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Comparison of Scale and Otolith Age Estimates for two Archer Fishes (*Toxotes jaculatrix*, Pallas, 1767 and *Toxotes chatareus*, Hamilton, 1822) from Malaysian Estuaries

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Abstract

A total of 85 specimens of archer fishes (*Toxotes chatareus* and *Toxotes jaculatrix*) from the estuaries of South Johore, Malaysia were examined for age determination using scales and otoliths aging methods. The accuracy of the methods was compared between scales and otoliths among the archer fishes. A linear relationship was found for both scale (r = 0.816) and otolith length (r = 0.971) with standard length (SL). Relationship between scale length and weight and otolith length and weight can be expressed by the formula $W = 0.0155L^{2.917}$, $W = 0.1082L^{1.834}$ respectively. Daily growth rings and annulus of scales count up confirmed that the ages of the samples for both species were mostly less than one years (<1) and the remaining samples were between one and two (1-2) years. We also observed that there were no remarkable differences between scale and otolith age reading and dissimilarity was only observed in very few samples of both species of archer fishes.

Key words: Archer fish, *Toxotes chatareus*, *Toxotes jaculatrix*, daily growth rings, otolith, scale

INTRODUCTION

The archer fish are a family (Toxotidae) of fresh-brackish water fish who have the ability to spit water droplets at aerial insects (either on the wing or resting on surfaces above the water), knocking them onto the water surface to be eaten [1]. There are seven species in the genus *Toxotes*, commonly referred to as archer fishes [2]. They are euryhaline, inhabiting primarily the brackish mangroves of the South Pacific and Indian Oceans, although they can also be found far upstream in fresh waters and in more saline coastal waters [3]. Archer fishes are migratory and spend most of their lives in highly tidal mangrove habitats [3-6] where they encounter a range of salinities (0-35) over various temporal and spatial scales [7].

There have been few reports on the biology and ecology of this fishes [8, 9, 10, 3-6]. Age and growth information is essential for a complete knowledge of life history, growth rates, age at sexual maturity, and average life span [11] moreover studies on the age and growth of fish are important for solving common problems in fishery management [12]. Determining the age of fish often involves counting increments in skeletal structures such as otoliths [13], opercula [14], vertebrae [15], scales [16], or fin spines and rays [17]. Certain species of fishes bear special organ or appendages that can be used to estimate their ages. For example, age determination in silurids catfishes are normally counts on concentric rings developed at the based of traverse section of pectoral spines [17] whiles in other teleost reads on annuli rings of the scales and sagittae otolith [11, 13]. However readability and reliability of age counts in fish species collected from the wild is subject to high ambiguity, due lack of details biological information. Perhaps larvae rearing in laboratory may provide the most accurate short-term age estimation but non-linear growth factors that controlled by wide range of variable such as nutrients, physico-chemical environmental factors and physiology of individual fishes may further impaired the age estimation in fishes.

Nevertheless, not all structures are of equal reliability or application, e.g., external structures such as scales may be taken without sacrificing fish, but are likely to underestimate age [18]. Currently, the interpretation of otolith structure is the primary method used for ageing Teleostean fishes [19], yet all methods of ageing must first be validated to both ensure that estimates are accurate, and to assess the precision of counts [18]. Recent research indicates that there is a close relationship between otolith weight and age [20]. Such relationships have been demonstrated in numerous species of both temperate and tropical fishes [20] other than archer fishes. We have recently described the population growth conditions of archer fishes [8] however; to the best of our knowledge no information is available on the age characteristics and method of age determination of archer fishes. Therefore, our main aim was to compare age estimates determined from scales and sagittae otoliths for the two archer fishes (*Toxotes jaculatrix*, Pallas, 1767 and *Toxotes chatareus*, Hamilton, 1822) inhabiting Malaysian estuaries. These data might help to facilitate further understanding about the biology of this fascinating fish species.

MATERIALS AND METHODS

Samplings of the fishes were carried out in the estuaries of south Johore (Latitude 01˚24'53N, Longitude 104˚09'44E) Peninsular Malaysia between November 2006 and April 2008. Samples were collected using 3 layered trammel, cast and scoop nets, traps as well as long lines. The mesh sizes of the trammel and cast nets were 4.2, 6.5, 7.5 cm and 2 cm respectively and of the scoop nets 1.5 cm. The length of the trammel net was 2000 cm; 250 cm for cast net and 40 cm diameter for scoop net.

Specimen identification was carried out in the field according to the description given by Allen [2].

Standard length (SL) of the fish was measured to the nearest centimeter (cm). Body weight was determined to the nearest 0.01g accuracy using an electronic balance. Sagittae otoliths were taken by dissection of the dorsal part of the fish head, where upper head sections were cut diagonally just below the base of the periscopic eyes. The Sagittae otoliths were processed to the desirable thickness and mounted on an epoxy-resin block prior to grinding using fine carbonized sand papers (# 1000, # 3000) [21, 22]. By contrast for each specimen about 10 scales were sampled from the central portion of the body below the lateral line [11, 23]. The scales were treated in 0.5% ammonia solution for at least 2 days, rinsed thrice with distilled water, dried and mounted between two microscope slides. Regenerated scales were discarded [11]. The mounted scales and otolith were labeled, observed and photographed under a HITACHI Table Top Scanning Microscope "TM -1000". The scales and otolith were weighted to the nearest 0.0001 g precision using an analytical balance, A & D "Model GR-200".

The daily increment or rings of the otoliths and scales were repeatedly counted using the Adobe Photoshop CS3 computer programme [21]. Age of the fishes was estimated based on back-calculation of the number of daily rings (age in days) as well as the annulus (age in years) on the scale, and otoliths as shown in Figure 1 [24, 25].

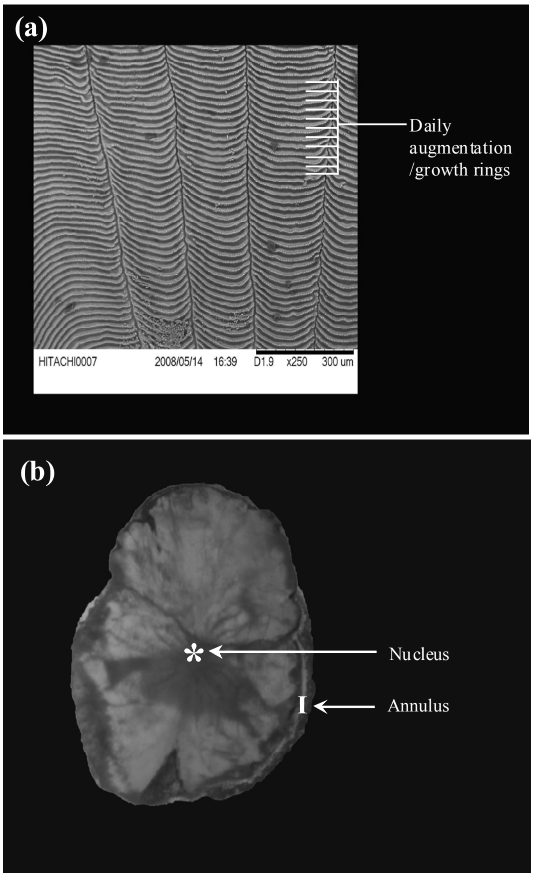

Figure 1. Electron micrograph showing daily increment/ growth rings (a) scale (b) otolith from an age 1+ individual archer fish (* = Nucleus, I = one annulus).

RESULTS

External morphology of scale and otolith

Scales of archer fishes are ctenoid, with 3–9 radii extending from the focus to the anterior margin. While the inner surface of the scale is smooth, the anterior and lateral fields of the outer surface are deposited with regular concentric circuli comprising individual platelets, and in the posterior field circuli are replaced by rows of ctenii (Figure 2).

On the other hand the sagittae otoliths are oval shape, with the rostrum (R) and the post rostrum (PR) clearly differentiated (Figures 3). The sulcus (S) extended from the anterior (A) area to the posterior (P) area and the internal face was slightly convex (Figure 3a, b). The dorsal (D) and ventral (V) margin of the otoliths is sinuate (rounded with regular wave-like curves) (Figure 3b).

The rate of somatic growth is indicated by the interspace between circuli. Rapid growth is characterized by circuli which are relatively far apart, and slow growth is characterized by closely packed circuli (Figures 2). An annulus is identified as the region with most densely packed circuli preceded and followed by regions of smooth transitions to regions with wide interspaces between circuli (Figure 1b, 2).

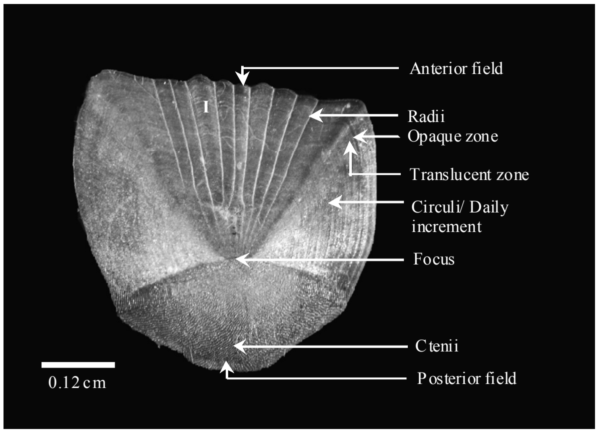

Figure 2. External view of scales (scale from an age 1+ individual archer fish, I= one annulus).

Growth checks or false-annuli are differentiated by their abrupt appearance or absence of the transition growth zones preceding and following the annulus, total width of the region, or by their relative position between annuli (Figure 2).

In our study we observed that there were no disparity between sizes and shapes of right (R) and left (L) otoliths of same individuals, therefore the following relationships were calculated with the measurements of the right otoliths (Figure 3a, 4). The largest (DM) and shortest (dm) otolith diameters were highly correlated (r^2 = 0.934 and S.D. = 0.020) (Figure 4).

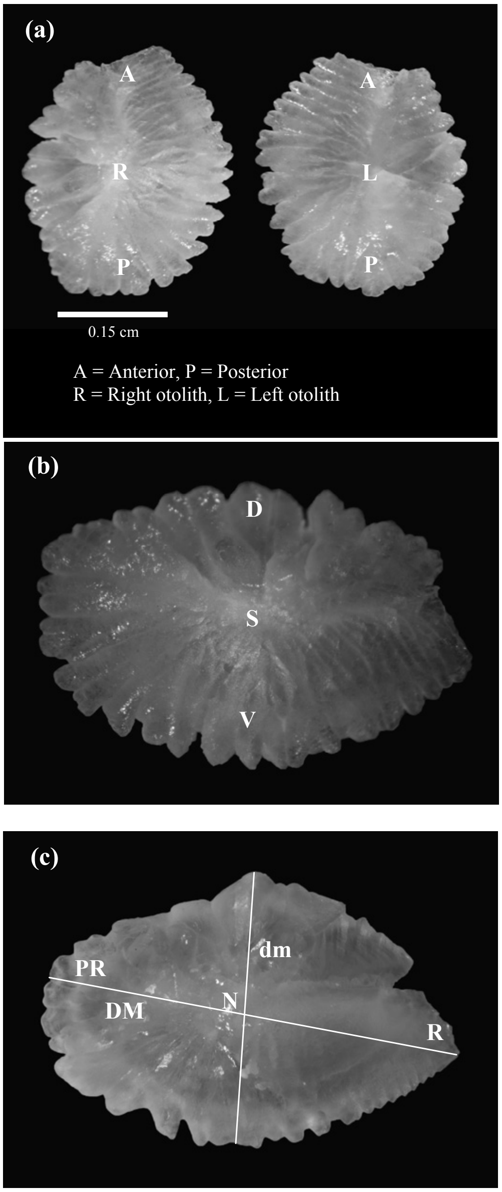

Figure 3. External morphology of the sagittae otolith (a) right and left otolith of archer fishes (b) D-dorsal, V-ventral, S-sulcus (c) dm-shortest diameter, DM-largest diameter, N-nucleus, R-rostrum, PR- Post rostrum.

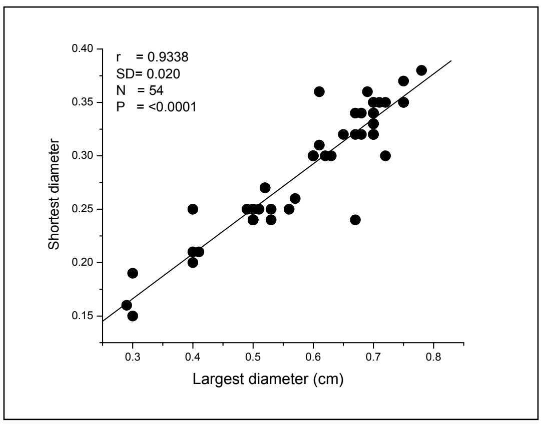

Figure 4. Relation between largest and shortest diameter of otoliths of archer fishes.

Age determination

A total of 85 archer fishes comprising *T. chatareus* and *T. jaculatrix* species were collected from the estuary of south Johore. Out of these specimens, a total of 33 *T. jaculatrix* and 21 *T. chatareus* individual scales and otoliths were examined and yielded interpretable age estimates. The remnant scales and otoliths were rejected because they were either broken or unreadable. Scales and otoliths for the two species showed clear growth zones with each zone consisting of wide translucent band and narrow opaque band (Figures 1, 2).

The length and weight of scales were highly correlated (r^2 = 0.924), similar result also observed in otolith length and weight (r^2 = 0.937), even though there was some divergences in their exponent "b" values (Figure 5). In scale the exponent "b" = 2.922 indicated that scale length augmented as scale weight increased (approaching to isometric type of growth form) while in otolith the "b" = 1.834, it played the opposing roll of growth form compared with scale.

On the other hand there was a linear correlation with scale and otolith length with fish standard length (SL) (r = 0.816, 0.971) respectively (Figure 6). The results demonstrated for the *T. jaculatrix* in the size of range 7.8-12.7 cm SL (n = 33) that estimated ages (both scales and otoliths analysis) were from 260-730 and 260-728, while for *T. chatareus* ranging from 6.9-12.4 cm SL (n = 21) the estimated ages were from 265-413 and 265-413 days, correspondingly (Figure 7).

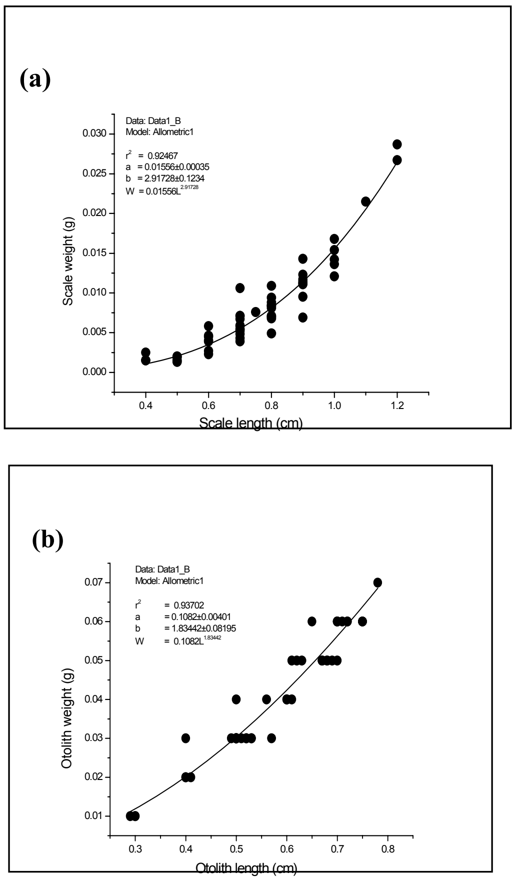

Figure 5. Relation of scale length and scale weight and otolith length and otolith weight of archer fishes (a) scale (b) otolith.

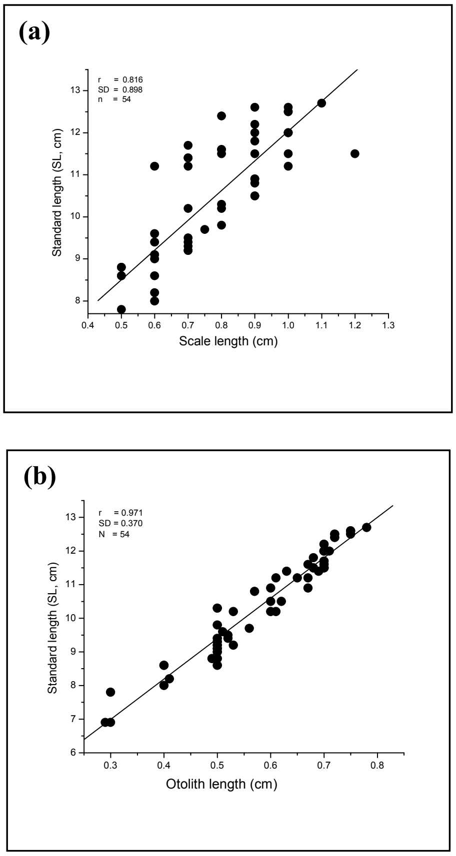

Figure 6. Relation of scale length and otolith length with SL of archer fishes (a) scale (b) otolith.

In the present study we observed that juvenile specimens (<1 years) were dominated in number than sub-adults or adults (1-2 years) specimens (Figure 7). We also noticed that the number of individuals in 1-2 years cohort were relatively higher in otolith ageing in comparison to scales ageing in both *T. chatareus* and *T. jaculatrix* species (Figures 7).

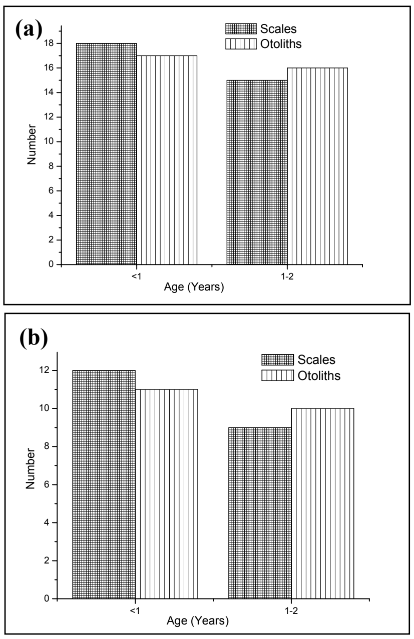

Figure 7. Age of archer fishes (<1= < 365 days, 1-2 = 365-730 days) (a) *T. jaculatrix* (b) *T. chatareus*.

DISCUSSION

Ageing of fishes from tropical waters has been reported through annual increments in calcified structures such as scales [24, 26], dorsal and pectoral spines [27, 28], vertebral centra [29], and otoliths [30]. Scales are the easiest to collect and process. Using scales as structures for ageing also avoids sacrificing the specimens like in ageing methods employing otoliths. Using scales for fish ageing, however, suffers drawbacks like difficulties in reading annuli, low precision [31], and that scale ages may become inaccurate when growth becomes asymptotic [32, 33].

But in the present study both scales and otoliths were found to be a very efficient and effective structure for ageing of archer fishes and the estimated ages from scales and otoliths were almost analogous for both *T. jaculatrix* and *T. chatareus* (Figure 7) fishes. We also have the same opinion with Sullivan et al. [34] that, otolith required prolonged preparation than removal of scale, and the otolith analysis demand special equipment for sectioning and is labor intensive. Besides, we also noticed that otoliths of the archer fishes often proved to be useless for age determination due to high opacity.

In this research the reliability of scale readings was increased by sampling scales only from a fixed position, where the scales have large uniform size, better symmetry, and high legibility [11]. On the other hand, as extremely senescent specimens were unavailable in this research, annuli readings have been relatively legible and reliable [11]. There is little information on the growth of archer fishes in the Asiatic regions, because the species is relatively scarce and specimen collection is cumbersome due to their sharp eye vision, movement speed and their paucity in the coastal waters.

In conclusion, the present study found that most of the archer fish population in the study areas comprises juvenile age group (<1 year) in comparison to sub-adult and adult age group (1-2 years). Our results also found that, the use of scales in age determination for archer fishes is more appropriate in comparison to otoliths. Furthermore the population of archer fishes species in Malaysian estuaries is dwindling over time due to fishing pressure and habitat destruction. Therefore the use of scales in age determination and life history study are pertinent for this rare fascinating fish species.

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REFERENCES

[1] Dill LM. 1977. Refraction and Spitting Behavior of Archerfish (*Toxotes chatareus*). Behavioral Ecology and Sociobiology. 2:169-184.

[2] Allen GR. 2004. *Toxotes kimberleyensis*, a new species of archerfish (Pisces: Toxotidae) from fresh waters of Western Australia. Records of the Australian Museum. 56:225-230.

[3] Froese R, Pauly D. 2005. Fish Base. Available at www.Fishbase.org.

[4] Allen GR. 1978. A review of the archer fishes (family Toxotidae). Records of the Western Australian Museum. 6(4):355-378.

[5] Luling KH. 1963. The archer fish. Scientific American. 209:100-109.

[6] Smith HM. 1936. The archer fish. Natural History. 38:2-11.

[7] Berletta M, Barletta-Bergen A, Saint-Paul U, Hubold G. 2005. The role of salinity in structuring the fish assemblages in a tropical estuary. Journal of Fish Biology. 66: 45-72.

[8] Simon KD, Mazlan AG. 2008. Length-Weight and Length-Length Relationship of Archer and Puffer Fish Species. The Open Fish Science Journal. 1:19-22.

[9] Simon KD, Mazlan AG. 2008. Trophodynamic analysis of archer fishes (*Toxotes chatareus* and *Toxotes jaculatrix*). In Proceedings of the IOC/WESTPAC 7th international scientific symposium 21-25 May 2008, The Magellan Sutera, Sutera Harbour Resort, Kota Kinabalu, Sabah, Malaysia.

[10] Temple SE. 2007. Effect of salinity on the refractive index of water: consideration for archer fish aerial vision. Journal of Fish Biology. 70:1626-1629.

[11] Chung KC, Woo NYS. 1999. Age and growth by scale analysis of *Pomacanthus imperator* (Teleostei: Pomacanthidae) from Dongsha Islands, southern China. Environmental Biology of Fishes. 55:399-412.

[12] Polat N, Bostanci D, Yilmaz S. 2001. Comparable Age Determination in Different Bony Structure of *Pleuronectes flesus luscus* Pallas, 1811. Inhabiting the Black Sea. Turkish Journal of Zoology. 25:441-446.

[13] Francis RICC, Paul LJ, Mulligan KP. 1992. Ageing of adult snapper (*Pagrus auratus*) from otolith annual ring counts: validation by tagging and oxytetracycline injection. Australian Journal of Marine and Freshwater Research. 43:1069-1089.

[14] Hostetter EB, Munroe TA. 1993. Age, growth, and reproduction of tautog *Tautoga onitis* (Labridae: Perciformes) from coastal waters of Virginia. Fisheries Bulletin. 91:45–64.

[15] Francis MP, Mulligan KP. 1998. Age and growth of New Zealand school shark, *Galeorhinus galeus*. New Zealand Journal of Marine and Freshwater Research. 32(3):427-440.

[16] Jones GP. 1980. Growth and reproduction in the protogynous hermaphrodite *Pseudolabrus celidotus* (Pisces: Labridae) in New Zealand. Copeia. 4:660-675.

[17] Davis TLO. 1977. Age determination and growth of the freshwater catfish, *Tandana tandanus* Mitchell, in the Gwydir River, Australia. Australian Journal of Marine and Freshwater Research. 28:119-137.

[18] Beamish RJ, McFarlane GA. 1983. The forgotten requirement for age validation in fisheries biology. Transactions of American Fisheries Society. 12(6):735-743.

[19] Stevenson DK, Campana SE . 1992. Otolith microstructure examination and analysis. Canadian Special Publication of Fisheries and Aquatic Sciences. 117:126.

[20] Lou DC, Mapstone BD, Russ GR, Davies CR, Begg GA. 2005. Using otolith weight-age relationships to predict age-based metrics of coral reef fish populations at different spatial scales. Fisheries research. 71:279-294.

[21] Mazlan AG, Rohaya M. 2008. Size, growth and reproductive biology of the giant mudskipper, *Periophthalmodon schlosseri* (Pallas, 1770), in Malaysian waters. Journal of Applied Ichthyology. 24:290-296.

[22] Secor DH, Dean JM, Laban EH. 1991. Manual for otolith removal and preparation for microstructural examination. Baruch Institute Technical Report, University of South Carolina, Columbia.

[23] Paul LJ. 1967. Early scale growth characteristics of the New Zealand Snapper, *Chrysophrys aurats* (Forster), with reference to selection of a scale-sampling site. New Zealand Journal of Marine and Freshwater Research. 2:273-92.

[24] Werder U, Soares GM. 1985. Age determination by sclerite numbers, and scale variations in six species from the central Amazon (Osteichthyes, Characoidei). Animal Research and Development. 21:23-46.

[25] Campana SE, Neilson JD. 1982. Daily growth increments in otoliths of starry flounder (*Platichthys stellatus*) and the influence of some environmental variables in their production. Canadian Journal of Fisheries and Aquatic Sciences. 39:937-942.

[26] Mayekiso M, Hecht T. 1988. Age and growth of *Sandelia bainsii* Castelnau (Pisces: Anabantidae) in the Tyume River, Eastern Cape (South Africa). South African Journal of Zoology. 23:295-300.

[27] Ezenwa BIO, Ikusemiju K. 1981. Age and growth determination in the catfish, *Chrysichthys nigrodigitatus* (Lacepede) by use of the dorsal spine. Journal of Fish Biology. 19:345-351.

[28] Pantulu VR. 1961. On the use of pectoral spines for the determination of age and growth of *Mystus gulio* (H). Proceeding National Institute of Science India. 27B:1-30.

[29] Brown CA, Gruber SH. 1988. Age assessment of the lemon shark, *Negaprion brevirostris*, using tetracycline validated vertebral centra. Copeia. 3:747-753.

[30] Fowler AJ, Doherty PJ. 1992. Validation of annual growth increments in the otoliths of two species of damselfish from the southern Great Barrier Reef. Australian Journal of Marine and Freshwater Research. 43:1057-1068.

[31] Lowerre-Barbieri S. Chittenden ME. Jr, Jones CM. 1994. A comparison of a validated otolith method to age weakfish, *Cynoscion regalis*, with the traditional scale method. United States Fish Bulletin. 92:555-568.

[32] Beamish RJ, McFarlane GA. 1987. Current trends in age determination methodology. pp. 15-42. *In*: R.C. Summerfelt & G.E. Hall (ed.) Age and Growth of Fish, Iowa State University Press, Ames, Iowa.

[33] Shepherd, GR. 1988. Age determination methods for northwest Atlantic species, weakfish *Cynoscion regalis*. pp. 71–76. Age Determination Methods for Northwest Atlantic Species (ed. In: Penttila, J, Derry LM), NMFS 72. 135 pp. NOAA Tech. Rep.

[34] Sullivan SO, Moriarty C, FitzGerald RD, Davenport J, Mulcahy MF. 2003. Age, growth and reproductive status of the European conger eel, *Conger conger* (L.) in Irish coastal waters. Fisheries Research. 64:55-69.