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Recent studies on age determination of Indian fishes using scales, otoliths and other hard parts

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ABSTRACT

At present it is customary to use the growth rings found in the scales, otoliths or other hard parts of fishes to assess the age at different periods of their lives. Though such rings were sometimes discovered in the past in India also, they were rejected in view of the absence of clear summers and winters in our waters as occurring in temperate waters where clear growth differences are known in the fishes and in their above said hard parts. Examination of the scales of *Cynoglossus semifasciatus* Day at Calicut in the middle of this century proved not only the annual periodicity of the ring formation but also the causes of the same. Such rings or annuli were later found in the other species of *Cynoglossus* at Calicut and also in many other fishes elsewhere by other workers, though in a few cases there were difficulties because of the occasional occurrence of abnormalities and false checks in the scales, making the interpretations a bit difficult. Later, coverage of more species from different centres revealed the widespread occurrence of growth rings (also called *annuli*) caused by factors other than seasons alone and their usefulness in age determinations. In the present paper the recent developments made in india in this discipline of fishery biology are briefly reviewed.

Introduction

Age and growth studies are important aspects of modern fishery biological researches, as information on these are essential for the scientific interpretation of the fluctuations in the fish populations from time to time and place to place and to evolve economic management policies for the concerned fisheries whether marine or otherwise.

Four main methods or their modifications are available at present for determining the age and growth rates of fishes: (1) Petersen's method of length-frequency analysis, (2) study of the annuli or annual rings occurring in the scales, otoliths or other hard parts of the body along with some other biological studies, (3) rearing the fishes in captivity under controlled or near-natural conditions and observing their growth as well as ring-formation in the scales, otoliths etc. and (4) tagging different sizes of the live fishes after noting data on their size, weight and scales and examining the recovered fishes for all the noted characters. As a matter of fact however, this last mothod is beset with difficulties because only some of the tagged fish are recovered owing to practical difficulties.

The length-frequency analysis method of Petersen is well known and is used by fishery biologists all over the world; however, in spite of the niceties of highly sophisticated techniques involved in the analysis of the length data, limitations still remain in using them for the enquiries on population parameters, particularly the different year-classes of each species in its fishery and their influence on the catch-compositions in future years by following the measurements. Often varification of data obtained by other methods such as rearing and scale-examination provides confirmatory evidence so that the results can be declared with confidence. At present, scales, otoliths and other hard parts like the operculum, clavicle, vertebral centra and even the finrays are studied in both marine and freshwater species with encouraging results. Scales and otoliths are the most frequently used items, particularly the scales which are easier to handle and work on. Bones, finrays and such other structures are also used occasionally, when scales and otoliths fail to give good results or in some cases, for comparison of results of different methods.

Tagging programmes have been useful only in a limited way for age determination in view of very little recovery of specimens for any far-reaching conclusions.

Rearing fishes in captivity for age and growth studies is occasionally done, but the difficulties here relate to the creation of suitable environmental and experimental conditions so that the results may reflect the happenings in the natural environment in all its details. Considering all the methods thus available at present, it has to be concluded that the age-ring method using scales, otoliths or other hard parts is the most satisfactory.

Our knowledge by the middle of the century

Menon (1950, 1953) has given a detailed review of the studies in this line during the first five decades of the century; his review not only gives a good summary of earlier work but also encourages workers in the tropical-regions of the world (especially India) to continue further studies by this method. He believed that internal physiological rhythms rather than environmental factors were determining the formation of the growth rings but when once their periodical regularity in appearance is proved they could be utilised for age determination.

Though some work was initiated in India even earlier by Rao (1935) on *Psettodes erumei*, Hora and Nair (1940) on *Hilsa ilisha*, Devnesan (1943) and Hornell and Nayudu (1924) on *Sardinella longiceps* and Chacko *et al.* (1948) on *Hilsa ilisha*, owing to lack of knowledge on the periodicity in the formation of rings in the forms studied, different interpretations were given regarding the age of those species, which are now proved wrong. Annuli were noticed in the mackerel at Calicut in the early years but subsequently the results seem to have been given up for reasons not known. Jones and Menon 1951 could not find useful rings in the *Hilsa* scales, while Chidambaram and Krishnamurthy (1951) could not find rings in the mackerel otoliths.

Progress during latter half of the century

Seshappa and Bhimachar (1951, 1956) found good growth rings in the scales of the Malabar sole *Cynoglossus semifasciatus* Day and confirmed by round-the-year observations of the scale margins at Calicut, that the rings were formed during the southwest monsoon period when food was scarce and the environmental factors such as salinity and temperature were also unfavourable. With lapse of time the rings were seen gradually to shift to positions "deeper" and "deeper" inside the area of the scale, away from the margin. The spaces between successive circuli were also found wider with increased availabiliy of the favourite food of the species in the environment which caused increased growth of the fish. Seshappa (1976, 1981) and Seshappa and Chakrapani (1984) continued further observations on the scales of *C. semifasciatu* and confirmed the earlier findings regarding the occurrence of annuli in them. Seshappa (1981) found good annuli in the other species of *Cynoglossus* also at Calicut they being *C. dubius, C bilineatus, C. macrolepidotus, C. puncticeps* and *C. lida.* Krishnan Kutty (1972) made a detailed study of the scales of *C. macrolepidotus* at Cochin and found the scales to be very useful for age and growth determinations. *C. dubius* and *C. macrolepidotus* both grow to fairly larger sizes than the Malabar sole. Occasional false rings also have been seen in the scales of *C. semifasciatus* and they were particularly dominant during 1980-'81 along the Kerala and Karnataka coasts presumably due to some adverse environmental happenings which could not be determined. But the false rings were useful along with the true rings for the comparison of samples from different centres for raciation studies.

Devasundaram (1952) found annuli in the scales of the mullet, *Mugil cephalus* but suspected their validity for age determination, though he could identify one ring in the 300-320 mm group, two rings in the 420-550 mm length-group and three rings in the 570-650 mm group. He also found a straight line relationship between the lengths of the scale and the fish.

Sarojini (1958 a, b) studied the annuli in the scales of *Mugil cephalus* and *M. parsia* of Bengal and found that in each species their number, identity and relative size were constant throughout life. The annuli were formed regularly about the same season every year and the lateral line scales were also same in number throughout the life of the fish. Contrary to the common belief these annuli were not spawning marks but were formed due to environmental factors like temperature.

Das (1959, 1964) and Das and Fotedar (1965) proved the existence of the annuli in the scales of many freshwater fishes of northern India such as, *Anabas testidunius, Mugil corsula, Hilsa ilisha, Cirrhina mrigala, C. reba, Labeo bata, Barbus sarana, Gadusia chapra* and *Notopterus chitala.*

Seshappa's finding of annuli in the scales of the 'ghol', *Pseudosciaena diacanthus* and the 'koth' *Otolithoides brunneus* was confirmed by Venkatasubba Rao (1961) and Narayanan Kutty (1962). In *P. diacanthus* the annuli ranged from a single one in a fish of 44.6 cm (mean lenth) to as many as eight in fish of 115.3 cm mean length. Otoliths also showed hyaline and opaque zones, the distances between successive hyaline zones being measured and taken for back-calculation of the fish lengths at different ages. Narayanan Kutty (1962) found one annulus in the smallest specimen of 140-149 cm (mean length) in *O. brunneus*. In both the species the results from scales and otoliths were in fair agreement. Srinivasa Rao (1971) also corroborated the validity of the rings and their annual nature in the 'ghol'. He also found a larval ring (perhaps equivalent to the larval ring reported by other authors in some fishes) but he differed from Venkatasubba Rao (1961) who thought that the cause of annuli formation was multiple, including both external (environmental) factors and inherent physiological rhythms in the fishes.

Qasim and Bhatt (1964) found clear annuli in the opercular bones of *Ophiocephalus punctatus* and used them for reading the age of the fish, this fish having a longevity of 4 to 5 years. Qasim (1973) reviewed the age determination studies in the Indian marine fishes and stressed the need to remember the general principles of fish growth in tropical conditions which differ greatly from those of the colder waters of the temperate and semi-temperate climates. He emphasised that wherever rings are found in the scales, otoliths etc. in our fishes, the causative factors and the annual regularity of their formation must be studied and confirmed before using them in the age determination work. He felt that the findings upto that period were not very encouraging in some forms studied and therefore experimental work was the only way out for them. He also pointed out that the practical use of the age determination method by means of scales etc. was limited in the case of many of our inshore fishes (these forming the dominant part of our catches at present), as most of them were short-lived and grow to only small sizes which do not involve many year-classes to be analysed.

Deshmukh (1973) found good annuli in both scales and otoliths in the 'karkara' *Pomadasys hasta* and studied them for about six years from the trawler landings along the Gujarat and Maharashtra coasts, and found 1, 2, 3 and 4 annuli respectively in the fish measuring 24.6, 34.6, 46.5 and 52.0 cm respectively in length. He fixed the temperature as responsible for the formation of the rings and that they were not spawning marks because two rings were already formed when the first spawning occurred.

Seshappa (1958, 1972) found clea annuli in the larger sizes of the Indian mackerel, *Rastrelliger kanagurta* on the west coast at different centres. It was found that while all specimens below 21 cm total length were without any rings in the scales, while those having 23 cm and above had the rings in a large number of specimens from Cochin to Karwar and Ratnagiri. Two rings were frequent in the fish measuring 25 cm and above in length while three to four rings were found in the largest fish (32 cm and larger). Rings were found frequently at Vizhinjam further south on the west coast and at Mandapam on the east coast. The cause of ring formation here was concluded to be the physiological stress on the metabolism due to the maturation process of the gonads in their advanced stages and also the spawning activity during which there was no feeding.

Luther (1973) found no rings in the scales of *R. kanagurta* of 25-27.9 cm length range in the Andaman Sea, there being only one annulus in specimens above 27.9 cm total length. Here also the ring formation was concluded to be due to the maturity and spawning stress as in the case of mainland mackerel mentioned above (Seshappa 1958, 1972). The Andaman mackerel, though classified still as only *R. kanagurta* (Jones and Silas, 1962) has been suspected to be of a different stock from that of the mainland of India, and the spawning size and age from the scales supported this view further. Jones and Silas (1962) did not examine the larger sizes from Andamans.

Dan (1980) found opaque and hyaline rings in the otoliths and opercular bones of the catfish *Tachysurus tenuispinis*, the hyaline rings showing an age of 3.5 years for a fish of 39.7 cm length. Govind and Gopal (1966) found valid growth rings in the cleithral bone of *Silonia childrenii*, while Nammalwar (1973) found upto five annuli in the vertebrae of *Pomadasys hasta* the number increasing gradually with increasing size. Soni and Benson (1986) used otoliths for age determination in *Boleophthalmus dentatus*. Menon (1986) found good annuli in the otoliths, vertebrae as well as pectoral spines of *Tachysurus thalassinus* at Mangalore and compared the data with those obtained in length-frequency analysis by probability graph and also the Bertalanffy formula. In addition he also reared specimens in an aquarium tank for 13 months from the embryo stage to a length of 315-320 mm. There was reasonably close agreement in the growth of the fish, from the different methods; this was 1, 2, 3 and 4 years of age at lengths of 251.3, 345.5, 451.7 and 523.6 mm respectively from the otoliths, there being also a larval ring at a fish length of 80-90 mm.

Much work has been carried out on age determination of the freshwater fishes of northern India by the staff of the Zoology Department in the University of Punjab. Tandon and Johal (1983 a) found annual rings in the scales of *Puntius sarana* from river Ghaggar in Rajasthan and in Sukhna lake in Punjab, formed during March-May owing to spawning stress. But food and temperature also were suspected to have added a role in the formation of these rings. False checks were noticed but left out correctly in the reckoning. The rings were examined through a micro-film reader and numbered 1, 2, 3 and 4 respectively at fish lengths of 23.3, 28, 36 and 41 cm respectively. In another paper in the same year Tandon and Johal (1983 b) described the phenomenon of growth compensation in the major carps *Cirrhina mrigala, Labeo rohita* and *Catla catla*. Specimens of the mrigal were examined from Rangamahal, of rohu from Rangamahal as well as river Sutlej, and of catla from Gobindsagar. In all these the growth was noticed to fall down in a certain year to be compensated by increased growth in the following year; a growth compensation of this nature seems to be a natural phenomenon that could occur at any stage, and the authors felt that it was due to availability of more space and food to the older fish and a "lesser selectivity of the present day tackles". Some workers seem to believe that this growth compensation is the same as Lee's (1920) phenomenon of apparent change in rate of growth (Shree Prakash and Gupta 1986).

Tandon and Johal (1983 c) who dealt with the age and growth of the mahseer *Tor putitora* (Hamilton) recorded as many as 17 annuli in the scales of a 127 cm long fish, the scales themselves measuring 6.7 by 6.12 cm. Growth compensation was noticed in this case also between the year-classes 2-3, 5-6, 8-9, 10-11 and 13-14. Based on the growth parameters and constants the authors recognised three phases in the life of the fish here, viz. an active growth phase in the first six years, a slow growth period in the next 6 years (7th to 12th years) and the old age phase in the last six years (13th to 17th years).

Johal and Tandon (1983) used scale-ring data successfully for determining the age and for prescribing an age-limit for the capture of catla and mrigal at that period in the Sukhna lake, Chandigarh. Catla had 8 annuli (age 8+ years) in the largest size-group while mrigal had only 3 rings (age 3+ years). Catla grew fast upto the end of first three years but after the age of 4+ years the weight increased faster than the length. The overall growth in both fishes was, however, quite slow. Back-calculations were successful upto L_8 in catla and L_3 in mrigal. Based on the study of growth curves it was decided that catla should not be caught in the first three years of life while all mrigal must be caught when they are over two years in age, to get optimum benefit from the fishery.

In 1986 Johal and Tandon published their work on *Labeo rohita* from Rangamahal and Harike on age and growth determinations by means of scale rings. They estimated all growth parameters and constants, and also noticed growth compensation between the ages of 4 & 5 at Rangamahal and between 5 & 6 and 7 & 8 at Harike. Of the three stages the third (old age) was absent and it was felt that the cause of this was a poor exploitation rate at those centres at that time. Johal and Tandon (1986) using the scale ring data found the growth compensation phenomenon in *Cyprinus carpio* . Growth compensation occurred after the 3rd year in Sukhna lake, after the 4th year in river Ghaggar and after 5 years in the Nangal lake while it occurred after the 6th year in the same lake. The compensation was noticed in the older fish only, the cause being guessed as selective mortality. The same authors in 1987 published their *scale ring studies* (continuation work) on *Cirrhina mrigala* at the above centres. The annuli were very good at all the centres though there were occasional false checks caused by unfavourable conditions. A larval ring was also noticed enclosing the first annulus not far from the growth centre of the scale. The rings were formed during February -June and especially in April-May, with "a probable association" with the monsoon conditions of the environment.

Johal and Kingra (1988) have discussed the harvestable size of the golden Mahseer *Tor putitora* for its conservation. This fishery was declining for some years in Gobindsagar in Himachal Pradesh and so its legal size limit for capture was raised from 30 to 40 cm length prompted by the age and growth rate data derived from the scale rings.

In 1989 and 1993 Johal *et al.* conducted studies on *Colisia fasciata* and *Labeo calbasu,* the former from a village tank in Ludhiana (Punjab) and the latter from river Ghaggar. Good annuli were found in both the species. *L. calbasu* populations grew better in the river than in the reservoir; juveniles of the 1+ and 0+ year-classes (i.e. the one-year and zero-year olds) as well as the advanced age phases of this species were absent in the catches. In *C. fasciata* the annual weight increased directly with age and there was a growth compensation between the third and fourth years.

The work of Johal and Tandon (1992) on *Catla catla* from Harike and Gobindsagar during July 1978-June 1981 showed the formation of the annuli in June-July coinciding with the commencement of spawning and the beginning of the southwest monsoon. Growth compensation was noticed between the 4th and 5th years, the old age phase occurring thereafter. All three growth phases were noticed in these samples.

Tandon and Johal (1993) conducted an electron-microscopic examination of the scales of *Labeo rohita* and *Puntius sarana*, and this disclosed a larval ring and also the phenomenon of growth compensation in *L. rohita* but not in *P. sarana*. Growth in both was fast upto the end of the first year and slowed down thereafter.

Tandon *et al.* (1993 a) worked out the growth parameters of *Tor putitora* from Gobindsagar and found annuli both in scales and opercular bones, they being designated as "winter-rings" formed during the November-February period. False checks were occasionally present but were duly identified and rejected. The results agreed with the earlier findings of Patani (1981) on the same species in the same area.

A chemical analysis work was made by Tandon and Johal (1993) on the mineral composition of the scales in *T. putitora* using the Energy Dispersive X-ray Micro-analysis technique, with interesting results. Calcium, iron, phosphorus and aluminium were found in the scale in its different regions or zones; a fall in iron level and increase in calcium resulted in the formation of an annulus. Rolling over of the scale margins was associated with excess deposition of aluminium. Johal and Dua (1994), using the same technique studied the chemical composition of the scales of *Danio (Danio) devario* and *Amblypharyngodon microlepis* and inferred that calcium, aluminium and iron were the major constituents of the scales. While phosphorus helped in the formation of phosphates; its concentration was found to vary in different regions of the scales.

Johal and Dua (1994) experimented on the effects of non-lethal doses of endosulfan and suggested that scales could also be used as indicators of pollution, as their surfaces became eroded with poisonous substances. They used scanning electron microscopy in this work also. These authors continuing work in the same lines on *Channa punctatus* (Johal and Dua, 1995) found the scale margins "disorganised" when exposed to endosulfan and that these scales contained phosphorus, calcium, aluminium, iron, sulphur, silica and chlorine elements in them.

Discussion

For a long time from the beginning of fishery research the length frequency study (initiated by Petersen) was the only method available for use in age determination in fishes. The discovery of regularly formed growth rings or annuli in the scales, otoliths and other hard parts has provided a dependable additional and alternative method to assess the size of the fish at various phases in its past life-history. Difficulties were encountered in some species (and regions) because of the occasional occurrence of what are known as false or abnormal rings with wrong structures and in wrong seasons, positions and places. These difficulties were overcome in a large majority of cases after a more detailed study of the nature of the true rings themselves in each case, as often the false or abnormal rings are caused by variations in the seasons and places of capture of the samples, environmental changes, food, temperature, salinity etc. each having its effects on the ring formation. In our waters, unlike in the temperate forms the normal appearance (form, structure as well as position of the annuli) of the scales has to be determined for each area and species separately in the beginning itself and the validity of the method for general adoption as a routine established. It is reassuring to note that in the studies conducted so far in this country, (leaving out a few exceptions) this caution has been duly exercised, especially after Qasim (1973).

The ring formation can also be due to inherent physiological causes but modified by food and other environmental factors. It is also to be remembered that while the determination of the cause of ring formation is indeed important, the establishment of its regular and annual nature are more important for using the scales in age determination which is the purpose for which their significance has been realised and their study was taken up at first. As stated above this question has been foremost in the schemes of work of all workers at present and in the past decades also.

Among earlier works abroad on chemical analyses of scales and otoliths connected with the age determination studies, special mention may be made of the works of Takaaki Irie (1960) and Eva Dannevig (1956). The former studied otoliths of two species of Japanese fishes by autoradiographs using calcium-45 as tracer to measure calcium deposits at the surface and scales were examined under the electron microscope. Otoliths grew mainly by the deposition of calcium as crystals; an opaque zone appeared as some protein was formed in the grooves between the calcium crystals, this being *influenced soley by the water temperature* and not by the calcium content of the water. Eva Dannevig (1956) cites the earlier workers in this field relating to the chemical composition of the otoliths and their zones in the cod. The percentage values of different constituents have been tabulated by her.

As presently known, the deposition of the different chemical elements takes place in the different zones of the scales and otoliths and they must naturally be reaching the fish and its scales or otoliths either directly during each particular season or they must be present in the body of the fish itself somewhere or the other before the season, and transported to the final sites (in the scales, otoliths etc.) under some physiological stimulus. In Irie's experiment mentioned above it is clear that it was the physiology of the fish and not the contents of the surrounding water that influenced the increased deposition of calcium in the otoliths. Therefore it is reasonable to expect that further work in this line may throw new light on the involvement of the different chemical elements in the formation of the regular rings or annuli in the scales and/or otoliths or any other hard parts of the body of a fish. However, it is quite clear that the findings in this respect will not in any way vitiate the usefulness of these annuli in age and growth studies in the species concerned subject to the country. The author therefore stresses the need for these studies to be continued more intensively as well as extensively on all important species of Indian fishes from all water bodies both marine and inland.

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