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Comparative studies on age and growth patterns of cultivated and wild *Catla catla* (Hamilton)

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Catla catla (Hamilton) is one of the fastest growing Indian major carps (IMCs) with increasing market demand. Consistent demand and exploitation invites the attention of ichthyologists for its conservation strategies. Age and growth studies play a pivotal role for managing the fishery stocks in different water bodies. Here, we studied the age and growth patterns using opercula of both farm grown as well as the wild grown *C. catla* adopting standard methodologies. Wild specimens were caught from Harike wetland (Ramsar site) and the cultivated one from a farm at Dhudike in Punjab. High value of correlation coefficient 'r' 0.976 (wetland) and 0.983 (farm) reveals the strong relationship in total length and operculum radius of the fish. *C. catla* achieved average total length from wetland and farm, respectively at 1st (273.44 mm) 2nd (427.44 mm) 3rd (525.49 mm) 4th (624.52 mm) 5th (744.98 mm) 6th (813.62 mm) and 1st (282.1 mm) 2nd (463 mm) 3rd (601.7 mm) year of age of opercular bones study. The growth parameters such as, index of species average size (φh) 135.6 (wetland) and 200.6 (farm), growth constant (C_{lt}) showed two growth phases from both localities i.e. sexual immaturity up to 2 years and sexual maturity afterwards. Whereas, growth characteristic (C_{th}) has revealed irregular growth pattern at wetland in comparison to growth of fish from farm. The results of this study concluded that the fish experienced more growth from the farm due to better and controlled conditions but, in wetland surrounding conditions were observed to be unfavourable for survival of the fish *C. catla*.

Keywords: Back calculation, Indian major carp, Opercular bones

Catla catla is an endemic to the riverine system in northern India, Pakistan, Nepal, Bangladesh and Myanmar. Due to the fastest growth of the fish, it forms an integral component, both in three and six-species composite carp culture. It is cost effective and has good market demand locally. In aquaculture, *C. catla* is the best choice as it fetches good income in short period compared to other fishes. Consistent demand has prompted the ichthyologists to work on conserving these species[1]. Age and growth studies are basic and provide imperative information that aid the fish biologists to formulate the guidelines for *in situ* conservation of fish fauna[2,3]. Different calcified structures, such as scales, opercular bones, vertebrae, pectoral and dorsal fin spines, otolith, etc. are being used to explore the age and growth in numerous fish species. Amongst varied hard parts opercular bones were found to be reliable parts of the skeleton for the determination of age in *Catla catla*[4], *Oreochromis aureus*[5] and *O. niloticus*[6]. Two growth zones, opaque and translucent collectively represent growth of one year on opercular bones in *Schizothorax o'connori*[7] but, concluded with underestimation of age in comparison with otolith and vertebrae of the fish. In *Boops boops*[8] and *Abramis brama*[9] opercular bones were also reported inferior for ageing. In recent decade, Indian authors focused to find the precise age structure from different hard parts being used to estimate age and growth in diverse fish species. Accurate selection of hard parts, such as vertebrae in *Sperata aor*[3], *Mastacembelus armatus* and *Ompok pabda*[10], *Salmophasia balookee*[11], opercular bones in *Catla catla*[4] and *Hypophthalmicthys molitrix*[10], scales in *Labeo rohita* and *Channa marulius*[4], *Cirrhinus mrigala*[12,13], otoliths in *Salmophasia balookee*[11] and thin-sectioned otoliths in *Sperata aor*[14] could play important role while framing conservational strategies for reported fish species in tropical fresh water bodies.

Harike wetland was reported with shrinking area and water table due to number of factors such as, silting, encroachment, fishing, plantation, grazing[15] and decline in fish biodiversity[16]. Increased pollution affected water quality[17]. In addition, decreasing trends in fishery capitals were also reported on an average 52.79% (Satluj) and 57% (Harike) during the period of 1999 to 2005[18]. Gradually, fish fauna has experienced great changes due to enhanced fishing pressure. Reported anthropogenic activities prompted the researchers to evaluate the existing status of *C. catla* at Harike Wetland (Ramsar site) in Punjab. Present study is an effort to estimate the age and growth pattern in *C. catla* from Harike wetland with the use of opercular bones. Opercula were selected first

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time for age and growth from this study area because scales sometimes get replaced with new ones before sampling. Regenerated scales could not be used to estimate the age and growth studies as such scales, lack focus. The study was also compared with farmed fish as it received supplementary diet in favourable conditions and will help to delineate the results with assurance.

Materials and Methods

Sampling

One hundred and six fish samples ranging between 280-875mm from the Harike wetland, (31°08′N to 31°23′N latitudes and 74°90′E to 75°12′E longitudes) and 130 fish samples ranging between 186-690mm from a private fish farm Dhudike, Punjab (30.75°N 75.33°E) were collected on monthly basis. Total length of each fish was measured in millimetres on the spot. Fish length was measured by using fish measurement board. All samples were collected from fish landing sites (using gill nets) at Harike and fish farm, Dhudike.

The opercular bones were removed from the left side of the head. Head was kept in hot water at 60°C for 2-15 minutes (depending on the size of the fish). Muscles attached on opercular bones were removed manually, dipped in 50% hydrogen peroxide solution for 15-20 minutes, dipped in xylol and then sun dried. The opercular bones after cleaning were stored in envelopes bearing the necessary data. Measurements of opercular bones were done with flexible scale. Opercular bones radii were measured from the focus to its outer margin for generating the regression relationship of opercular bones versus total fish length. The annual rings became much clearer with storage[19,20].

Back Calculation and growth parameters

To find the fish length prior to sampling and calculations for various growth parameters, standardized methodologies were used.

i. Back calculated length [20]

$$Ln = \frac{on}{o} * l$$

ii. Specific rate of linear growth[21]

$$C_l = \frac{l_n - l_{n-1}}{l_{n-1}} 100$$

iii. Index of species average size[22]

$$\varphi h = \frac{\sum_{h=1}^{n_{j+a}} h}{n_{j+a}}$$

iv. Growth constant[21]

$$C_{lt} = \frac{\log l_n - \log l_{n-1}}{0.4343} \frac{t_2 + t_1}{2}$$

v. Growth characteristics[23]

$$C_{th} = \frac{\log l_n - \log l_{n-1}}{0.4343} l_{n-1}$$

where l, Total length of the fish at the time of capture; O_n, opercular bone radius of the annulus ‘n’ at fish length; O, opercular radius (measured from center of the focus to outer margin of the opercular bone); l_n and l_{n-1} are mean computed total fish length at ultimate and penultimate age; J, juveniles; a, adults; n, number; and h, absolute increase in length; t_1 and t_2 are the time intervals between the ultimate and penultimate age.

Results and Discussion

Correlation of total fish length versus opercular radius (LORR)

During the present course of work, a highly correlated linear relationship was observed between total fish length and lateral opercular bones radii. Results were based on opercular bones of 89 and 116 samples from Harike wetland (H) and a private fish farm, Dhudike (D). LORR study reflected intercept (a), 1.366 (H) 0.6 (D), slope (b), 0.0927 (H) 0.0933 (D), correlation (r), 0.976 (H) 0.983 (D), correlation coefficient (r^2), 0.95 (H) 0.967 (D) from both the localities (Fig. 1 A and B). The linear relationship between total fish length and lateral scale radius was observed for *Catla catla*[24] and *Channa* marulius[25]

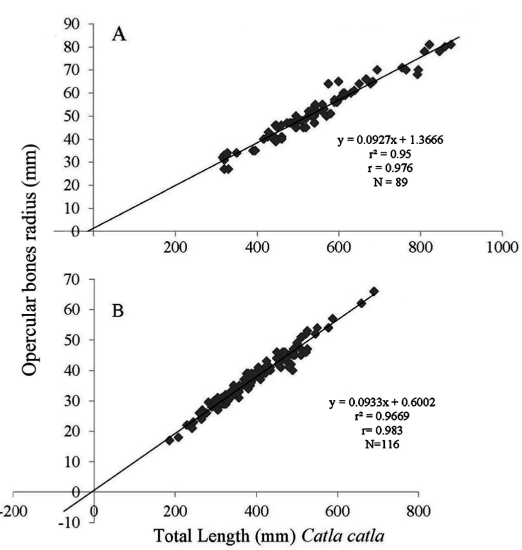

Fig. 1 — Linear relationship between total length and opercular bones radius (mm) of *Catla catla* from (A) Harike wetland; and (B) Dhudike fish farm

from Gobindsagar and Harike wetland. During literature survey, no published work for LORR was accessed in any of the commercial food fish found in Indian fresh water habitats.

Opercular bones based back calculation

Close observations of opercular bones depict distinct markings or annuli. Number of these annuli represented the age classes of the fish and distance between the two annuli indicated growth pattern of *C. catla* in two selected water bodies. In present study, total 6+ (H) and 3+ (D) age classes were counted. The back calculated average length (273.44, 427.44, 525.49, 624.52, 744.98 and 813.62 mm,) for age classes 1+, 2+, 3+, 4+, 5+, 6+ (H); and (282.1, 463 and 601.7 mm) for age classes 1+, 2+, 3+ (D) were observed respectively (Table 1).

A well dried opercular bone depicted rings when viewed against a narrow and bright beam of light. During spring and summer with wider gaps and in winter with lesser gaps between two growth lines on opercular bones (OBs) were observed. These growth lines collectively appear in the form of light and dark bands. Consequently, alternate light (i) and dark bands (ii) together depict the growth of one year or annual growth (Fig. 2A). Similar findings were reported with translucent and opaque growth zones (together form annulus) in other calcified structures, such as sectioned otolith of *Sperata aor*[3], both otoliths and vertebrae of *Salmophasia balookee*[11], vertebrae of threatened sharks (*Carcharhinus coatesi*, *C. fitzroyensis*, *C. macloti*, *Eusphyra blochii and Hemipristis elongate*)[26], *C. catla*[27] and dorsal fin spines of *Balistes polylepis*[28]. The rings that were not

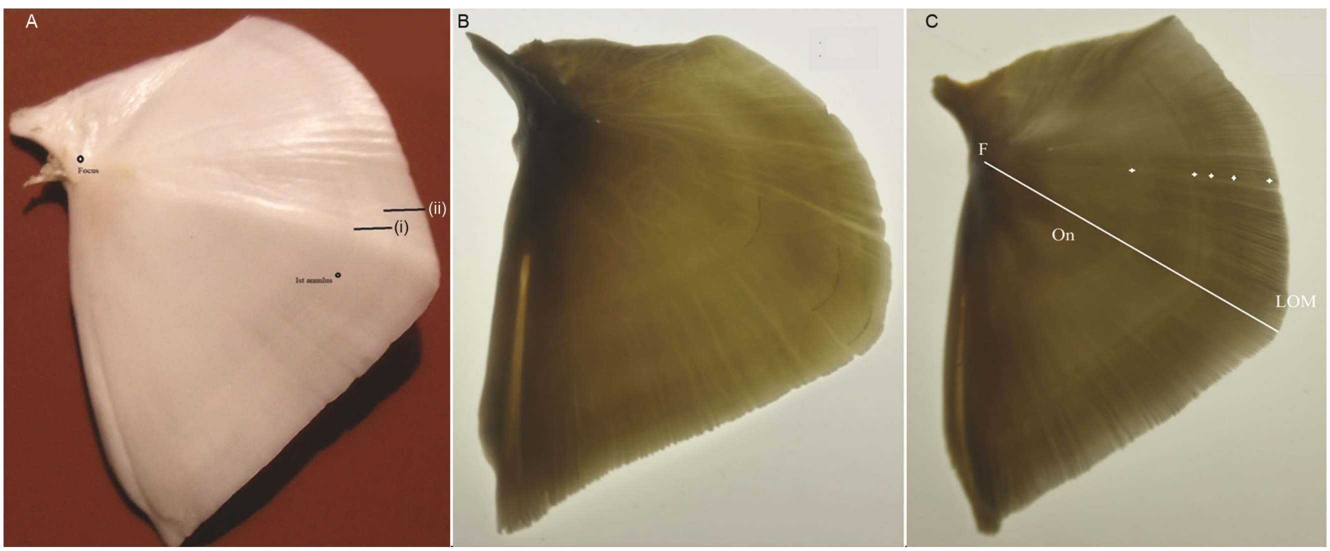

Fig. 2 — Photographs of opercular bones of *Catla catla* (A-C) +1, +3 & +5 age classes respectively. [F, Focus; On, opercular bone radius; and LOM, Lateral opercular bone margin]

Table 1 — Back-calculated lengths (mm) of *Catla catla* (Hamilton-Buchanan) using opercular bones during July, 2012 to June, 2014 from Harike wetland and Dhudike fish farm

Age classes	No. of specimens and collection sites		Average total length (mm) at the time of capture	Back calculated lengths					
	Harike	Dhudike		L_1	L_2	L_3	L_4	L_5	L_6
1	30		423.33 (316-520)	268.48					
		53	349.67 (290-352)	250					
2	37		525.02 (428-616)	275.2	466.1				
		29	482.7 (430-540)	295.3	442.4				
3	12		649.75 (590-755)	261.65	397.91	543			
		3	645.67 (588-690)	300.9	483.6	601.7			
4	5		783.6 (755-810)	277.5	427.15	506.39	627.54		
5	2		835 (822-847)	304.6	462.51	535.33	599.4	735.6	
6	2		867.5 (860-875)	253.2	382.54	517.26	646.6	754.36	813.62
Total	88		L (mm)	273.44	427.24	525.49	624.52	744.98	813.62
		85	492.68 (290-690)	282.1	463	601.7			

[L_1, L_2, L_3, L_4, L_5, L_6 = Back-calculation in the respective age class(es)] complete around the focus were taken as false rings. Authors found easiness to identify the annuli on OBs up to age classes 4+ whereas in age classes 5+ and 6+ early year's rings were not as easy to identifiable as in younger fish age classes. The OBs have thick focus and this thickness fanned out towards its periphery. Repercussions of thickness often made first and second annulus to be less distinct. Similar observations have also been described in *C. catla*[4], *Hypophthalmichthys molitrix*[29], *Schizothorax o'connori*[7] and recommended opercular bones superior than scales for age estimation in early years of the fish life. In temperate water fishes, OBs are well recognized and more suitable calcified structures for age and growth studies in *Esox lucius*[30], *Perca fluviatilis*[31] and *Moxostoma anisurum*, *M. carinatum*, *M. macrolepidotum* and *M. valenciennesi*[32].

Growth parameters

Annual length increment (h) revealed irregular pattern as it showed almost static growth at 3+ (98.25 mm) and 4+ (99.03 mm) age classes from wetland. Whereas, at farm the "h" indicated regular decline in increment of fish length that is usually found in Indian major carps. Consistent decline in 'h' among IMCs as the fish advances in age under normal conditions[33,34] is a natural phenomenon. Index of species average size (φh) 135.6 (wetland), 200.6 (farm) were observed. More age classes with low value of this growth parameter from wetland in comparison to farmed fish revealed that fish experienced more competition at wetland during progress in fish age. Hence, above mentioned results concluded that the values of φh assist to compare the growth rate of same species from two different water bodies. Thus, this parameter is very useful to delineate the policies to manage and conserve present status of the concerned water body. Earlier studies indicated overall growth of a particular species[21] and growth rates of different species or conspecific species in different water bodies[33,34], inter and intra-specific level of competition[20] and hence, facilitated to categorize the commercial importance of fish species[13] from selected water bodies.

Growth constant (C_{lt}) helps to find the life span of the fish[20]. In present study, two growth periods (1st asexual and 2nd sexual) were reported from both the localities. The first value 0.669 (wetland) and 0.744 (farm) expresses that fish was in first period of life up to 2+ years. The abrupt change in value of this parameter 0.669 to 0.311 (wetland) and 0.744 to 0.393 (farm) from 2nd to 3rd years (Table 2) depicts that some physiological change took place. At age classes 3+ fish enters into 2nd phase i.e. mature or sexual phase of life. The constancy in values from 3-5 years showed that fish was in the mature phase of the life. Fish from private fish farm have also shown two periods of the life from the observed values i.e. (sexually immature stage and sexual stage). Similar findings of this growth pattern in *Catla catla* were reported from Harike[24] (Punjab), Sukhna lake[34] (Chandigarh), Asan pond[35] (southern Rajasthan). Whereas, at Gobindsagar reservoir[24] (Himachal Pradesh), rivers Bhagirathi (Uttarakhand) and Sutlej[33] (Punjab) *C. catla* showed three distinct phases in life i.e. immature, mature and old ages.

Growth characteristic (C_{th}) is supportive to find the periods of life where the 1st ends and 2nd commences[36]. In present study, *C. catla* from wetland observed to be at the verge of losing its growth characteristic as no remarkable distinction of growth

Table 2 — Summary of growth data of *Catla catla* based on opercular bones collected during July, 2012 to June, 2014 from Harike wetland and Dhudike fish farm

Symbol	Collection sites	L_1	L_2	L_3	L_4	L_5	L_6
L	Harike	273.44	427.24	525.49	624.52	744.98	813.62
	Dhudike	282.1	463	601.7			
h	Harike	273.44	153.8	98.25	99.03	120.46	68.64
	Dhudike	282.1	180.9	138.7			
Φh	Harike			135.6			
	Dhudike			200.6			
C_l	Harike		56.246	22.996	18.845	19.288	9.213
	Dhudike		64.126	29.956			
C_{th}	Harike		122.025	88.431	90.725	110.147	65.658
	Dhudike		139.81	121.32			
C_{lt}	Harike		0.669	0.311	0.259	0.264	0.132
	Dhudike		0.744	0.393			

[L (mm) Back calculated average length, h (mm) Annual increment, Φh Index of Specific average size, C_l Specific rate of linear growth, C_{th} Growth characteristics and C_{lt} Growth constant, L_1- L_6 age classes] was observed in different age classes (Table 4). The values generated from this parameter were showing abrupt change at age classes 4+ and 5+ and at 5+ and 6+ years. This study indicated stress in surrounding environment from this parameter and confirms with earlier findings which stated that fish does not show clear-cut distinctions in its growth and such population loses its growth characteristic[19,21]. According to authors, anthropogenic activities reported by various researchers[15-18] indicating change in pattern of ecology of Harike wetland that may lead to worsen the present status of fish. In addition, combination of both anthropogenic and natural elements was observed, such as discharge of domestic and industrial effluents[17], silting due to erosion and agricultural drainage into catchment area are causal factors of general ecological degradation in the Harike wetland[37,38].

Conclusion

The above results suggest that for estimation of the age in *Catla catla*, opercular bones are satisfactory measured up to age classes 4+ and from different growth parameters, fish was found to be in stress, in comparison to farmed fish. Authors believe that there is need of such more basic studies to frame the policies for conservation of economically important vulnerable fish, *C. catla* in riverine system. This is an appeal to officials and fishery managers to employ results of present research work while framing policies for sustainable fishery management.

Conflict of interest

Authors have no competing interests.

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