Proc. Indian Acad. Sci. (Anim. Sci.), Vol. 93, No. 5, September 1984, pp. 411–417.

Bionomics of hill-stream cyprinids. IV. Length-weight relationship of *Labeo dero* (Ham.) from India

SANDEEP K MALHOTRA and R S CHAUHAN
Department of Zoology, University of Garhwal, Srinagar 246 174, India

MS received 8 September 1983; revised 5 March 1984

Abstract. Parabolic equations describing the body length-body weight relationships in 311 *Labeo dero* (Ham.) are determined. The differences between regression coefficients of the two sexes and length classes were highly significant. The difference between regression coefficients of the two length classes was significant at 5% level.

Keywords. Parabolic equations; coefficient of determination; heterogeneity; correlated variance; allometric.

1. Introduction

Labeo dero (Ham.) is of immense economic value in the Garhwal region and is found almost throughout the year in the rivers Khoh, Nayar, Bhagirathi and Alaknanda of the Himalayan riverine ecosystems. Earlier works by Hora and Mukherjee (1936), Lal and Chatterjee (1962), Singh (1964) and Grover (1971) included only faunistic studies, brief biological notes etc. The length–weight relationship in fish is of primary importance, among other things, in the precise assessment of the viability of fish stock under different geographical conditions. The general concept of length–weight relationship is that the weight of fish varies as the cube of its length. But as the specific gravity and shape or body outline of the fish is subjected to changes, the cube law need not always hold good (Rounsefell and Everhart 1953). Nevertheless, most workers have failed to report statistical significance of the departures from cubic relationship that they had recorded in such studies. This aspect has been considered in the present account of the length–weight relationship of *L. dero* in the Himalayan riverine ecosystem (650 mASL). The present investigation is aimed at getting more information on the general biology of this fish at higher altitudes and is part of an investigation into the biology and fishery of hill-stream fishes, results of certain aspects of which have already been published earlier (Malhotra *et al* 1980a, b; Chauhan and Malhotra 1981; Chauhan *et al* 1981; Malhotra 1981a, b, 1982).

2. Materials and methods

Three hundred and eleven *L. dero** (5·3–64 cm in length) were studied. The methods of collection of fish samples at 650 mASL and their analysis were reported earlier

* sex of 10 fishes could not be ascertained.

(Malhotra 1981a; Chauhan *et al* 1981). The length–weight relationship was estimated using the formula, $W = aL^n$ where W is the weight, L the body length, and a and n are constants. Logarithmic transformation of the equation may be written as

$$\log W = \log a + n \log L$$

where, $\log W$ is the dependent variable (y), $\log L$ the independent variable (x), n the regression coefficient or slope (b), and $\log a$ the y-intercept. Analysis of covariance, t-test (Snedecor and Cochran 1967), coefficient of determination (r^2) (Croxton 1953), values of the least squares regression slopes and the proportion of correlated variance (ρ^2) (Zeller and Carmines 1978) were computed.

3. Results

The morphological parameters of the fish including body weight are given in table 1.

3.1 *Estimated regressions*

An initial assessment of the sex revealed that the same equation would not fit the data for the entire length range and break occurred between the < 17 cm and > 17·1 cm classes. Separate parabolic equations and linear regressions were, therefore, computed for different groups as mentioned in table 2. The significance of the differences between the regression coefficients was tested by the method of analysis of covariance. The

Table 1. Mean values of non-meristic characters of *Labeo dero* (Ham.).

Category	Sample size	Mean ± SE			
		Total length (cm)	Standard length (cm)	Body weight (g)	TL/SL ratio
Female	155	23·8078 ± 0·7108	19·3426 ± 0·5862	237·7484 ± 33·6577	1·2308 ± 0·4310
Male	146	21·7593 ± 0·6011	17·5548 ± 0·5428	151·0616 ± 20·4487	1·2395 ± 0·0534
Pooled	311	22·7058 ± 0·4555	18·4199 ± 0·3914	190·9839 ± 19·5298	1·2327 ± 0·0303
< 17 cm	178	14·4596 ± 0·1803	14·1020 ± 0·3116	73·3539 ± 2·4755	1·0254 ± 0·0102
> 17·1 cm	133	24·3619 ± 0·4804	23·8638 ± 0·6426	346·3358 ± 41·7160	1·0209 ± 0·0241

Table 2. Regression equations describing length-weight relationship in *Labeo dero* (Ham.).

Category	Logarithmic equations	Parabolic equations
Female	$\log W = \bar{2}\cdot9030 + 2\cdot4905 \log L$	$W = 0\cdot00125\ L^{2\cdot4905}$
Male	$\log W = \bar{2}\cdot5083 + 2\cdot0101 \log L$	$W = 0\cdot003102\ L^{2\cdot0101}$
Pooled	$\log W = \bar{2}\cdot6961 + 2\cdot2377 \log L$	$W = 0\cdot002013\ L^{2\cdot2377}$
< 17 cm	$\log W = \bar{0}\cdot5980 + 1\cdot3281 \log L$	$W = 0\cdot252348\ L^{1\cdot3821}$
> 17·1 cm	$\log W = \bar{2}\cdot9564 + 3\cdot9512 \log L$	$W = 0\cdot001106\ L^{3\cdot9512}$

Table 3. Analysis of covariance between the regression coefficients (b) for *Labeo dero* (Ham.).

N	< 17 cm 178	> 17·1 cm 133	Female 155	Male 146	Pooled 311
$\Sigma(X-\bar{X})^2$	3·0130	3·8586	3·8756	3·7959	4·1706
$\Sigma(Y-\bar{Y})^2$	5·2868	7·4972	7·4356	6·9500	7·5669
$\Sigma(X-\bar{X})(Y-\bar{Y})$	3·7522	5·5781	5·6051	5·2268	5·7428
$b\Sigma(X-\bar{X})(Y-\bar{Y})$	5·1859	22·0402	13·9595	10·5064	11·4150
ρ^2	0·1602	0·6363	0·7924	0·5100	0·5597
r^2	0·1597	0·6372	0·7221	0·5075	0·5595

ρ^2 = Proportion of correlated variance; r^2 = Coefficient of determination; N = Number of observations.

relevant data are given in table 3. The test for heterogeneity of the regressions is given below:

Source of variation	df	Sum of squares	Mean square	F
Deviation from average total regression	612	0·554959	—	—
Deviation from individual regression within samples	609	0·533458	0·000875957	—
Difference	3	0·021501	0·007167	8·182

$F_{1\%} = 3{\cdot}83$

The differences between regression coefficients were significant at 1 % level.

The test of heterogeneity was again performed for the two sexes (within and with each of the two length classes) and for the two length classes (within) as shown below:

	F	$F_{1\%}$	$F_{5\%}$	Degree of freedom
Between male and female fishes	0·12	6·76	3·89	1; 300
Between < 17 and > 17·1 cm	3·90	6·70	3·86	1; 310
Between sexes and < 17 cm	14·065	4·66	3·02	2; 477
Between sexes and > 17.1 cm	51·143	4·66	3·02	2; 432

It is seen that the differences between the regression coefficients of the last three groups were significant at different levels while the difference within sexes was not significant at 5 % level.

On application of student's t-test the regression coefficients of the sexes, < 17 and > 17·1 cm length classes were significantly different from 3 at 1 % level. The results are given below:

Length class (cm)	$b-3$	t	Degree of freedom	$t_{1\%}$
< 17	−1·6179	−18·855	176	2·58
> 17·1	0·9512	3·819	131	2·62
Sexes	−0·7497	−4·414	299	2·58

A comparison of the regression lines of the length–weight relationship of *L. dero* has been presented in table 4. According to the standardized least squares linear regression line, for each standard unit of length, the fish gained 0·8482–0·9343; 0·7124–0·7159; 0·7480–0·7483; 0·3996–0·4009; and 0·7880–0·8075 of a standard unit of weight for females, males, pooled, < 17 cm and > 17·1 cm length classes of *L. dero*, respectively.

A plot of log *W* (mean values) *vs* log *L* (mean values in < 17 and > 17·1 cm length classes at 5 cm class interval) in 311 fish, the linear regressions for separate groups and pooled data are shown in figure 1.

Table 4. Comparison of the regression lines of length-weight relationship of *Labeo dero* (Ham.).

	Sample size	Variance		Covariance	Standardized least squares regression slope predicting		$(P < 0{\cdot}001)$
		Length	Weight		*X* from *Y*	*Y* from *X*	
Female	155	1·6852	5·2453	3·4148	0·8482	0·9343	0·8498
Male	146	1·6316	4·7857	3·0624	0·7124	0·7159	0·7124
Pooled	311	1·6779	5·0742	3·2500	0·7480	0·7483	0·7480
< 17 cm	178	0·7625	3·0364	1·5018	0·4009	0·3996	0·3996
> 17·1 cm	133	1·7315	5·3701	3·4543	0·7880	0·8075	0·7982

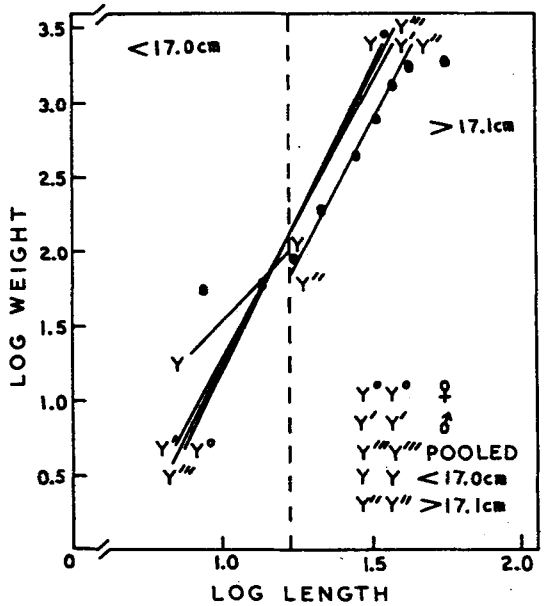

Figure 1. Length-weight relationship of *Labeo dero* (Ham.).

4. Discussion

Earlier workers (Menon 1952; Chauhan and Ramakrishna 1953; Srivastava 1968; Sultan and Shamsi 1981), recorded different morphometric characters in various fish. However, in the present investigation no major differences were found in the ratio values of total *vis a vis* standard length of *L. dero.*

There was a highly significant correlation ($P < 0{\cdot}001$) of length–weight for female, male, pooled, < 17 cm and > 17·1 cm length classes (table 4). Based on the coefficient of determination (r^2) (Croxton 1953), more than 72% of the variation in weight in females, 50% in males, 55% in pooled, and 63% in > 17·1 cm length class was attributable to the variation in the length of *L. dero.* However, only 15·97% of the variation in weight in < 17 cm class was attributable to the variation in length of fish. Similarly the proportion of correlated variance (ρ^2) suggests that 79·2443% variance in length in female fish, 50·9965% in males, 55·9702% in sexes pooled, and 63·6285% in fish of > 17·1 cm class was associated with weight while only 16·0174% variance in length in fish of < 17 cm class was associated with weight.

The fish of larger length class (> 17·1 cm) showed higher regression coefficient value ($b = 2{\cdot}9564$) than the smaller ones *viz* < 17 cm ($b = 0{\cdot}5980$) further supporting similar observations of Malhotra (1982) on *Tor tor* (Ham.) in Garhwal Himalayas. The authors agree with the partial explanation offered by Sekharan (1968) in *Sardinella* spp. that such a difference in the regression coefficient values could be due to a relatively rapid change in the body outline of the fish. In the present study, size groups > 17·1 cm increase in length more rapidly than those of smaller length classes (< 17 cm). This is also supported by the present results based on proportion of correlated variance and coefficient of determination. Both these parameters indicate remarkable association (50–80%) between degree of variance in fish weight and variation in fish length in larger fish (> 17·1 cm) than smaller ones (< 17 cm) where this association showed poor agreement (*i.e.* < 20%). Hart (1946) indicated an increase in fish length after the attainment of sexual maturity. According to the observations of the authors on the state of maturity and breeding most specimens of *L. dero* attained maturity when the average fish size was around 17 cm. Hence the remarkably higher value of linear regression coefficient ($b = 2{\cdot}9564$) in fish of > 17·1 cm appears to have a correlation with the maturity state of fish.

As a depends upon the obesity of the fish (LeCren 1951), by comparing the $\log a$ values it is evident that the general fatness in the two sexes shows no significant difference ($F_{1;300} = 0{\cdot}12$) in the present study like those reported by Misu (1964), Narasimham (1970), Mojumdar (1971), Vinci and Nair (1974), and Malhotra (1982). The difference in general fatness of size classes was significant ($F_{1;310} = 3{\cdot}90$). The regression for pooled lot was calculated. The n values (2·2377) indicate that the growth rate is lesser than the cube length. Similar deviations were reported earlier by Krishnamoorthi (1971), Mojumdar (1971), Vinci and Nair (1974), Qadri and Mir (1980), Sultan (1981), and Malhotra (1982). Significant departures of the regression coefficients from the isometric growth value have been reported by Narasimham (1970), Vinci and Nair (1974), Qadri and Mir (1980), and Malhotra (1982). This departure in the present study was significant at 1% level for both the sexes and length classes. The preferability of the exponential formula $W = aL^n$ used in the present analysis over the cubic formula $W = CL^3$ (W = weight, L = length, and C = constant) has been justified in earlier studies (LeCren 1951; Sekharan 1968; Eggleston 1970; Narasimham 1970;

Krishnamoorthi 1971; Mojumdar 1971; Vinci and Nair 1974; Qadri and Mir 1980). Beverton and Holt (1957) discussed the merit of both allometric and cubic formula and remarked that the former worked much better since a and n of allometric formula varied within a wide range for very similar data and are very sensitive to even quite unimportant variations in n. Hence in the present investigation high values of coefficient of correlation indicates that allometric relationship of length and weight is suitable for the fish.

· This paper is part of D.Sc. thesis of S K Malhotra submitted to the University of Garhwal, Srinagar.

References

Beverton R J and Holt S J 1957 On the dynamics of exploited fish populations; *Fish. Invest.* **19** 533

Chauhan B S and Ramakrishna J 1953 Fauna of Balangir district (formerly Patna state), Orissa. I; *Fish. Rec. Indian Mus.* **51** 404

Chauhan R S and Malhotra S K 1981 Log-normal distribution of parasitization index and gastro-parasitic index in the fish-cestode relationships of hill-stream fishes; *Curr. Sci.* **50** 917–918

Chauhan R S and Malhotra S K 1984 Association of temperature with establishment and survival of pseudophyllidean cestodes in hill-stream fishes; *Curr. Sci.* **53** (in press)

Chauhan R S, Malhotra S K and Capoor V N 1981 The distribution and abundance of cestodes in eleven species of teleosts from Garhwal Himalayas with a note on host biology; *Himalayan J. Sci.* **1** 15–30

Croxton F E 1953 Elementary statistics with applications in medicine; *The biological science* (New York: Dover) 376 p

Eggleston D 1970 *A symposium on the Japan current* (Japan: Jap. Soc. Sci. Fish.) (ed.) J C Mar 417–424

Grover S P 1971 Some biological notes on *Barilius bendelisis* (Ham.); *Indian J. Fish.* **18** 182–183

Hart T J 1946 Report on the trawling surveys on the Patagonian continental shelf; *Discovery Rep.* **223** 223–408

Hora S L and Mukherjee D D 1936 Fishes of the Eastern Doons, United Provinces; *Rec. Indian Mus.* **38** 133–146

Johnson A G and Horton H F 1972 Length–weight relationship, food habits, parasites, and sex and age determination of the ratfish, *Hydrolagus colliei* (Lay and Bennett); *Fish. Bull.* **70** 421–429

Krishnamoorthi B 1971 Length–weight relationship in *Nemipterus japonicus* of Andhra–Orissa coast; *Indian J. Fish.* **18** 1–21

Lal M B and Chatterjee P 1962 Survey of Eastern Doon fishes with certain notes on their biology; *J. Zool. Soc. India* **14** 203–243

Le Cren E D 1951 The length–weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*); *J. Anim. Ecol.* **20** 201–219

Malhotra S K 1981a Cestode infection in freshwater fishes of Garhwal Himalayas, India; *Geobios* **8** 90–92

Malhotra S K 1981b Systems models for parasite pathways in ichthyoparasitology of the Himalayan riverine ecosystem; *Curr. Sci.* **50** 874–875

Malhotra S K 1982 Bionomics of hill-stream cyprinids. III. Food, parasites and length-weight relationship of Garwhal mahaseer, *Tor tor* (Ham.); *Proc. Indian Acad. Sci. (Anim. Sci.)* **91** 479–485

Malhotra S K, Chauhan R S and Capoor V N 1980a Nematode infection in relation to some ecological aspects of hill-stream fishes; *Geobios* **7** 193–198

Malhotra S K, Chauhan R S and Capoor V N 1980b Statistical analysis of cestode infection in relation to some ecological aspects of hill-stream fishes in Garhwal Himalayas, India; *Indian J. Helminthol.* **32** 43–52

Menon M A S 1952 On collection of fish from Manipur, Assam; *Rec. Indian Mus.* **2** 270–285

Misu H 1964 Fisheries biology of the ribbonfish (*Trichiurus lepturus*) in the East China and Yellow Seas; *Bull. Seikai Reg. Fish. Res. Lab.* **32** 1–58

Mojumdar P 1971 Length–weight relationship in the cat-fish, *Tachysurus thalassimus* (Ruppell); *Indian J. Fish.* **18** 179–182

Narasimham K A 1970 On the length–weight relationship and relative condition in *Trichiurus lepturus* Linn; *Indian J. Fish.* **17** 90–96

Qadri M Y and Mir S 1980 Length–weight relationship of *Oreinus plagiostomus* (McClell.); *Geobios* **7** 158–159

Rounsefell G A and Everhart W H 1953 *Fishery science: Its methods and applications* (New York: John Wiley) 444 p

Sekharan K V 1968 Length–weight relationship in *Sardinella albella* (Val.) and *S. gibbosa* (Bleek.); *Indian J. Fish.* **15** 166–174

Singh P P 1964 Fishes of the Doon valley; *Ichthyologica* **3** 86–92

Snedecor G W and Cochran W G 1967 *Statistical methods* (Iowa: State Univ. Press) 593 p

Srivastava G J 1968 Fishes of Eastern Uttar Pradesh *Vishwavidyalaya Prakashan*, 140 p

Sultan Salim 1981 Length–weight relationship in the cat-fish *Mystus vittatus* (Bloch.); *Geobios* **8** 140–141

Sultan Salim and Shamsi M J K 1981 Morphometric study of *Puntius sarana* (Ham.) of the river Kali; *Geobios* **8** 17–21

Vinci G K and Nair A K K 1974 Length–weight relationship in the threadfin bream, *Nemipterus japonicus* along the Kerala coast; *Indian J. Fish.* **21** 299–302

Zeller R A and Carmines D G 1978 *Statistical analysis of social data* (Chicago: Rand McNally) 397 p