

サバ科魚類3種の稚魚期における種判別のための形態計測と判別式の算出

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Morphometry and the determination of the discriminant for distinguishing the three scombrid fish species at the juveniles stage.

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Abstract : Linear discriminant functions for identifying three scombrid fish species at the juveniles stage were derived. The Juveniles of the Bluefin tuna (n=16) reared at Kinki University in June 2012 and those of the long-tailed tuna (n=8) and bullet Tuna (n=13) collected by surface trawl in the western part of the Japan Sea on Tenyo-Mar, a fisheries training vessel of National Fisheries University, in August 2012, were used as the Juvenile samples. We selected a total of nine measuring regions for these juveniles specimens, used as the explaining variables the values of the morphological measurement at each of these regions, which were standardized by the fork length, and obtained the discriminant. The accuracy rate of the discriminant was 94.4% (p=0.00) for the *Thunnus* fishes (bluefin tuna and long-tailed tuna) and bullet Tuna and 91.3% (p=0.02) for bluefin tuna and long-tailed tuna. The result of the morphological measurement supported the contribution ratio for the discriminant. In addition, we made a simplified discriminant by using “body depth,” the measured region with a high contribution ratio, for the discrimination between the *Thunnus* fishes and bullet Tuna and “body depth” and “length between the base of the pelvic fin and the fork of the tail fin” for the discrimination between bluefin tuna and long-tailed tuna.

Key words : Fisheries, Fishery management, Fishery resources, Morphometry, Juveniles

Introduction

Japan has led the world both in the catches and import of *Thunnus orientalis* (hereinafter referred to as “bluefin tuna”), and the supply of this fish in Japan has been increasing since 1990¹⁾. In this situation, efforts have been continued to study the situation of bluefin tuna resources with higher accuracy than in the past, and researches have also been made to identify the spawning season and grounds of this fish. It has been suggested that the main spawning grounds of bluefin tuna exist in the sea areas around the Southwest Islands and Daito Island and that this fish spawns in the Japan Sea, too, though only in a

small quantity²⁾.

Since 2010, National Fisheries University, an independent administrative agency, has been taking part in the project for promoting international resources assessment together with the Fisheries Research Agency, also an independent administrative agency and the representative of the project, and other organizations, and has continued the survey of the spawn, larvae and juveniles of bluefin tuna using its fisheries training vessels. The survey on the fisheries training vessel has been conducted as part of the practical training for the third-grade students in the university’s department of fishery science and technology. The fisheries training

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vessels have greatly been expected as the places for training fisheries engineers that play the role of research vessels of marine sciences (marine biology, marine physics and marine resource science)³⁾. Training on a fisheries training vessel is one of a few chances for students on board not only to learn communal life and seamanship but also to experience “real fisheries,” such as fishing activities, scientific studies on fisheries and investigations on fisheries resources.

In the investigation on the spawn, larvae and juveniles of bluefin tuna on the university's fisheries training vessel, we are conducting our own surface trawling for juveniles, whose swimming ability is greater than eggs and larvae, in addition to the investigation using horizontally towed ring nets for eggs and larvae, which is conducted together with the survey vessels of the Fisheries Research Agency and other project members. In surface trawling study, there are some cases where the juveniles of *T. tonggol* (longtail tuna), the fish belonging to the same genus as Pacific bluefin tuna, and those of *Auxis rochei* (bullet tuna), a scombrid fish as bluefin tuna, are caught in a large quantity together with those of bluefin tuna. Because of this, there arises the need to discriminate these juveniles from those of bluefin tuna.

Longtail tuna is one of the smallest in tuna species, which matures at a length of 60 cm or so⁴⁾, and it has been suggested that this fish has its spawning grounds in the sea areas off Japan, too⁵⁾. Immature bluefin tuna looks like mature longtail tuna, but while the tip of the pectoral fin of mature longtail tuna reaches the basal part of the second dorsal fin, that of bluefin tuna does not⁶⁾. But the difference in measurable traits between juvenile and young bluefin tuna and longtail tuna is very small, and although the morphological differences have been identified between the young bluefin tuna and longtail tuna whose fork length is 17 cm or more⁷⁾, we have at present to rely on species discrimination by DNA analysis for smaller individuals. As for the method for species discrimination other than the biological technique referred to above, the study by Iguchi, *et al.* on the mathematical technique using the values of the measured parts obtained from graphic data⁸⁾ deals with the efficient

application of the discriminant function to species discrimination for such species as mountain trout and brook trout.

This study aimed at identifying the characteristics of the measurable traits of the juveniles of the three scombrid fishes having similar morphology, i.e., Pacific bluefin tuna, longtail tuna and bullet tuna, and at establishing a discriminant equation for distinguishing these juveniles by using linear discriminant analysis for the purpose of compiling the texts for giving students the opportunity to learn from experience not only biological knowledge but also mathematical knowledge in the trawl training courses on the fisheries training vessel.

Materials and methods

The Pacific bluefin tuna (n=16) reared at the Oshima Experiment Station of the Fisheries Laboratory of Kinki University in June 2012 and the longtail tuna (n=8) and bullet tuna (n=13) collected in the western part of the Japan Sea on Tenyo-Maru, a fisheries training vessel of National Fisheries University, in August 2012, were used as the juvenile specimens for this study. The juveniles of the longtail tuna and bullet tuna were the individuals identified by the species discrimination using DNA analysis (base sequence analysis). The measured parts were A-E: fork length, A-B: head length, C-D: length of the pectoral fin, A-F: snout length, I-J: body depth, G-H: eye diameter, I-E: length between the basal part of the first dorsal fin and part of the fork, J-E: length between the basal part of the pelvic fin and part of the fork, and K-L: depth of the caudal peduncle (Fig.1).

Linear discriminant functions were used for the species discrimination by discriminant analysis. Discriminant analysis is the method for making the discrimination in question on the basis of the observed values of variables. In this study, we adopted linear discriminant analysis (hereinafter referred to as “LDA”), a type of discriminant analysis. LDA is the technique for making the discrimination in question based on the linear form (linear expression) of variables, x_1 , ..., and x_p . The discriminant equation is as follows:

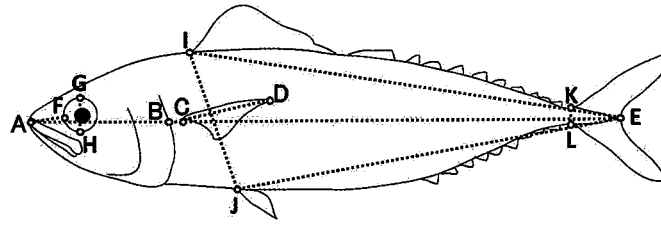


Fig. 1. Measured parts of specimens

A-E: Fork length. A-B: Head length. C-D: Length of pectoral fin. A-F: Snout length. I-J: Body depth. G-H: Eye diameter. I-E: Length between the basal part of the first dorsal fin and part of the fork. J-E: Length between the basal part of the pelvic fin and part of the fork. K-L: Depth of caudal peduncle.

$$y = a_1x_1 + a_2x_2 + \dots + a_px_p + b \quad (1)$$

(y: objective variable; xp: explanatory variable; ap: discriminant coefficient; b: constant term)

We used the values obtained by standardizing by dividing the measured values at all of the measured parts by the fork length as the explanatory variables and obtained the discriminant equation by *LDA*.

Results

Discriminant analysis

Discriminant equation for tuna species (bluefin tuna and longtail tuna) and bullet tuna: $7.763AB/AE - 0.710AF/AE + 84.541IJ/AE^* + 31.929GH/AE + 45.354CD/AE + 32.590IE/AE - 30.342JE/AE + 75.010KL/AE - 31.786$ ($*p < 0.05$).

Discriminant equation for bluefin tuna and longtail tuna: $-92.394AB/AE + 227.033AF/AE - 215.791IJ/AE^{**} - 61.525GH/AE + 70.239CD/AE + 79.260IE/AE - 129.817JE/AE^* + 252.000KL/AE + 80.111$ ($**p < 0.01$ $*p < 0.05$)

The accuracy rate of the species discrimination by *LDA* using the values standardized by dividing the values measured at the eight measured parts by the fork length was 94.4% between tuna species and bullet tuna (Fig.2) and 91.3% between bluefin tuna and longtail tuna (Fig.3).

In this study, we decided, in an attempt to raise the efficiency of discrimination on the fisheries training vessel, to make simplified discriminant equations by using as the explanatory variables "body depth," the measured

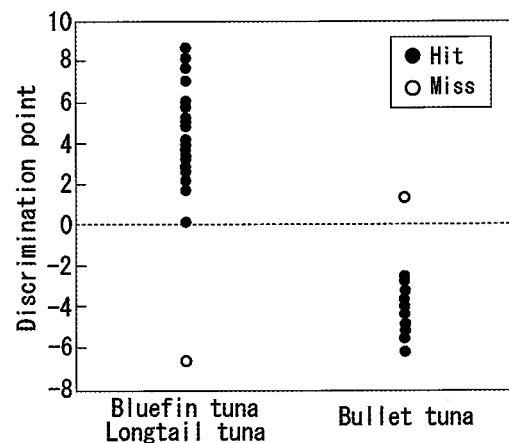


Fig. 2. Discrimination points of tuna species (bluefin tuna and longtail tuna) and bullet tuna
Black circles: hits in discrimination;
White circles: misses in discrimination;
Hit percentage in discrimination: 94.4%

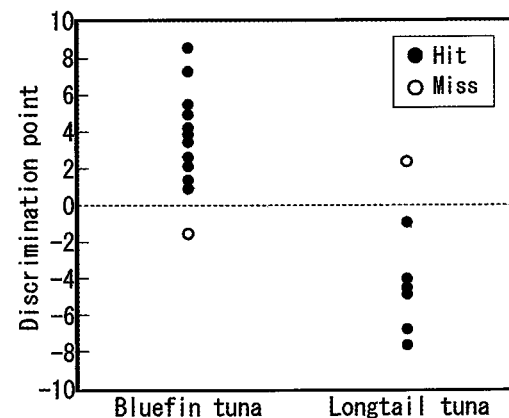


Fig. 3. Discrimination points of bluefin tuna and longtail tuna
Black circles: hits in discrimination;
White circles: misses in discrimination;
Hit percentage in discrimination: 91.3%

part whose contribution rate was high, for the discrimination between tuna species (bluefin tuna and longtail tuna) and bullet tuna, and the two measured parts, "body depth" and the "length between the basal part of the pelvic fin and part of the fork," for the discrimination between bluefin tuna and longtail tuna. The discriminant equations thus made are as follows:

Simplified discriminant equation for tuna species (bluefin tuna and longtail tuna) and bullet tuna:

$$y = 123.968 \text{ IJ/AE} - 25.795$$

(Hit percentage in discrimination: 94.4%; 0>bullet tuna, 0<tuna species)

Simplified discriminant equation for bluefin tuna and longtail tuna:

$$y = -95.445 \text{ IJ/AE} - 25.838 \text{ JE/AE} + 40.844$$

(Hit percentage in discrimination: 78.3%; 0>bluefin tuna, 0<longtail tuna)

Morphometry

Clear differences were observed in the average values in the frequency analysis of the values obtained by dividing the body depth of tuna species and bullet tuna by the fork length (Fig.4) (Mann-Whitney's U test $p < 0.001$). Differences in the averages were seen, too, in the

frequency analysis of the values obtained by dividing the body depth of bluefin tuna and longtail tuna by the fork length (Fig.5) (Mann-Whitney's U test $p < 0.001$) and the values obtained by dividing the length between the basal part of the pelvic fin and part of the fork of these two species by the fork length (Fig.5) (Mann-Whitney's U test $p < 0.1$), although the differences were less clear than those in the former case.

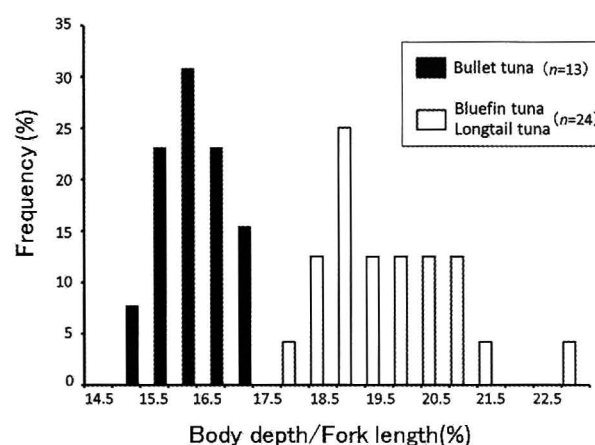


Fig. 4. Frequency distribution of body depth/fork length. Black bars: bullet tuna; White bars: tuna species (bluefin tuna and longtail tuna); Statistical differences were observed in the average values (Mann-Whitney's U test $p < 0.001$).

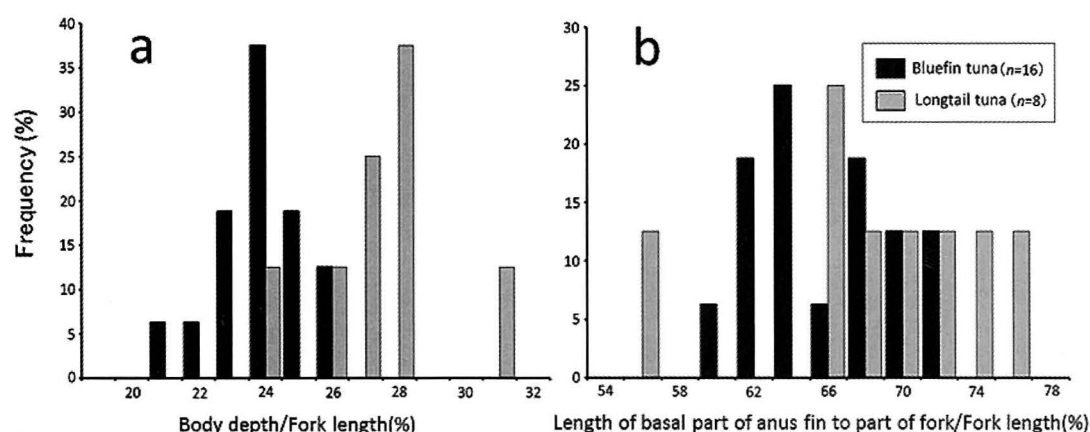


Fig. 5. (a) Frequency distribution of body depth/fork length. Black bars: bluefin tuna; Gray bars: longtail tuna. Statistical differences were observed in the average values (Mann-Whitney's U test $p < 0.001$). (b) Frequency distribution of length between the basal part of the pelvic fin and part of the fork/fork length. Black bars: bluefin tuna; Gray bars: longtail tuna. Small statistical differences were observed in the average values (Mann-Whitney's U test $p < 0.1$).

Discussion

The hit percentage of the discriminant equation using the values measured at the eight regions standardized by the fork length as the explanatory variables showed a high value both between tuna species and bullet tuna and between bluefin tuna and longtail tuna. The measured parts having a high contribution rate to the discriminant equation between tuna species and bullet tuna was body depth. It can be considered that this reflected the type of physic of bullet tuna that has great body depth and a spindle-shaped body. For bluefin tuna and longtail tuna, body depth and the length between the basal part of the pelvic fin and part of the fork recorded a high contribution rate to the discriminant equation. In addition, the outcome of the morphometry suggested that bluefin tuna had smaller body depth relative to the fork length than longtail tuna and that the basal part of the pelvic fin was closer to the caudal peduncle side (Fig. 5). For these points, there will be the need to make further examination of the measuring method and other factors.

We were able to achieve high accuracy by these simplified discriminant equations: the hit percentage for discrimination between tuna species and bullet tuna was 94.4% and that for discrimination between bluefin tuna and longtail tuna was 78.3%. The number of the measured parts whose contribution to the discriminant equations obtained by this study was observed was only a few: one for tuna species and bullet tuna and two for bluefin tuna and longtail tuna. Thus we made the simplified discriminant equations by using all of the measured parts whose contribution to the discriminant equation was confirmed. But in the case where it was found that many measured parts contributed to the discriminant equation, if we take account of efficiency of species discrimination, we should adopt the measured parts with a higher contribution rate only in establishing a discriminant equation.

As stated above, we were able to get the discriminant equations having high hit percentage in this study, but the bluefin tuna specimens used were cultured individuals. Thus, differences in the hit percentage may

arise according to differences in the body shape between natural and cultured fishes⁹⁾, and there will be the need to examine discriminant equations considering the different morphology of natural and cultured fishes in the future. In addition, species discrimination by linear discriminant analysis supposes that the measured parts of fish specimens in question will show iso-ratio growth. For bluefin tuna, it is when the standard length grows to 90 mm or so that it reaches the stage of iso-ratio growth of the measured parts¹⁰⁾; because the specimens used in this study were those with fork length of about 100 mm, which are considered to roughly be within the applicable scope of linear discriminant analysis. It has been known that fish at the larva and juvenile stage generally does not show iso-rate growth and needs a certain period of time before it begins to show stable growth¹¹⁾. Therefore, in the case where this study is applied to other species in the years ahead, it will be required that consideration is given to changes in the hit percentage of discrimination depending on the growth stages of such other species.

If the students on board the fisheries training vessel use the discriminant equation established in this study in making species discrimination work in their practical training, they will be able to clearly understand the measurable traits to be noted in comparing a certain fish species with its closely-related species and to deepen their knowledge and sense about the morphology of fishes. In addition, species discrimination by the mathematical technique will help not only students doing graduation work of fishes but also those learning navigation and operation skills and about related machines improve their knowledge of the application and use of mathematical science.

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サバ科魚類3種の稚魚期における種判別のための形態計測と判別式の算出

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要 旨

本研究では、サバ科魚類3種の稚魚の種判別のための線形判別式を算出した。2012年6月に近畿大学で養殖されたクロマグロ (n=16)、2012年8月に日本海西部で水産大学校練習船・天鷹丸において表層トロールにより採集したコシナガ (n=8) およびマルソウダ (n=13) の稚魚を試供魚として使用した。これらの試供魚に対し、計9ヶ所の計測部位を設け、それぞれの形態計測値を尾叉長で標準化した値を説明変数とし、判別式を算出した。マグロ属魚類とマルソウダ間における判別式の判別率的中率は、94.4% (p=0.00)、クロマグロとコシナガ間における判別式の判別率的中率は、91.3% (p=0.02) であり、実測した形態計測の結果も判別式への寄与率を支持する結果となった。また、練習船での判別作業の効率向上のため、マグロ属魚類 (クロマグロとコシナガ) とマルソウダ間の判別には、寄与率が高かった計測部位である「体高」、クロマグロとコシナガ間では「体高」と「腹鰭基部から叉入部の長さ」の2計測部位を説明変数として用いることで簡易的な判別式を作成することができた。

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