A STUDY OF MORPHOLOGICAL VARIATIONS IN OTOLITHS OF DIFFERENT SPECIES OF *LABEO* ON THE BASIS OF GROWTH AND GENDER

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Abstract: A study was carried out to study the sexual and ecological age growth variations in the morphology of otoliths (sagitta) among various native species of the genus *Labeo* from Meerut region viz. *Labeoangra, Labeocalbasu, Labeogonius*and*Labeorohita.* The data obtained was photographed and statistically analysed. From the studies of saggitta of the four species of *Labeo* collected, it is clearly evident that otoliths (sagitta) are species specific in shape, size and structure. Based on the results of morphometric variations the Otoliths of the four species of *Labeo*, showed no significant differences between right & left sagitta ($P<0.05$). The lack of significant differences between right & left sagittae is consistent with the observation that the pair of Otoliths are specular images of each other. Noticeable differences were observed among the four species in otolith morphometric variables.

Keywords: *Labeo* sp., Otololith, Sagittae, Morphometry, Growth, Gender

INTRODUCTION

Each individual fish species possesses three pairs of otoliths in the inner ear viz, Sagitta, Lapillus and Asteriscus, the largest of which are the sagittae. The sagittae are the most variable between species. The otoliths are composed primarily of aragonite. They also contain 0.7 to 10% organic matter in the form of a protein known as otolin. The structure of the otoliths (Sagitta) is three dimensional but they do not necessarily grow at the same rate equally in all dimensions. Otoliths of each species have characteristic, shape and feature. For this reason otoliths are widely used in the systematic research of the teleost fishes. Morphology and morphometries of sagittae have been used in trophic studies and in identification of populations or species (Botha, 1971; Messieh, 1972; Beamish, 1979; Yefanov and Khorevin, 1979) and to determine ages. The shapes and proportional sizes of the otoliths vary with fish species. Otoliths is the only calcified structures that grows throughout the life of fish, are metabolically inert and are typically available as historical time series because of routine age and growth assessments. The otolith radius is significantly related to fish body size (e.g. fork length) and daily increment accumulating in periods of faster growth (Neilson and Geen, 1987; Campana and Neilson, 1985; Breadford and Green, 1987; Campana 1990). One of the most appreciated characteristics of the otoliths is the lack of resorption. After the death and decomposition of a fish, otoliths and statoconia may be preserved within the body of an organism or be dispersed before burial and fossilization. Dispersed otoliths are one of the many microfossils which can be found through a micropalaeontological analysis of a fine sediment. Otolith have been used for taxonomy, age, growth and population studies. Besides age and growth determination, otolith have been the objects of study in many different fields, such as fish biology, larval fish ecology, species identification, fish stock identification and environmental reconstruction of the fish habitat. Otoliths have a distinctive shape which is highly species specific, but varies widely among species.

Labeo species (Carps) belonging to family: Cyprinidae, are well adapted for pisciculture, as they grow to a large size and all have food value. They can live in almost any condition. It is an herbivore and is treated as a delicacy in Orissa, Bihar and Uttar Pradesh. It is relished very much in food and rich in protein content. Carps are cultivated in specially constructed water ponds, having adjacent breeding areas. Mostly cultivated with *Catla* in fresh water ponds & lakes in the absence of carnivorous fish. It is also used as a game fish where it is specially introduced into water reservoirs for the purpose of sport fishing.

According to Jayaram (1981), several species of *Labeo* has been reported from India so far. Out of which available in Meerut region are: *Labeoangra* (Hamilton, 1822) *Labeocalbasu* (Hamilton, 1822) *Labeogonius* (Hamilton, 1822) *Labeorohita* (Hamilton, 1822)

The aim of the present study was to find out sexual and ecological age to growth variations in the morphology of sagitta among various species of the genus *Labeo* (Cuvier) from Meerut region. The data so obtained was photographed and statistically analyzed.

MATERIAL AND METHOD

For the present investigation fishes were obtained from the local fish market or from various water bodies and fish farms in and around Meerut and

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Hastinapur region with the help of fisherman. Fish specimens were collected during the period 2009-2014. Morphologically all the four species of genus Labeo were identified using Day's fauna (1878) and Jayaram (1981). In the present study, more than 100 specimens belonging to both sexes of each species of Labeo were observed. Sagittae (largest of three otoliths) from both sides were taken out and 30 best formed sagittae were studied in detail for its morphology and morphometry i.e. length, width and weight (mass). Length and width of otoliths were measured with the help ofImage pro plus ver.6.1 software. Otolith mass was measured by using Microbalance. Light microscopy was performed to observe morphological characters. Total length (TL; in centimeter i.e. most anterior point to the posterior tip of the caudal fin) was considered and measured to the nearest millimeter and body weight (TW in grams) was recorded prior to the removal of otoliths.

The otoliths (Sagitta) were removed as soon as the fish was sacrificed. A frontal head cut at the level of the top of the eye was established for the removal of sagittal otoliths (Brothers, 1987). Then, the otoliths were cleaned in the water container and observed under a binocular microscope prior to grinding. Each dried otolith was stored in a plastic vials. The date and identification number were labeled on the plastic vials. The otoliths were stored in such a way as to ensure they occupy the minimum space and are well-preserved and easy to identify. Otoliths were stored in vials, dry ready for use immediately. Growth structures are more easily visible in newly collected otoliths. They were therefore read as quickly as possible.

Preparation for Examination

The cleaned otoliths were kept in 70% ethanol for two to three hours and were allowed to dry for a while. The otoliths were fixed with the convex side up showed rings more clearly than those mounted with the concave side down. Otoliths were ground and polished to improve clarity of the rings for seasonal growth increments. The otoliths were ground on the sandpaper no. 0 and polished with Silicon carbide.

Otolith Reading

Otolith microstructures were read under a transmitted and reflected light microscope with 100x, magnifications. The rings were counted from the nucleus towards the posterior edge of the otolith. The oil immersion (Cedar wood oil) was dropped in the otolith centered the slide in order to increase the visibility of the micro increments. Length and width of otoliths were measured with the help of Image Pro-Plus version 6.1 software.

The polished otoliths were washed in water and dried under a gentle heat source such as a lamp or moderate oven (60°C) and mounted on a slide and photographed under Stereo microscope.

Statistical Analysis

The relationship between fish size (TL), otolith size (length and width) and fish Weight (TW) and otolith mass (OM) were determined using least squares linear regression for the following parameters: fish length (TL)- Otolith lengh (OL), fish length (FL)- Otolith width (OW) and fish weight (TW)- Otolith mass (OM).The regression coefficients were compared and when significant differences (P<O.05) were calculated, If the equations did not differ statistically, a single linear regression was reported for each parameter. The significance of the Linear regressions were verified using F-test. Fishers' variance test was applied for comparing the slopes of the estimated relations for males and females of *Labeosps. (Labeoangra, Labeocalbasu ,Labeogonius , Labeorohita).* Linear regressions were obtained for each sex to investigate possible sexual differences.

An ANCOVA was performed separately for each species to test if the slopes of the fish length to Otolith length and width; fish weight to Otolith mass depended on sex and to observe interspecific variations in the morphological parameters. (Dependent variables for the study were Otolith length, Otolith width and Otolith mass).

RESULT AND DISCUSSION

The study revealed that both the right and left otoliths were almost identical and no sexual differences were also observed in all the four species studied.

In *Labeoangra,* the dorsal margin is smoother and ventral has a depression below the antirostrum, in both the sexes. Notch separating rostrum from antirostrum is straight Ostium and Cauda are tubular and directed upwards or dorsally. Anterior end is pointed and posterior end is rounded. In *L. calbasu, the* dorsal margin is wavy and irregular and ventral margin with depression below the antirostrum. Notch between rostrum and antirostrum is well defined. Ostium and Cauda are tubular and straight. Anterior end more pointed and posterior end irregular.

In the case of *L. gonius,*sagitta is more wide as compared to its length. Dorsal margin is wavy and ventral margin has a depression below the antirostrum. Notch separating rostrum from antirostrum is deep and well-marked. Ostium and cauda arestructurally similar to that of other *Labeo* species. Dorsal margin in is smooth or slightly wavy, ventral margin with a depression near the antrirostrum in *L.rohita.* Rostrum and antirosturm is well marked.

From the above observations on sagitta of the four species of Labeo collected from Meerut region, it is clearly evident that otoliths (sagitta) are species specific in shape, size and structure. (Harvey *et al*; 2000, Battaglia*et al*., 2010).

Noticeable differences were observed among the four species in otolith morphometric variables.

Table: 1 clearly indicate that Otolith length (OL) and Otolith width (OW) varies with Total Fish Length (FL) and Otolith mass (OM) with the Fish weight.

In *L.angra* otolith length is 0.61 % in male and 0.63%in female of the total fish length. In *L.calbasu* otolith length is 0.41 % in male and in female 0.40%, of the total fish length. In *L.gonius*and *L.rohita*, the otolith length is 0.65% and 0.71 % in male and 0.66% & 0.71in female of the total fish length, respectively. This indicates that *L.rohita* showed the largest otolith both in male and female followed by *L. gonius* and *L. angra.* The smallest and the lightest otoliths were observed in *L.calbasu.*These results are in accordance with the observations of many scientists that the morphometry of the sagittae and otoliths in fishes are species specific. (Platt and Popper, 1981 Gauldie, 1988). There are very few descriptions of sex-specific growth effect (Ahmad &Alghais, 1997, Munday*et al.*, 2004). Several studies demonstrate that Otolith growth is more closely associated to time than fish size. (Munday*et al.*, 2004; Fey 2006).

In contrast, if a growth effect was present, females would be expected to have relatively smaller otoliths than males because somatic growth is higher in females. This fact may depend on the interaction of genetic, endocrinological and environmental conditions with somatic growth (Fey, 2006). Although, the size of the fish and Otolith size are correlated, Otolith size tends to be somewhat more correlated with fish age than fish length. (Templeman and Squises 1956, Boehlert 1985). Various studies have been done in the past, which generally focused on the relationship between size of fish and sagitta. (Wylie, 1987; Gamboa 1991; Garanaderio and Silva 2000; Harvey *et al.*, 2000; Waessle*et al.*, 2003 and Battaglia*et al.*, 2010).

Table 1. Showing range and mean of fish length, fish weight, otolith length, otolith width and otolith mass of the species studied.

Fish Species	Gender	FL (cm)	FM (gm)	OL (mm)	OW (mg)	OM (mgm)	Percentage		
							OL/TL	OW/TL	OM/FM
Labeoangra	**Male**	24-29	128-144	1.56-1.67	1.12-1.28	0.04-0.08	0.61	0.43	0.40
	Female	22-26	120-130	1.33-1.57	1.09-1.28	0.04-0.08	0.63	0.48	0.43
Labeocalbasu	**Male**	24-34	160-180	1.10-1.24	0.72-0.90	0.02-0.05	0.41	0.29	0.20
	Female	24-34	160-180	1.10-1.26	0.74-0.88	0.02-0.05	0.40	0.28	0.20
Labeogonius	**Male**	26-32	450-600	1.85-1.95	1.26-1.40	0.03-0.05	0.65	0.45	0.071
	Female	26-32	450-600	1.89-1.97	1.26-1.44	0.03-0.05	0.66	0.43	0.073
Labeorohita	**Male**	21.5-30.	110-140	1.68-1.83	1.24-1.49	0.04-0.08	0.71	0.56	0.38
	Female	21.8-30.5	105-140	1.66-1.87	1.28-1.50	0.03-0.08	0.73	0.56	0.37

Actually, Otolith size can be better used to interpret fish age than fish length.The interspecific variations in shape and size of the Otolith of *Labeo* species are also reported in the present study. The topography of the inner surface i.e shape of Ostium, width of cauda and type of depression in the dorsal area and ventral was the most variable feature as also exemplified in sciaenid fishes (Chao, 1978; Ramcharitar*et al.*2004; Pawan Kumar *et al.*, 2012). The results of the present investigation, provide useful information on Total length vs Otolith length, Fish Length vs Otolith Width, Fish mass/weight vs Otolith Mass relationships for the *Labeo* species.

The analysis of the morphometric parameters using paired student's t- test, showed no significant differences between the right and left sagittae in both males and females. Since the morphological and morphometric characters of the left and right otoliths did not differ statistically, anyone of them (preferably right otoliths) were selected randomly for each individual of all the four species and simple linear regression was performed for each species for establishing relationship between Total Fish length with Otolith length and otolith width; Fish weight or mass with Otolith mass. The regression slopes for the measures of the sagittae of male and female showed no significant differences when comparing them with Fishers test. The parameters compared with Total fish length (TL) were Otolith Length (OL) and Otolith Width(OW); Fish weight (FW) with Otolith mass (OM). Morphometric relationships among the characters compared were established using simple linear regression model which bests fits the data distribution. The appropriateness of the linear model was determined by plotting the residuals against the independent variables.

The relationship between Fish total length and otolith morphometric measurements COL: OW) is linear and most of the variability is explained by regression equation. These calculations based on morphometric parameters were subjected to Fishers Variance test and ANCOVA test to evaluate Interspecific Variations which are given in Tables1-3.

Table 1. Ancova test inter specific variation in labeo species: combined analysis between fish length & otolith length

Species* Gender
Dependent Variable: OTOLITH LENGTH

Species	Gender	Mean	Std. Deviation	N
La	Male	1.6300	.02573	30
	Female	1.5240	.06234	30
	Total	1.5770	.07136	60
Lc	Male	1.1667	.03968	30
	Female	1.1690	.04071	30
	Total	1.1678	03988	60
Lg	Male	1.8973	.04748	30
	Female	1.9057	.03451	30
	Total	1.9015	.04137	60
Lr	Male	1.7177	.18281	30
	Female	1.7613	.04257	30
	Total	1.7395	.13342	60
Total	**Male**	**1.6029**	**.28736**	**120**
	Female	**1.5900**	**.28532**	**120**
	Total	**1.5965**	**.28492**	**240**

Levene's Test of Equality of Error Variances*
Dependent Variable: OTOLITH LENGTH

F	dfI	Df3	Sig
7.309	.8	231	.000

Test the null hypothesis that the error variance of the dependent variable is equal across groups a Design. FISH LENGTH + Species + Species* Gender

Test of Between – Subject Effects
Dependent Variable: OTOLITH LENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	18.192a	8	2.274	434.246	.000
FISH LENGTH	.138	1	.138	26.269	.000
Species	17.928	3	5.976	1141.174	.000
Gender	.003	1	.003	496	.000
Species* Gender	.115	3	.38	7.309	.000
Error	1.210	231	.005		
Total	**19.402**	**240**			

a. R Squared = .938 (Adjusted R Squared =.935)

1. Species

Dependent Variable: OTOLITH LENGTH Dependent

Species	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
La	1.592[a]	.010	1.572	1.611
Lc	1.149[a]	.010	1.129	1.169
Lg	1.878[a]	.010	1.857	1.898
Lr	1.767[a]	.010	1.746	1.789

Covariates appearing in the model are evaluated at the following values : FISH LENGTH = 26.7200

2. Gender

Variable: OTOLITH LENGT

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	1.600 [a]	.007 [a]	1.580	1.606
Female	.402 [a]	402 [a]	1.587	1.613

Covariates appearing in the model are evaluated at the following values : FISH LENGTH = 26.720

Table 2. ANCOVA TEST INTER SPECIFIC VARIATION IN LABEO SPECIES: Combined Analysis between fish Length & Otolith Length

Species* Gender
Dependent Variable: OTOLITH LENGTH

Species	Gender	Mean	Std. Deviation	N
La	Male	1.5187	.04023	30
	Female	1.1727	.07148	30
	Total	1.1657	.05794	60
Lc	Male	1.1727	07148	30
	Female	.8240	.06072	30
	Total	.8260	.06071	60
Lg	Male	1.3383	.05292	30
	Female	1.3340	.06083	30
	Total	1.3362	.05657	60
Lr	Male	1.3597	.05430	30
	Female	1.3553	.05917	30
	Total	.3575	.05635	60
Total	**Male**	**1.1702**	**.22163**	**120**
	Female	**1.1725**	**.22102**	**120**
	Total	**1.1713**	**.22086**	**240**

Levene's Test of Equality of Error Variances*
Dependent Variable: OTOLITH WIDTH

F	dfI	Df3	Sig
6.250	.7	233	.000

Test the null hypothesis that the error variance of the dependent variable is equal across groups a Design. FISH LENGTH + Species + Gender+ Species* Gender

Test of Between – Subject Effects
Dependent Variable: OTOLITH LENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	11.1430	8	1.393	623.699	.000
FISH LENGTH	.272	1	.272	121.820	.000
Species	10.862	3	3.621	1621.260	.000
Gender	.007	1	.007	3.295	.000
Species* Gender	.031	3	.010	4.681	.000
Error	566	231	.002		
Total	**11.659**	**240**			

a. R Squared = .938 (Adjusted R Squared =.935)

1. Species

Dependent Variable :OTOLITH LENGTH Dependent

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	1.177 [a]	.004	1.168	1.185
Female	1.166 [a]	.004	1.57	1.174

Covariates appearing in the model are evaluated at the following values: FISH LENGTH = 26.7200

2. Gender

Variable :OTOLITH LENGTH

Species	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
La	1.186	.007	1.174	1.199
Lc	1.800	.007	.787	.813
Lg	1.303	.007	1.289	1.316
Lr	1.397	.007	1.383	1.411

Covariates appearing in the model are evaluated at the following values : FISH LENGTH = 26.7200

3. Species* Gender

Dependent Variable:OTOLITH LENGTH

Species	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
La	Male	1.160a	.004	1.1143	1.177
	Female	1.212a	.009	1.194	1.230
Lc	Male	.799a	.009	.781	.816
	Female	.801a	.009	.783	.818
Lg	Male	1.305a	.009	1.287	1.319
	Female	1.300a	.009	1.282	1.323
Lr	Male	1.399a	.009	1.381	1.417
	Female	1.394a	.009	1.376	1.413

Covariates appearing in the model are evaluated at the following values : FISH LENGTH = 26.7200

Table 3. ANCOVA TEST INTER SPECIFIC VARIATION IN LABEO SPECIES: Combined Analysis between fish Length & Otolith Length

Descriptive Statistics

Dependent Variable: OTOLITH LENGTH

Species	Gender	Mean	Std. Deviation	N
La	Male	.0550	.01480	30
	Female	.543	.01633	30
	Total	.0547	.01546	60
Lc	Male	.0350	.00938	30
	Female	.0353	.00937	30
	Total	.0352	.00930	60
Lg	Male	.0387	.00730	30
	Female	.0387	.00730	30
	Total	.0387	.00724	60
Lr	Male	.0460	.01163	30
	Female	.0460	.01163	30
	Total	0460	.01153	60
Total	**Male**	**.0437**	**.01341**	**120**
	Female	**.0450**	**.01365**	**120**
	Total	**.0436**	**.01350**	**240**

Levene's Test of Equality of Error Variances*

Dependent Variable : OTOLITH WIDTH

F	dfI	Df3	Sig
6.652	.7	232	.000

Test the null hypothesis that the error variance of the dependent variable is equal across groups a Design. FISH LENGTH + Species + Gender+ Species* Gender

Test of Between – Subject Effects

Dependent Variable: OTOLITH LENGTH

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	.0310	8	.002	12.957	.000
FISH LENGTH	5.8266	1	.005	.448	.000
Species	.011	1	.004	27.760	.000
Gender	1.230	1	1.2308	.001	.002
Species* Gender	5.572E	3	1.857E	.014	.002
Error	030	231	.000		
Total	.500	**240**			

a. R Squared = .310 (Adjusted R Squared =.286)

1. Species

Dependent Variable: OTOLITH LENGTH

Species	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
La	.056a	.003	.051	.62
Lc	.036a	.002	.032	.040

Lg	.034a	.007	.22	.047
Lr	.048a	.003	.042	.50

a. Covariates appearing in the model are evaluated at the following values: FISH WEIGHT = 238.003**3.**

Species* Gender

Dependent Variable: OTOLITH LENGTH

Species	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
La	Male	0.56a	.003	0.30	0.63
	Female	0.56a	.003	.050	.062
Lc	Male	.036a	.003	.031	.041
	Female	.036a	.003	.031	.041
Lg	Male	034a	.007	.021	.048
	Female	.0340a	.007	0.21	.048
Lr	Male	0048a	.007	.041	.054
	Female	.048a	.007	.041	.054

a. Covariates appearing in the model are evaluated at the following values: FISH WEIGHT = 238.003

All the four species were put to Fishers variance test and ANCOVA which clearly indicates high interspecific variability in Shape, Size and weight of all the four species studied.

REFERENCES

Ahmad, S., Al-Ghais, S. M. (1997) - Relation between age and heavy metal content in the otoliths of PomadasysstridensForska? I 1775 collected from the Arabian Gulf. Archives Environmental Contamination ToxicoI., 32:304-308.

Battaglia, P., Malara, D., Romeo, T., Andaloro, F., (2010) - Relationship between otolith size and fish size in some mesopelagic and bathypelagic species from the Mediterranean Sea (Strait of Messina), Italy. Sci. Mar., 74:605-612.

Boehlert, G. W. (1985) - Using objective criteria and multiple regression models for age determination in fishes. US. Fish. Bull., 83:103-117.

Botha, L. (1971) - Growth and otolith morphology of the Cape hakes *Merlucciuscapensis* Cast. and*Merlucciusparadoxus* Franca. Invest. Rep. Div. Sea Fish., S. Afr., 97:1-32.

Bradford, M. L, Geen, G. H. (1987) - Size and growth of juvenile chinook salmon backcalculated from otolith growth increments. P., 453-461. In: R. C. Summerfelt and G. E. Hall [eds]. Age and Growth of Fish. Iowa State University Press. Ames, Iowa.

Bradford, M. J., Geen, G. H. (1992) - Growth estimates from otolith increment widths of juvenile chinook salmon (*Oncorhynchustshawytscha*) reared in changing environments. J. Fish BioI., 41:825-832.

Brothers, E. B. (1987) - Methodological approaches to the examination of otoliths in aging studies. In: R C. Summerfelt and G. E. Hall [eds]. Age and Growth ofFish. Iowa State University Press. Ames, Iowa. 319- 330.

Campana, S. E., Neilson, J. D. (1985) - Microstructure ofFish Otoliths. Can. J. Fish. Aq. Sci., 42:1014 - 1032.

Campana, S. E. (1990) - How reliable are growth back-calculations based on otoliths? C. J. Fish. Aquat. Sci., 47:2219-2227

Chao, L. N. (1978) - A basis for classifying western Atlantic Sciaenidae (*Teleostei: Perciformes*). NOAA Tech. Rep. Cir., 415:64 pp.

Day, F. (1878) - The Fishes ofIndia, being a natural history of the fishes known to inhabit the seas and fresh waters of India; Burma & Ceylon I & II: XXXVII pg., 363-368.

Fey, D. P. (2006) - The effect of temperature and somatic growth on otolith growth: the discrepancy between two clupeid species from a similar environment. J. Fish. BioI., 59:197-242.

Gamboa, D. A. (1991) - Otolith Size versus Weight and Body-Length Relationships for Eleven Fish Species of Baja California, Mexico. Fish. Bull. U. S., 89:701- 706.

Granadeiro, J. P., Silva, M. A. (2000) - The use of otoliths and vertebrae in the identification and size-estimation of fish in predator-prey studies. Cybium, 24:383-393.

Gauldie, R. W., Nelson D. G. A. (1990) - Otolith growth in fishes. Compo Biochem. Physiol., 97 A:2.119-135.

Harvey, J. T., Loughlin, T. R, Perez, M. A., Oxman, D. S. (2000) - Relationship between fish size and otolith length for 63 species of fishes from the Eastern North Pacific Ocean. U. S. Dept. of Commerce NOAA. Technical Report NMFS 150.

Munday, F., Hodges, A. L., Choat, J. H., Gust, N. (2004) - Sex-specific growth effects in protogynous hermaphrodites. Can. J. Fisher. Aq. Sci., 61:323-327.

Neilson, J. D., Geen, G. H. (1982) - Otoliths of Chinook salmon (*Oncorhynchustshawytscha*): daily growth increments and factors influencing their production. Can. J. Fish. Aquat. Sci., 39:1340-1347.

Platt, C., Popper, A. N. (1981) - Fine structure and function of the ear. In W. N. Tavolga, A. N. Popper, and R R Fay (eds.): Hearing and Sound Communication in Fishes. New York: Springer-Verlag, pp. 3-38.

Ramcharitar, J., Deng X., Ketten D., Popper A.N. (2004) – Form and function in the unique inner ear of a teleost: the silver perch. J. Comp. Neurology, 475:531-539.

Templeman, W., Squires, H.J. (1956) – Relationship of otoliths lengths and weights in the haddock *Mellanogrammousanglefins* (L) to the rate of growth of fish. J.Fish Res. Bd. Canada., 13:467-487.

Waessle, J.A., Lasta, C.A., favero, M. (2003) – Otolith morphology and body size relationships for juvenile Scianidae in the Rio de la Plata estuary (35-36 S). Scientia Marina, 67:233-240.

Wyllie Echeverria, T. (1987) – Relationship of otolith length to total length in rock fishes from northern and central California. Fish. Bull., 85:383-387.