THE VALUE OF OTOLITHS IN FRESH WATER FISHERIES
BIOLOGY AND TAXONOMY

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INTRODUCTION

The primary aim of this paper is an attempt to stimulate interest in the use of otoliths in fresh water fish biology in South Africa, as these structures have hitherto been grossly neglected. The paper is divided into three parts. The introduction briefly reviews international otolith research. The second part deals more specifically with otoliths as an aid to taxonomy and finally the use of otoliths in fresh water fisheries biology is discussed.

According to Stinton (1975) otoliths were first observed by Aristoteles in the 3rd century B.C. but only began to attract wider attention during the 19th century. Cuvier (1828) was the first to recognize their specificity. Shepard (1914) was the first fresh water fish biologist who described a few mormyrid otoliths. This was followed by Frost (1925bb and 1925c) who described some otoliths of fishes belonging to the Cypriniformes and the Siluriformes. Only in 1956 did the first major work regarding fresh water fish otoliths appear when Berinkey described the asterici otoliths of the Hungarian Cypriniformes. More attention was at this time, however, given to the otoliths of marine fishes (Frost 1925a, b & c, 1926, 1927, 1928, 1929 and 1930, Chaine et Duvergier 1934, 1935, 1936 and 1942, Bauen-Rullan 1956, 1958, 1959, 1960 and 1961). Since then this trend has been continued on a limited scale by Kotthaus (1967-1977), Karrer (1971), Fitch and Barker (1972), Trewavas (1977) and Hecht (1978a and b). Much attention has also been given to fossil otoliths - again however, with special emphasis on marine fishes (Weiler, 1942, Stinton 1966, Nolf 1970, Gaemers 1971 and Schwarzhans 1976).

The common names of fish used in this paper are according to Jackson (1975). The author has recently started building up a reference collection of fresh water fish otoliths. The aim of this collection is twofold. Firstly for the purpose of more elaborate systematic studies on South African fresh water fish otoliths. Secondly the collection will be available to workers wishing to identify fish remains from otoliths found in the stomachs of piscivorous predators.

Otoliths and Taxonomy

Three "earstones" or otoliths are found in the capsule audita on either side of the neorocranium. According to their structure the three otoliths are termed the sagitta, the astericus and the lapillus (Koken 1884). Except in the fishes of the orders Cypriniformes and Siluriformes, the sagitta is the largest of the three. The astericus, which is star shaped in the cypriniform fishes, is the largest of the three otoliths; and in the siluriform fishes, which include the barbels, catfishes and squerers, the lapillus is the largest. It is the sagittal otolith which is usually used for taxonomical purposes, as these show many more recurring features for comparative descriptions than either the lapillus or the astericus.
Although variations do occur the important sagittal features may be described as follows (see also Hecht 1978a and Fig. 1). The most important feature is the sulcus acusticus, a usually shallow furrow situated mid-majorty of cases indicates the anterior and posterior divided into an anterior wide ostium and a posterior usually superior and inferior, both of which are ridge-like borders on the dorsal and represented by a raised structure. In certain cases the colliculum occurs as antero-ventrally is the rostrum, usually larger than the antero-dorsally is the rostrum. In certain cases one or both of the rostra may be absent as in the case of the Mormyformes. The excisura ostiil is a V-shaped intrusion between the rostrum and the antirostrum. Its presence or absence the ontogeny of a species, genus, family or order. The sculpture of the outer. The dorsal and ventral areas are also important as regards their size, presence or absence. Similarly the presence of absence of dorsal grooves aspects include the natures of the medial and lateral faces of the otolith i.e. the case, or otherwise. The lateral side of the sagitta is usually devoid of any and to lesser extent in the Cypriniformes and Siluriformes. The otolith otolith-breadth relationship as well as the otolith-length/otolith-depth/ third of the sagittae as a taxonomic aid. Figure 2 shows the sagittal otoliths of the marine barbel, the marine barbel, Plotosus limbatis and the fresh water silver barbel Euptopus depressrostris: these represent three the figure clearly shows the similarity of otoliths of different families of the same order. The diagnostic features of the Siluriformes sagittae are the slender elongated rostrum and the presence of the ridge-like colliculum. Figure 3 shows the sagitta of E. depressrostris, T. feliceps and the sagitta close relationship between the Siluriformes and the Cypriniformes. This figure shows a otoliths must only be regarded as a taxonomic aid, they do not allow for the taxonomic purposes.

Figure 4 shows the distinctness of the otoliths of the Mormyformes (note the absence of both the rostrum and the antirostrum as mentioned above). It may perhaps be briefly mentioned that according to their sagittal structure the Salmonidae, which include the various trout species,
Sagittae of *Eutropius depressirostris* (top), *Barbus marequensis* (bottom left) and *Tachysurus feliceps* (bottom right).

Fig. 3

Sagittae of *Gnathonemus macrolepidotus* (top) and *Petrocephalus catastoma* (bottom) (Mormyridae).

Fig. 4

Left and right sagittae of a rainbow trout, *Salmo gairdneri*.

Fig. 5

do not fit into the general pattern of the Mormyridae as suggested by Jackson (1975); instead they should be included into the Salmoniformes as stated by Greenwood, et al. (1966) (compare Figs. 4 and 5). Figure 6 shows representative sagittae of perciform families. Included are the sagittae of the Mozambique tilapia, *Sarotherodon mossambicus*, the large mouthed black bass, *Micropterus salmoides*, the black tail or dassie, *Diplodus sargus* (marine) as well as the banded tilapia, *Tilapia sparmanni*. The figure clearly demonstrates the similarity of perciform otoliths, whether from marine or fresh water fishes. Characteristic of the perciform otoliths is the geometric shape and the clear definition of the sulcus acusticus.

Hopefully, by including the above figures, it has become sufficiently clear that otoliths should be incorporated to a greater extent into fresh water fish taxonomy than they have been up to the present time. Although marine ichthyologists are giving an ever increasing weight to otoliths (Collette and Chao 1975, Trewavas 1977) it must also be borne in mind that the systematic description of otoliths as an aid to taxonomy is still in its very early stages.

Otoliths and Fisheries Biology

The sagittal otoliths of eight of the ten fresh water teleostean orders
short term temperature fluctuations may, however, cause the deposition of 'false rings' or secondary rings on scales (Lee 1920). Such secondary rings could result in an overestimation of age. Hecht (1976) found this whilst working on demersal trawl fish species of the Eastern Cape coast and subsequently discontinued their use. Similarly, Baird (1974) experienced difficulties in successfully ageing mackerel, Scomber japonicus, using scales and also subsequently discontinued their use. Moreover, it has been noticed that in large specimen (>31cmTL) of Sarotherodon mossambicus, the rings are crowded towards the scale margin, which makes the reading difficult and more often than not results in an underestimation of age. Le Roux (1961) also mentions the problem of 'cutting over' which may also result in an underestimation of age.

It is well known that the pectoral spines of silurid fishes like the silver barbel, E. depressirostris and the sharp tooth catfish, C. gariepinus possess a hollow lumen which increases progressively with fish length (see Fig. 7). The possibility, therefore, exists that rings may be resorbed during the process of lumen enlargement, probably resulting in an underestimation of age.

Fig. 6

Sagittae of Tilapia sparmanni (top left), Sarotherodon mossambicus (bottom right) (Cichlidae), Diplodus sargus (top right) (Sparidae) and Micropterus salmoides (bottom left) (Centrarchidae).

occurring in South Africa (Jackson 1975) could possibly be used for biological studies such as age and growth. However, in the Cypriniformes and the Siluriformes the asteriscus and the lapillus should be used for age and growth studies respectively. For feeding studies the sagittal otoliths of all orders are used as they are more characteristic than any one of the other two. Age and growth studies on South African fresh water fishes have mainly been conducted using scales and the pectoral spines of fishes not possessing scales (Le Roux, 1961, Gaigher 1969 and Van der Waal and Schoonbee 1976). It appears that there has been no attempt to use otoliths for ageing except unsuccessfully by Van der Waal and Schoonbee (1975) working on the sharp tooth catfish, Clarias gariepinus.

A number of questions, however, arise when considering the scale and pectoral spine methods of ageing. Before continuing, however, it must hastily be added that experience has shown that the otolith technique of ageing also has its problems. It has been adequately documented that ring deposition on scales, spines and otoliths is caused by two major factors, viz. reproductive seasonality and seasonal temperature changes (Hickling 1933, Segerstråle 1933, Garrod 1959, June, and Roithmayer 1960 and Moreau 1974). Frequency of ring deposition caused by reproductive seasonality can easily be detected on scales, spines and otoliths. Severe
Similar to scales and spines when otoliths are used for age determination, the frequency of annual ring deposition has to be determined over a representative sample. This has to be done before any growth calculations may be attempted. Moreover, it must be determined whether a correlation exists between otolith length and fish length (Baird 1970, Botha 1971, Geldenhuys 1973 and Hecht 1977).

Pectoral spines, otoliths and scales have been collected on a monthly basis since October 1977 of four indigenous fresh water fish species from various localities in Lebowa and Venda. The four species include Sarotherodon mossambicus, Barbus marequensis, Clarias gariepinus and Eutropius depressirostris. Initial investigations have shown that otoliths are easier to read than either scales or spines. Moreover, it has been found that for all species concerned otoliths have a higher percentage readability than relatively good correlation between the number of rings on the otolith of the between otolith length and total fish length was found for all species. It has tentatively been found that one opaque and one hyalin ring are deposited on the otolith in the case of S. mossambicus, C. gariepinus and B. marequensis. In E. depressirostris two opaque and two hyalin rings are deposited on the otolith annually.

Some otoliths can be read whole e.g. those of S. mossambicus although better readings can be made from sections. Considering the size and the hard, brittle and usually opaque nature of otoliths due to their chemical composition (Degens et. al 1969), it is not at all surprising that they have not been used as much as scales and spines. A new apparatus has, however, recently been developed by Rauck (1976) of the Bundesforschungsanstalt für Fischerei in Hamburg, W. Germany. This technique allows 0.1 mm highly polished sections to be made. The apparatus was similarly used to cut sections from pectoral spines.

A number of figures have been prepared to show the rings on otolith sections. These are compared with scales and sections of silurid spines. Figures 9 and 10 show spine and otolith sections of the same respective fish. From these two figures it becomes evident that otoliths are read with greater ease than pectoral spines. Figure 11 shows a sagittal section of S. mossambicus, again illustrating ring formation. Figure 12 compares a scale and an otolith of the same mozambique tilapia and Figure 13 shows a section of a silver barbel otolith showing very legible rings.
Fig. 10
Spine and lapillus section of *Clarias gariepinus* (TL = 109 cm). (Age = 12 years).

Fig. 11
Sagittal section of *Sarotherodon mossambicus* illustrating ring formation. (SL = 27.0 cm) (Age = 8 years). One opaque and one hyalin ring deposited annually.

Fig. 12
Scale and sagittal section of *Sarotherodon mossambicus* illustrating distinct sagittal rings. (SL = 27.0 cm) (Age = 8 years).

Fig. 13
Lapillus section of *Eutrichius depressirostris* illustrating distinct ring formation. (TL = 33.2 cm) (Age = 5 years). Two opaque and two hyalin rings deposited annually.
Finally otoliths, due to their gross morphology and other diagnostic features as well as the positive correlation usually found between otolith and fish length, are ideally suited for feeding studies. These two aspects allow for both prey identification as well as the calculation of prey size. As previously mentioned a reference collection of fresh water fish otoliths has been started which should greatly facilitate the study of feeding habits of piscivorous predators such as otters, birds as well as fish. As far as could be ascertained otoliths have not previously been used in the interpretation of feeding habits in fresh water fisheries biology in South Africa. Otoliths of marine fish have, however, been successfully used for this purpose by Fitch and Brownell Jr. (1968 and 1971).

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ABSTRACT

The purpose of this paper is a twofold attempt to stimulate interest in the use of otoliths in freshwater fish biology in South Africa. Firstly the specific nature of otoliths and how they may, therefore, aid in taxonomy is discussed. Secondly it is shown that otoliths can be successfully used for ageing and subsequent growth studies. Their advantage over spines and scales in growth studies is also discussed.

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