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Length–Weight Relationship of the Crucian carp, *Carassius carassius* in Relation to Water Quality, Sex and Season in Some Lentic Water Bodies of Kashmir Himalayas

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Abstract

In order to assess the impact of water quality, sex and seasons on the length-weight relationship, we examined the exotic fish, *Carassius carassius* in three water bodies of Kashmir Himalayas. The 'b' value was higher in lake having the lowest nutrient enrichment level, showing that water quality may influence the growth of a fish. The results showed positive allometric growth (b>3.0; heavy group) in Manasbal and Anchar Lakes and isometric growth of equal increment of both parameters of length and weight in the Dal Lake. The correlation between length-weight relationships showed significant (P<0.05) positive trend. Females showed 'b' value more than males in two lakes (Anchar and Manasbal lakes), whereas 'b' value was high in males (b = 2.8) in Dal Lake. Data showed significant (P<0.05) differences in 'b' value between male and female sexes in two lakes and insignificant (P>0.05) relationship in Anchar Lake. Multiple comparisons also showed significant (P<0.05) differences in 'b' values among different seasons in Dal Lake. In addition, 'b' value showed significant (P<0.05) difference with some physico-chemical features in Dal lake. Finally, we concluded that length-weight relationship in case of Crucian carp showed significant variation in three lakes with respect to water quality, season and sex.

Keywords: Water quality, *Carassius carassius,* length-weight relationship, allometric growth.

Introduction

The length-weight relationship and condition factor of fish has got significant role in fishery management. These relationships can be used in estimating the average weight at a given length group (Beyer, 1987) and in estimating the health status of the fish population (Bolger and Connoly, 1989). Length-weight relationships are very useful for fisheries research because they allow the conversion of growth-in-length equations to growth-in-weight, biomass estimation, and condition of the fish and differences of life histories of fish species (Froese and Pauly, 1998; Moutopoulos and Stergiou, 2002).

There has been paradigm shift in using fish based biological indicators in aquatic ecosystems. The trend has now shifted towards ecological indicators, which started at the beginning of 20th century (Simon 1999) and was initially proposed by James Karr (Karr 1981). Ecotoxicologists may favour use of standard toxicity tests of fish at the laboratory for assessing the environmental stressors. Although laboratory tests provide useful information on how fish fauna respond to a particular environmental stress, they also have short comings/limitations (Cairns, 1983; Adam and Greeley, 2000). Therefore, further studies are needed in field conditions to increase our horizon on the ecological realism (Vidal, 2008) and to see whether the fish-assemblage attributes (called metrics) which reflect the impact of contamination on the fresh water ecosystems could be used as an effect indicator.

Deteriorating habitat quality has become a debatable question for ecologists and a significant research has been done on the relationship between deteriorating environmental quality and fish health (e.g., Adams *et al.*, 1993; Burke *et al.*, 1993; Able *et al.*, 1999). Some of the study has been focused on the role of anthropogenic factors on the commercially important marine fish species and fresh water fishes (Grosse *et al.*, 1997). There are also examples where researchers have compared biological parameters in different ecosystems (water bodies having different trophic status) in order to assess the influence of the environmental factors on fish growth. Tsoumani *et al.* (2006), for example, compared the length–weight relationships of the cyprinid fish *Carassius gibelio* (Bloch, 1782) in 12 commercially important lakes of Greece which differed in water quality and concluded that some of the factors (like phosphorus concentrations) may have impact on the 'b' value of length-weight relationship.

The fresh water bodies of the Kashmir Himalayas has got great commercial importance. The ecology of these lakes has changed considerably in the last few decades due to illegal encroachments, tourism, and other human activities, which has resulted in decreased water quality. Consequently, these factors are expected to have an adverse effects on fishes both physiologically and morphologically. In this scenario, limnologists as well as aquatic biologists in this part of world are concerned about the ecological impact of deteriorating environmental conditions on aquatic fauna.

Although fish condition is relatively well-studied aspect in fish of Kashmir Himalaya, very few studies have related it with water quality and trophic status of lake ecosystems. It is therefore necessary to have an assessment of overall impact of an altered environment on different aspects of fish. In order to fill this gap we framed a plan to assess the impact of altered water quality on the condition based indices (here length-weight relationship) which are also known as qualitative health indicators of a fish.

The overarching goal of our study was to evaluate the impact of deteriorating water quality on the length-weight relationship of the fish and for this purpose; we analyzed the fish in three valley lakes showing differences in water quality. Our hypothesis was that with the increase in cultural eutrophication (cultural eutrophication is different from normal eutrophication as latter is comparatively slow and is a natural process) of lakes, water quality decreases and this in turn affects the condition-based indices (length-weight relationship). In addition, we predicted that season, sex and water quality may have an impact on length -weight relationship. This study further focused on the importance of using condition based indices to assess habitat quality and environmental stressors in lakes with different levels of nutrient enrichment. We studied Crucian carp, *Carassius carassius* as it is found in all the three lakes.

Materials and Methods

Study Area

The valley of Kashmir is situated in the middle of the Himalayas between the northwest and southeast (33°01′–35°00′N latitude and 73°48′–75°30′ E longitude) at an altitude ≥1500 m above sea level. The study was carried out in 3 valley lakes, viz., the Anchar Lake (34°01′ N, 74°02′ E), Dal Lake (34°07′ N, 74°52′ E), and Manasbal Lake (34°15′ N, 74°40′E). The Anchar Lake is situated towards northwest of Srinagar city at an altitude of 1583 m (5,194 ft) with a maximum depth of 3 m. Major portion of lake is dominated by submerged and free-floating macrophytes. Three sites were selected for the present study-Anchar ghat, Anchar centre, and Anchar inlet. The Dal Lake is an urban lake that lies to the east of Srinagar city, at the foot of Zabarwan Hills, and is situated at an average elevation of 1,583 m (5,194 ft) above sea level with a maximum depth of 6 m (20 ft). Four sites were selected at Dal Lake, namely, Hazratbal basin, Gagribal basin, Nagin, and Bud Dal. Manasbal Lake is a rural lake situated at a distance of 32 km from Srinagar city. Its length and breadth are approximately 3.2 and 1 km, respectively. The lake is situated at the altitudinal zone of 1,585-1,600 m (5,200-5,200 ft) with a maximum depth of 13 m (43 ft). Four sites were selected at this lake, one at the centre and 3 at the periphery.

Physico-Chemical Features

The physico-chemical characteristics of water were analysed as per the methods described by the Council for Scientific and Industrial Research (CSIR, 1974), Mackereth *et al.* (1978) and the American Public Health Association (APHA, 1998). Water temperature, conductivity, and transparency were recorded on the spot, whereas samples were fixed at the sampling site in accordance with the azide modification of Winkler method (APHA, 1998) for the estimation of dissolved oxygen. Measurements were made using the following equipment/method(s): water temperature, Celsius mercury thermometer calibrated up to 0.1°C; transparency, Secchi disc; hydrogen ion concentration, digital pH meter (Microprocessor pH System-1011E); conductivity, Systronics model 104 conductivity meter; total hardness, EDTA method (CSIR, 1974); total alkalinity and chloride, as per Mackereth *et al.* (1978); ammonical nitrogen, phenate method (APHA, 1998); and nitrate-nitrogen, salicylate method (CSIR, 1974).

Fish Collection and Biometric Analysis

Live *C. carassius* specimens were collected either directly from the selected sampling sites with a cast net or procured from local fishermen as soon as they brought their catch to the landing centre. For biometric analysis fish total length (TL; to the nearest 1mm), standard length (ST; to the nearest 1mm), fork length (FL; to the nearest 1mm) and weight (Wt; to the nearest 1g) were calculated. In total, specimens 184 (86 males and 99 females) were collected throughout the sampling period. Of these, 51 were from Anchar Lake, 70 from Dal Lake and 64 from Manasbal Lake.

The length-weight relationship was calculated by using Le Cren's (1951) formula. The formula is as below:

$$W=aL^b$$

where 'W' and 'L' are weight and length respectively and 'a' and 'b' are constants. For the practical purpose this relationship was expressed in its logarithmic form as:

Log W = Log a + b Log L (Le Cren, 1951)

The values of the constants a and b was determined by fitting a straight line to the logarithmic of L and W, or by computing them from the following normal equation:

Log a = Σlog W. $\Sigma(\log L)^2$ – Σlog L.(Σlog L.log W) / N. $\Sigma(\log L)^2$- $(\Sigma\log L)^2$ and b = ΣlogW-Nloga / ΣlogL

we classified fish samples according to following criteria: light group, $b<3.0$; isometric growth, $b=3.0$ and heavy group, $b>3.0$. The ideal value of $b=3.0$ indicates the fish are having the isometric growth of equal increment of both parameters (Ricker, 1973).

Statistical Analysis

We used Students' t-test to compare the difference of 'b' between male and female specimens. All data were subjected to one-way analysis of variance (ANOVA) to compare the 'b' value among the three lakes. Linear regression statistics was used to analyse the length-weight relationship in three lakes. We also used box plot to compare the 'b' value among three lakes. In addition we also carried out multiple comparisons with One Way ANOVA (Tukey HSD and LSD). Correlation coefficients were used to see the relationship between "b" value and physico-chemical features. All tests were performed by using SPSS software 11.5 (SPSS Inc., Chicago, IL, USA).

Results

Water Quality

The range of various physico-chemical features, calculated from the three lakes are presented in Table 1. These lakes have been studies from time to time by different limnologists with the aim to categorise these lakes according to approved international standards (OECD, 1982). According to our study, all the three lakes have reached to the level of eutrophic condition, but the level of trophic state varies, with Anchar Lake being the most eutrophic and Manasbal Lake being the least nutrient enriched. Our results are in confirmation with the loading concept of Rawson (1939), Ohle (1956), Admondson (1961), and OECD (1998) and support the findings of Pandit and Yousuf (2002). The marked difference in the water quality of the three lakes clearly depicts the influence of anthropogenic stresses on the lakes.

Inter Lake Variation of Length-weight Relationship

The length-weight distribution of crucian carp in three lentic water bodies is tabulated in Table 2. The lengths ranged from 9.1–18.9 cm in Anchar Lake, 10–18.3 cm in Dal Lake and 10–18.9 cm in Manasbal Lake while the weights were between 12.5–145 g in Anchar Lake, 13.5–95.5 g in Dal Lake and 13.5–145 g in Manasbal Lake.

All relationships were significantly linear ($r>0.9$, $P<0.01$). Our results showed that 'b' values ranged between 2.72–3.29 (Manasbal Lake) in three lakes indicating positive allometric growth (Table 2). The 'b' value was insignificantly lower (ANOVA, $F=0.45$, $P=0.66$) in lake with highest nutrient enrichment level. The determination coefficients (R^2) for LWRs (length-weight relationships) was greater than 0.91 in all the lakes with the highest in Anchar Lake (0.97), thus showing a good fit to the line of regression. Overall, the regression model applied was significantly good enough in predicting the outcome variable of length–weight relationship ($P<0.0005$). Each of the box plot statistics of 'b' value (median, UQ, LQ) for Manasbal Lake was higher than other two lakes. Overall, it appears from the box plot analysis that the fish from Manasbal Lake shows a better growth in comparison to fish in other two lakes (Figure 1).

Table 1. The range of physico-chemical characteristics of water in the three Lakes

Parameter	Anchar		Dal		Manasbal	
	max	min	max	min	max	min
Water temp.(ºC)	30	6	30	6.5	29.3	6
Air temp. (ºC)	34	9	31.2	6.8	31.6	6.9
Depth (m)	1.7	0.6	2.6	2	7.4	6.1
Transparency (m)	0.94	0.4	2	1.5	3.6	2.9
pH	8.4	6.5	8.4	7.4	8.5	7.2
Conductivity (µ Scm^{-1})	265	212.2	280	243	200	111
Dissolved oxygen (mg L^{-1})	4.4	1.15	6.3	4.9	6.9	5.6
Free CO2 (mg L^{-1})	34.2	18.9	3.5	1.5	1.2	0.5
Alkalinity (mg L^{-1})	272.3	207.5	164.2	129.3	192	131.6
Chloride (mg L^{-1})	42.4	17.6	20.3	9.9	24.3	10.5
Ammonia-N (µg L^{-1})	560	374	190.3	149.2	194	169
Nitrate-N (µg L^{-1})	253.7	215.4	330.1	307.3	197.2	140.2
Total phosphate (µg L^{-1})	262.5	160.3	202	159.4	70.2	45.2
Total hardness (mg L^{-1})	255.2	125.2	170.2	140	130.2	97.2

Table 2. Parameter estimates of length-weight relationships in *Carassius carassius*

Lake/Sex of Fish	N	Total length (cm)		Weight (g)		Parameters of the relationship			
		Min.	Max.	Min.	Max.	Log a	b	CI (b)	R^2
Anchar Lake									
Male	19	10.6	18.4	21.5	109.0	-4.18	2.72	-	0.96
Female	32	9.1	18.9	12.5	145.0	-5.25	3.23	-	0.97
Combined	51	9.1	18.9	12.5	145.0	-5.04	3.13	2.3-3.7	0.97
Dal Lake									
Male	34	10.0	18.3	13.5	95.5	-5.24	3.20	-	0.91
Female	36	10.6	18.3	18.5	95.5	-4.45	2.83	-	0.93
Combined	70	10.0	18.3	13.5	95.5	-4.85	3.02	2.5-3.5	0.92
Manasbal Lake									
Male	33	10.0	18.4	13.5	99.0	-4.76	2.98	-	0.95
Female	31	12.7	18.9	39.0	145.0	-5.25	3.22	-	0.92
Combined	64	10.0	18.9	13.5	145.0	-5.40	3.29	2.7-3.6	0.96
Overall	185	10.2	18.6	17.5	119.4	-4.93	3.06	2.9-3.2	0.94

CI (b) is the confidence interval of b
R^2 coefficient of determination

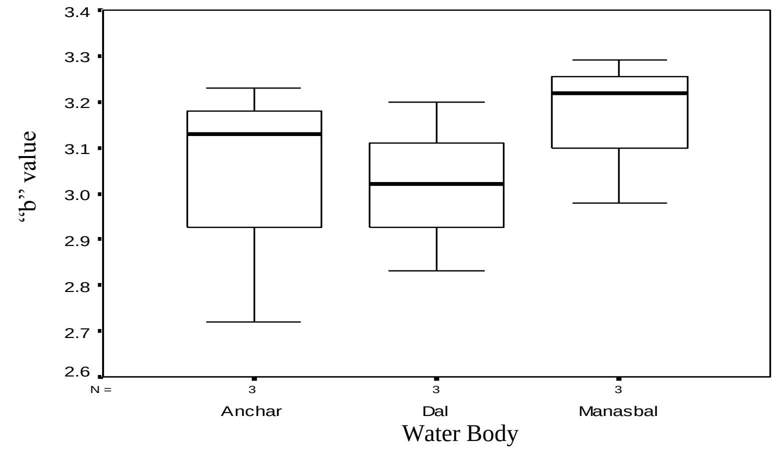

Figure 1. Box plot showing comparison of 'b' among the three lakes.

Effect of Physico Chemical Features on L-W Relationship

The monthly variation in physico-chemical features showed significant ($P<0.05$) differences with "b" value in the Dal Lake. The water temperature showed a significant positive correlation with the "b" value (r*p* = 0.8, $P<0.01$; r*s* = 0.93, $P=0.0001$; Figure 2). Similarly, some other parameters also showed significant positive correlation. In addition significant negative correlations were also observed between physico-chemical features and "b" value. The correlation between "b" value and environmental variables in Dal Lake is presented in Table 3.

Effect of Sex on L-W Relationship

Sexes showed significant ($P<0.05$) differences in "b" value in two lakes (Dal and Manasbal Lakes) while as trend was different in Anchar Lake where sexes showed insignificant ($P>0.05$) differences.

Effect of Season on L-W Relationship

Statistically seasons showed significant differences in "b" value in Dal Lake ($F=5.8$; $p=0.02$). Multiple comparisons showed significant differences among different seasons: Winter vs Spring (Tukey HSD; $P=0.02$), winter vs summer (Tukey HSD; $P=0.04$), winter vs autumn (Tukey HSD; $P=0.31$). Similarly LSD comparisons also showed significant differences among different seasons (Table 4).

Discussion

Inter Lake Variation of Length-weight Relationship

In previous studies some research workers have taken interest in the length-weight relationship of *Carassius carassius*. Yousuf *et al*. (1992) for example conducted studies on the biological aspects of fish in Manasbal Lake and found that the Crucian Carp (*C. carassius*) possessed "b" value of 2.47. In past,

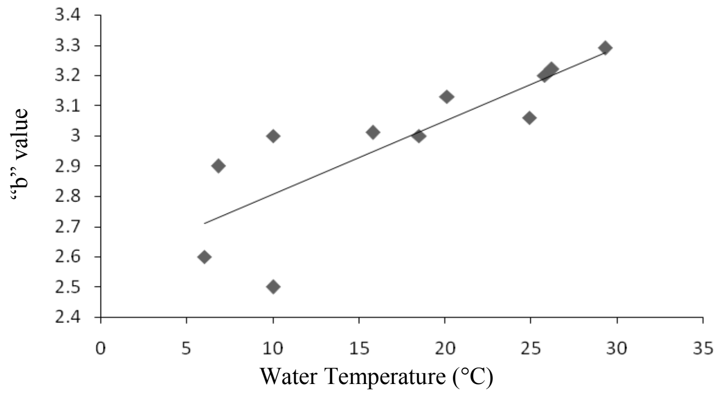

Figure 2. 'b' value of *Carassius carassius* collected from Dal Lake plotted against water temperature in different months. The relationship is significant ($y = 0.024x + 2.565$; $R^2 = 0.681$; $P<0.05$).

Table 3. Correlation between "b" value and environmental variables in Dal Lake

Parameter	r_p	P-value	r_s	P-value
Water temp. (ºC)	0.82**	0.001	0.93**	0.0001
Air temp. (ºC)	0.884**	0.00	0.884**	0
Depth (m)	-0.623*	0.04	-0.623*	0.04
Transparency (m)	-0.889**	0.001	-0.889**	0.001
pH	0.742**	0.009	0.742**	0.009
Conductivity (µ Scm^{-1})	0.948**	0.00	0.948**	0
Dissolved Oxygen (mgL^{-1})	-0.759**	0.007	-0.759**	0.007
Free CO_2 (mg L^{-1})	0.639*	0.034	0.639*	0.034
Alkalinity (mg L^{-1})	0.497	0.12	0.497	0.12
Chloride (mg L^{-1})	0.683*	0.02	0.683*	0.02
Ammonia-N (µg L^{-1})	0.925**	0.00	0.925**	0
Nitrate-N (µg L^{-1})	0.603*	0.05	0.603*	0.05
Total phosphate (µg L^{-1})	0.847**	0.001	0.847**	0.001
Total Hardness	0.888**	0.00	0.888**	0

r_p is Pearson Correlation, r_s is Spearman's correlation, * Correlation significant at 0.05 (2-tailed), **Correlation significant at 0.01 (2-tailed),

Table 4. Multiple comparison tests (Tukey HSD & LSD) in "b" value in Dal Lake

Tukey HSD	P-Value	LSD	P-Value
Winter vs Spring	0.02*	Winter vs Spring	0.005*
Summer vs Winter	0.04*	Summer vs Winter	0.01*
Autumn vs Winter	0.32	Autumn vs Winter	0.1

* Mean difference is significant at 0.05 level.

researchers have pointed out that limnological features of water bodies in the Kashmir Himalayas show differences in water quality and trophic status and so inter specific differences in length-weight relationship could be due to the changed environmental factor (Zuthshi *et al*., 1980). Present study also supports their findings.

The fish showed positive allometric growth (b>3.0; heavy group) in Manasbal and Anchar lakes and isometric growth of equal increment of both parameters of length and weight in the Dal Lake. It has been reported by some fish biologists that 'b' values usually range from 2.5 to 4.0 for many fish species (Pervin and Mortuza, 2008). Although, Smith (1996) had adopted two groups; flattened group (b=2.65 to 2.75) and heavy bodied (b = 2.91 to 3.06) which can be used for restricted species of fish, but the grouping which we adopted in our study reflects the pattern which is widely accepted (Salam *et al.*, 2005; Cherif *et al.*, 2008).

Effect of Physico-Chemical Features on L-W Relationship

The results from the present study shows that length-weight relationship in Dal Lake is influenced by some of the physico-chemical features. Similar observations were mentioned by earlier workers from this region as well as from other researchers who stated that length–weight relationship is influenced by physico-chemical parameters of water (Sunder and Subla, 1984a; Weatherley and Gill, 1987). It has been reported that prevailing environmental conditions (Przybylski, 1996; Tsoumani *et al*., 2006) and intrinsic factors (Knaepkens *et al*., 2002) are related to the growth of fish. However, this speculation needs further investigation on other exotic as well as in endemic fish.

Effect of Sex on L-W Relationship

Females showed 'b' values more than males in two lakes (Anchar and Manasbal lakes). The mean regression exponent in L-W relationship of male and female showed closeness to 3.0 ($b \geq 3.0$). Our study coincides with the findings of Muchlisin *et al.* (2010) which stated that the 'b*'* value of female *Poropuntius tawarensis,* was slightly higher than in males. However, the slightly higher value of 'b' in males (Dal Lake) coincides very well with the findings of Jhingran (1961). The 'b' values showed significant differences in Dal ($P=0.03$) and Manasbal lakes ($P=0.02$) with respect to sex, while as insignificant difference in Anchar Lake ($P=0.054$, tendency to show significance). It also seems that the value of 'b' in two sexes varies with habitat (Yousuf *et al*., 2001). Significant differences in 'b' values in two lakes with respect to sex could be due to the differences in feeding intensity between male and female (Shafi and Qudus, 1974; Pervin and Mortuza, 2008) and severe environmental conditions in hypertrophic lake (Anchar Lake) may undermine the effects of feeding intensity in the Anchar Lake and as such insignificant relationship.

Effect of Season on L-W Relationship

Our results are in conformity with the earlier reports of Tesch (1971) who stated that season may influence the L-W relationship. Arslan *et al*. (2004), for example, found 'b' value recorded in the winter was significantly lower than 3.0 ($P<0.01$) indicated a negative allometric growth during this season. Our results also showed 'b' value lower than 3 (Average $b = 2.6$; $P<0.01$) in winter season. In other seasons average 'b' slightly deviated from isometric growth i.e. 3. There has been continuous debate on the impact of seasons on the L-W relationship in fish and majority of fish biologists believe that 'b' value's are dependent on physiological growth condition such as gonad development or food availability (Jennings *et al.*, 2001), biological and environmental condition, geographical, temporal and sampling factor (Bagenal and Tesch, 1978; Froese, 2006).

Conclusions and Suggestions

In summary, our study shows that alteration in water quality, season and sex may influence the length-weight relationship. Multiple comparisons showed significant differences in 'b' values among different seasons in Dal Lake. In future, we need holistic approach to elucidate the effects of eutrophication/environmental deterioration on the fish health. The incorporation of various indices (biological, physiological, biochemical etc.) will represent an integrative measure which is essential as it is generally not known which environmental stress responses or combinations of responses might be affected and therefore suitable for revealing the effect of water quality on fish health. Although there is a debate among fish biologists whether to use biometric indices for assessing the environmental quality, still these can be used as early warning indicators which can provide useful information to authorities dealing with environment related issues.

References

Able, K.W., Manderson, J.P. and Studholme, A.L. 1999. Habitat quality for shallow water fishes in urban estuary: the effect of man-made structures on growth. Mar. Ecol., 187: 227–235.

Adam, S.M. and Greely, M.S. 2000. Ecotoxicological indicators of water quality: Using multi-response indicators to assess the health of aquatic ecosystems. Water, Air and Soil Pollution, 123: 103-115.

Adams, S.M., Brown, A.M. and Goede, R.W. 1993. A quantitative health assessment index for rapid evaluation of fish condition in the field. Trans. Am. Fish. Soc., 122: 63–73.

American Public Health Association 1998. Standard methods for the examination of water and wastewater. American Public Health Association, the American Water Works Association and the Water Environment Federation. 20th Ed. Washington, DC: 1220

Beyer, J.E. 1987. On length-weight relationship. Computing the mean weight of the fish of a given length class. Fishbyte, 5: 11–13.

Bolger, T. and Connoly, P.L. 1989. The selection of suitable indices for the measurement and analysis of fish condition. J. Fish Biol., 34: 171–182.

Burke, J.S., Peters, D.S. and Hanson, P.J. 1993. Morphological indices and otolith microstructure of Atlantic croaker, *Micropogonias undalatus*, as indicators of habitat quality along an estuarine pollution gradient, Environ. Biol. Fishes, 36: 25–33.

Cairns, J.J. 1983. Are single species toxicity tests alone adequate for estimating environmental hazard? Hydrobioloy, 100: 47-57

Cherif, M., Zarrad, R., Gharbi, H., Missaoui, H. and Jarboui, O. 2008. Length-weight relationships for 11 fish species from the Gulf of Tunis (SW Mediterranean Sea, Tunisia). Panam JAS. 3: 1–5.

Froese, R. and Pauly, D. 1998. Fishbase: concepts, design and data sources. ICLARM, Manila.

Grosse, D.J., Scholz, P.M., Hirshfield, M.F., Meaburn, G.M. and Fletcher, M. 1997. Fisheries and pollution: an overview. Trans. Am. Fish. Soc., 126: 1357–1380.

Jhingran, A.G. 1961. Studies on the maturity and fecundity of the Gangetic Anchovy *Setipinna phasa* (Ham.). Indian J. Fish., 8: 291-311

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries, 6: 21-27

Pandit, A.K. and Yousuf, A.R. 2002. Trophic status of Kashmir Himalayan lakes as depicted by water chemistry. J. Res. Dev., 2: 1–12.

Knaepkens, G., Knapen, D., Bervoets, L., Hanfling, B., Verheyen, E. and Eens, M. 2002. Genetic diversity and condition factor: a significant relationship in Flemish but not in German populations of the European bullhead (*Cottus gobio* L.). Heredity, 89: 280–287.

Le Cren, E.D. 1951. The length-weight relationship and seasonal cycle in gonadal weight and condition in the perch, *Perca fluviatilus*. J. Animal Ecol., 20: 201–219.

Mackereth, F.J.H., Heron, J. and Talling, J.F. 1978. Water analysis: some revised methods for limnologists. Freshwater Biological Association, Scientific Publication, 120 pp.

Moutopoulos, D.K. and Stergiou, K.I. 2002. Length–weight and length–length relationships of fish species from the Aegean Sea (Greece). J. Applied Ichthyol., 18: 200–203.

Muchlisin, Z.A., Musman, M. and Siti Azizah, M.N. 2010. Length-weight relationships and condition factors of two threatened fishes, *Rasbora tawarensis* and *Poropuntius tawarensis*, endemic to Lake Laut Tawar, Aceh Province, Indonesia. J. Applied Ichthyol., 26: 949–953.

Arslan, M., Yildirim, A. and Bektas, S. 2004. Length-weight relationship of Brown Trout, *Salmo trutta* L., inhabiting Kan Stream, Coruh Basin, North-Eastern Turkey. Turkish Journal of Fisheries and Aquatic Science, 4: 45-48

OECD 1982. Eutrophication of waters: Monitoring, assessment and control. OECD, Paris, 154 pp.

Ohle, W. 1956. Bioactivity, production, and energy utilization of lakes. Limnology and Oceanography, 1: 139–149.

Pervin, M.R. and Mortuza, M.G. 2008. Notes on length-weight relationship and condition factor of freshwater fish, *Labeo boga* (Hamilton) (Cypriniformes: Cyprinidae). Univ. J. Zool. Rajshahi Univ., 27: 97–98.

Przybylski, M. 1996. Variation in fish growth characteristics along a river course. Hydrobiology, 325: 39–46.

Rawson, D.S. 1939. Some physical and chemical factors in the metabolism of lakes. In Problems of Lake Biology. Publication of the American Association for the Advancement of Science, 9–26.

Ricker, W.E. 1973. Linear regression in fisheries research. J. Fish Res. Board Can., 30: 409–434.

Salam, A., Naeem, M. and Kauser, S. 2005. Weight length and condition factor relationship of a freshwater wild *Puntius chola* from Islamabad, Pakistan. Pak. J. Biol. Sci., 8: 1112-1114.

Shafi, M. and Quddus, M.M. 1974. Length-weight relationship and condition factor in *Hilsa hilsa* (Hamilton) (Clupeiformes: Clupeidae). Bangladesh Journal of Zoology, 2: 179–185.

Simon, T.P. 1999. Assessing the sustainability and biological integrity of water resources using fish condition CRS Press, Boca Raton, Florida.

Smith, K.M.M. 1996. Length-weight relationships of fishes in a diverse tropical freshwater community, Sabah, Malaysia. J. Fish Biol., 49: 731–734.

Sunder, S. and Subla, B.A. 1984a. Fish and fisheries of R. Jhelum, Kashmir. Zoologica Orientalis, 1: 34–39.

Tesch, F.W. 1971. Age and growth. In: W.E. Ricker (Ed.), Fish Production in Fresh Waters. Blackwell, Oxford: 98–130.

The Council for Scientific and Industrial Research. 1974. An Analytical Guide. National Institute for Water Research, Pretoria South Africa.

Tsoumani, M., Liasko, R., Moutsaki, P., Kagalou, I. and Leonardos, I. 2006. Length–weight relationships of an invasive cyprinid fish (*Carassius gibelio*) from 12 Greek lakes in relation to their trophic states. J. Applied Ichthyol., 22: 281–284.

Vidal, L.B. 2008. Fish as ecological indicators in Mediterranean freshwater ecosystems. PhD thesis Girona: University of Girona, Spain.

Weatherley, A.H. and Gill, H.S. 1987. The biology of fish growth. Academic Press, London, 443 pp.

Jennings, S., Kaiser, M.J. and Reynolds, J.D. 2001. Marine Fisheries Ecology. Blackwell Science Ltd., London, 277 pp.

Bagenal, T.B. and Tesch, F.W. 1978. Age and growth. In: T. Bagenal (Ed.), Methods for the Assessment of Fish Production in Fresh Waters, 3rd Edition. Blackwell Scientific Publications, London, 365 pp.

Froese, R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. J. Applied Ichthyol., 22: 241-253. doi: 10.1111/j.1439-0426.2006.00805.x

Yousuf, A.R. and Pandit, A.K. 1992. Breeding biology of *Schizothorax niger* Heckel: Fecundity. Fish and Fishery Biology and Aquatic Ecology. Kash. Uni., India: 55-62

Yousuf, A.R., Firdus, G., Balkhi, M.H. and Pandit, A.K. 1992. Studies on the Length-weight relationship in some cyprinid fishes in Manasbal Lake, Fish and Fishery Biology and Aquatic Ecology. Kash. Uni., India: 199-206

Yousuf, A.R., Firdous, G. and Pandit, A.K. 2001. Length-weight relationship in *Schizothorax niger* Heckel, an endemic lacustrine fish of Kashmir. Journal of Research and Development, 1: 54-59

Zutshi, D.P., Subla, B.A., Khan, M.A. and Wanganeo, A. 1980. Comparative limnology of nine lakes of Jammu and Kashmir. Himalayan Hydrobiol., 72: 101–112.