Voyager: Voll. V, Dec. 2014,   111-121: 2014
ISSN :0976-7436 : INDEXED AND ABSTRACTED

Study of Morphology of Internal Ear of Some Freshwater Fishes With Special Reference to Otoliths

Nisha Manish
Associate Professor, Dept. of Zoology
Meerut College, Meerut

Abstract

To observe interspecific variation and the structural organization of the auditory system in teleost fishes, it is of great concern to study the gross morphology and structure of the internal ear and otoliths in fishes because inter-specific variation in the teleost ear is associated with sound production. Further, otoliths present in the ear contribute to playing an important role in balancing during the movement. These calcareous structures have also proven to be useful in the estimation of age and growth. So, an attempt has been made to study the gross morphology of the internal ear of some freshwater fishes with special reference to the morphology of otoliths.

Keywords: *Fishes, Internal ear, morphology , otolith.*

© 2015 Journal Anu Books   Authors are responsible for any plagiarism issues.

Voyager: Voll. V, Dec. 2014, 111-121: 2014
ISSN :0976-7436 : INDEXED AND ABSTRACTED

Introduction

Due to diverse abilities in hearing (Ladic and Popper, 2004; Popper and Fay, 2011), structural variations in the internal ear (popper, 1977; Popper, 1981; Buran *et* al., 2005; Deng *et al.* ,2011) and morphology of otoliths (Nolf, *et al.*, 1985), fishes have always been a topic of interest amongst the researchers. Theotoliths are found to be used in estimation of age and growth in the fishes (Rodriguez Mendoza,2006). The present communication deals with the comparative study of the internal ear of some freshwater fishes with special reference to otoliths present in the respective end organs viz. Utriculus, Seculus, and Legena A perusal of literature showed the importance of the internal ear (Popper and Platt, 1993; Kasumyan, 2004b). and its connection with the air bladder for sound production in teleosts (Popper and Fay,1993; Platt, 1988; Schulz *et al,2013*.; Coombs and Popper, 1980,1982). So, it became mandatory to first study the morphology of the internal ear for further investigation in terms of the connection with the air bladder. So an attempt has been made to study the comparative orientation, position, and gross morphology of the internal ear with special reference to its otoliths.

Four fishes viz. *Notopterus chitala (Ham.)*, *Cirrhinus mrigala (Ham.), Clarias batrachus (Linn.),* and *Xenentodon cancila* (Ham.) belonging to the family Notopteridae, Cyprini,Claridae, and Belonidae respectively, were taken for the study of the morphology of the internal ear and their otoliths.

Material and Methods

The gross morphology of the internal ear is studied through dissections in situ as well as outside the animal by permanent preparations. In order to expose the internal ear, first, the gill arches in the head region were removed so as to expose the ventral side of the auditory capsule. Dorsally, the auditory capsule consists of frontals, supraoccipital, partial, sphenotic, and pterotic bones. Ventrally, the capsule made up occipital, basioccipital,prootic and epiotic.The bones of the ventral side of auditory capsules were removed to expose the internal ear. After Studying in situ, it was taken out and preserved in 70%alcohol. Staining was done with Aceto carmine. Slides were examined under the microscope and figures were drawn with the help of camera lucida.To remove otoliths the saccule was exposed and with the help of forceps the otoliths are taken out carefully Any tissue adhering to the otolith was removed from the otoliths .5%sodium hypochlorite solution was used for cleaning.

Observations

The internal ear studied in all the fishes herein, exhibits the generalized plan as in teleosts. It is a complicated hollow structure with transparent walls and filled with endolymph.

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

Voyager: Voll. V, Dec. 2014, 111-121: 2014
ISSN :0976-7436 : INDEXED AND ABSTRACTED

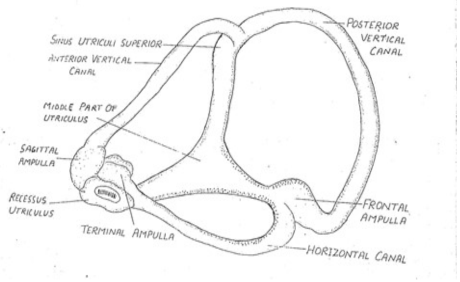


Fig.1-Internal ear of *N. chitala*

It lies ventrally and laterally in the auditory region of the cranial cavity above the medulla. The auditory capsule consists of four paired bones vizsphenotic, pterotic, prootic, and epiotic bones. The sphenotics form the anterior boundary of the auditory region. The prootic bones are flat and somewhat rounded bones lying on the ventral side of the auditory region. The epiotic bones form the posterior side of the auditory region.

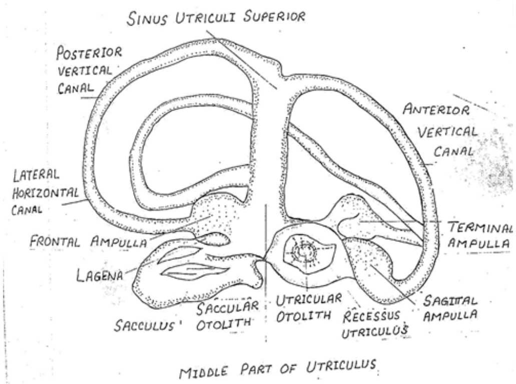


Fig. 2 Internal ear of *C. mrigala*

In all the fishes, the inner ear consists of two parts, an upper and a lower part. The upper part consists of utriculus and three semicircular canals while the lower part includes the sacculus and lagena.

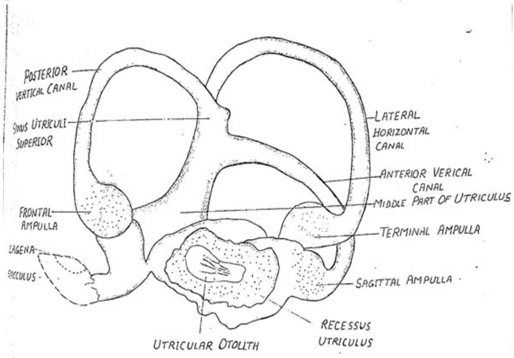


Fig. 3. Internal ear of *C. batrachus*
(image drawn by camera lucida)

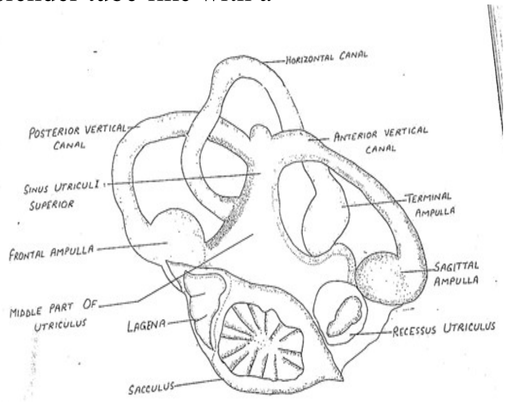
The utriculus is divided into three parts i.e.the upper part sinus utriculi superior, the middle part, and the lower part recesses utriculus which is connected with sacculus and lagena on its side. From the upper part of the utriculus, originates the anterior and posterior vertical canals.

The middle part of the utriculus is broader in which opens the horizontal canal; the lower part of the utriculus is the recessusutriculus. Recessusutriculus contains an otolith known as lapillus. The lapillus consists of calcium carbonate. It bears light and dark lines of growth in all the fishes studied herein. The sensory epithelium macula is present in the recesses utriculus in all the fishes in the present study.

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

Voyager: Voll. V, Dec. 2014, 111-121: 2014
ISSN :0976-7436 : INDEXED AND ABSTRACTED

The anterior vertical canal is a slender tube-like with a



constant diameter but becomes wider at the site of origin

Fig 4-Internal ear of *X.cancila*

i.e. from the dorsal end of sinus utriculi superior. At the other end, it turns into a spherical ampulla known as sagittal ampulla.

The posterior vertical canal (canalisfrontalis) also arises from the dorsal end of utriculi superior along with the anterior vertical canal. After its origin, it becomes curved and enters the groove on the ventral side of the supraoccipital and epiotic bones. Like another canal, it also ends in a distinct ampulla known as the frontal ampulla.

The lower portion of the internal ear includes the sacculus and lagena. The otolith present in the sacculus is known as Sagitta. Just posterior to the sacculus, the lagina is situated on the floor of the cranium. It is smaller than the sacculus in all the fishes studies herein. The otolith present in the lagena is known as asteriscus. It also bears light and dark lines of growth. (Fig.1,2,3,4)

The utricular otolith i.e. the lapillus in *N.chitala*is somewhat round in shape with wing-like projections on one margin. In*X.cancila* it is the smallest amongst all the fishes studied herein. (Fig.5a,8a)

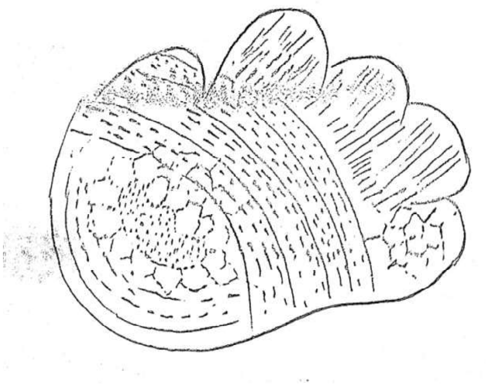


Fig. 5a.- Lapillus of *N. chitala*

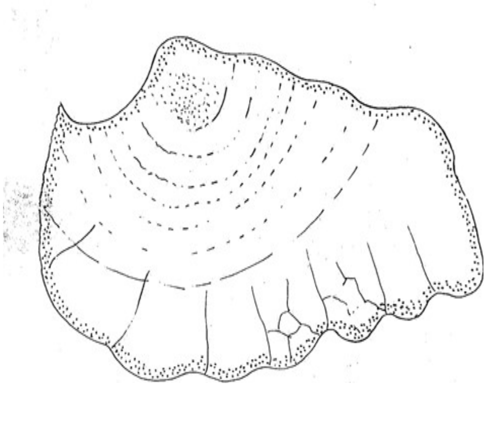


Fig.5b- Sagitta of *N. chitala*

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

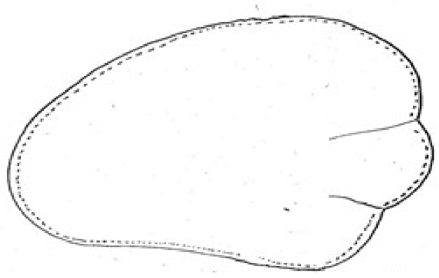


Fig.5c- Asteriscus of *N. chitala*

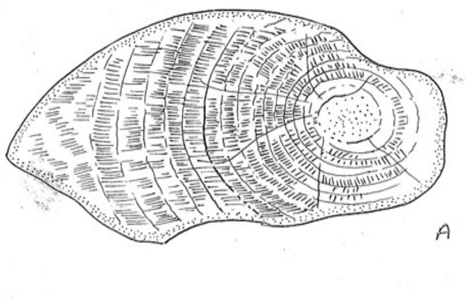


Fig.6a- Lapillus of *C. mrigala*

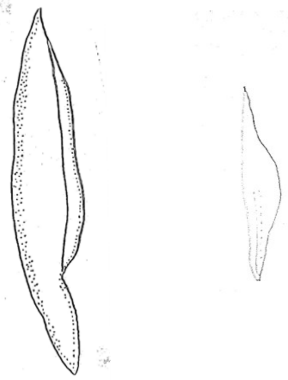


Fig. 6b- Sagitta of *C.mrigala* & 6c- Asteriscus of *C.mrigala*

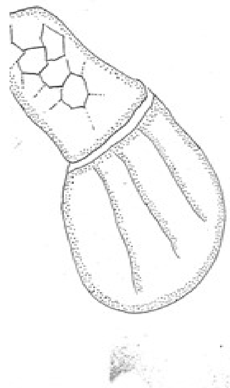


Fig.7a-Lapillus of *C. batrachus*

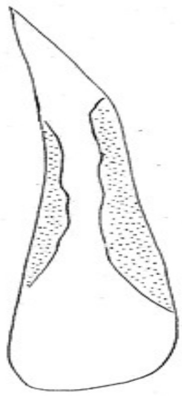


Fig.7b- Sagitta of *C.batrachus*

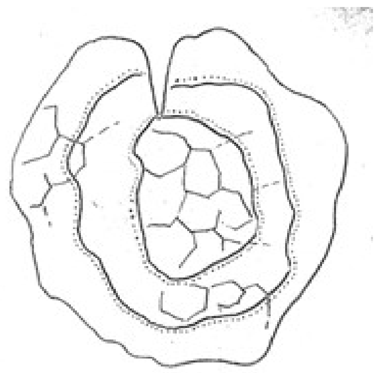


Fig7c-Asteriscus of *C.batrachus*

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

Voyager: Voll. V, Dec. 2014, 111-121: 2014
ISSN :0976-7436 : INDEXED AND ABSTRACTED

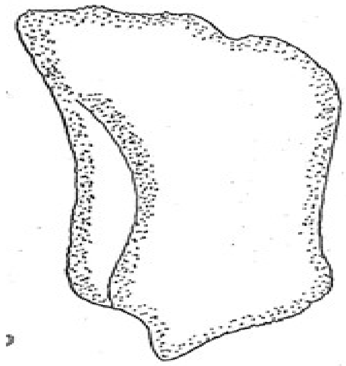


Fig.8a- Lapillus of*X.cancila*

Fig.8b-Sagitta of *X.cancila*

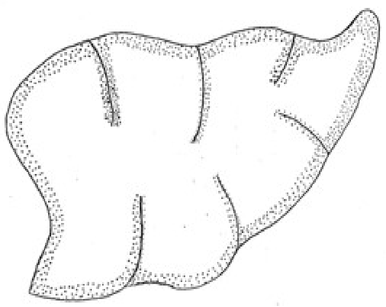


Fig.8c-Asteriscus of*X.cancila*

The saccular otolith i. e. the sagitta is quite large in *X. cancila*as compared with the other three fishes studied. It is somewhat oval in shape with irregular margins. It bears lines of growth. (Fig. 5b,6b,7b,8b)

In all the fishes studied herein the asteriscus is somewhat rounded in shape and smallest in size.

Discussions

As described previously (Retzieus *et al.*1881, Popper, 2011) the inner ear has a generalized plan as in teleosts, in all the fishes studied herein. It lies in the auditory capsule consisting of four pairs of bone sphenotc, pterotic ,prootic, and epiotic. In elasmobranchs, however, the inner ear lies in an otic capsule made up of cartilage; it is located just posterior to the large optic capsules. (Popper and Fay, 1977) The inner ear consists of two portions, an upper and a lower portion. The upper portion consists of utriculus and three semicircular canals, while the lower portion is made up of sacculus and lagena.

The semicircular canals in all the fishes studied are of uniform diameter but there exist some interspecific variations. The semicircular canals of *Notopterus chitala* and *Cirrhinus mrigala* are slender as compared with *clarias batrachus*. However, in *Xenentodon cancila* these are wider than others. Tandon and Pandey (1976) studied the internal ear of *Wallago attu* and stated that it differs in its topography from the common types known. They also observed that the ampulla of the horizontal canal is

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

the largest of three ampullae in the *wallagoattu*. However, in *N. chitala, C. mrigala* and *clarias batrachus* all the three ampullae of the three semicircular canals are of equal size, while in *Xenentodon cancila* the frontal ampulla is largest than the other three fishes studied. (Fig.1,2,3,4)

The utriculus is more or less triangular in all the fishes studied in the present communication. Tandon and Pandey (1976) observed that the utriculus is comparatively smaller and vertically placed in the middle of the auditory capsule. The author also observed a vertically placed utriculus. The upper part of utriculus, the utriculi superior, is slender in *Notopterus Chitala* while in *Xenentodon cancila* it is quite broader. (fig.1,4)

The lower part recesses utriculus is somewhat oval and rounded in all the fishes studied and presents posteroventral to the sagittal and the terminal ampullae. In *Cirrhinus mrigala*, *Notopterus chitala,* and *Xenentodon cancila* it is smaller than that of *clariasbatrachus*(Fig.1,2,3,4).The sacculus lies on the floor of the cranium in all the fishes studied herein.In *N.chitala, Cirrhinus mrigala* and *X. cancila,* it is larger than *C. batrachus* in the present study. Tandon and Pandey (1976) observed in *Wallago attu* that the sacculus covers a large area of the labyrinth between the ampullae of the horizontal and posterior vertical canal. The sacculus is larger than the lagena and utricle in *P. mexicana* (Schulz-Mirbach *et al.*, 2011) The utricle lies in a rostro- lateral position to the saccule and connected with each other by a wide opening. The lagena is situated in the postero-lateral position of the saccule (Schulz-Mirbach *et al.*, 2011) The author observed that the right and left saccules are present at an angle with the posterior ends lying close to the midline of the body in *N. chitala.*

Schulz-Mirbach *et al.* (2011) studied the inner ear of *Poecilia mexicana* and stated a number of important features. In *P. mexicana,* the utricle is connected rostrally instead of dorso-rostrally to the saccule, and the macula sacculi, therefore, is very close to the utricle. However, in the present study, it is present dorsally to the saccule.

As described previously the otolith present in the recessus utriculus is the lapillus. Dark and light lines of growth have been observed on the otoliths.

The lapillus is somewhat oval in *C. mrigala* and *Clarias batrachus*; the outer wall bears vertically disposed sensory epithelium, the macula. In *C. Mrigala*, the sagitta appears to be an elongated calcareous congregation. It is more elongated in comparison to *N. chitala.*

The otoliths present in these three end organs i. e. utriculus, sacculus, and lagina are a congregation of calcium carbonate as described by Popper et al. (2005). A Number of scanning electron microscopy studies have shown the variations in shape and size in the otoliths of three end organs (John Umar Ramcharitar

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

et al., 2004) Further, it is stated that the shape varies from species to species (Zorica *et al.*, 2010) the shape of otoliths shows a great variation ranging from round, elongated to irregular, (Hunt *et al.1992*; Tuset *et al.*, 2008). According to Ýlkyaz *et al.*, (2011), the shape of otoliths plays an important role in the identification of species and estimation of age and growth. The author also observed that all the otoliths of the end organs viz. Utriculussacculus and lagena are variously shaped in all the four fishes studied herein ranging from rounded, elongated to irregular calcareous mass. The lapillus of *N. chitala* is round at one end while on the other end it has some projections. It bears light and dark lines of growth. (Fig.5a)

The otolith present in the sacculus, the sagitta, is larger than the utricular otolith in *Notopterus chitala*. It is fan-shaped bearing dark and light lines of growth. The sagittas of *C. batrachus* is an elongated structure while in *X. cancila,* it is with some projections on the margin.(Fig.7b,8b) The light and dark lines of growth were observed. However, In *W. attu* the wing-like sagitta has an irregular rectangular outline. It is convex as seen on the exposed side while concave from the opposite side (Pandey and Tandon, 1976).

A number of workers have described the inner ear of elasmobranchs and found that it is similar to that of that found in teleosts with some variations.*(e.g.,* Lowenstein,1971; Retzius, 1881 Tester *et al.,* 1972), having the three semicircular canals with three otolithic areas containing the sensory epithelium, the macula. The author has also observed the disposed maculae in the three otolithic end organs.

It has been investigated that when fish moves in a sound field, the movement of otolith takes place in relation to the fish body and the sensory epithelium of end organs, thus stimulating the sensory hair cells (Popper *et al.*, 2005),

Studies have shown that unlike the teleosts, where otolith is a comparatively larger stony structure, in a number of species of elasmobranchs, the otolithic material is a small calcareous mass ranging from 2-50 micron embedded in the gelatinous matrix. These are known as otoconia or statoconia (Tester *et al.,* 1972; Popper and Rechard, 1977). Studies have shown the function of otolithic organs in the ray, *Raja clavata* and it was demonstrated that utriculus is related to maintaining the change in position during the movement,thus controlling the postural responses (Lowenstein and Roberts, 1950; Lowenstein, 1971). Lowenstein and Roberts (1950) further showed that the utriculus and sacculus maculae function as gravistatic receptors and the lagena plays an important role in maintaining the equilibrium. However, this aspect was not studied by the author in the present study and the author opined that further research may be carried out and one can correlate the aforesaid functions with that in the teleosts.

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

Schulz *et al.*(2011) studied the morphology of otoliths in situ and 3D structure of sensory epithelia of two ecotypes, of freshwater fish *Poeciliamexicana* by scanning electron microscopy, m-CT analyses, and immunocy to chemical methods and observed the variations mainly in the thickness of the otolithic membrane, shape, and curvature of the macula lagenae and in the curvature of the macula sacculi have been shown in two ecotypes of *P. mexicana.* However, the author only studied the position of the otolith and the presence of sensory epithelium in the macula, in the four fishes studied herein.

Conclusions

From the above study, it may be concluded that the gross morphology of the internal ear is more or less similar except for some minor variations in the diameter of semicircular canals and its lodgement in the skull. Moreover, variations in the shape and size in otoliths are species-specific and may play an important role in the identification of fish species.

References

Buran, B. N., Deng, X., Popper, A.N. (2005) Structural variation in the inner ears of four deep-sea elopomorpha fishes. *J. Morphol* .265: **215–225**.

Coombs,S. and Popper, A. N.(1982). "Structure and Function of the Auditory System in the Clown Knifefish*Notopteruschitala*," *J. Exp. Biol*. 97:**225–239**

Coombs, S. and Popper, A. N. (1979) "Hearing Differences Among Hawaiian Squirrelfish (Family Holocentridae) Related to Differences in the Peripheral Auditory System," *J. Comp. Physiol*. 132A, **203–207**.

Deng X, Wagner H-J, Popper AN (2011) The inner ear and its coupling to the swim bladder in the deep-sea fish Antimorarostrata (Teleostei: Moridae). *Deep-Sea Res I* 58: **27–37.**

Hunt, J.J.,(1992). Morphological characteristics of otoliths for selected fish in the Northwest Atlantic . *J Northw. Atl. Fish. Sc*i.; 13:**63-75**

Ýlkyaz. AT, Metin G, KinacigilH.T.(2011). The use of otolith length and weight measurements in age estimations of three Gobiidae species (*Deltentosteusquadrimaculatus, Gobiusniger,* and *Lesueurigobiusfriesii*). *Turk. J Zool;* 35(6):**819-827.**

Kasumyan, A. O.(2004b). "Vestibular System and Sense of Equilibrium in Fish," *J. Ichthyol.* 44 (Suppl. 2), **S224– S268**

Ladich F, Popper AN (2004) Parallel evolution in fish hearing organs. In: Manley GA, Popper AN, Fay RR, eds. Evolution of the vertebrate auditory system. New York: *Springer*. **pp 95–127.**

Lowenstein, O. and T. D. M. Roberts. (1950). The equilibrium function of the otolith organs of the thornback ray *(Raja clavata). J. Physiol.* 110:**392- 415.**

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

Lowenstein, O. (1971). The labyrinth. *In* W. Hoar andD. Randell (eds.), *Physiology of fishes,Academic Press, New York.* 5:.**207-240.**

Nolf, D. (1985) Otolithpiscium. *Handbook of paleoichthyology* 10: **1–145.**

Platt,1988 "Equilibrium in the Vertebrates: Signals, Senses, and Steering Underwater," in *Sensory Biology of Aquatic Animals*, Ed. by J. Atema, R. R. Fay, A. N. Popper, and W. N. Tavolga *Springer-Verlag, New York*. **783–809.**

Popper, A N.and Richard R. FAY (1977).Structure and Function of the Elasmobranch Auditory System *AMER. ZOOL.,* 17: **443-452**

Popper, A.N. (1977) Scanning electron microscopic study of the sacculus and lagena in the ears of fifteen species of teleost fishes. *J Morphol* 153: **397-418**

Popper AN (1981) Comparative scanning electron microscopic investigations of the sensory epithelia in the teleost sacculus and lagena. J Comp Neurol 200: **357–374.**

Popper, A. N.and R. R. Fay,(1993). "Sound Detection and Processing by Fish: Critical Review and Major Research Questions," Brain Behav. Evol. **41**, **14–38**

Popper, A.N.,(2011): Auditory system morphology. Encyclopedia of Fish Physiology: From Genome to Environment. Edited by: Farrell A. P., San Diego: Academic, **252-261**

Popper,A. N. and Platt, C.(1993) "Inner Ear and Lateral Line," in *The Physiology of Fishes*, Ed. by D. H. Evans *CRC Press, Boca Raton*. **99–135.**

Popper, A.N., Ramcharitar, J., Campana, S.E.(2005): Why otoliths? Insights from inner ear physiology and fisheries biology. *Mar Freshw Res.*, 56: **497-504**. 10.1071/MF04267.

Popper, A.N., Fay, R.R. (2011) Rethinking sound detection in fishes. *Hear Res* 273: **25–36**

John Umar, Ramcharitar, Xiaohong Deng, Darlene Ketten, Popper, A. N. (2004)Form and function in the unique inner ear of a teleost: The silver perch (*Bairdiellachrysoura*). *Comp. Neurol*. 475:**531–539,** Wiley-Liss, Inc.) C.

Retzius,G,Das(1881) Gehörorgan der Fische und Amphibien.Gehörorgan der Wirbelthiere. Stockholm: *Samson &Wallin*, 1: **1-222**

Rodriìguez Mendoza, R. P.(2006). Otoliths and their applications in fishery science. *Ribarstvo*.64(3):**89-102.**

Schulz-Mirbach T, Heß M, Plath M (2011) Inner Ear Morphology in the Atlantic Molly *Poeciliamexicana*—First Detailed Microanatomical Study of the Inner Ear of a Cyprinodontiformes Species. PLoS ONE 6(11): e27734. doi:10.1371/journal.pone.0027734

Schulz-Mirbach,TMartinHeß, Brian D Metscher&Friedrich Ladich (2013)A unique swim bladder-inner ear connection in a teleost fish revealed by a combined high-

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.

resolution microtomographic and three-dimensional histological study.*bmcbiol.biomedcentral.com.* Article number 75

Tandon, R.S.and Pandey, K.C. (1976).On the functional morphology of labyrinth-Weberianossicles-swim bladder complex of freshwater fish *Wallagoattu.J.Zool.Soc. India,*28,**139-145**

Tester, A.L., Kendall, J .I. and Milisen.W. B. (1972). Morphology of the ear of the shark genus *Car charhinus*with particular reference to the macula neglecta. *Pacific Sci.* 26:**264-274.**

Tuset, V.M., Lombarte, A., Assis, C.A. (2008) Otolith atlas for the western Mediterranean, north and central-eastern Atlantic. *Sci Mar* 72(S1): **7– 19**

Zorica, B., Sinovcic, G., Cikeskec, V. (2010)Preliminary data on the study of otolith morphology of five pelagic fish species from the Adriatic Sea (Croatia). *ActaAdriatica.*; 51(1):**85-92**

© 2015 Journal Anu Books Authors are responsible for any plagiarism issues.