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The velocity and acceleration of length growth of a fresh water major carp of India, *Catla catla* spawned in two rearing conditions

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ABSTRACT

Two popular methodological techniques, autoregressive and finite difference methods were employed simultaneously to analyse growth data of *Catla catla* (Ham.) spawn procured from artificial and semi natural incubating systems. The experimental results indicated a preponderance of semi natural incubating system over its counterpart as far as length increments of 50 spawn over a 24-day period of observations were concerned. It was also revealed that both the methodologies can be used with precision for the purpose of curve fitting.

Introduction

The technique of repeated measurement has been extensively used to analyse biological growth data (Anderson, 1978). The significance of this statistical analysis is that it deals effectively with the problem of intercorrelation among observations, an important though frequently ignored property of repeated measurement data. The other alternative approaches are autoregressive and finite difference techniques. All these methodologies have predictive capabilities on short and long term basis. In this study we have used both the techniques to analyse length increment/day data of 50 spawn of *Catla catla* (Ham.) over 24 days. The comparison of the two techniques to analyse length increments of the carp from two systems is revealed from this communication.

Materials and method

The seminatural incubation system (SIS) of a fish farm of Bankura, West Bengal, are essentially improvised pits (each 4.40 m length x 2.40 m width x 0.45 m depth) excavated on the bank of dry bund which is a shallow depression enclosed on three sides by earthen embankments, impounding fresh rain water from the catchment area during the monsoon period to simulate riverine conditions. These bunds provide large shollow areas serving as spawning grounds for the carps. The artificial incubation system (AIS) (from the same fish farm), is provided with the 'Chinese' hatcheries with cement construction (each 2.4 m length x 1.2 m width x 0.3 m depth) with the usual infrastructure for egg incubation. Fertilised eggs, obtained by conventional hypophysation of brood fishes reared in the same bund were transferred to the two incubating systems for hatching. Stocking density was ascertained by measuring eggs in specially prepared containers capable of accommodating 25 to 30 thousand eggs. Physical and chemical nature of the ambient medium of the bund and the two incubating systems were recorded during the period of collection of hatched spawns. Maximum diurnal temperature ranged from 29 to 30.50°C, pH 6.8 to 7.1 and dissolved oxygen 8.68 to 10.2 ppm. The differences in respect to these parameters between the two systems were observed to be negligible during the study period. Three days old hatched eggs were collected from the two incubating systems and stocked separately in experimental hoopnets. Comparable numbers of eggs (5,000) were kept in each hoopnet using the measuring containers used by the local fishermen. The hoopnets (rearing place of the spawn) were fabricated according to the conventional way to maintain identicl ecological conditions as far as practicable (Basu, *et al.*, 1991). For this purpose, rectangular iron supports (1.50 m x 1.40 m x 0.90 m) were fixed on four pieces of even sized bamboo impressed deeply into the pond bed, 1,20-1.50 m away from the bank. Nylon mosquito nets with sufficiently dense mesh were placed inside rectangular iron support for rearing spawn.

The pond water was monitored daily for temperature (30 - 30.5°C,) pH (6.5-7.5), dissolved oxygen (5.8-10.86 ppm) and dissolved free carbon dioxide (5.39-7.55 ppm) (APHA.1975). Weekly counts of zooplankton (114-125 /l) were made by using Sedgwick Rafter Counting Cell with 1000 squares (Basu *et al.*, 1991) to estimate natural food resource in the pond during the 24 days period of study.

The experimental protocol involved daily collection from each hoopnet 50 spawn (10 spawn at a time with 5 replications) starting from 5 days of age over 24 days and determining their total length in mm. For this purpose, a measuring board provided with an accurately graduated millimetre scale was used (Bagenal, 1978). 'Simple random sampling without replacement' method (Mead and Curnow, 1983) was used for collection of spawn from the hoopnets.

The autoregressive method assumed the following growth model to describe the data.

$$x_t = a+bx_{(;} \quad \text{.......................} (1)$$

Where x = length, t = time and b, a = regression coefficients and their intercepts, respectively.

Estimates

$$x_t = a+bx_{t\,x} \quad \text{.......................} (2)$$

Given x at any stage the next value of x can be obtained by this regression. Long term prediction is also possible by the same estimate provided the initial x is known. In this communication, only the short term prediction is dealt with.

The other method used here involves the application of finite difference after Hills (1968). When time points are equally spaced, it is customary to use orthogonal polynomials for replacing the number of observations by a smaller number of variable that adequately describes the growth curve (Rao, 1959). Kowalski (1972) observed that orthogonal polynomials generally fail to provide a directly interpretable summary of the data. To overcome this, Hills (1968) suggested the use of finite difference method in the line of Box (1950). According to him, the first difference between two successive length observations were considered to be the velocity of length increment whereas the second difference obtained from two successive velocity data were supposed to be the acceleration of length increment of the carps during the period of observations. Instead of using orthogonal polynomials, here basically, the total number of observations were to be replaced by the more readily interpretable quantities:

X_j , the initial value .... (3)

$\sum_{t=2}^{T} \Delta x_t / (T-1)$, the average velocity of length increments .... (4)

and $\sum^{T} \Delta^2 x_t / (T-2)$, the average acceleration of length increment.... (5)

where T = the number of observations over time t and Δ = successive differences. (4) and (5) were replaced, from computational point of view, by:

$(x_T - x_1)/(T-1)$ .... (6)

$(x_T + x_1 - x_{T-1} - x_2)/(T-2)$ .... (7)

respectively. Studies on these quantities may be initiated on an individual-by-individual basis and averaged over the total number of individuals to describe these aspects of the growth curve for the group. Additionally, in the line of Goldstein (1979) we may use finite difference to investigate whether the shape of the growth curve is different portions of the time scale. In fact, these are the data-analytic advantage of the use of finite difference method. Thus in the case of equally spaced time points, Hills (1968) suggested the tests on finite differences. The goodness-of-fit R_2 test was also performed by using the formula:

$$R^2 = \frac{\sum xy - (\sum x)(\sum y)/n}{(\sum x^2 - (\sum x)^2/n)(\sum y^2 - (\sum y)^2/n)} \quad \ldots (8)$$

where x = observed values, y=predicted values after fitting. The statistical significance of these R^2 values were checked by performing F-tests.

$$F = \frac{R^2/1}{(1-R^2)/(n-2)} \quad \ldots (9) \quad df=1,(n-2)$$

A package programme (GAUSS) that runs on PC compatible microcomputer (Edlefson and Jones, 1985) was used for computation.

Results

This study has two broad objectives-curve fitting by autoregressive and finite difference methods with the available data and a simultaneous approach to compare the length growth rate of carps obtained from two incubating systems. For the first order of difference of length of the species (velocity), good approximation of the observed pattern was obtained by applying both the methodologies irrespective of the incubating system but for second order of difference of length (acceleration) method, particularly in seminatural incubating system (Table 3). It appears that the autoregressive technique shows more flexibility in describing length acceleration of carps in comparison to finite difference (Figs. 1-4). Also the seminatural incubating system is a better exponent of growth as compared to its counterpart (Table 1). Significant correlations were observed by the length velocity and acceleration curves by using both the processes (Table2).

Discussion

The shape of the growth curve for carps is most likely to vary between populations or species under study. Consequently, the growth function that

TABLE 1. *Day-by-day length (mm) variation of spawn of* C. catla *(Ham.) procured from two incubating systems (artificial and seminatural). Results are mean length of10 carps ± S.E. of 5 replications*

Days	SIS	AIS	t-values
5	6.4 +0.088	6.12 +0.14	1.48 NS
6	6.57 +0.090	6.10 +0.13	
7	6.68 +0.010	6.14 +0.14	
8	6.88 +0.12	6.16 +0.18	
9	6.94 +0.12	6.20 +0.17	3.43*
10	7.02 +0.14	6.22 +0.20	
11	7.10 +0.13	6.24 +0.22	
12	7.12 +0.14	6.28 +0.15	8.45**
13	8.00 +0.16	7.50 +0.17	
14	9.02 +0.15	7.98 +0.22	
15	10.0 +0.18	8.00 +0.32	
16	12.72+0.19	8.55 +0.18	13.62***
17	12.80+0.17	9.50 +0.12	
18	14.48+0.18	10.28+0.10	
19	15.50+0.19	11.40+0.22	
20	16.05+0.15	14.14+0.15	6.64**
21	16.80+0.21	14.28+0.18	
22	17.55+0.20	14.98+0.14	
23	18.00+0.19	15.00+0.13	
24	18.24+0.22	15.75+0.24	8.27**

NS: Non-significant, *P< 0.05, ** P<0.01, ***P<0.001.

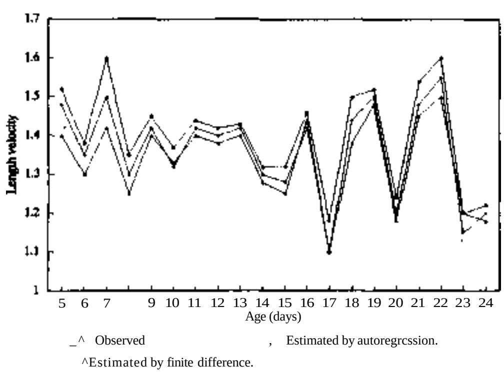

Fig. 1. Average estimated legth velocity of *C. catla* spawns procured from seminatural icubating system.

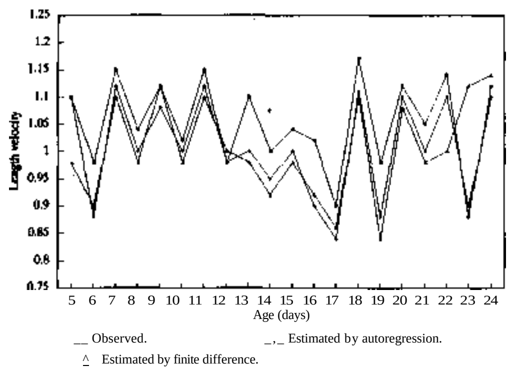

Fig. 2. Average estimated length velocity of *C. catla* spawns procured from artificial incubating system.

provides the best representation of growth data may also vary. Thus it is essential to asses the goodness-of-fit in any comparison among growth functions (Bethea *et al.*, 1975). In the present case there is no variation of species or populations but two different methodologies were applied which may produce different growth curves under identical experimental conditions. Also, the source of incubation was different. The results of the comparison of good-

TABLE 2. *Correlation coefficients (r) for the observed and expected values estimated by two methods for the day-by-day, average length data from 10 samples (5 replications) over 24 days*

Source	Velocity		
	Observed	Estimated by autoregression	Estimated by finite difference
SIS	0.3312	0.4313**	0.4010**
AIS	-0.1471	0.3939**	0.2120*
		Acceleration	
SIS	-0.1572	0.1718*	0.1510*
AIS	-0.7414	0.1279*	0.1012

*P < 0.05, **P < 0.01.

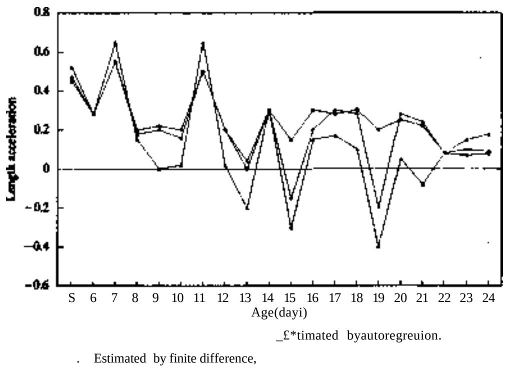

Fig. 3. Average estimated length acceleration of *C. catla* spawns procured from seminatural icubating system.

ness-of-fit between the curves revealed greater flexibility of autoregressive method in comparison to the finite difference method. It was highly dependent on the source of incubation, particularly in case of length acceleration. This source-specificity was less prominent when correlation data were compared (Table 2). Thus the variation in length from the two incubation system is comparable. So far as the observed length velocity is concerned the carp spawn from SIS grew uniformly whereas the negative correlation indicated an impeded growth of the spawn from AIS. When, however, the data were explained in terms of acceleration it is noteworthy that the correlations were always negative (Table 2). Interpreted at face value, this would suggest that the fishes with the most rapid acceleration which increased at one time were the ones which decreased most rapidly at the next moment. It seems that better explanation for the observed acceleration correlation should be a negative feedback homeostatic mechanism with 'catch up' and 'catch down' phenomena exhibiting the possible effects of random environmental disturbances to growth (Harrison and Brush, 1990). This 'catch up' and 'catch down' phenomena are also evident from the number of 'spikes' in length velocity and acceleration (Figs.1-4). Gasser *et al.* (1985) have focussed on acceleration as a means of identifying the midgrowth (prepubescent) spurt of human children. In their opinion, acceleration may be a useful parameter for gaining insight into the regulation of growth (Gasser *et al.,* 1984). Again Hills' procedure can be effectively dealt with data collected at unequal time intervals which makes it

TABLE 3. R^2 *goodness-of-fit computed by using autoregressive and finite difference method in the length growth study ofC* catla *reared in two incubating systems. (F values with degrees of freedom, 1,8)*

Incubating System	Auto regression velocity	Finite difference	Auto-regression acceleration	Finite difference
SIS	0.9894 (746.7***)	0.9203 (92.3***)	0.6293 (13.5**)	0.3367 (4.06)
AIS	0.4998 (7.9*)	0.4817 (7.4*)	0.8608 (49.4***)	0.5289 (8.9*)

* Significant at 5% level, ** Significant at 1% level, *** Significant at 0.1% level.

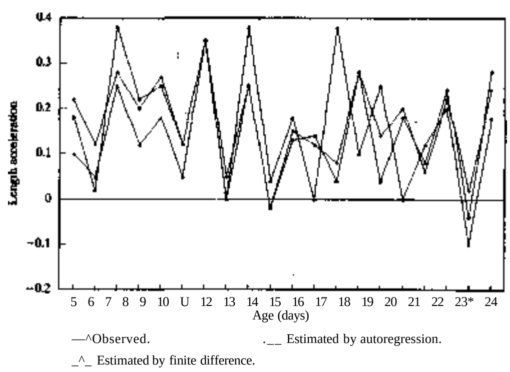

Fig. 4. Average estimated length acceleration of *C. catla* spawns procured from artificial incubating system.

particularly appropriate for various surgical and experimental studies where observations are taken at short intervals prior to and soon after intervention (eg. surgery) and at progressively longer intervals following intervention. This approach is specially suitable for analysing time-dependent phenomena in single sample in which the data are collected at unequal or equal-length time intervals. In fishery science there is a possibility to use finite difference method to identify the 'thrust/problems areas' where nutrition may be applied to reinforce growth. These 'thrust areas' are the retarded/negative growth areas identified by negative velocity /acceleration of growth rate. Unfortunately, studies on growth velocity and acceleration of Indian major carps are scarce. As a result direct comparison with a parallel study is difficult. Nevertheless a complex metabolic function like growth process needs to be addressed from various angles to elucidate the kinetics of its mechanism. The two different methodological approaches tested in the present communication can not only be used to approximate the real data closely but also they may provide a window for a better insight into the biological growth process of carps.

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