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Otolith and body length relations in the spiny siganid (*Siganus spinus* Linnaeus 1758)

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Relationships between otolith morphometrics and fish body size of the spiny siganid *(Siganus spinus* Linnaeus 1758) caught from Lagonoy Gulf, Philippines were determined from wild-caught pre-settlement juveniles. Thirty individuals with 29.2-33.3 mm standard length were examined and their raw sagittae were extracted and measured. Sagittal width can be estimated from standard length (R^2= 0.68). Relationships between otolith length and total weight were low with coefficient of determination (R^2) of 0.17. Moderate relationships were found between otolith length and total length (R^2= 0.28) and otolith length and standard length (R^2=0.35). Regression between the aspect ratio of the caudal fin and otolith length (R^2= 0.25) suggests that the balance function of the otolith may reveal in the fin.

Key words: spiny siganid, *Siganus spinus*, otolith, aspect ratio, pre-settlement juveniles

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INTRODUCTION

Several fishes were studied on the relationships of otolith length and body length such as the Pacific Halibut, *Hippoglossus stenolepsis* (Southward 1973), *Anguilla anguilla* (Appelbaum 1978), for various sciaenids such as *Cynoscion guatucupa, Macrodon ancylodon, Micropogonias funier* and *Paralonchurus brasiliensis* (Waessle et al. 2003) and the Arctic Cod (*Boreogadus saida*), Atlantic Cod (*Gadus morhua*), *Ammodytes dubius*, *Clupea herengus* and *Mallotus villosus* (Lidster et al. 1994). Lidster et al. (1994) revealed that linear regression of the body length and otolith length provided good fit to all species they studied. They concluded that right and left otoliths could be combined in equations predicting body length. Waessle et al. (2003), in particular, concluded that the otolith length and otolith mass are good indicators of fish standard length and fish weight. They also found that the sagittal morphology of juvenile sciaenids showed strong changes in the course of their metamorphosis.

In coral reef fishes very few studies have been conducted on otolith size and fish body size relationship for the family Siganidae. In the Philippines, otoliths of *Siganus guttatus* and *S. spinus* have been studied to infer on their early life history traits from examination of the microstructure of polished sagittae (Soliman et al. 2009, Soliman et al. 2010). In these studies they regressed radii of transversely-polished sagittae with fish body size which yielded high linear relationship. In Yamada and Shibuno (2007), the sagittal radius and standard length of *S. guttatus* and *S. fuscescens*, were regressed and yielded moderate linear relationship for *S. guttatus* and although *S. fuscescens* yielded significant relationship but the result was not described in the report. Studying the otolith is vital to provide absolute age data for fisheries management and to contribute information to the biology of the species (Green 2009). Determining the otolith length/width through the use of fish body morphometrics will be considerably less expensive and less time consuming. The differences in growth rate in otolith are also detectable using the result of otolith size and fish size relationship (Strelcheck et al. 2003). They showed this in the study on wild-caught juvenile gag *Mycteroperca microlepis* which were fed at two different levels until fish attained similar size, where they found that growth rates were significantly affected by food availability and this were also manifested on its otolith size. The sagittal lengths of *Mycteroperca microlepis* were longer (9%) and sagittal weights were heavier (21%) in the fish fed with low food allotment than those fed with high food allotment.

The present study examined the relationship of the morphometrics of raw sagittae and body size in the spiny siganid *Siganus spinus* using juvenile fish caught in the wild. It also focused on the aspect ratio of the caudal fin which was an important factor in the study of fish ecology. Palomares et al. (1989) used the aspect ratio of the caudal fin as a measure of the average activity and/or metabolic levels of the fish while Denny (2005) and Fisher et al. (2007) studied the aspect ratio of the fin to determine the swimming performance of the fish. This study hypothesizes aspect ratio of the caudal fin correlates with otolith morphometrics (i.e. length, width) to reveal the balance function of the otolith in the caudal fin.

MATERIALS AND METHODS

Siganus spinus pre-settlement juveniles or fish that have not undergone metamorphosis were collected in the off-reef site in San Miguel Island, Tabaco City (in the south side of Lagonoy Gulf) by personnel of the Coastal Resource Management Unit, Bicol University Tabaco Campus (BUTC), Tabaco City. Lagonoy Gulf is located between 123°31'37"E to 124°21'36"E and 13°44'30"N to 13°10'33"N. Samples were caught using bagnet in September 2009. Samples were preserved in 80% ethanol and brought to BUTC Laboratory for detailed analysis.

Morphometric measurements were obtained using vernier caliper with 0.01mm accuracy. Fish total length (FL, mm) was measured from the tip of the upper jaw to the tip of the tail. Standard length (SL, mm) was measured from the tip of the upper jaw to the caudal peduncle. Total weight (TW, g) of samples were determined using electronic balance with 0.01 g accuracy.

Whole, unpolished sagittae were used. Sagittae were extracted and laid in glass slide for analysis of their morphometric measures. Sagittae were used because of its large size compared to other otoliths (i.e. lapillus and asteriscus). Otolith length (OL, in µm) was measured from the tip of the rostrum to its base. Otolith width (OW, in µm) was measured along the longest axis crossing from the core to the otolith edge. Measurements of the otolith were done using the Olympus microscope CX41 and RATOC Ver. 5 Otolith Image Analyzer Program (RATOC System Engineering Co. Ltd).

Aspect ratio of the caudal fin is an important factor in the study of the fish ecology. Palomares et al. (1989) used the aspect ratio of the caudal fin as a measure of the average activity and/or metabolic levels of the fish. Aspect ratio (A) was measured and correlated with otolith size and fin size. It is a pure number computed as

$$A = h^2/s$$

where: A is the aspect ratio,
h is the height (in mm) of the caudal fin and
s = the surface (shaded) area (in mm^2) of the caudal fin (Figure 1).

The caudal fin was photographed using a 12 mega-pixel digital camera. The Digimizer Ver. 3.7 (MedCalc Software, copyright © 2005-2009, Belgium) Image Analysis Software was used to measure the height and the surface area of the caudal fin from its digital image.

The relationship of fish body length and otolith length was examined through simple linear regression. For the relationship of otolith size and total weight, the regression equation used was a power function expressed as:

$$Y = a*x^b$$

where: Y = is the dependent variable;
a = is the intercept;
x = is the independent variable (or covariate) and
b = is the slope of regression coefficient.

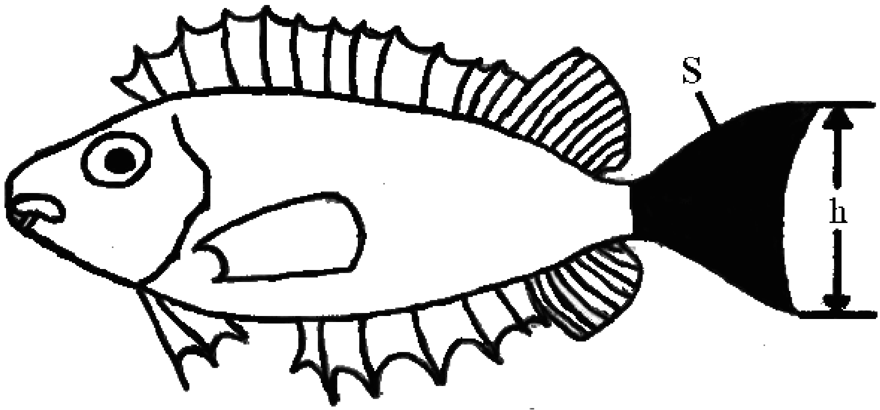

Figure 1. Variables used to compute the aspect ratio ($A = h^2/s$) of the caudal fin in *Siganus spinus*.

Test for normality of the residual was done using the Shapiro-Wilk's test which is most reliable for small samples (<50). All analysis was done using PASW Statistics, Release Ver. 18.0.0 (SPSS Inc. 2009, Chicago, IL, USA).

RESULTS

Thirty individuals of *S. spinus* were examined of their body size and otolith length (Table 1). Mean SL (±SD) was of 30.7 ± 0.93 mm with a range of 29.4 to 33.3 mm. The mean (± SD) otolith width (OW) was 410.8 mm ± 20.5. Positive relationships were found on 11 of the 12 regression analyses. The results of the examination on the relationships of the OW and OL with TL of the fish showed significant positive linear relationship (Table 2). Similar results were observed in the regression of SL vs OW and SL vs OL. There was no significant linear relationship between TL vs A which indicates fish body growth may not correspond to growth on the aspect ratio of the caudal fin. However, it is unclear that SL and A showed significant relationship. On A and OW, a significant relationship was observed as well as with A and OL. TW and OW and TW and OL showed a positive linear relationship.

The regression model explained 57-68% of the variance for three relationships namely the TW vs OW, TL vs OW and SL vs OW. Positive linear regression was obtained in scatter graph for OW and OL with TL and SL (Figure 2). Regression of OL vs TW, TL and SL showed moderate relationships with R^2 values of 0.17, 0.28 and 0.35, respectively. The lowest value was obtained in the regression between TL and A with a value of 0.12 that showed non-significant relationship in the t-test. Except for this regression, all 11 showed significant relationships using the t-test. Regression between A and OL explained 25% of the variance. A significant relationship was also found between aspect ratio of caudal fin to otolith width and otolith length which could indicate that the balance function of the otolith could reveal in the caudal fin.

Table 1. Otolith and body size measurements of *Siganus spinus* (n = 30).

Parameter	Mean ± SD	Minimum	Maximum
Total weight	0.6 ± 0.1	0.5	0.7
Total length	37.4 ± 1.1	35.5	40.5
Standard length	30.7 ± 0.9	29.2	33.3
Otolith width	410.8 ± 20.5	376.0	459.6
Otolith length	528.0 ± 30.8	476.1	620.9
Aspect ratio	0.6 ± 0.1	0.4	0.9

Table 2. Relationships between otolith morphometrics and fish body size measures in *Siganus spinus* (n = 30).

Parameter*	Equation	R^2	t-value
OW vs TW	$OW=514.4*TW^{0.4053}$	0.57	6.11
OL vs TW	$OL=601.9*TW^{0.2293}$	0.17	2.30
OW vs TL	OW= -130.9+(14.5OW)	0.62	6.76
OL vs TL	OL= 142.4+(10.4OL)	0.28	3.32
OW vs SL	OW=-75.1+(15.8SL)	0.68	7.49
OL vs SL	OL=122.7+(13.2SL)	0.35	3.86
OW vs A	OW=458.2+(-84.6A)	0.27	-3.27
OL vs A	OL=594.2+(-125.5A)	0.25	-3.05
A vs TL	A=1.6+(-0.03TL)	0.12	-1.98**
A vs SL	A=2.1+(-0.05SL)	0.23	-2.88
A vs OW	A=1.5+(-0.002OW)	0.13	-2.05
A vs OL	A=1.7+(-0.002OL)	0.33	-3.70

*OW = Otolith width; TW = Total width; OL = Otolith length; TL = Total Length; SL = Standard length; A = Aspect ratio

**Statistically not significant; all other relationships are significant at 5% level.

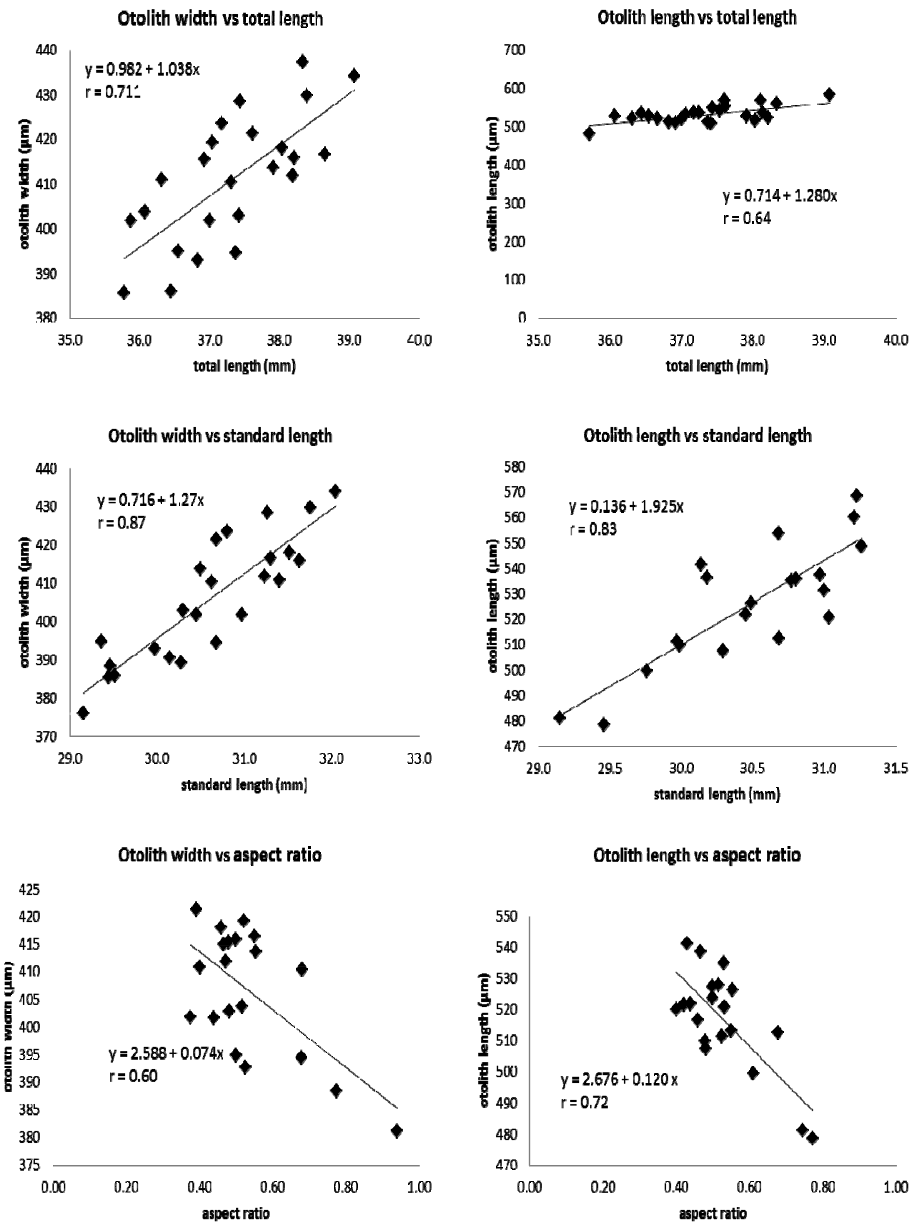

Figure 2. Relationships of : (a) Total weight and otolith width; (b) Total weight and otolith length; (c) Standard length and otolith width; (d) Standard length and otolith length; (e) Aspect ratio and otolith width and (f) Aspect ratio and otolith length in *Siganus spinus*.

DISCUSSION

The positive relationships between otolith width/length and fish body size measurements imply that otolith size can be determined from its fish body size measurements. A change in the body size corresponds to a change in the otolith size. The highest R^2 between OW and SL suggests that SL is the better predictor for OW. The regression coefficients between OW and SL obtained were not close to unity because the juveniles were at the critical stage of transition from larval to juvenile stage. Wilson and McCormick (1997) explained that this is a period where somatic growth affects the growth of the otolith coincident with settlement.

All of the few similar studies among siganids revealed similar positive relations between otolith measurements and fish body size. For *S. guttatus* and *S. fuscescens*, Yamada and Shibuno (2007) found positive linear regression between the sagittal radius and standard length for both species. For *S. spinus* (Soliman et al. 2010) and *S. guttatus* (Soliman et al. 2009) regressed sagittal radius and standard length which yielded significant linear regression. Both studies used polished sagittae. The present study used raw sagittae that afforded a practical advantage because otolith polishing is time-consuming. The information on otolith size and body size relations in the siganids strengthens the validity of inference on the relationship between fish age and otolith increment from hatching to settlement.

The growth of juvenile *S. spinus* was allometric implying that the growth of the caudal fin was not proportionally related to the growth of the fish total length. This may be explained by the complex processes during the early life stage of the fish wherein the body shape, morphology, metabolism swimming abilities were affected by the metamorphosis phenomenon which result to an allometric growth pattern (Gisbert et al. 2002). Allometric growth was a distinctive feature of the larval period (Fuiman & Werner 2002) including pre-settlement juveniles.

The significant relationship between aspect ratio and otolith size suggests that the balance function of the otolith may reveal in the caudal fin. Otoliths are a primary balance structure of the fish which the tail shares with the same function in addition to propelling the fish to movement. As the various fins of the fish give it stability, it is hypothesized that this balance function is being channeled in a shared fashion among the various fins of the fish. Aspect ratio was relatively high which is expected at this life phase of the fish. The pre-settlement juveniles are active swimmers and travel in a wide area to search food and breeding ground (Fisher 2005). In some studies, aspect ratio was used to determine food consumption (Palomares & Pauly 1998) and in determining swimming speed (Fisher 2005).

In conclusion, otolith morphometrics can be estimated from fish body size. Standard length is the best predictor for estimating the otolith width. Otolith function for balance may be revealed through the movement dynamics of the caudal fin. Investigating relationships between otolith morphometrics and aspect ratio of the other fins can shed light on otolith balance function vis-à-vis hydrodynamics of the various fins.

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