0.064	-0.158	0.824
Character 2	2.060	-1.358	0.855
Character 3	0.297	0.334	-0.349
Character 4	0.355	1.254	-0.121
Character 5	-0.959	0.097	-0.277
Character 6	-0.173	-0.049	-0.663
Character 7	0.566	0.896	0.956
Character 8	0.233	-0.164	-0.088
Character 9	0.112	0.824	-0.084
Character 10	-0.001	-0.305	-0.759
Character 11	-1.212	-0.526	0.049
Character 12	-0.625	-0.072	0.050

Wilk's Lambda (λ) parameter was used in the discrimination of stocks based on the proportion of within-species variability to the total variability. This measurement evaluates the degree to which the observed patterns of variation in the morphometric data were associated with the grouping variables. Among the discriminant analysis of the specimens, 4 groups of short mackerel were distinguished (Wilk's Lambda, $p < 0.001$) (Table 4). This outcome showed significant morphological variation among the four populations. Furthermore, the DF1 vs. DF2 scatter plot showed that the specimens from Chumphon, Prachuap Khiri Khan, Surat Thani, and Chonburi provinces were clustered around their centroid and were overlapping with each other (Figure 3).

Table 4. Statistical significance of the originate discriminate equations for Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.471	216.774	36	<0.001
2 through 3	0.729	91.085	22	<0.001
3	0.901	29.882	10	0.001

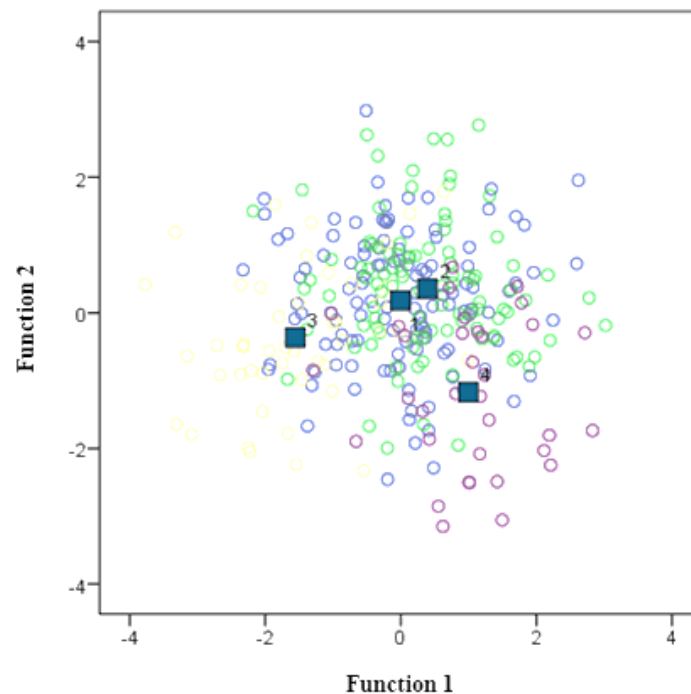


Figure 3. Scatter plot of equation 1 (x-axis) against equation 2 (y-axis) of the morphometrics of *R. brachysoma*: 1=Chumphon, 2=Prachuap Khiri Khan, 3=Surat Thani, 4=Chonburi

According to the results presented in Table 5, the discriminant analysis achieved corrected classification rates ranging from 42.9% to 76.1% for the different populations studied. Overall, 54.88% of individuals could be accurately classified into their respective groups using the discriminant functions. The highest ratio of correctly classified was in Surat Thani population (76.1%).

Table 5. Predicted group and cross-validated classification results of discriminant analysis of *R. brachysoma*

			Predicted Group Membership				Total
Province			1	2	3	4	
Original	Count	1	51	32	19	17	119
		2	19	53	9	17	98
		3	6	5	35	0	46
		4	2	5	3	24	34
	%	1	42.9	26.9	16.0	14.3	100.0
		2	19.4	54.1	9.2	17.3	100.0
		3	13.0	10.9	76.1	0.0	100.0
		4	5.9	14.7	8.8	70.6	100.0

Description: 1=Chumphon, 2=Prachuap Khiri Khan, 3=Surat Thani, 4=Chonburi

The results of this research achieved from the morphometric attributes of short mackerel varied significantly between the studied populations. Overall, the discriminant analysis achieved a total accuracy of 54.88% in predicting the group membership of short mackerel individuals based on the morphometric attributes $[(51+53+35+24)/297]$. The observed pattern of similarity between short mackerel populations from geographically sampling locations may be due to various factors. One possible explanation is that these populations belong to the same larger population, which undergoes seasonal migrations across different regions of the study area. This would result in high levels of genetic and morphological similarity between individuals from different sampling locations within the same season.

Additionally, the proximity of the sampling locations may mean that the short mackerel populations are exposed to similar environmental and habitat conditions, which can influence their morphology and behavior. As a result, individuals from these populations may exhibit similar patterns of morphological variation. Differences of short mackerel morphology can be caused by ecological conditions, biochemical, physiological, genotype and phenotype adaptations [1]. The figure of 54.88% was lower than that found in other studies of Indian mackerel (*Rastrelliger kanagurta*) that used truss morphology [13, 20]. This may have been because the truss network system is highly effective at capturing creature shape [24]. However, this study used conventional morphometrics as part of our preliminary identification of the short mackerel population. The next study will involve the use of truss analysis.

Morphometric variations of the short mackerel among different populations in this research may be correlated with phenotypic variations in genetic diversity and environmental factors. Indaryanto *et al.* [2] reported genetic variation of *R. brachysoma* using mitochondrial DNA sequence analysis (mtDNA). Furthermore, the transient behavior of mackerel may be conducive to the conglomeration of fish from different populations. Colihueque *et al.* [26] found that the morphometric variations of *Trichomycterus areolatus* Valenciennes 1846 might be associated with variations in habitat [27].

4. Conclusions

Stock identification analysis is of the principles in developing an advantageous policy for the harvest and conservation of fish such as short mackerel. This research provided the basis for classification of short mackerel in the Gulf of Thailand using 12 morphological characters. The weight of all studied samples (N=297) ranged between 52.61 and 64.73 g (mean = 58.16±18.09) and standard length ranged from 131.97 to 142.04 mm (mean = 138.42±12.43). The results of this research

suggest that short mackerel exists as a single stock along the Gulf of Thailand and decrease in the harmonious morphological characteristics of the populations varies with the distance throughout the Gulf of Thailand, i.e., Surat Thani and Chonburi. However, in the case of the short mackerel, the fish being a migratory species produces a greater possibility of combination of genetic stocks.

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