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REVIEW

Stock Characteristics and Management Insights for Common Carp (*Cyprinus carpio*) in Anatolia: A Review of Weight–Length Relationships and Condition Factors

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Abstract

The common carp (*Cyprinus carpio*) is a species of primary importance for commercial inland fisheries of Anatolia, where it is native to some areas but has become almost ubiquitous due to historical translocations. Yet, there are concerns that this 'semi-naturalised' species can ultimately pose a threat to aquatic ecosystems, especially when present at high biomass levels. For estimating the latter, knowledge of length–weight relationship (WLR) and condition factor (K) parameters is needed, and these also represent useful indicators of fish population dynamics in general. In this study, WLR and K parameter values from published literature data were comprehensively reviewed for 68 and 75 common carp stocks, respectively, from 52 water bodies across Anatolia, which were surveyed between 1953 and 2011. Overall, Anatolian common carp stocks were characterised by slightly negative allometric growth, which became more pronounced in some over-exploited stocks and/or under critical conditions of pollution and water quality. This tendency to negative allometric growth was unlike other stocks world-wide, which showed isometric growth. Also, no altitudinal gradients were detected in the parameters under study and only slight differences amongst waterbody types (i.e. man-made lakes, natural reservoirs and water courses) were revealed (possibly a result of biassed sampling). It is argued that the level of nativeness present in Anatolian common carp stocks may be responsible for the observed patterns and differences relative to domesticated/feral common carp stocks introduced to non-native areas world-wide. This finding should be accounted for when evaluating ecological benefits vs economic losses of intervention measures for control.

Keywords: Isometric, allometric, wild, feral, domesticated.

Anadolu Sazanı Stok Karakteristikleri ve Yönetim Anlayışı: Ağırlık-Boy Ilişkileri ve Kondisyon Açısından Bir Değerlendirme

Özet

Anadolu'nun ticari içsu balıkçılığı açısından önemli bir türü olan sazan (*Cyprinus carpio*), bazı alanlarda doğal olarak yayılış göstermesine karşın tarih boyunca yapılan taşımalar nedeniyle günümüzde neredeyse her alanda rastlanır hale gelmiştir. Bununla birlikte, yayıldığı bu alanlarda yarı-yerel olarak kabul edilebilen bu türün özellikle yüksek biyomas düzeylerinde olduğunda, sucul ekosistem için bir tehdit oluşturabileceğine yönelik kaygılar bulunmaktadır. Biyomasın hesaplanması için aynı zamanda balık polulasyon dinamiğinin göstergeleri arasında olan boy-ağırlık ilişkisi (BAİ) ve kondüsyon faktörü (K) parametrelerinin bilinmesi gerekmektedir. Bu çalışmada, Anadolu'daki 52 su kütlesinde 1953–2011 yılları arasında yapılan çalışmalara ait yayınlanmış literatür taranarak 68 sazan stokunun BAİ verileri ve 75 stokun K parametreleri kapsamlı bir şekilde değerlendirilmiştir. Genel olarak, Anadolu'daki sazan stoklarının hafif negatif allometrik büyüme gösterdiği, aşırı sömürülen ve/veya su kalitesinin ve kirliliğin kritik düzeyde olduğu su kütlelerinde bulunan stoklarda ise hafif negatif allometrik büyümenin daha belirgin olduğu tespit edilmiştir. Bu hafif negatif allometrik büyüme eğilimi, dünyaki diğer sazan stoklarında genel olarak rastlanan izometrik büyümeden farklılık göstermektedir. İncelenen parametrelerde rakıma bağlı bir değişim tespit edilmemekle birlikte, çalışılan su kütlesi tipleri (yapay göller, doğal rezervuarlar ve akarsular) arasında (muhtemelen yönlendirilmiş örnekleme sonucu) parametrelerin az bir oranda farklılık gösterdikleri gözlenmiştir. Bu çalışmada, Anadolu sazan stoklarında görülen "yerel olma" düzeyinin BAİ ve K değerleri üzerindeki etkili olabileceği ve dünya genelinde yerel olmayan bölgelere aşılanan evcil-yabani sazan stokları arasında gözlenen farklılıkların nedeni olabileceği tartışılmıştır. Bu bulgu, müdahale önlemleri nedeniyle oluşacak ekonomik kayıplara karşı ekolojik faydaların değerlendirilmesi açısından büyük bir önem taşıyabilir

Anahtar Kelimeler: Izometrik büyüme, allometrik büyüme, yabanıl, yabanileşmiş, evcil.

Introduction

Knowledge of species-specific weight–length relationships (WLR) and condition factors (*K*) is important for the study of fish population biology and dynamics, as it allows to: (i) estimate the weight from the length of individual fish or from length classes; (ii) assess standing crop biomass when the length–frequency distribution is known; (iii) compute relative condition and relative weight; (iv) convert growth-in-length to growth-in-weight equations to predict weight-at-age in stock assessment models; and (v) compare the life-history parameters and size-structure of populations from different locations (e.g. Anderson and Gutreuter, 1983; Froese, 2006).

Over the past six decades, a large number of studies on common carp (*Cyprinus carpio*) population structure and dynamics has been carried out in freshwaters of Anatolia (*sensu lato*: see http://www.britannica.com/EBchecked/topic/22897/ Anatolia [Accessed 09/08/2013]). This is because common carp, which is native to some parts of Anatolia (Vilizzi, 2012), is now almost ubiquitous throughout the Region, having been subjected to intensive translocations since the 1960s (Innal and Erk'akan, 2006). Indeed, common carp currently represents the most important species for inland fisheries of Turkey along with the tarek (or 'inci kefali') *Alburnus tarichi* (Turkish Statistical Institute, 2012). However, biomanipulation studies (Beklioglu *et al.*, 2003; Beklioglu and Tan, 2008) and modelling of resistance to bioturbation (Tan and Beklioglu, 2006) have also indicated that at critical biomass levels common carp can have detrimental effects on shallow lake ecosystems of Anatolia. On the wake of these findings, a debate has recently begun to re-appraise the status of this 'semi-naturalised' (*sensu* Copp *et al.*, 2005) species in several areas of introduction across the Region (Önsoy *et al.*, 2011; Tarkan *et al.*, 2012).

Previous summaries of WLR and *K* for common carp stocks in Anatolia have either been restricted to a certain study area (Tarkan *et al.*, 2006) or limited to a representative subset of studies drawn from the available literature (for WLR: Kılıç, 2003; Torcu-Koç *et al.*, 2006; Yılmaz *et al.*, 2010b; for *K*: Balık and Ustaoğlu, 1987; Bircan, 1995, 1998; Karataş *et al.*, 2007; Yılmaz *et al.*, 2007; Yağcı *et al.*, 2008b). The aim of the present study was therefore to provide a 'near-comprehensive' (cf. Balon, 1982 for caveats), state-of-the-art review of WLR and *K* for common carp stocks from Anatolian freshwaters based on an extensive collection of literature data. It is envisaged that the availability of such a dataset synthesis will contribute to refine future studies on common carp basic biology in freshwaters of Anatolia, with special emphasis on population structure and dynamics. The ultimate objective of this review is therefore to help inform better management options aimed to strike a balance between the widely-recognised species' economic value for inland fisheries and the recent mounting debate about its potential impacts on aquatic ecosystems.

Materials and Methods

Data on WLR and *K* for common carp stocks in Anatolia were collated from all published literature sources available to the authors, including peer-reviewed papers, thesis dissertations, conference proceedings, and reports. A stock was defined after Begg *et al.* (1999) as a 'semi-discrete group of fish with some definable attributes of interest for management purposes' (see also Begg and Waldman, 1999). Notably, stocks sampled in different years or periods from the same location were regarded as different (e.g. due to immigration/emigration, recruitment and mortality, stocking and exploitation by fishing). Also, the term 'stock' will be used throughout to refer both to the combined sexes and to males and females separately (i.e. 'sexed stocks').

Both WLR and *K* studies were first categorised according to waterbody type (i.e. man-made reservoirs, natural lakes, water courses), then by location, and within each location by sampling year/period (in case of repeated sampling), and finally by sex (if determined for males and females, otherwise only for the combined sexes). For WLR, the number of specimens *n* in the sample, the estimated parameters for the equation $L=aW^b$ (where *L* is the length of the fish, in cm or mm; *a* and *b* are the intercept and slope parameters, respectively; *W* is the weight of the fish, in g), along with (whenever available) the coefficient of determination r^2, the minimum and maximum length (in cm, converted from mm as required: see below), as well as the type of length (fork length: FL; total length: TL) and metric (cm or mm) used were reported as provided in the original source study. Similarly, for each of the stocks reviewed for *K* the corresponding mean *K* values (from the equation $K=W/aL^b$) along with the number of specimens *n* in the sample (whenever available) and the length type used were provided. Notably, in those studies where only *K* values for individual age classes or months of sampling were reported, the arithmetic mean of those values was computed.

Whenever the WLR was expressed only in its logarithmic form (i.e. $\text{Log}(a)=b\text{Log}(L)$), parameter *a* was obtained by the anti-logarithmic transformation (Log is logarithm to the base 10). As the majority of studies measured length in cm and expressed it as FL, conversion factors $a'=a10^b$ and $a_{FL}=a_{TL}(\text{FL/TL})^{-b}$ (where FL/TL=0.894, as derived from FishBase: Froese and Pauly, 2013) were used for all those studies reporting length in mm and/or TL (Froese, 2006). The resulting (standardised) intercept value was then indicated as $a^{(\prime)}$ (that is, either *a* or a'). Similarly, for those studies using TL the original value of *K* was converted into *K*' (i.e. relative to FL) based on the formula $K' = r^3 K_{TL}$, with r equal to the FL/TL conversion factor above. The resulting values were then indicated as $K^{(\prime)}$ (that is, either K or K').

For the WLR, a plot of Log($a^{(\prime)}$) vs b for all stocks reviewed was produced to detect outliers, which were identified as those values lying more than one standard deviation off the regression line (Stergiou and Moutopoulos, 2001) and excluded from subsequent analyses (Froese, 2006). The same linear regression plot was also used to locate stocks both within and outside the isometric interval [2.5,3.5] defined by parameter b, with values <2.5 and >3.5 indicating negative and positive allometric growth, respectively (Froese, 2006).

Summary statistics were computed for the WLR parameters $a^{(\prime)}$ and b and for $K^{(\prime)}$ relative to all stocks, separately for the combined sexes, males and females, as well as for the waterbody types (combined sexes only). To test for the presence of an altitudinal gradient, b and $K^{(\prime)}$ (combined sexes only) were plotted against the altitude of the corresponding location and a regression line fitted to the data. Further, differences in mean b and mean $K^{(\prime)}$ between sexes and amongst waterbody types (combined sexes only) were tested by permutational analysis of variance (PERANOVA), following normalisation of the data and using a Euclidean dissimilarity measure, and with significant differences followed by *a posteriori* pair-wise comparisons (PERMANOVA+for PRIMER v6; 9999 unrestricted permutations of the raw data) (Anderson *et al.*, 2008).

For comparison with common carp stocks world-wide, data on WLR were obtained from FishBase and preliminarily 'parsed' by eliminating all stocks from Turkey as well as those records including parameter values flagged as 'doubtful', plus any duplicate entries. As lengths were reported as SL (standard length), FL or TL, the coefficient FL/SL = 1.093 (after FishBase) also was used along with the one for FL/TL (see above) to calculate $a^{(\prime)}$. Summary statistics were then computed for parameters $a^{(\prime)}$ and b for all stocks and for the combined sexes only. Finally, differences in b and in the form factor $a^{(\prime)}_{3.0} = 10^{\mathrm{Log}(a^{(\prime)}) - S(b-3)}$ (where S is the slope of the regression of Log($a^{(\prime)}$) vs b: Froese, 2006) between Anatolian and world-wide stocks (combined sexes only) were tested by PERANOVA (as above). All tests of significance were at α=0.05.

Results

In total, 67 studies published between 1958 and 2012 were reviewed. These studies provided WLR and/or K data for common carp stocks across 52 water bodies of Anatolia, comprising 20 man-made reservoirs, 28 natural lakes, and 4 water courses. Altitude of the water bodies ranged 0–2193 m ASL; latitude and longitude 36°25′N–41°44′N and 26°67′E–44°09′N, respectively, hence spanning the entire Region (Table A.1).

Weight–Length Relationships

Data on WLR were obtained for 68 common carp stocks (135 sexed: 65 combined sexes, 35 males, 35 females) from 43 water bodies of Anatolia (16 man-made reservoirs, 23 natural lakes, and 4 water courses). These were described in 56 studies, with sampling carried out from 1972 to 2008 (Table A.2).

A plot of Log($a^{(\prime)}$) vs b revealed four outliers out of the 135 sexed stocks (Figure 1). These outliers, which resulted from lower than expected Log($a^{(\prime)}$) values, included the female stock from Lake Akşehir (1987–1988 sampling), and the stocks from Lake Tödürge (males, females and combined sexes; 2007 sampling) (Table A.2). Because of their outlier values, these stocks were excluded from subsequent analyses, which were carried out on the remaining 131 sexed stocks.

The mean b value for the 131 sexed stocks and broken down across the combined sexes, males and females was always below the isometric value of 3, which was not included in the corresponding 95% CIs in either case (Table 1). This indicated an overall negative allometry, i.e. a tendency for fish to increase less in thickness as they grew as would be expected for normal growth. This was evident upon inspection of Figure 1, where the great majority of the stocks (n=118; 87.4% of the total) lay to the left of the isometric line (b<3), and with 12 of these located within the negative allometry (b<2.5) portion of the graph. Amongst the latter stocks were those from Mamasın Reservoir and again from Lake Tödürge (1985–1986 sampling). The remaining stocks (n=17; 12.6% of the total) lay to the right of the isometric line (b>3), with only one stock (females from Lake Sera) located within the positive allometry (b>3.5) portion of the graph. Finally, a plot of b vs altitude resulted in a non-significant regression relationship, indicating the lack of an altitudinal gradient (Figure 2a).

There were no significant differences in mean b values between males and females ($F_{1,65}^{\#}$=0.14, $p^{\#}$=0.710; $^{\#}$=permutational value) (Table 1). On the other hand, comparison of mean b values for common carp stocks across the three different waterbody types pointed to a higher value in water courses (b>3) relative to both natural lakes and man-made reservoirs, whose corresponding 95% CIs did not include the isometric value of 3 (Table 1). However, these differences were not significant ($F_{2,61}^{\#}$=2.15, $p^{\#}$=0.130).

Of the 62 common carp WLR records listed on FishBase (as of 09/08/2013), 42 were retained after parsing (Table A.3). Of these sexed stocks, 35 (83.3%) were from countries where common carp has been introduced and the remaining 7 (16.7%) where it is native. The mean value of b was very close to 3, and was included within the 95% CI interval, indicating isometric growth (Figure 1). Also, the b

Table A.1. Water bodies of Anatolia for which literature data on length-weight relationship (WLR) and/or condition factor K parameters for common carp stocks were reviewed. Altitude in m ASL

Study area	Province	Latitude	Longitude	Altitude
Man-made reservoirs				
Almus Reservoir	Tokat	40°25′N	36°54′E	788
Altınkaya Reservoir	Samsun	41°21′N	35°43′E	220
Apa Reservoir	Konya	37°36′N	32°54′E	1048
Aslantaş Reservoir	Osmaniye	37°27′N	36°27′E	135
Bayramiç Reservoir	Çanakkale	39°82′N	26°67′E	181
Beytepe Pond	Ankara	39°87′N	32°83′E	978
Çamlıgöze Reservoir	Sivas	40°13′N	38°04′E	743
Değirmigöl-Dolutaş Reservoir	Van	38°35′N	44°09′E	2193
Derbent Reservoir	Samsun	41°27′N	35°50′E	63
Dönerdere Pond	Van	38°43′N	44°07′E	2089
Gelingüllü Reservoir	Yozgat	39°60′N	35°04′E	1008
Hirfanlı Reservoir	Kırşehir	39°27′N	33°51′E	845
Kapulukaya Reservoir	Kırıkkale	39°38′N	33°26′E	725
Keban Reservoir	Elazığ	38°48′N	38°45′E	848
Kemer Reservoir	Aydın	37°57′N	38°52′E	275
Köçköprü Reservoir	Van	39°14′N	43°33′E	1778
Mamasın Reservoir	Aksaray	38°41′N	34°21′E	1100
Ömerli Reservoir	İstanbul	41°03′N	29°22′E	63
Sarıyar Reservoir	Ankara	40°02′N	31°25′E	462
Seyhan Reservoir	Adana	37°02′N	35°19′E	56
Natural lakes				
Bafra Balık Lakes	Samsun	41°34′N	35°54′E	0
Lake Akşehir	Konya	38°36′N	31°18′E	954
Lake Beyşehir	Konya	37°47′N	31°33′E	1123
Lake Çavuşçu	Konya	38°21′N	31°52′E	1023
Lake Çernek	Samsun	41°38′N	36°04′E	0
Lake Çıldır	Ardahan	41°39′N	43°04′E	1963
Lake Eber	Afyon	38°39′N	31°10′E	968
Lake Eğirdir	Isparta	38°03′N	30°51′E	917
Lake Eymir	Ankara	39°49′N	32°49′E	973
Lake Gölcük	İzmir	38°48′N	39°40′E	1382
Lake Gölhisar	Burdur	37°08′N	29°30′E	947
Lake Haçlı	Muş	39°02′N	42°30′E	1582
Lake Hafik	Sivas	39°51′N	37°23′E	1289
Lake Işıklı	Denizli	38°14′N	29°54′E	816
Lake İznik	Bursa	40°43′N	29°52′E	83
Lake Karaboğaz	Samsun	41°40′N	35°47′E	2
Lake Karamık	Afyon	38°25′N	30°48′E	1028
Lake Köyceğiz	Muğla	36°91′N	28°65′E	0
Lake Kuş	Balıkesir	39°38′N	27°53′E	14
Lake Liman	Samsun	41°44′N	35°40′E	0
Lake Marmara	Manisa	38°61′N	27°98′E	74
Lake Mogan	Ankara	39°46′N	32°47′E	975
Lake Sapanca	Sakarya	40°43′N	30°15′E	30
Lake Sera	Trabzon	41°00′N	39°44′E	103
Lake Süleyman	Konya	38°03′N	28°46′E	1000
Lake Tödürge	Sivas	39°88′N	37°60′E	1305
Lake Uluabat	Bursa	40°10′N	28°35′E	2
Lake Yeniçağa	Bolu	40°46′N	32°01′E	989
Water courses				
Bendimahi Stream	Van	38°55′N	43°38′E	1650
Hatay Province[1]	Hatay	36°25′N	36°10′E	85
Karasu Stream	Van	38°17′N	43°01′E	1700
Sakarya River	Sakarya	41°12′N	30°64′E	800

[1] Includes Asi River, Lake Gölbaşı, Karasu Stream and Afrin Stream (included into Water courses given the predominance of this waterbody type).

Table A.2. Estimated parameters of the WLR ($W = aL^b$) for 135 common carp stocks of Anatolia

ID	Waterbody type	Year/ Period	Sex	*n*	*a*[(1)]	*b*	r^2	L_{min}	L_{max}	*L*	Metric	Source
Man-made reservoirs												
1	Almus Reservoir	1987	C	148	0.029834653	2.8338025	–	20.4[4]	39.9[4]	FL	mm	Akyurt (1987a)
2		2002–2003	C	307	0.00705	3.3191	0.9437	14.0	36.0	TL	cm	Karataş *et al.* (2007)
3	Altınkaya Reservoir	1990–1993	C	611	0.16324	2.37603	–	9.5	67.7	FL	cm	Bircan and Erdem (1994)
4		2003–2004	M	65	0.0415	2.778	0.99	22.9	69.6	TL	cm	Yılmaz *et al.* (2010a)
5			F	77	0.0316	2.866	0.99	21.1	77.6	TL	cm	Yılmaz *et al.* (2010a)
6			C	142	0.0357	2.825	0.99	21.1	77.6	TL	cm	Yılmaz *et al.* (2010a)
7	Apa Reservoir	1981	M	119	0.06420	2.58120	–	15.5[4]	56.4[4]	FL	cm	Erdem (1984a)[5]
8			F	123	0.0399	2.67441	–	13.0[4]	59.1[4]	FL	cm	Erdem (1984a)[5]
9		2001	M	108	0.055902	2.71	0.93	17.0	50.8	FL	mm	Mert *et al.* (2008)
10			F	105	0.043033	2.53	0.93	16.5	52.5	FL	mm	Mert *et al.* (2008)
11			C	251	0.036508	2.83	0.93	13.8	52.5	FL	mm	Mert *et al.* (2008)
12	Aslantaş Reservoir	1990–1991	C	130	0.01952	2.94036	–	10.9	44.5	FL	cm	Erdem *et al.* (1992)
13	Bayramiç Reservoir	2002–2003	M	162	0.026	3.01	0.84	13.1	42.5	FL	cm	Çolakoğlu and Akyurt (2011)
14			F	189	0.024	3.02	0.91	12.8	47.9	FL	cm	Çolakoğlu and Akyurt (2011)
15			C	351	0.025	3.01	0.87	12.8	47.9	FL	cm	Çolakoğlu and Akyurt (2011)
16	Değirmigöl-Dolutaş Reservoir	1994–1996	C	212	0.0229	2.969	0.997	8.1[4]	48.2[4]	FL	cm	Çetinkaya *et al.* (1995–1999)[6]
17	Derbent Reservoir	2003–2004	M	49	0.0259	2.923	0.870	36.3	60.0	TL	cm	Yılmaz *et al.* (2010a)
18			F	48	0.0292	2.896	0.98	16.0	75.0	TL	cm	Yılmaz *et al.* (2010a)
19			C	97	0.0290	2.894	0.97	16.0	75.0	TL	cm	Yılmaz *et al.* (2010a)
20	Dönerdere Pond	1994–1996	C	288	0.0277	2.888	0.994	8.0[4]	24.3[4]	FL	cm	Çetinkaya *et al.* (1995–1999)[6]
21	Gelingüllü Reservoir	1994	C	373	0.0255	3.0292	0.98	16.8	45.4	FL	cm	Ekmekçi (1996a)
22		1998–2000	C	633	0.0215	3.0226	0.9666	11.7	63.8	FL	cm	Kırankaya & Ekmekçi (2004)
23		2002–2005	C[1]	796	0.0283	2.9814	0.9597	11.5	71.5	FL	cm	Kırankaya (2007)
24		2002–2005	C[2]	283	0.0272	2.9631	0.9814	10.5	61.9	FL	cm	Kırankaya (2007)
25	Hirfanlı Reservoir	1974	M	807	0.15450	2.39531	–	8.0	66.0	FL	cm	Karabatak (1977)[6,7]
26			F	738	0.07830	2.58798	–	8.0	69.0	FL	cm	Karabatak (1977)[6,7]
27			C	1545	0.09585	2.53111	–	8.0	69.0	FL	cm	Karabatak (1977)[6,7]
28		1975	M	397	0.06264	2.64583	–	12.0	70.0	FL	cm	Karabatak (1977)[6,7]
29			F	418	0.04143	2.75415	–	13.0	69.0	FL	cm	Karabatak (1977)[6,7]
30			C	815	0.05700	2.67130	–	13.0	70.0	FL	cm	Karabatak (1977)[6,7]
31		1996–1997	M	109	0.0864284	2.5482	–	15.2	38.0	FL	mm	Elmas (1999)
32			F	83	0.1107605	2.5174	–	16.9	40.0	FL	mm	Elmas (1999)
33			C	206	0.0820463	2.5764	–	12.7	40.0	FL	mm	Elmas (1999)
34		1996–1998	M	237	0.0734632	2.60	–	11.8	57.4	FL	cm	Yılmaz *et al.* (2007)
35			F	219	0.0558879	2.66	–	12.7	56.3	FL	cm	Yılmaz *et al.* (2007)
36			C	456	0.0730254	2.69	–	11.8	57.4	FL	cm	Yılmaz *et al.* (2007)
37		2004–2005	M	83	0.0236	2.943	0.992	13.3	45.4	FL	cm	Yılmaz *et al.* (2010b)
38			F	65	0.0202	2.991	0.992	11.3	42.5	FL	cm	Yılmaz *et al.* (2010b)
39			C	148	0.0218	2.967	0.992	13.3	45.4	FL	cm	Yılmaz *et al.* (2010b)
40	Kapulukaya Reservoir	1991–1993	M	177	0.021877347	2.97	–	21.5	70.2	FL	mm	Yılmaz (1994)
41			F	176	0.026556844	2.96	–	23.3	71.0	FL	mm	Yılmaz (1994)
42			C	402	0.026915044	2.92	–	12.2	71.0	FL	mm	Yılmaz (1994)
43	Kemer Reservoir	2006	C	92	0.0174	3.0372	0.9826	10.94	28.54	FL	cm	Özcan and Balık (2007)
44	Köçköprü Reservoir	1999–2001	M	152	0.0356	2.892	0.986	18.3	50.4	FL	cm	Elp et al. (2008)
45			F	139	0.0545	2.737	0.895	12.7	61.7	FL	cm	Elp et al. (2008)
46			C	328	0.0396	2.847	0.951	8.2	61.7	FL	cm	Elp et al. (2008)
47	Mamasın Reservoir	1980–1981	M	139	0.213352	2.374481	–	10.0	56.0	FL	cm	İkiz (1988)6
48			F	129	0.223382	2.387746	–	11.0	65.0	FL	cm	İkiz (1988)6
49			C	268	0.216301	2.382813	–	10.0	65.0	FL	cm	İkiz (1988)6
50	Ömerli Reservoir	1995	C	51	0.0149	3.14	0.986	12.8	84.0	TL	cm	Tarkan et al. (2006)

Table A.2. Continued

ID	Waterbody type	Year/Period	Sex	*n*	$a^{(1)}$	*b*	r^2	L_{min}	L_{max}	*L*	Metric	Source
51	Seyhan Reservoir	1975–1976	C	–	0.06580	2.676	–	–	–	FL	cm	Sarıhan and Özdöl (1983)
52		1986	C	549	0.0240	2.972	–	13.5	54.3	FL	cm	Karakoç and Sarıhan (1987)
53		2006–2007	C	105	0.0360	2.90	–	11.2	71.5	TL	cm	Erguden and Goksu (2009)
Natural lakes												
54	Bafra Balık Lakes	1988–1990	C	634	0.02041	2.96248	–	8.3	60.3	FL	cm	Bircan (1993)
55		2003–2004	M	74	0.0378	2.802	0.97	22.5	52.0	FL	cm	Yılmaz *et al.* (2012)
56			F	81	0.0328	2.838	0.98	23.8	52.4	FL	cm	Yılmaz *et al.* (2012)
57			C	155	0.0349	2.822	0.97	22.5	52.4	FL	cm	Yılmaz *et al.* (2012)
58	Lake Akşehir	1978	C	150	0.05652	2.67619	–	30.0	66.0	FL	cm	Erdem (1980)[6]
59		1987–1988	M	365	0.028	2.8213	–	14.3[4]	53.0	FL	cm	Çetinkaya (1992)
60			F	423	0.029	2.3078	–	14.2[4]	55.0	FL	cm	Çetinkaya (1992)
61			C	788	0.031	2.7862	–	14.3[4]	55.0	FL	cm	Çetinkaya (1992)
62		1992–1993	M	507	0.0345	2.7779	0.9983	10.8	43.1	FL	cm	Alp *et al.* (1994)
63			F	557	0.0278	2.8539	0.9960	11.3	44.6	FL	cm	Alp *et al.* (1994)
64			C	1064	0.0281	2.8438	0.9986	10.8	44.6	FL	cm	Alp *et al.* (1994)
65	Lake Beyşehir	1979–1981	C	698	0.1050	2.5164	–	8.0	69.0	FL	cm	Erdem (1983a)[6]
66		1981	M	187	0.16395	2.40804	–	14.5[4]	67.0[4]	FL	cm	Erdem (1984b)[6]
67			F	212	0.06619	2.62298	–	16.7[4]	68.6[4]	FL	cm	Erdem (1984b)[6]
68			C	399	0.119340	2.48022	–	14.5[4]	68.6[4]	FL	cm	Erdem (1984b)[6]
69		2005	M	52	0.026196	2.914	0.992	20.1[4]	53.2	FL	cm	Çetinkaya *et al.* (2006)[8]
70			F	36	0.024548	2.887	0.975	20.5[4]	61.0	FL	cm	Çetinkaya *et al.* (2006)[8]
71			C	321	0.022	2.939	0.994	9.5[4]	61.0	FL	cm	Çetinkaya *et al.* (2006)[8]
72	Lake Çavuşçu	1979–1981	C	776	0.064	2.6144	–	8.5	72.2	FL	cm	Erdem (1983a)[5]
73		1981	M	200	0.01399	2.99196	–	16.3	60.5	FL	cm	Erdem (1983b)
74			F	222	0.01861	2.93826	–	17.0[4]	61.5[4]	FL	cm	Erdem (1983b)
75	Lake Çernek	1999–2000	M	136	0.0745	2.5837	–	19.5	41.0	FL	cm	Demirkalp (2007a)
76			F	137	0.2218	2.2674	–	19.0	46.0	FL	cm	Demirkalp (2007a)
77			C	434	0.0547	2.6654	–	15.5	46.0	FL	cm	Demirkalp (2007a)
78	Lake Eber	1978	M	218	0.03619	2.78298	–	10.0	81.0	FL	cm	Erdem (1982)[6]
79			F	233	0.13395	2.50804	–	9.0	79.6	FL	cm	Erdem (1982)[6]
80			C	451	0.06313	2.61012	–	9.0	81.0	FL	cm	Erdem (1982)[6]
81	Lake Eğirdir	1979–1981	C	717	0.077	2.5683	–	8.0	69.0	FL	cm	Erdem (1983a)[6]
82	Lake Eymir	1978	C	213	0.024254	2.9619	–	24.8	61.1	TL	mm	Tanyolaç (1979)
83	Lake Gölcük	1984–1986	C	262	0.0324307	2.84	0.908	7.0	46.0	TL	mm	Balık and Ustaoğlu (1987)
84	Lake Gölhisar	1994	M	324	0.0243	2.8874	–	10.5	46.0	FL	cm	Alp and Balık (2000)
85			F	369	0.0258	2.8676	–	10.5	49.4	FL	cm	Alp and Balık (2000)
86			C	693	0.0252	2.8739	–	10.5	49.4	FL	cm	Alp and Balık (2000)
87	Lake Haçlı	1987	M	70	0.046057	2.786499	–	14.8	44.6	FL	mm	Akyurt (1987b)
88			F	88	0.029177	2.927246	–	15.3	74.5	FL	mm	Akyurt (1987b)
89			C	158	0.039925	2.846947	–	14.8	74.5	FL	mm	Akyurt (1987b)
90	Lake Işıklı	1989–1990	M	207	0.0542	2.6928	0.997	21.9	37.8	FL	cm	Yılmaz *et al.* (1992)
91			F	110	0.01479	3.1022	0.994	20.7	36.0	FL	cm	Yılmaz *et al.* (1992)
92			C	317	0.02290	2.9973	0.998	16.0	37.8	FL	cm	Yılmaz *et al.* (1992)
93		1990–1991	M	201	0.02492	2.9223	0.999	23.2	65.5	FL	cm	Yılmaz *et al.* (1992)
94			F	172	0.02456	2.9133	0.999	23.0	63.5	FL	cm	Yılmaz et al. (1992)
95			C	373	0.02429	2.9224	0.999	17.5	65.5	FL	cm	Yılmaz et al. (1992)
96		2004	C	158	0.03500	2.841	–	11.8	80.0	FL	cm	Yağcı et al. (2008a)
97	Lake İznik	2003–2004	C	12	0.034	2.83	0.986	14.2	48.8	TL	cm	Tarkan et al. (2006)
98		2006	M	55	0.0253	2.9233	0.993	13.74	44.24	FL	cm	Yağcı et al. (2008b)
99			F	64	0.026	2.9242	0.997	13.24	70.4	FL	cm	Yağcı et al. (2008b)
100	Lake Karaboğaz	2004	M	6	0.0421	2.761	0.99	24.8	35.8	TL	cm	Yılmaz et al. (2010a)
101			F	30	0.0271	2.898	0.97	28.7	44.3	TL	cm	Yılmaz et al. (2010a)
102			C	36	0.0272	2.895	0.98	24.8	44.3	TL	cm	Yılmaz et al. (2010a)
103	Lake Karamık	2002–2003	C	108	0.0245	2.952	0.996	9.0	70.4	FL	cm	Balık et al. (2006)
104	Lake Kuş	1987–1988	C	91	0.0530670	2.687	0.994	6.3	34.5	FL	mm	Balık and Ustaoğlu (1990)
105	Lake Liman	2002–2005	M	141	0.0289	2.863	–	21.0	41.0	FL	cm	Demirkalp (2007b)
106			F	121	0.0282	2.874	–	19.0	46.0	FL	cm	Demirkalp (2007b)
107			C	262	0.0283	2.871	–	19.0	46.0	FL	cm	Demirkalp (2007b)
108	Lake Marmara	1990–1991	C	157	0.027917	2.989	0.990	8.4	24.5	FL	cm	Balık et al. (1997)
109	Lake Mogan	1972	C	272	0.0143	3.0030	–	32.8	61.4	TL	cm	Tanyolaç (1975)
110		1982–1984	M	446	0.02644	2.81335	–	19.0	76.0	FL	cm	Düzgüneş (1985)
111			F	470	0.02523	2.83045	–	19.0	76.0	FL	cm	Düzgüneş (1985)
112			C	916	0.02573	2.82366	–	19.0	76.0	FL	cm	Düzgüneş (1985)
113	Lake Sapanca	2002–2003	C	170	0.0425	2.79	0.989	16.8	45.5	TL	cm	Tarkan et al. (2006)
114	Lake Sera	1986	M	47	0.0041	3.4380	0.9930	17.9	47.5	FL	cm	Okumuş and Tekelioğlu (1987)
115			F	55	0.0026	3.5672	0.9926	18.6	50.8	FL	cm	Okumuş and Tekelioğlu (1987)
116			C	102	0.0034	3.4847	0.9778	17.9	50.8	FL	cm	Okumuş and Tekelioğlu (1987)
117	Lake Tödürge	1985–1986	M	284	0.1641	2.30578	–	9.5	42.8	FL	cm	Erdem (1988)
118			F	326	0.1299	2.30576	–	10.0	41.5	FL	cm	Erdem (1988)
119			C	610	0.1506	2.48873	–	9.5	42.8	FL	cm	Erdem (1988)
120		2007	M	115	0.00850	2.85340	–	8.5	38.9	FL	cm5	Ünver and Yıldırım (2011)
121			F	96	0.01030	2.84970	–	8.3	40.5	FL	cm5	Ünver and Yıldırım (2011)
122			C	211	0.00960	2.8523	–	8.3	40.5	FL	cm5	Ünver and Yıldırım (2011)

Table A.2. Continued

ID	Waterbody type	Year/Period	Sex	*n*	$a^{(\prime)}$	*b*	r^2	L_{min}	L_{max}	*L*	Metric	Source
124			F	133	0.0469	2.8100	0.9286	19.0	77.0	TL	cm	Kılıç (2003)
125			C	281	0.0411	2.8439	0.9443	19.0	77.0	TL	cm	Kılıç (2003)
Water courses												
126	Bendimahi Stream	1994–1996	C	49	–	2.860	0.998	9.6[4]	51.3[4]	FL	cm	Çetinkaya *et al.* (1995–1999)[6]
127	Hatay Province	2003	C	95	0.0338	3.1120	0.983	20.0	35.2	TL	cm	Özcan (2008)
128	Karasu Stream	1993–1994	C	184	0.0298	3.202	0.996	10.2[4]	30.3[4]	FL	cm	Çetinkaya *et al.* (1995)
129		1994–1996	C	182	0.0128	2.928	0.995	8.9[4]	55.8[4]	FL	cm	Çetinkaya *et al.* (1995–1999)[6]
130		2007–2008	M	123	0.0287	2.888	0.986	10.7	38.4	FL	cm	Şen and Elp (2009)
131			F	159	0.0301	2.989	0.986	10.4	44.3	FL	cm	Şen and Elp (2009)
132			C	297	0.0221	2.952	0.987	10.4	44.3	FL	cm	Şen and Elp (2009)
133	Sakarya River	1988–1989	M	155	0.0247	3.0204	–	17.4	67.5	FL	cm	Ölmez (1992)
134			F	192	0.0145	3.0434	–	16.6	68.1	FL	cm	Ölmez (1992)
135			C	347	0.0131	2.9798	–	16.6	68.1	FL	cm	Ölmez (1992)

[1] Mirror carp.
[2] Scale carp.
[3] Outlier value (see Figure 1).
[4] Based on average length value.
[5] Reported in mm in source study but converted to cm due to resulting $a^{(\prime)}$ values (see below) severely out of range if based on the previous metric.
[6] Previously reviewed in Torcu-Koç *et al.* (2006).
[7] Same as Karabatak (1994).
[8] Same as Çubuk *et al.* (2006).
ID = individual stock identifier (see Figure 1); Year/Period: year or period of sampling; Sex: M = Male, F = Female, C = Combined; *n* = number of specimens; $a^{(\prime)}$ = original (*a*) or adjusted to FL and/or cm (*a*′) intercept value (number of digits as per source); *b* = slope value (number of digits as per source); r^2 = coefficient of determination; L_{min} and L_{max} : minimum and maximum length in sample (cm); *L*: FL = fork length, TL = total length.

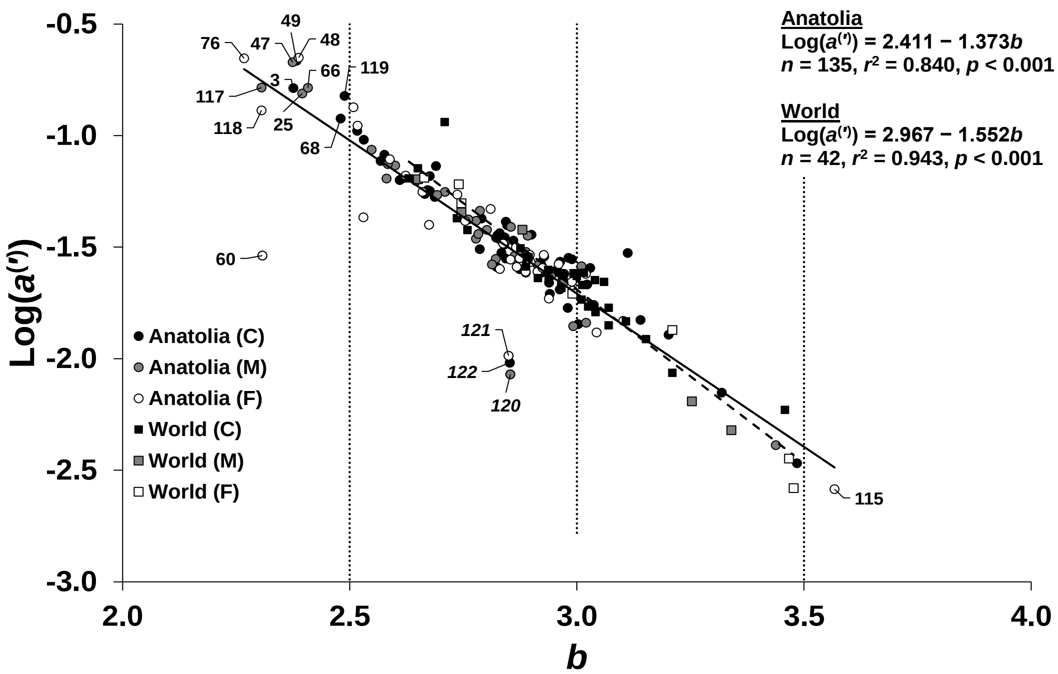

Figure 1. Plot of Log($a^{(\prime)}$) *vs b* for the weight–length relationship (WLR) of 135 common carp stocks from freshwaters of Anatolia (see Table A.1) and 42 world-wide (see Table A.4).Stocks include combined sexes, males and females. ID (cf. Table A.1) is provided for those Anatolian stocks lying in the negative and positive allometric portions of the graph, as well as for five outlier stocks (labelled in italics). Regression line equations are given for Anatolia (solid line) and world-wide (dashed line) along with summary statistics.

Table 1. Summary statistics for the WLR parameters of 131 common carp stocks from Anatolia (Table A.1) and 42 world-wide (Table A.4). See also Figure 1. L = Lower; U = Upper; CI = Confidence interval; SE = Standard error

				n	Mean	L 95% CI	U 95% CI	SE	Min	Max
Anatolia		All stocks	$a^{(')}$	131	0.0482	0.0405	0.0559	0.0039	0.003	0.223
			b	131	28.230	27.848	28.612	0.0195	2.267	3.567
	Sex	Combined	$a^{(')}$	64	0.0433	0.0340	0.0525	0.0047	0.003	0.216
			b	64	28.539	28.038	29.041	0.0256	2.376	3.485
		Males	$a^{(')}$	34	0.0536	0.0372	0.0701	0.0084	0.004	0.213
			b	34	27.826	27.074	28.579	0.0384	2.306	3.438
		Females	$a^{(')}$	33	0.0521	0.0337	0.0705	0.0094	0.003	0.223
			b	33	28.045	27.182	28.908	0.0440	2.267	3.567
	Waterbody type	Man-mad res.	$a^{(')}$	27	0.0470	0.0294	0.0647	0.0090	0.007	0.216
			b	27	28.590	27.771	29.408	0.0418	2.376	3.319
		Natural lakes	$a^{(')}$	31	0.0436	0.0324	0.0549	0.0057	0.003	0.151
			b	31	28.202	27.509	28.895	0.0354	2.480	3.485
		Water courses	$a^{(')}$	6	0.0244	0.0180	0.0309	0.0033	0.013	0.034
			b	6	30.056	29.040	31.073	0.0519	2.860	3.202
World-wide		All stocks	$a^{(')}$	42	0.0303	0.0233	0.0372	0.0035	0.003	0.115
			b	42	29.692	29.014	30.371	0.0346	2.630	3.477
		Combined	$a^{(')}$	29	0.0288	0.0208	0.0367	0.0041	0.006	0.115
			b	29	29.614	28.986	30.241	0.0320	2.630	3.458

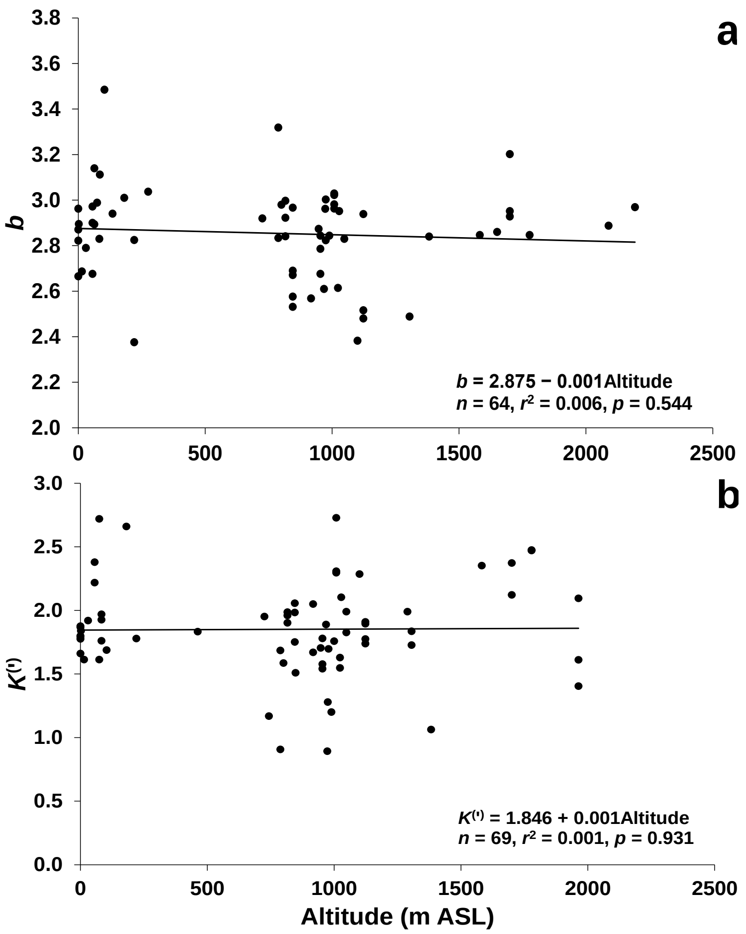

Figure 2. (a) Plot of WLR parameter *b* *vs* latitude for 64 common carp stocks (combined sexes only) from freshwaters of Anatolia. The regression line equation is provided along with summary statistics. (b) Plot of the original or adjusted condition factor $K^{(')}$ *vs* latitude for 69 common carp stocks (combined sexes only) from freshwaters of Anatolia (see Table A.5). The regression line equation is provided along with summary statistics.

Table A.3. Estimated parameters of the WLR ($W = aL^b$) for common carp stocks world-wide, with indication of species' status (after FishBase: Froese and Pauly, 2013). $a^{(\prime)}$ = original (a) or adjusted (a') parameter. All lengths in cm. Other columns as per Table A.2

Country	Location	Year	*n*	$a^{(\prime)}$	*b*	r^2	L_{min}	L_{max}	Length	Status
Belgium	Flanders	1992–2009	2158	0.0242	2.993	0.990	2.1	87.1	TL	Introduced
China	–	–	–	0.022	3.06	0.992	–	–	SL	Native
China	Ergis River	2007	18	0.115	2.709	0.986	20.0	51.3	TL	Native
China	Lake Niushan, Yangtze River	2002–2004	315	0.0208	2.966	0.986	12.4	82.4	TL	Native
France	–	–	–	0.0235	3	–	–	–	TL	Introduced
Iraq	Lake Razzazah	1982	–	0.006	3.458	–	–	–	TL	Introduced
Iraq	Lake Tharthar	1982	–	0.0122	3.152	–	–	–	TL	Introduced
Japan	Shioda Plain, Nagano Prefecture	–	67	0.024	3.015	–	16.5	36.6	TL	Introduced
Japan	Shioda Plain, Nagano Prefecture	–	88	0.00864	3.21	–	31.5	57.1	TL	Introduced
Japan	Shioda Plain, Nagano Prefecture	–	31	0.0377	2.759	–	13.0	41.5	TL	Introduced
Japan	Shioda Plain, Nagano Prefecture	–	98	0.0228	2.938	–	25.0	43.9	TL	Introduced
Kenya	Lake Naivasha	2004–2005	132	0.0147	3.108	0.980	5.8	55.3	FL	Introduced
Laos	Mekong River	–	55	0.0214	3.012	0.976	8.4	47.1	FL	Introduced
Philippines	Pampanga River, Candaba	2007–2008	–	0.029	2.89	0.970	5.8	60.1	SL	Introduced
Russian Federation	Atrek river	1972–1982	–	0.025	2.937	0.992	12.0	59.1	FL	Native
South Africa	Lake Gariep, Orange River	2006–2008	275	0.03570	2.829	0.970	–	–	FL	Introduced
Spain	Araquil River, Navarra	1993–1996	43	0.017	3.07	0.994	7.1	59.1	TL	Introduced
Spain	Lake Albufera	2000	112	0.071	2.65	0.978	–	–	TL	Introduced
Spain	Lake Albufera	2002	10	0.022	3.04	0.980	–	–	TL	Introduced
Spain	Segura River Basin (resevoirs)	2002–2004	614	0.0184	3.01	0.994	1.7	56.1	FL	Introduced
USA	Alabama	–	352	0.014	3.07	–	35.6	77.1	TL	Introduced
USA	Alabama	–	31344	0.0643	2.63	–	2.5	35.6	TL	Introduced
USA	Bear Lake, Utah	–	109	0.0162	3.041	–	16.9	53.1	SL	Introduced
USA	Cache Valley, Utah	–	191	0.0313	2.876	–	6.8	40.9	SL	Introduced
USA	Clear Lake, Utah	–	–	0.0230	2.914	–	12.5	73.0	SL	Introduced
USA	Des Moines River, Iowa	1958	517	0.0171	3.025	–	18.0	77.1	TL	Introduced
USA	Ft. Randall Lake, South Dakota	–	–	0.0427	2.736	–	12.7	45.8	TL	Introduced
USA	Salt River, Missouri	–	–	0.0285	2.894	–	–	–	TL	Introduced
USA	Salt Springs Valley Reservoir, California	–	53	0.0259	2.888	–	19.0	44.6	FL	Introduced

value (combined sexes) for the world-wide common carp stocks was significantly higher than the one for Anatolian stocks ($F_{1,91}{}^{\#}$=6.03, $p^{\#}$=0.016) (Table 1). Whereas, form factors for common carp stocks from Anatolia (n=64; S_{Anatolia}=−1.417; mean $a^{(\prime)}{}_{3.0}$=0.0213, 0.0202–0.0223 95% CI) and world-wide (n=29; $S_{\text{World-wide}}$=−1.419; mean $a^{(\prime)}{}_{3.0}$=0.0215, 0.0196–0.0234 95% CI) were nearly identical and did not differ significantly ($F_{1,91}{}^{\#}$=0.05, $p^{\#}$=0.830).

Condition Factors

Data on K were obtained for 75 common carp stocks (167 sexed: 65 combined sexes, 49 males, 49 females) from 46 water bodies of Anatolia (16 man-made reservoirs, 27 natural lakes, and 3 water courses). These were described in 61 studies, with sampling carried out from 1953 to 2011 (Table A.4)..A plot of $K^{(\prime)}$ vs altitude resulted in a non-significant regression relationship, indicating the lack of an altitudinal gradient (Figure 2b). Also, there were no significant differences in mean $K^{(\prime)}$ between males and females ($F_{1,96}{}^{\#}$=0.01, $p^{\#}$=0.986) (Table 2). Conversely, there were significant differences in mean $K^{(\prime)}$ amongst waterbody types ($F_{2,66}{}^{\#}$ = 3.35, $p^{\#}$<0.043), with common carp stocks from natural lakes having a lower mean $K^{(\prime)}$ value relative to those from man-made reservoirs ($p^{\#}$=0.018) and water courses ($p^{\#}$=0.172: statistically non-significant likely due to limited sample size), and with no significant differences between man-made reservoirs and water courses ($p^{\#}$=0.914) (Table 2).

Discussion

The findings of the present study indicate that, overall, common carp stocks from freshwaters of Anatolia were characterised by a slightly negative allometric growth, except possibly for stocks sampled from water courses. This tendency toward negative allometry became more evident upon comparison with world-wide stocks, even though the form factor remained similar. Further, no altitudinal gradients were detected, pointing to a homogeneity in growth;

Table A.4. Estimated parameters of the condition factor $K=W/L^b$ for 167 common carp stocks of Anatolia

Waterbody type	Year/Period	Sex	*n*	$K^{(\prime)}$	*L*	Source
Man-made reservoirs						
Almus Reservoir	1987	C	148	1.685	FL	Akyurt (1987a)
	2002–2003	M	127	0.956	TL	Karataş *et al*. (2007)
		F	180	0.993	TL	Karataş *et al*. (2007)
		C	307	0.907	TL	Karataş *et al*. (2007)
Altınkaya Reservoir	1990–1993	M	279	1.742	FL	Bircan (1998)
		F	311	1.752	FL	Bircan (1998)
		C	590	1.779	FL	Bircan (1998)
Apa Reservoir	1981	C	242	1.827	FL	Erdem (1984a)
	2001	M	108	1.9843	FL	Mert *et al*. (2008)
		F	105	1.9629	FL	Mert *et al*. (2008)
		C	251	1.9900	FL	Mert *et al*. (2008)
Bayramiç Reservoir	2002–2003	C	351	2.66	FL	Çolakoğlu and Akyurt (2011)
Beytepe Pond	1983–1984	M	64	1.6452	FL	Atalay (1985)
		F	61	1.7008	FL	Atalay (1985)
		C	125	1.6972	FL	Atalay (1985)
Çamlıgöze Reservoir	2010–2011	C	27	1.1691	TL	Dirican and Çilek (2012)
Değirmigöl-Dolutaş Reservoir	1994–1996	M	85	2.098	FL	Çetinkaya *et al*. (1995–1999)
		F	42	2.118	FL	Çetinkaya *et al*. (1995–1999)
Dönerdere Pond	2003–2004	M	50	2.050	FL	Çetinkaya *et al*. (1995–1999)
		F	45	2.057	FL	Çetinkaya *et al*. (1995–1999)
Gelingüllü Reservoir	1994	M	159	2.3525	FL	Kırankaya and Ekmekçi (2004)
		F	226	2.3060	FL	Kırankaya and Ekmekçi (2004)
		C	407	2.2960	FL	Kırankaya and Ekmekçi (2004)
	2002–2005	M[1]	247	2.6950	FL	Kırankaya (2007)
		F[1]	325	2.7456	FL	Kırankaya (2007)
		C[1]	796	2.7289	FL	Kırankaya (2007)
	2002–2005	M[2]	122	2.3400	FL	Kırankaya (2007)
		F[2]	126	2.3338	FL	Kırankaya (2007)
		C[2]	283	2.3088	FL	Kırankaya (2007)
Hirfanlı Reservoir	1994–1995	M	72	2.0760	FL	Karaca (1995)
		F	53	2.0827	FL	Karaca (1995)
		C	147	2.0566	FL	Karaca (1995)
	1996–1998	M	237	1.7851	FL	Yılmaz *et al*. (2007)
		F	219	1.7120	FL	Yılmaz *et al*. (2007)
		C	458	1.7519	FL	Yılmaz *et al*. (2007)
	2004–2005	M	83	1.9793	FL	Yılmaz *et al*. (2010b)
		F	65	1.9919	FL	Yılmaz *et al*. (2010b)
		C	148	1.9837	FL	Yılmaz *et al*. (2010b)
Kapulukaya Reservoir	1991–1993	M	177	1.9394	FL	Yılmaz (1994)
		F	176	1.9151	FL	Yılmaz (1994)
		C	402	1.9525	FL	Yılmaz (1994)
Keban Reservoir	2004–2006	M	135	1.5073	FL	Güç (2006)
		F	118	1.4999	FL	Güç (2006)
		C	253	1.5093	FL	Güç (2006)
Köçköprü Reservoir	1999–2001	C	311	2.475	FL	Elp *et al*. (2007)
	1999–2001	M	152	2.4600	FL	Elp *et al*. (2008)
		F	139	2.464	FL	Elp *et al*. (2008)
		C	323	2.471	FL	Elp *et al*. (2008)
Mamasın Reservoir	1980–1981	M	139	2.336	FL	İkiz (1988)
		F	129	2.241	FL	İkiz (1988)
		C	268	2.286	FL	İkiz (1988)
Sarıyar Reservoir	1985–1987	M	–	1.818	FL	Ekmekçi (1996b)
		F	–	1.789	FL	Ekmekçi (1996b)
		C	348	1.833	FL	Ekmekçi (1996b)
Seyhan Reservoir	1974	C	150	2.38	FL	Sarıhan (1980)
	1975–1976	C	–	2.219	FL	Sarıhan and Özdöl (1983)
Natural lakes						
Bafra Balık Lakes	1986–1988	M	254	1.8129	FL	Demirkalp (1992)
		F	251	1.8436	FL	Demirkalp (1992)
		C	505	1.7999	FL	Demirkalp (1992)
	1988–1990	M	303	1.7950	FL	Bircan (1995)
		F	318	1.8524	FL	Bircan (1995)
		C	634	1.7951	FL	Bircan (1995)
	2003–2004	M	74	1.8810	FL	Yılmaz *et al*. (2012)
		F	81	1.858	FL	Yılmaz *et al*. (2012)
		C	155	1.869	FL	Yılmaz *et al*. (2012)
Lake Akşehir	1953	C	67	1.78	FL	Numann (1958)
	1978	C	150	1.578	FL	Erdem (1980)
	1987–1988	M	–	1.522	FL	Çetinkaya (1992)
		F	–	1.577	FL	Çetinkaya (1992)
		C	128	1.541	FL	Çetinkaya (1992)

Table A.4. Continued

Waterbody type	Year/Period	Sex	n	K(')	L	Source
	1992–1993	M	507	1.6980	FL	Alp *et al.* (1994)
		F	557	1.7237	FL	Alp *et al.* (1994)
Lake Beyşehir	1953	C	28	1.7750	FL	Numann (1958)
	1979–1981	C	698	1.895	FL	Erdem (1983a)
	1981	C	399	1.910	FL	Erdem (1984b)
	2005	M	52	1.8200	FL	Çetinkaya *et al.* (2006)
		F	36	1.7070	FL	Çetinkaya *et al.* (2006)
		C	153	1.7391	FL	Çetinkaya *et al.* (2006)
Lake Çavuşçu	1979–1981	C	776	1.629	FL	Erdem (1983a)
	1981	C	422	1.548	FL	Erdem (1983b)
Lake Çernek	1999–2000	M	136	1.765	FL	Demirkalp (2007a)
		F	137	1.7240	FL	Demirkalp (2007a)
		C	364	1.776	FL	Demirkalp (2007a)
Lake Çıldır	1988–1989	C	59	1.4050	FL	Özdemir and Temizer (1992)
	1991–1993	M	296	1.8617	FL	Yerli (1996)
		F	147	1.8633	FL	Yerli (1996)
		C	374	2.0950	FL	Yerli (1996)
	1991	M	204	1.9386	FL	Yerli and Zengin (1996)
		F	91	1.7929	FL	Yerli and Zengin (1996)
		C	296	1.6116	FL	Yerli and Zengin (1996)
Lake Eber	1978	C	451	1.889	FL	Erdem (1982)
Lake Eğirdir	1958	C	104	2.05	FL	Numann (1958)
	1979–1981	C	776	1.670	FL	Erdem (1983a)
Lake Eymir	1978	M	96	0.8948	TL	Tanyolaç (1979)
		F	116	0.9093	TL	Tanyolaç (1979)
		C	212	0.89	TL	Tanyolaç (1979)
Lake Gölcük	1984–1986	M	–	1.016	TL	Balık and Ustaoğlu (1987)
		F	–	1.011	TL	Balık and Ustaoğlu (1987)
		C	262	1.063	TL	Balık and Ustaoğlu (1987)
Lake Gölhisar	1994	M	324	1.704	FL	Alp and Balık (2000)
		F	369	1.706	FL	Alp and Balık (2000)
		C	693	1.705	FL	Alp and Balık (2000)
Lake Haçlı	1987	M	70	2.350	FL	Akyurt (1987b)
		F	88	2.357	FL	Akyurt (1987b)
		C	158	2.352	FL	Akyurt (1987b)
Lake Hafik	1985–1986	M	84	1.99	FL	Cengizler and Erdem (1989)
		F	57	1.96	FL	Cengizler and Erdem (1989)
		C	141	1.99	FL	Cengizler and Erdem (1989)
Lake Işıklı	1989–1990	M	207	1.9507	FL	Yılmaz *et al.* (1992)
		F	110	2.0291	FL	Yılmaz *et al.* (1992)
		C	317	1.9863	FL	Yılmaz *et al.* (1992)
	1990–1991	M	201	1.9962	FL	Yılmaz *et al.* (1992)
		F	172	1.9162	FL	Yılmaz *et al.* (1992)
		C	373	1.9026	FL	Yılmaz *et al.* (1992)
	2004	M	61	1.9561	FL	Yağcı *et al.* (2008a)
		F	66	2.0075	FL	Yağcı *et al.* (2008a)
		C	127	1.9607	FL	Yağcı *et al.* (2008a)
Lake İznik	1953	C	89	1.761	FL	Numann (1958)
	2001	M	138	1.7475	FL	Özeren (2004)
		F	241	1.8400	FL	Özeren (2004)
		C	385	1.9267	FL	Özeren (2004)
	2006	M	55	1.958	FL	Yağcı *et al.* (2008b)
		F	64	1.983	FL	Yağcı *et al.* (2008b)
		C	119	1.970	FL	Yağcı *et al.* (2008b)
Lake Karamık	2002–2003	C	96	2.1037	FL	Balık *et al.* (2006)
Lake Köyceğiz	1986–1988	M	126	1.5720	FL	Yerli (1991)
		F	187	1.6711	FL	Yerli (1991)
		C	381	1.6611	FL	Yerli (1991)
Lake Kuş	1953	C	41	1.613	FL	Numann (1958)
	1987–1988	M	25	2.337	FL	Balık and Ustaoğlu (1990)
		F	19	2.572	FL	Balık and Ustaoğlu (1990)
Lake Liman	2002–2005	M	121	1.868	FL	Demirkalp (2007b)
		F	141	1.943	FL	Demirkalp (2007b)
		C	288	1.876	FL	Demirkalp (2007b)
Lake Marmara	1953	C	139	1.613	FL	Numann (1958)
	1990–1991	C	151	2.7200	FL	Balık *et al.* (1997)
Lake Mogan	1972	M	136	0.892	TL	Tanyolaç (1975)
		F	136	0.890	TL	Tanyolaç (1975)
	1982–1984	M	446	1.2642	FL	Düzgüneş (1985)
		F	470	1.2900	FL	Düzgüneş (1985)
		C	916	1.2792	FL	Düzgüneş (1985)

Table A.4. Continued

Waterbody type	Year/Period	Sex	n	K(')	L	Source
Lake Sapanca	1953	C	37	1.92	FL	Numann (1958)
Lake Sera	1986	M	47	1.741	FL	Okumuş and Tekelioğlu (1987)
		F	55	1.634	FL	Okumuş and Tekelioğlu (1987)
		C	102	1.688	FL	Okumuş and Tekelioğlu (1987)
Lake Süleyman	1953	C	249	1.758	FL	Numann (1958)
Lake Tödürge	1985–1986	M	284	1.947	FL	Erdem (1988)
		F	326	1.813	FL	Erdem (1988)
		C	610	1.836	FL	Erdem (1988)
	2007	M	115	1.7071	FL	Ünver and Yıldırım (2011)
		F	96	1.7529	FL	Ünver and Yıldırım (2011)
		C	181	1.7271	FL	Ünver and Yıldırım (2011)
Lake Uluabat	1953	C	102	1.84	FL	Numann (1958)
Lake Yeniçağa	2002	M	148	1.1629	TL	Kılıç (2003)
		F	133	1.2130	TL	Kılıç (2003)
		C	281	1.2009	TL	Kılıç (2003)
Water courses						
Bendimahi Stream	1994–1996	M	12	2.111	FL	Çetinkaya *et al.* (1995–1999)
		F	11	2.017	FL	Çetinkaya *et al.* (1995–1999)
Karasu Stream	1993–1994	C	339	2.373	FL	Çetinkaya *et al.* (1995)
	1994–1996	M	64	2.381	FL	Çetinkaya *et al.* (1995–1999)
		F	59	2.307	FL	Çetinkaya *et al.* (1995–1999)
	2007–2008	M	123	2.105	FL	Şen and Elp (2009)
		F	159	2.137	FL	Şen and Elp (2009)
		C	297	2.122	FL	Şen and Elp (2009)
Sakarya River		M	155	1.572	FL	Ölmez (1992)
		F	192	1.589	FL	Ölmez (1992)
		C	347	1.586	FL	Ölmez (1992)

[1] Mirror carp.
[2] Scale carp.
Year/Period: year or period of sampling; Sex: M = Male, F = Female, C = Combined; *n* = number of specimens; *K* = original condition factor value. $K^{(')}$ = original (*K*) or adjusted to FL (*K'*) condition factor value (number of digits as per source, except for values with four digits derived as the arithmetic mean from age classes or months of sampling); *L*: FL = fork length, TL = total length

Table 2. Summary statistics for the (original or adjusted) condition factor K(') of 145 common carp stocks from Anatolia (see also Table A.4). L = Lower; U = Upper; CI = Confidence interval; SE = Standard error

Statistic		*n*	Mean	L 95% CI	U 95% CI	SE	Min	Max
	All stocks	167	18.442	17.854	19.030	0.0300	0.890	2.746
Sex	Combined	69	18.515	17.625	19.404	0.0454	0.893	2.729
	Males	49	18.384	17.264	19.504	0.0571	0.892	2.695
	Females	49	18.399	17.283	19.515	0.0569	0.890	2.746
Waterbody type	Man-made res.	22	19.985	18.080	21.889	0.0972	0.907	2.729
	Natural lakes	44	17.660	16.749	18.571	0.0465	0.893	2.720
	Water courses	3	20.273	15.725	24.821	0.2320	1.586	2.373

whereas, the only possible differences in condition factor were identified amongst waterbody types.

The lower-than-expected (i.e. outlier) values recorded for Lake Akşehir and Lake Tödürge, which reflected a tendency for fish to assume a more fusiform body shape (cf. Froese, 2006), are in agreement with the reported overall poor state of common carp stocks in those water bodies as a result of over-exploitation by commercial fishing (Çetinkaya, 1992; Ünver and Yıldırım, 2011). Also, in Lake Akşehir competition for benthic food resources between common carp and the locally dominant fish species (i.e. chub *Squalius cephalus* and endemic *Alburnus nasreddini*) is likely to have further contributed to the poorer condition of these stocks (Alp *et al.*, 1994). Whereas, in Lake Tödürge, the slightly brackish waters due to the gypsum-rich lithology around this karstic lake (Magnin and Yarar, 1997) may have acted as an additional stressor promoting higher negative allometry. Finally, the negative allometric values detected for the stocks from Mamasın Reservoir are a likely reflection of poor water quality due to contamination and eutrophication (Elhatip and Kömür, 2008; Ersan *et al.*, 2009).

A possible explanation for the overall slightly negative allometric growth (hence, more fusiform body shape) of Anatolian stocks relative to their world-wide counterparts is that common carp is known to be native to some areas of Anatolia (namely, the ecoregions of Northern Anatolia, Western Transcaucasia and Upper Tigris and

Euphrates: see Abell *et al.*, 2008). In this respect, the wild (i.e. native) common carp from the Caspian and Black Sea (the likely common ancestor of native common carp in Anatolia: Memiş and Kohlmann, 2006) is known to have an elongated and torpedo-shaped body, as opposed to its deeper-bodied domesticated/feral forms (Balon, 1995). It can therefore be argued that historical translocations of common carp across Anatolia (Innal and Erk'akan, 2006) may have resulted in a mixture of both wild and domesticated forms, with the latter originating from farmed strains. This is unlike other non-native areas of the world (e.g. western European countries, North America), where only domesticated forms were initially introduced and eventually established in the wild (e.g. McCrimmon, 1968; Panek, 1987; Copp *et al.*, 2005; Vilizzi, 2012). These domesticated pond forms are known to revert eventually to the feral form, which is only reminiscent of the wild form because of the retention of several domesticated meristic characters (Balon, 1995).

As the world-wide dataset used in the present study was dominated by stocks from countries where common carp has been introduced (overall, an unbiassed reflection of the species' distribution at the global scale: see Weber and Brown, 2009), the resulting higher value of *b* is not unexpected. Moreover, due to the presence in Chinese freshwaters of the native sub-species *C. carpio haematopterus* (instead of *C. c. carpio*, the sub-species of the present study) (see Vilizzi, 2012), the only world-wide stock likely to have included common carp of native origin comparable to most Anatolian stocks was the one from the Russian Federation, hence restricting even further the 'native' proportion of studies in the world-wide dataset. Finally, the lack of differences in form factor between Anatolian and world-wide common carp stocks suggests that, despite the slightly negative allometry in Anatolian common carp, the overall short and deep body shape typical of the domesticated/feral forms is still retained.

The lack of an altitudinal gradient in both *b* and $K^{(\prime)}$ values suggests that growth in this species can be regarded as overall homogeneous across Anatolian freshwaters. Although only altitude was used in the present study, this is thought to have represented a reliable proxy for the range of climate types encountered across the Region, ranging from arid to temperate and cold (Kottek *et al.*, 2006). To this end, the widely-documented higher resilience and hardiness of domesticated/feral forms of common carp relative to their native counterparts (Balon, 2004, 2006) is likely to have played a key role in the growth response of Anatolian stocks under different ranges of water temperature and seasonality. Clearly, further (review) studies are needed that address the more specific growth features linked to length-at-age and weight-at-age relationships.

The differences recorded in both WLR and *K* amongst waterbody types were overall more qualitative than quantitative, as indicated by either a lack of (*b* values) or weak ($K^{(\prime)}$ values) statistically significant differences. However, this was likely a result of the strong bias introduced in sampling common carp stocks from man-made reservoirs and natural lakes relative to those from water courses. In fact, given the limited number of stocks sampled in the latter waterbody type, the finding of higher *b* and $K^{(\prime)}$ values is a strong indication that the more oxygenated stream waters may have enhanced growth and condition of common carp stocks in streams and rivers. Interestingly, this is another possible reflection of the level of nativeness likely to be present in Anatolian common carp stocks (Memiş and Kohlmann, 2006), given that the wild form is known to be better adapted to lotic habitats (Balon, 2004; Balon, 2006).

The overall homogeneity in WLR and *K* detected in the present study (also accounting for the temporal extent of the dataset, which included repeated sampling of some study areas over time) may actually facilitate implementation of management measures for common carp in Anatolian freshwaters (Önsoy *et al.*, 2011; Tarkan *et al.*, 2012). This is an issue that becomes especially crucial given the warm and, in some cases, extreme (i.e. dry) climatic conditions typical of most areas of Anatolia, which may favour further spread of common carp as a result of increasingly unstable habitat conditions (i.e. due to the alternation of droughts and floods). These have been found to be ideal for the species' successful spawning and recruitment in the absence of less resilient native species (Bajer and Sorensen, 2009; Vilizzi, 2012), and also in light of the fact that common carp population dymamics are known to occur at larger scales than those of most other fish species (e.g. Jones and Stuart, 2009; Butler and Wahl, 2010; Daniel *et al.*, 2011). In addition, the applicability of an overall WLR (as provided by the mean parameter values in the present study) at the regional level is likely to prove useful in assessing biomass levels of common carp in critical areas (such as those flagged for conservation/rehabilitation purposes) as well as in gauging these levels against potential biomass 'thresholds' (e.g. Tan and Beklioglu, 2006). In fact, identification of the latter will help inform better management options for common carp in Anatolian freshwaters, pending careful evaluation of the ecological benefits vs economic losses brought about by intervention measures for control (Vilizzi, 2012).

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