www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 17: 217-221 (2017) DOI: 10.4194/1303-2712-v17_1_24

SHORT PAPER

Morphometric Relationships of *Coptodon guineensis* and *Sarotherodon melanotheron* (Perciformes, Cichlidae) in Two Lakes of Benin (Western Africa)

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Received 03 March 2016
Accepted 08 August 2016

Abstract

Relationships between fish weight and length, otolith length and fish length, and otolith weight and length were analysed in two cichlid fish species, Coptodonguineensis(Günther, 1862) and SarotherodonmelanotheronRüppell, 1852 (Perciformes, Cichlidae), collected in two lakes in southern Benin (western Africa). The analysis of covariance (ANCOVA) was used to detect differences in the relationships between the specimens of the two species collected in the two lakes.To the authors' best knowledge, this study represents the first reference available on morphometric relationships for C. guineensis and S. melanotheron in the investigated area.

Keywords: Guinean tilapia, blackchin tilapia, morphometric relationships, Benin, western Africa.

Introduction

The analysis of morphometric relationships is used in fisheries assessment and management, as they can be used to make comparisons between species, populations, and stocks (King, 1995). For example, the length-weight relationship is widely used in fish biology, physiology, ecology, and stock assessment. As a matter of fact, size is generally more relevant than age, mainly because several ecological and physiological factors are more size-dependent than age-dependent (Santos *et al*., 2002).

In fisheries studies, weight-length relationship has many different uses, including the estimation of weight-at-age (Petrakis and Stergiou, 1995), as well as the conversion of growth-in-length equations to growth-in-weight.

Furthermore, the weight-length relationship allows fish condition to be estimated, and used in the analysis of ontogenetic changes (Ferraton *et al*., 2007) and for inter-regions life-history trait comparisons (Petrakis and Stergiou, 1995; Morey *et al*., 2003).

The relationship between fish size and otolith length may have application in feeding studies, as the rebuilding of body size and prey biomass from otolith measurement can be possible involving correlations between specific morphological features of the prey (such as otolith length) and prey size (length) (Jobling and Breiby, 1986;Battaglia *et al*., 2010). For example, rebuilding prey biomass from measurement of otoliths found in stomach contents of predator species is possible by means of the application of a back-calculation formula linking prey size and otolith size (Granadeiro and Silva, 2000; Waessle *et al*., 2003; Battaglia *et al*., 2010).

Although huge work has been done (Froese *et al*., 2014), information on weight-length relationship and fish size and otolith sizerelationships is still scarce for some tropical and sub-tropical fish species (Harrison, 2001; Ecoutin *et al*., 2005). This paper aims at providing information on morphometric relationships by means of comparative analyses between body size and otolith size measurements in two brackish water cichlid fish species, Guinean tilapia, Coptodonguineensis (Günther, 1862), and blackchin tilapia, SarotherodonmelanotheronRüppell, 1852, from Lake Ahémé and Porto-Novo Lagoon in southern Benin (western Africa). The coasts of these two lakes are densely populated and are affected by highly intensive anthropogenic impact, both in terms of fishing pressure and pollution. Very little is known on the biology and ecology of the fish species inhabiting those lakes. This study represents a first step in collecting data on fish populations in the area necessary to move towards the knowledge on the status of these resources.

Materials and Methods

Fish samples were collected during fishing operations using two fishing gears commonly used by local fishermen: gill nets (200m x 1.30m, 25, 40 and 50 mm mesh) and cast nets (6 m diameter of the net, 20 mm mesh size). The sampling activities were performed in Lake Ahémé and Porto-Novo Lagoon in February 2015 at depth ranging from 0.5 to 2.5 m.

Lake Ahémé is located in the southern area of Benin (6° 20’ N and 1° 55’ E) (Figure 1). The lake has a surface area of 78 km^2 during the dry season and 100 km^2 during flood season (Dedjiho *et al*., 2014). The lake is 24 km long and is deeper in its the northern area. The lake communicates with the sea through the Ahô Canal, 10 km long. During the dry season, seawater flows into this channel and causes an increase in water salinity in the southern part of the lake (Villanueva *et al*., 2006). The main freshwater input into Lake Ahémé is from the Couffo River at its northern part. Porto-Novo Lagoon (6° 25’ N and 2° 38’ E) is smaller than Lake Ahémé and has a triangular shape with an area of 30 km^2 during the wet season and 20 km^{2}in the rest of the year. It is 6 km long, while width varies between 2 and 4 km. Porto-Novo Lagoon is connected to the Lagos Lagoon (Nigeria) to the east and to Nokoué Lake to the west. The salinity within the lagoon can vary from oceanic (due to tidal influence) to freshwater (depending on the freshwater inputs from several tributaries) (Adandédjan *et al*., 2011; 2012).

Total length (TL) was measured to the nearest 0.1 cm from the anterior tip of the snout to the end of the pinched caudal fin. Wet weight was recorded to the nearest 0.1 g. Otoliths (sagittae) were removed through a cut in the cranium to expose them and then cleaned and stored dry in glass vials. Sagittae were collected from different fish length groups to ensure that the obtained sample is more representative and the estimated parameters are more robust. Each otolith was placed with the sulcus acusticus oriented through the observer and its length was measured using hand-held Vernier callipers on the axis between the rostrum and post-rostrum axis. Otolith weight was measured to the nearest 0.001 g.

Linear regression analysis was used to describe the relationships between fish weight and length, otolith length and fish length, and otolith weight and length. The analysis of covariance (ANCOVA) was used to test the effect of the categorical factor Lake (two categories: Lake Ahémé and Porto-Novo Lagoon). The categorical factor splits the relationship between dependent and independent variables into several linear equations, one for each level of the categorical factor. Regression lines are then compared by studying the interaction of the categorical factor with the continuous independent variable (Zuur *et al*., 2007). If the interaction is significantly different from zero, it means that the effect of the continuous covariate on the response depends on the level of the categorical factor. In other words, the regression lines have different slopes. The fish weight-length and the otolith weight-length relationships were analysed by means of the power equation $w = al^b$, where w is weight (g) and l is length (Fish Total Length, cm; otolith length, mm). Parameters a and b were estimated from log-transformed data (Ricker, 1973):$\log(w) = \log(a) + b \log(l)$.

Data exploration and analyses were carried out with the package R, vers. 3.2.2 (R Core Team, 2015). An assumed significance level of 5% was used in all statistical analyses.

Weight-length relationship has an isometric growth pattern when “b” = 3 (i.e. relative growth of both variables is identical) (Ricker, 1973). When “b” is < 3, the relative growth is negative allometric(defined ashypoallometry), while if “b” is > 3, the growth is positive allometric(hyperallometry). The “b”values of the fish weight-length relationships

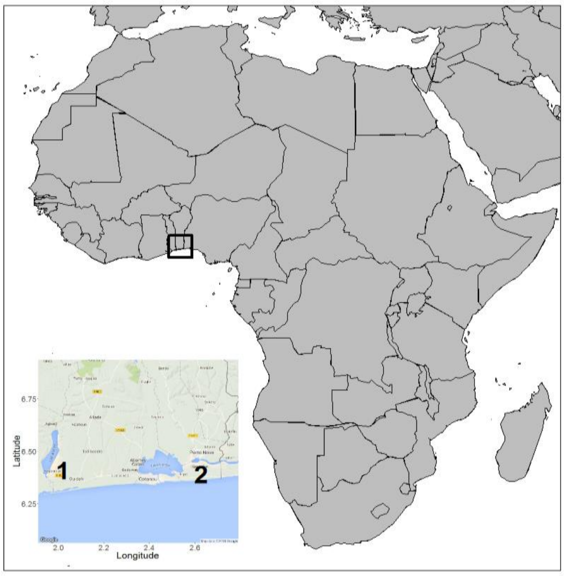

Figure 1. Investigated sites: Lake Ahémé (1) and Porto-Novo Lagoon (2) (southern Benin, western Africa).

were tested using a Student's t-test (confidence level of 95%) in order to verify the null hypothesis of isometric growth (H_0: $\beta = 3$).The individual values of the condition factor were calculated using the following formula:$K = (w/l^b) \cdot 100$

where w is the weight (g), l the total length (cm) and b is from the weight-length relationship (Bagenal and Tesch, 1978). A Student's t-test (confidence level of 95%) was used to detect difference in condition factor values estimated in the two lakes.

Results and Discussion

Morphological features were measured and recorded on a total of 276 specimens caught during the experimental fishing trials (135 C. guineensis individuals and141 S.melanotheron). The measurements recorded by species in the two sampling sites, Lake Ahémé and Porto-Novo Lagoon, are shown in Table 1. The results of the meristic relationships analyses are summarized in Table 2. In S. melanotheron, the interaction between size and lake was significant; therefore, two models (one for each lake) were estimated to describe the weight – length relationship. In C. guineensis, the interaction between size and lake was not significant, and a single set of parameters were estimated for the weight – length relationship combining the data from the Lake Ahémé and Porto-Novo Lagoon. Although significant difference between Lake Ahémé and Porto-Novo Lagoon was detected by the ANCOVA in the weight-length relationship of S. melanotheron, the Student's t-tests showed that both b values were consistent with an isometric growth. The same applies to the single b value computed for C. guineensis. Therefore a single condition factor value was calculated for C. guineensis (K = 1.84 ± 0.26 standard deviation, SD), while two different values were estimated for S. melanotheron: 1.32 (± 0.12 SD) and 2.38 (± 0.29 SD) in Lake Ahémé and Porto-Novo Lagoon, respectively. While the condition factor K obtained from the Porto-Novo Lagoon data is similar to that reported by Ndimele *et al.* (2010) for S. melanotheron in Ologe Lagoon (Nigeria), the K value in Lake Ahémé is significantly lower, as highlighted by the Student's t-test ($t = -21.2$, $P<0.05$).

Also for the otolith length – fish length relationship, significant difference between Lake Ahémé and Porto-Novo Lagoon was highlighted by means of ANCOVA in S. melanotheron, while no significant difference was observed in C. guineensis.As far as the otolith weight – length relationship is concerned, no significant difference between the two sites was observed in S. melanotheron, while the ANCOVA detected a significant interaction of the categorical factor (lake) with the continuous independent variable (otolith length) in C. guineensis. Therefore, two different sets of parameters were estimated for this species.

Although some information already exist on weight-length relationship and other morphometric parameters of the two species in adjacent areas (Lalèyè, 2006; Dunz and Schliewen, 2010; Ndimele *et al.*, 2010), this study represents the first reference on the comparative analysis of body and otolith size measurements in two different sites. The differences

Table 1. Meristic measurements: size ranges in Sarotherodonmelanotheron and Coptodonguineensis in Lake Ahémé and Porto-Novo Lagoon. TL: Fish Total Length; WW: Fish Wet Weight; OL: Otolith length; OW: Otolith weight

Species	Area	no. of specimens	TL (cm)	WW (g)	OL (mm)	OW (g)
S. melanotheron	Lake Ahémé	50	7.5-21.0	4.0-158.2	1.6-4.0	0.015-0.161
	Porto-Novo Lagoon	91	6.9-22.2	6.0-187.2	2.0-5.0	0.019-0.231
C. guineensis	Lake Ahémé	45	9.5-16.2	14.0-69.4	2.1-3.6	0.030-0.092
	Porto-Novo Lagoon	90	5.9-21.1	3.0-197.8	1.6-4.9	0.018-0.184

Table 2. Analysis of meristic relationships in Sarotherodonmelanotheron and Coptodonguineensis in Lake Ahémé and Porto-Novo Lagoon: summary of the results. SE: standard error; F: ANOVA F-test (H_0: $\beta = 0$); p: probability of the ANOVA F-test; r^2: coefficient of determination. When the ANCOVA results were not significant, only one set of parameters were estimated combining the two sites

Species	Area	a	SE	b	SE	F	p	r^2
A. Weight – Length relationship								
S. melanotheron	Lake Ahémé	0.012	0.002	3.111	0.082	1294.8	<0.05	0.964
	Porto-Novo Lagoon	0.008	0.011	2.902	0.087	2318.0	<0.05	0.984
C. guineensis	Sites combined	0.018	0.001	2.948	0.156	3006.1	<0.05	0.971
B. Otolith length – fish length relationship								
S. melanotheron	Lake Ahémé	0.618	0.137	0.168	0.011	216.1	<0.05	0.911
	Porto-Novo Lagoon	0.232	0.114	0.225	0.009	639.1	<0.05	0.886
C. guineensis	Sites combined	0.581	0.127	0.189	0.010	336.6	<0.05	0.826
C. Otolith weight – otolith length relationship								
S. melanotheron	Sites combined	0.006	0.001	1.993	0.178	482.7	<0.05	0.883
C. guineensis	Lake Ahémé	0.016	0.005	1.850	0.298	208.4	<0.05	0.876
	Porto-Novo Lagoon	0.004	0.001	2.075	0.113	187.1	<0.05	0.806

detected in some of the relationships analysed in the present study (i.e.,those in terms of weight-length relationship and condition factor in S. melanotheron)can reflect spatial variation due to the influence of water physical and chemical characteristics (e.g., environmental variables, such as salinity; variation in pollutants) or food availability on fish growth (Mommsen, 1998;Adandédjan *et al*., 2011; 2012). However, a more robust sampling scheme covering the entire year shall be essential in order to gather sufficient data, and relate biological parameters to environmental and anthropogenic factors, while the present study is based on data collected in a single sampling survey.In fact, seasonal variations in relative growth and condition are known in several fish species (Safran, 1992; Richter *et al*., 2000; Bolognini *et al*., 2013).

Although further data and information on the structure of the populations of C. guineensis and S. melanotheronare needed, it is to be hoped that the results of the present study will provide a preparatorycontribution to future population dynamics and stock assessment studies in such densely populated and intensively impacted areas (e.g., fishing pressure, pollution) as the lagoons in southern Benin (western Africa).

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