Short communication

Length weight relationships of fish species collected after impoundment of the Three Gorges Reservoir (TGR) in China; a study carried out in the upper Yangtze River

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Abstract The Three Gorges Dam in the upper Yangtze River in China is the largest hydropower project in the world. Length- weight relationships (LWRs) are reported for fish species collected from three locations of the reservoir from November 2010 to October 2011. Fish were collected from the local fishing boats using 1.5 cm nylon mesh trap nets or 4, 5 and 6 cm nylon mesh gillnets (100- 120 m long × 1.4-1.5 m high). A total of 7,311 fish representing 49 species of 11 families were collected during the study period. There were 2,680 fish belonging to 32 species of 8 families sampled in Zigui (near the dam) reach, 2,845 fish representing 46 species of 8 families in Wanzhou (middle of the reservoir) reach and 1,786 fishes representing 38 species of 8 families in Fuling (upper reservoir) reach. The family with the highest number of species was Xenocyprididae. The intercept (a) and slope (b) of LWRs are useful in fisheries science in many ways. Therefore, the present study provides baseline data on LWRs of the economically valuable and most abundant fish species in the recently commissioned Three Gorges Reservoir.

Keywords: Allometric growth, Freshwater fish, Hydropower reservoir, Isometric growth

INTRODUCTION

The Three Gorges Reservoir (TGR) in the upper Yangtze River is the largest hydropower scheme in the world (Kittinger et al. 2009; Yang et al. 2011). Although there are economic and social benefits to the society through construction of dams and reservoirs, they bring about some impacts on the riparian habitats (Poff and Hart 2002; Poff et al. 2007). Therefore, the effects of dams on riverine fish species have been of greatly concern today (Baxter 1977; Greathouse et al. 2006). Some researchers have shown changes in both fish assemblage structure and their diversity with the impoundment (Wu et al. 2004; Agostinho et al. 2008). The effects of river impoundments on fish assemblage structure at downstream portions have been widely investigated (Taylor et al. 2014), but less in upstream changes (Franseen and Tobler 2013).

The length (L) - weight (W) relationship (LWR) of fish can be estimated using equation, $W=a\ L^b$, where a and b are constants, and the growth and condition of the fish are known to be influenced by several factors such as season, food, temperature and physical activity (Pauly 1983; Petrakis and Stergiou 1995; Froese 2006). The LWR of the fish is important in the biological studies of the fish, their stock assessment and estimation of biomass from length measurements (Krause et al. 1998; Valle et al. 2003; Offem et al. 2009). LWRs of fish provide information on the condition of fish, their growth pattern and comparative life histories of fish species between regions. They are useful to elucidate the possible differences between separate unit stocks of the same species indicating the wellbeing of the species (Le Cren 1951; Kumolu-Johnson and Nadimele 2011). The constants (a and b) of LWRs are useful in fisheries science in many ways including comparison of life history and morphology of fish populations (Petrakis and Stergiou 1995). Fish are poikilothermic animals that live permanently in water so that their metabolic activities are directly affected by changes in the ambient temperature of the habitat (Parrish and Mallicoate 1995). Some studies have shown LWRs of the fish species in the TGR collected using different fishing gears (Chen et al. 2016; Wei et al. 2019). However, the information on the LWR of fish species along the TGR after impoundment is scanty. Therefore, the present study attempts to provide baseline data on LWRs of economically valuable and most abundant fish species collected from three reaches of the upper Yangtze River of the TGR.

MATERIALS AND METHODS

Fish sampling was monthly carried out in three areas of the TGR in the main stream of the upper Yangtze River from November 2010 to October 2011, Zigui reach (near the dam, about 1.9 km from the dam) (30°51' N, 111°00' E), Wanzhou reach (middle reservoir, about 300 km up of the dam) (30°49' N, 108°23' E) and Fuling reach (upper reservoir, about 500 km away from the dam) (29°42' N, 107°23' E) (Figure. 1). Monthly sampling was carried out for 8-10 days and during each sampling visit, 5-8 fishing boats (40-50% boats) were selected for sampling fish. Fish were collected from the local fishing boats using 1.5 cm nylon mesh trap nets or 4, 5 and 6 cm nylon mesh gillnets (100- 120 m long × 1.4-1.5 m high). Fish samples collected from fishers were placed in ice and transported to the laboratory and samples were frozen at -20°C and stored until analyses. The specimens were sorted and identified. The total length (TL) of each fish was measured from the tip of the snout to the longest caudal- fin ray to the nearest 0.1 cm. Weight (W in g) of the fish was recorded on an electric balance sensitive to 0.001g, after blot-drying excess water from the body.

Statistical analysis

Using linear regression analysis, the relationships between TL and W of each fish species were determined for $\log_{10}$ transformed data in the three sampling regions of the reservoir separately. The log transformed relationship was $\log W = \log a + b \log L$, where W is the body weight (in g), L is the total length (in cm), log a is the intercept of the regression and b is the slope. All the statistical analyses were considered as significant at 5% probability ($p<0.05$). All statistical analyses were performed using SPSS 16.0 software.

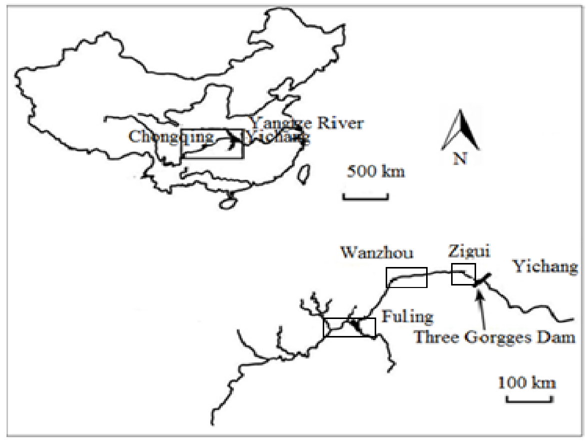

Fig 1 The three sampling locations along the longitudinal profile of the three Gorges reservoir.

RESULTS

A total of 7,311 fish representing 49 species of 11 families were collected during the study period. There were 2,680 fish belonging to 32 species of 8 families sampled in Zigui (near the dam) reach. 2,845 fish representing 46 species of 8 families in Wanzhou (middle of the reservoir) reach and 1,786 fishes representing 38 species of 8 families in Fuling (upper reservoir) were collected. The family with the higher number of species was Xenocyprididae (Table 1). Sample descriptive statistics and estimated parameters of the LWR for Zigui, Wanzhou and Fuling sites are summarized in Tables 2, 3 and 4 respectively. In Zigui, the sample size ranged from 41 for *Hypophthalmichthys molitrix* to 621 for *Hemiculter bleekeri*. The sample size in Wanzhou ranged from 57 for *Leiocassis longirostris* and 509 for *Hemiculter bleekeri*. In Fuling, the sample size ranged from 51 for *Rhinogobio cylindricus* to 183 for *Saurogobio dabryi*.

Table 1 Presence (+) / absence (-) of fish species along three reaches of the Three Gorges Reservoir.

Species	**Family**	**Zigui**	**Wanzho**	**Fuling**
Rhodeus ocellatus	Acheilognathidae	+	+	+
Hemibagrus macropterus	Bagridae	-	+	+
Leiocassis longirostris	Bagridae	+	+	+
Pseudobagrus fluvidraco	Bagridae	+	+	+
Pseudobagrus nitidus	Bagridae	+	+	+
Pseudobagrus vachelli	Bagridae	+	+	+
Botia superciliaris	Botiidae	-	-	+
Leptobotia pellegrini	Botiidae	-	-	+
Leptobotia rubrilaris	Botiidae	-	-	+
Parabotia banarescui	Botiidae	-	+	+
Parabotia fasciata	Botiidae	-	+	+
Myxocyprinus asiaticus	Catostromidae	-	+	+
Micropterus salmoides	Centrachidae	-	+	-
Channa argus	Channidae	-	-	+
Misgurnus anguillicaudatus	Cobitidae	+	+	+
Cyprinus carpio	Cyprinidae	+	+	+
Carassius auratus auratus	Cyprinidae	+	+	+
Carassius auratus gibelio	Cyprinidae	-	+	+
Folifer brevifilis	Cyprinidae	-	+	+
Procypris rabaudi	Cyprinidae	-	+	+
Ctenogobius giurinus	Gobiidae	+	+	+
Coreius guichenoti	Gobionidae	+	+	+
Coreius heterodon	Gobionidae	+	+	+
Gobiobotia abbreviata	Gobionidae	-	-	+
Pseudorasbora parva	Gobionidae	+	+	-
Rhinogobio cylindricus	Gobionidae	+	+	+
Rhinogobio typus	Gobionidae	+	+	+
Rhinogobio ventralis	Gobionidae	-	-	+
Sarcocheilichthys sinensis	Gobionidae	-	+	-
Saurogobio dabryi	Gobionidae	+	+	+
Saurogobio gymnocheilus	Gobionidae	+	+	+
Squalidus atromaculatus	Gobionidae	-	+	+
Neosalanx taihuensis	Salangidae	+	-	-
Protosalanx hyalocranius	Salangidae	+	-	-
Silurus asotus	Siluridae	+	+	+
Silurus soldatovi meridionalis	Siluridae	+	+	+
Siniperca chuatsi	Sinipercidae	+	+	+
Monopterus albus	Synbranchidae	+	-	-
Ctenopharyngodon idella	Xenocyprididae	+	+	+
Culter dabryi	Xenocyprididae	+	+	+
Culter erythropterus	Xenocyprididae	+	+	+
Culter mongolicus	Xenocyprididae	-	+	-

Elopichthys bambusa	Xenocyprididae	+	+	-
Hemiculter bleekeri	Xenocyprididae	+	+	+
Hemiculter leucisculus	Xenocyprididae	+	+	+
Hemiculter sauvagei	Xenocyprididae	-	+	-
Hypophthalmichthys molitrix	Xenocyprididae	+	+	+
Hypophthalmichthys nobilis	Xenocyprididae	+	+	+
Megalobrama amblycephala	Xenocyprididae	+	+	+
Mylopharyngodon piceus	Xenocyprididae	+	-	-
Opsariichthys uncirostris	Xenocyprididae	+	+	-
Parabramis pekinensis	Xenocyprididae	-	+	-
Pseudobrama simoni	Xenocyprididae	-	+	-
Pseudolaubuca engraulis	Xenocyprididae	-	+	-
Squaliobarbus curriculus	Xenocyprididae	-	+	-
Xenocypris argentea	Xenocyprididae	-	+	-
Xenocypris davidi	Xenocyprididae	+	+	-
Zacco platypus	Xenocyprididae	-	+	-

Table 2 Descriptive Statistics and estimated parameters of the length-weight relationship for the fish species collected from Zigui reach of the Three Gorges Reservoir. N - number of specimens; mean – mean value; Min – minimum value; Max – maximum value; a – intercept of LWR; b – slope of LWR; r^2 – coefficient of determination.

		Length characteristics			Weight Characteristics			Parameters of the relationship			
Species	N	Mean	Min	Max	Mean	Min	Max	a	b	SE(b)	r^2
Aristichthys nobilis	43	21.8	11.5	70.0	347.729	10.659	8500.000	0.005	3.175	0.108	0.972
Carassius auratus auratus	76	15.1	10.8	19.5	58.768	23.500	178.500	0.028	3.003	0.195	0.856
Culter dabryi	56	19.8	13.5	30.5	68.559	23.500	217.305	0.018	2.712	0.223	0.856
Cyprinus carpio	44	19.7	13.5	32.1	99.379	23.750	412.000	0.007	3.073	0.294	0.853
Hemiculter bleekeri	621	10.4	7.0	14.7	19.108	7.000	22.112	0.003	3.388	0.042	0.955
Hemiculter leucisculus	375	10.4	6.5	14.8	8.380	0.520	19.000	0.006	3.037	0.069	0.916
Hypophthalmichthys molitrix	41	18.3	13.5	43.4	65.932	23.500	537.000	0.012	2.892	0.162	0.944
Pseudobagrus fluvidraco	93	12.5	4.5	22.5	17.679	0.863	120.550	0.011	2.795	0.109	0.872
Pseudobagrus nitidus	79	11.7	5.5	16.2	13.700	1.427	43.230	0.018	2.637	0.138	0.909
Pseudobagrus vachelli	90	12.4	8.9	20.2	14.932	4.793	50.600	0.022	2.546	0.175	0.841
Rhinogobio cylindricus	64	9.8	6.8	11.6	8.800	1.975	38.975	0.816	4.061	0.375	0.816
Rhinogobio typus	201	10.1	6.4	17.5	6.842	1.582	38.975	0.005	3.032	0.044	0.980
Saurogobio dabryi	278	11.2	7.7	15.0	7.700	9.098	18.690	0.010	2.784	0.021	0.992
Saurogobio gymnocheilus	260	10.6	5.5	13.2	8.834	2.250	18.600	0.011	2.757	0.088	0.890

Table 3 Descriptive Statistics and estimated parameters of the length-weight relationship for the fish species collected from Wanzhou reach of the Three Gorges Reservoir. N - number of specimens; mean – mean value; Min – minimum value; Max – maximum value; a – intercept of LWR; b – slope of LWR; r^2 – coefficient of determination.

		Length characteristics			Weight Characteristics			Parameters of the relationship			
Species	N	Mean	Min.	Max.	Mean	Min.	Max.	a	b	SE(b)	r^2
Carassius auratus auratus	218	12.3	6.8	30.2	37.247	4.681	557.710	0.008	3.224	0.054	0.971
Cyprinus carpio	70	18.1	13.5	29.6	62.750	23.500	196.166	0.019	3.750	0.189	0.870
Hemiculter bleekeri	509	10.4	7.0	14.8	8.970	1.757	24.744	0.003	3.419	0.045	0.958
Hemiculter leucisculus	326	10.3	5.5	14.7	9.007	0.867	22.112	0.002	3.535	0.062	0.954
Leiocassis longirostris	57	15.9	10.5	20.5	45.878	13.500	117.500	0.019	3.018	0.202	0.880
Pseudobagrus fluvidraco	117	12.7	7.0	26.7	15.777	3.345	120.767	0.009	2.866	0.121	0.821
Pseudobagrus nitidus	198	11.5	3.8	15.9	12.303	1.250	39.750	0.015	2.688	0.081	0.921
Pseudobagrus vachelli	187	12.3	7.5	25.5	14.970	3.750	50.660	0.017	2.665	0.133	0.828
Rhinogobio typus	155	14.7	9.7	19.7	20.054	5.984	44.910	0.007	3.020	0.640	0.965
Sarcocheilichthys sinensis	62	12.5	9.2	17.5	25.299	7.000	53.700	0.008	3.104	0.103	0.969
Saurogobio dabryi	140	13.6	7.7	18.5	16.091	5.984	44.910	0.014	2.673	0.070	0.955
Saurogobio gymnocheilus	150	10.7	4.6	13.0	8.670	19.000	1.950	0.014	2.653	0.098	0.910
Squalidus atromaculatus	87	10.4	6.5	13.0	9.031	1.757	23.300	0.002	3.490	0.175	0.908

Table 4 Descriptive Statistics and estimated parameters of the length-weight relationship for the fish species collected from Fuling reach of the Three Gorges Reservoir. N - number of specimens; mean – mean value; Min – minimum value; Max – maximum value; a – intercept of LWR; b – slope of LWR; r^2 – coefficient of determination.

		Length characteristics			Weight Characteristics			Parameters of the relationship			
Species	N	Mean	Min	Max	Mean	Min	Max	a	b	SE(b)	r^2
Carassius auratus auratus	90	16.8	9.0	28.0	96.382	7.800	377.500	0.011	3.141	0.059	0.985
Cyprinus carpio	81	18.0	12.0	29.6	65.610	23.500	299.888	0.023	3.697	0.209	0.823
Hemiculter bleekeri	137	10.4	4.1	14.8	9.220	1.350	24.700	0.006	3.080	0.107	0.927
Hemiculter leucisculus	119	10.7	6.5	17.1	10.106	1.500	50.847	0.003	3.324	0.101	0.950
Leiocassis longirostris	125	18.2	11.7	33.5	61.688	9.700	283.192	0.005	3.178	0.092	0.952
Pseudobagrus fluvidraco	129	16.4	8.0	34.9	41.3	3.70	192.118	0.007	2.910	0.125	0.914
Pseudobagrus nitidus	135	16.2	10.0	23.0	29.771	6.685	78.597	0.015	2.684	0.088	0.936
Pseudobagrus vachelli	175	17.3	6.7	27.5	42.016	4.500	166.755	0.024	2.572	0.043	0.977
Rhinogobio cylindricus	51	9.9	6.8	11.6	8.920	2.200	34.900	0.001	3.990	0.394	0.820
Rhinogobio typus	73	16.8	10.5	20.2	32.866	5.849	71.084	0.002	3.418	0.167	0.920
Rhinogobio ventralis	178	16.7	10.5	20.2	34.602	5.849	85.780	0.012	3.360	0.080	0.980
Saurogobio dabryi	183	10.7	6.5	13.0	8.683	1.780	21.258	0.008	2.913	0.065	0.958
Saurogobio gymnocheilus	100	10.1	3.5	13.0	9.034	1.240	19.975	0.014	2.653	0.098	0.910

DISCUSSION

The length-weight relationship (LWR) is an important factor in the biological study of fishes and their stock assessment and it describes the important information on growth patterns and growth rates of fish. Further, it describes the functional regime in the weight distribution of a sub population (Morato et al. 2001). The fish grows isometrically when the b equal 3 (Rahim et al. 2009) and when the b value was different from 3, it shows the negative or positive allometric growth pattern (Amin et al. 2008). Mainly the b values depend on both the shape and fatness of the species. Chen et al. (2016) reported LWRs of 55 fish species in the TGR. The LWRs of nine fish species collected from the TGR were given by Gong et al. (2018). The LWRs of 15 fish species in the three reaches (lower, middle and upper) from the TGR were reported by Wei et al. (2019). In this study, LWRs of the economically valuable and most abundant fish were presented. Because of the ecological and economic importance of these species and also as this reservoir has been recently filled, the data on their functional LWR might be important when studying growth and population parameters.

CONCLUSION

The present study provides baseline data on LWRs of the economically valuable and most abundant fish species in the recently completed TGR. The relationships presented from in this study can be used in studying growth and population studies of the fish in TGR.

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