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Age Estimation of Fish Using Otolith and Fish Measurements in a Multi-species Fishery: A Case Study for *Pagellus erythrinus* (L., 1758) from İskenderun Bay (NE Mediterranean Sea)

[1]M. Fatih Can and [2]Suat Sahinler
[1]Faculty of Fisheries, Mustafa Kemal University, 31040, Hatay, Turkey
[2]Department of Biometry, Faculty of Agriculture, 31040, Hatay, Turkey

Abstract: Age determination of fish in a multi-species fishery from the otolith or other hard parts of fish is time consuming and expensive process. There are some relationships between otolith and fish age. In this study, Otolith length (O_l), Otolith width (O_{wt}), Otolith weight (O_w), Fish length (L_f) and Fish weight (W_f) were used to estimate the age of Common pandora, *Pagellus erythrinus* (L., 1758), using the general linear regression model; $Y= X\beta+\epsilon$. Among the model with one variable, the model with Otolith length (O_l) variable was the best one, $t = -2.101+0.691(O_l)$ ($R^2 = 0.862$). Adding the other variables to the model did not have any significant effect on R^2 values.

Key words: *Pagellus erythrinus*, otolith, age estimation, İskenderun Bay

INTRODUCTION

Fish ageing is a basic tool for cohort analysis in fish stock assessment. The quality of the fish ageing procedure directly influences the reliability of the scientific advice in fisheries management. Presently, no fast, objective and widely applicable method exists to determine the age of fish. The most commonly used ageing technique is counting the annual structures in the hard part of fishes, such as scale, otolith, etc.[1,2].

Otoliths are used extensively in fishery studies to determine age, growth rates and length-age relationships[3], but are useful only when age determination can be precise and accurate. Conventional methods of age determination are based on the examination of growth increments in fish otolith structure and correct determination of the age supposed that annuli in otoliths could be identified and counted[4].

Recent research indicates that there are some relationships between otolith size and age[3-5]. These relationships have great potential for estimating age and age structure in fish.

The fishery characteristic of the Mediterranean Sea is multi-species. Common pandora, *Pagellus erythrinus* (L., 1758), is one of the important demersal fish species and also has high market value in Iskenderun Bay (NE Mediterranean Sea). It was reported that annual total amount of landing was about $67x10^3$ kg[6] and it provides about 4% of the total biomass of economic demersal fish assembles in İskenderun Bay[7].

Age estimation is very important to make precise decisions on fish stock management. Although the age of common Pandora can be determined from the otoliths or other hard structures, the age estimation is time-consuming and also expensive process particularly in multi-species fisheries as seen in Mediterranean Sea.

Therefore, the objective of the present study was to look for alternative methods, which are faster and inexpensive, to determine the age of Common Pandora by using some relationships between fish age and otolith length, otolith width, otolith weight, fish length and fish weight.

MATERIALS AND METHODS

Common Pandora speciesmen were collected by using bottom trawl during the fishing cruises between 1999 and 2000 on board the R/V Mustafa Kemal-1 in Iskenderun Bay, Turkey. A total of 140 specimen in different length groups were studied. The Total Length (TL) in cm and body weight in g was recorded. Otoliths were removed while the fish fresh and only the sagittae were examined in the study.

Left sagittae was weighted to the nearest 0.01 mg. Otolith length (O_l) and width (O_w) were measured to the nearest 0.01 mm using a compass. Otolith length and width were considered as the distance from the anterior tip to the posterior tip and dorsal edge to the ventral edge across the nucleus perpendicular to the otolith length[5]. Otoliths were

Corresponding Author: Dr. M. Fatih Can, Faculty of Fisheries, Mustafa Kemal University, 31040, Hatay, Turkey
Tel: +90 326 245 58 45 E-mail: fcan@mku.edu.tr

immersed in glycerine and read by using a compound microscope using reflected light following standard techniques. As a rule, the two authors read each otolith independently and coincident interpretations were accepted[8].

For age correction, the following formulas[9] were used based on the GSI values of common pandora;

$$Y_{cor} = T + CT$$

Where:

CT=((((SM-1)*30+SD)-(((NBM-1)*30)+NBD))/365,

Y_{cor} is corrected age, T is age read from otoliths annulus, CT is correction coefficient, SM is sampling month, SD is sampling date, NBM is nominal birth month (June for this species) and NBD is nominal birth date (15th of June).

Fish age (t) was considered as the dependent variable and Otolith length (O_l), Otolith weight (O_w), Otolith width (O_{wt}), fish length (L_f) and fish weight (W_f) were considered as independent variables in order to explain the variation in fish age and to find the best model. Then, all of the models with independent variables were fitted orderly and examined with respect to all statistics that indicate the usability of the model.

The data were analyzed by multiple regression analysis method which could deal with up to 5 variables using the general linear regression model $Y = X\beta + \epsilon$. In this model Y is an nx1 vector of observations, X is an nxp matrix of the levels of the regressor variables, β is a px1 vector of the regression coefficients and ϵ is an nx1 vector of random errors with $\varepsilon_i \sim NID(0,\sigma^2)$[10,11]. Variable selection statistics were used to determine non-significant variables[10]. For this purpose, in each stage outliers, leverage points and influential points were identified and then, outliers were omitted based on the results[12]. At the same time, the models were controlled with regard to the assumptions of the Ordinary Least Squares method, auto-correlation and collinearity[13,14]. All data analyzes were carried out by using SPSS©[15].

RESULTS AND DISCUSSION

Fish age was related to some otolith and fish measurements (Table 1). Among the models with one variable, the model with O_l variable was the best one: $t = -2.101+0.691(O_l)$ (Table 1 and Fig. 1). The model has tested for significance of regression and found to be significant ($p<0.000$). For this model, the coefficient of determination (R^2) was 0.862 and other important statistics were given in Table 1.

Among the models with two variables, the model with O_l and L_f variables was the best on: $t = -2.162+0.497(O_l) + 0.083 (L_f)$ with $R^2 = 0.868$ (Table 1 and Fig. 2).

It was found that adding the Lf variable to the model did not have significant effect on the model. Further more, adding the other variables gradually to the model did not have great effect on R^2 value. For example, the equation 3 had six variables: $t = -2.690+0.344(O_l) + 0.0156 (L_f) + 3.525 (O_w) - 0.0058 (W_f) + 0.116 (O_{wt})$ with $R^2=0.871$ (Table 1). Based on the results, we conclude that otolith length might be considered as sufficient measurement to estimate the age of *Pagellus erythrinus*.

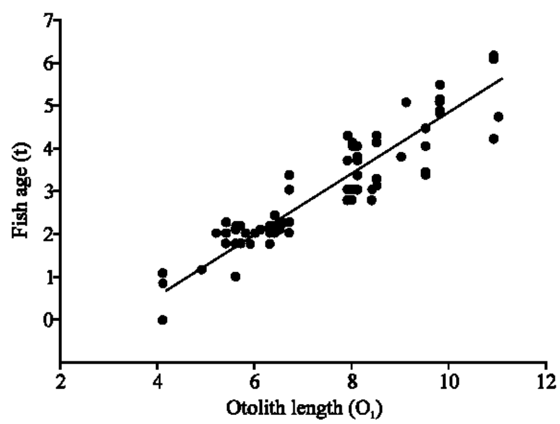

Fig. 1: Scatter plot of otolith length(O_l) vs fish age(t) and fitted line; $t = -2.101+0.691(O_l)$, $R^2=0.862$

Table 1: Fish age estimation equations and related descriptive statistics

	Eq.1 ($t=\alpha+\beta_1 O_l$)			Eq. 2 ($t=\alpha+\beta_1 O_l+\beta_2 L_f$)				Eq. 5 ($t = \alpha+\beta_1 O_l+\beta_2 O_{wt}+\beta_3 O_w+\beta_4 L_f+\beta_5 W_f$)		
Variables	$\hat{\beta}_j$	SE ($\hat{\beta}$)	t_i	$\hat{\beta}$	SE ($\hat{\beta}$)	t_i	...	$\hat{\beta}$	SE ($\hat{\beta}$)	t_i
Constant	-2.101	0.18	-11.7**	-2.162	0.178	-12.1**	...	-2.690	0.447	-6.013**
Otolith length (O_l)	0.691	0.024	29.1**	0.497	0.084	5.92**	...	0.344	0.147	2.349*
Length of fish (L_f)	-	-	-	0.083	0.034	2.407*	...	0.0156	0.056	2.793**
Otolith weight (O_w)	-	-	-	-	-	-	...	3.525	2.962	1.19
Weight of fish (W_f)	-	-	-	-	-	-	...	-0.0058	0.003	-1.852
Otolith width (O_{wt})	-	-	-	-	-	-	...	0.116	0.162	0.712
Regression	SSE= 32.895,	R^2=0.862,	p=0.00	SSE= 31.542,	R^2=0.868,	p=0.00		SSE= 30.717,	R^2=0.871,	p=0.00
	s^2=0.242,	F=849.34,	N=138	s^2=0.234,	F=442.5,	N=138	...	s^2=0.233,	F=178.4,	N=138

*: Denote the coefficient is significant at 5% significance level, **: Denote the coefficient is significant at 1% significance level

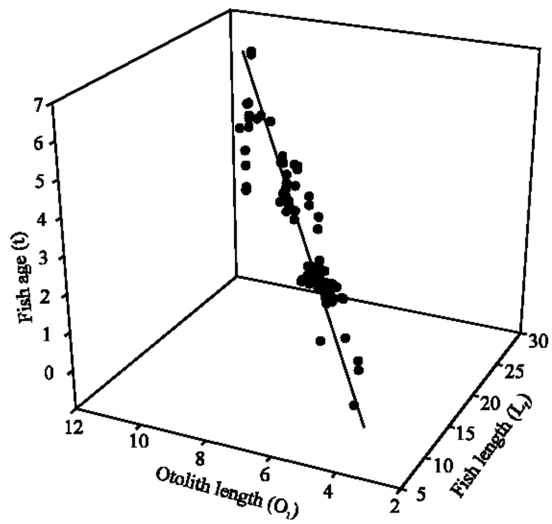

Fig. 2: Scatter plot of otolith length (O_l) and fish length (L_f) vs fish age (t) and fitted line; $t= -2.162+0.497 (O_l) + 0.083 (L_f)$, $R^2= 0.868$

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