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A Re-assessment of the Growth Index for Quantifying Growth in Length of Fish with Application to Roach, *Rutilus rutilus* (L., 1758)

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A B S T R A C T

Comparative assessments of mean growth rates in length across fish populations are useful for gaining insights into the conservation, management and control of species, especially at larger scales of distribution. The purpose of this study was to refine the Growth Index (GI), a useful measure for comparing species-specific growth rates in fish. Using literature-based length-at-age data for 299 populations of roach *Rutilus rutilus*, a widespread freshwater fish of Eurasian distribution, the GI was calibrated and the previously semi-quantitatively defined 'slow', 'average' and 'fast' growth categories were quantitatively re-defined. A threshold value of 114% GI separated 'slow' from 'average' growth populations and of 155% GI 'average' from 'fast' growth populations. Slow growth rates were identified along the entire latitudinal range of the species' distribution, whereas below ≈37ºN all types of growth were encountered, indicating the importance of waterbody-related environmental factors in affecting growth in roach. Given the relatively widespread usage of the GI, species-specific calibrations leading to improved definition of corresponding growth bands are recommended for other widespread fish species of both economic value and ecological concern.

Keywords: Caspian roach, latitude, length-at-age, von Bertalanffy growth function

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REVIEW

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Boyca Büyümeyi Ölçen Büyüme İndeksinin Tekrar Değerlendirilmesi: Kızılgöz, *Rutilus rutilus* Uygulaması

Öz: Balık populasyonları arasında boyca ortalama büyüme oranlarının karşılaştırmalı değerlendirmeleri özellikle yaygın dağılımları olan balıklarda türlerin kontrolü, yönetimi ve korunmasına yönelik bilgi edinme anlamında yararlıdır. Sunulan çalışmanın amacı balıklarda türe özgü büyüme oranlarını karşılaştırmada kullanışlı bir ölçü olan Büyüme İndeksi (Bİ)'ni düzenlemektir. Geniş bir Avrasya dağılımına sahip yaygın tatlı su balığı kızılgöz, *Rutilus rutilus* türünün 299 populasyonunda literatür tabanlı yaştaki boy verileri kullanılarak, Bİ kalibre edilmiş ve daha önce yarı kantitatif olarak 'yavaş', 'ortalama' ve 'yüksek' olarak tanımlanan büyüme kategorileri kantitatif olarak tekrar tanımlanmıştır. Eşik değeri olarak %114 Bİ 'yavaş' büyüyen popülasyonları 'orta' hızda büyüyen popülasyonlardan ayırırken, %155 Bİ değeri 'orta' hızda büyüyen popülasyonlardan 'hızlı' popülasyonları ayırmıştır. Yavaş büyüme oranları türün bütün enleme bağlı dağılım alanından tespit edilirken, ≈37ºN enleminin altında bütün büyüme tiplerine rastlanılmıştır bu durum da kızılgözün büyümesini etkileyen su kütlesine bağlı faktörlerin önemini göstermiştir. Bİ'nin nispeten yaygın kullanımı dikkate alındığında, büyüme kategorilerinin gelişmiş tanımlamalarını yapmaya yönelik türe özgü kalibrasyonların yapılması ekonomik değeri olan ve ekolojik önemi olan diğer geniş dağılımlı balık türleri için önerilir.

Anahtar kelimeler: Kızılgöz, enlem, yaş-boy, von Bertalanffy büyüme fonksiyonu

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Introduction

Knowledge of fish growth is fundamental for understanding species' life histories, population dynamics and fisheries sustainability (Beddington and Kirkwood 2005; Frisk et al. 2005), and in this respect comparative studies on freshwater fish growth at the regional (e.g. Britton et al. 2012; Vilizzi et al. 2013, 2015b), continental (e.g. Copp et al. 2009) and trans-continental scale (e.g. Copp et al. 2004) have provided useful insights for conservation, management and control. Typically, comparative assessments of population mean growth rates in length have relied on the use of indices, which represent a convenient way to summarise growth especially in widespread fish species (Britton 2007; but see Zivkov et al. 1999).

The roach *Rutilus rutilus* (Linneaus, 1758) is a widespread eurythermal cyprinid of native Eurasian distribution (Froese and Pauly 2015) that is abundant in rivers, lakes and reservoirs, but also encountered in brackish waters (Pęczalka 1968; Kozlovskiy 1992; Lappalainen et al. 2005; 2008). This species is valued for recreational fishing throughout Europe (Frimodt 1995) and its generalist feeding habits, combined with the high densities often achieved under favourable habitat conditions, make it a strong competitor with other fishes (Griffiths 1997). This leads sometimes to severe population reductions or even extinction in the species' introduced areas of distribution (Harrod et al. 2001). In this respect, intra-continentally roach has recently expanded its southern and western European range of distribution following introductions in the 19th century into the Italian (Volta and Jepsen 2008) and Iberian peninsulas (García-Berthou 1999) and into Ireland (Harrod et al. 2001). Whereas, translocations have occurred across much of Great Britain (Copp et al. 2005; Graham and Harrod 2009), Anatolia (Turkey; Ergüden et al. 2008) and in the Xinjiang Province of China (Hui Wei, pers. comm.).

One comparative index that has been used for quantifying growth in length of fish is the Growth Index (GI: Hickley & Dexter 1979). The GI categorises the growth of a fish population semi-quantitatively into 'slow', 'average' or 'fast' if less than, greater than or equal to, respectively, a reference value of 100. The GI has so far been applied to a number of species including *R. rutilus* (Cowx 1989) as well as other cyprinid (Treer et al. 1997; 1998; 2000; Tarkan et al. 2011; Emiroğlu et al. 2012) and non-cyprinid fishes (e.g. Treer et al. 1998). However, an intrinsic limitation with the definition of the GI is that it does not provide for a confidence interval against which to gauge the growth of a population either above or below average (see 'Sorites paradox': Vilizzi 2011), nor does it clearly define the range in values of the three resulting growth bands. The aim of this study was therefore to: (i) calibrate the GI based on a near-comprehensive dataset of growth in length of *R. rutilus* across its entire range of Eurasian distribution, and (ii) re-define the corresponding 'slow', 'average' and 'fast' growth bands accordingly. Based on the outcomes of the present quantitative evaluation, an overall assessment is made of the growth of *R. rutilus* across its distributional range, with special emphasis on the southern limits where the species has also been introduced.

Materials and Methods

Data collation and analysis

Growth data for *R. rutilus* were obtained from tables, text or figures as available in publications from the peer-reviewed and gray literature, including primary and secondary sources (i.e. data opportunistically retrieved through the former). A necessary condition for inclusion of a study into the review was that it should provide mean length-at-age (LAA) values for the population(s) under investigation. An exception was the study by Wilson (1971) on *R. rutilus* from Chew Valley Lake (England, UK), which was excluded from the review due to reported errors in age estimates (see White and Williams 1978).

Growth data for populations of the Caspian roach *R. r. caspicus* (Yakovlev, 1870) were also included for both historical and taxonomical reasons. In the former case, a number of studies has incorporated this taxon into large-scale life-history trait comparisons (e.g. Kas'yanov et al. 1995; Zivkov and Raikova-Petrova 2001; Lappalainen et al. 2008), and for consistency this approach was followed in the present review. In the latter case, phylogenetic studies have so far provided inconclusive evidence to categorise the Caspian roach as a different species (i.e. *R. caspicus*), hence contrary to Froese and Pauly (2015). Thus, despite low genetic divergence between *R. caspicus* and *R. frisii* (Nordmann, 1840) (the latter from the Black and Azov Sea basins, but also from part of the Caspian Basin and Lake İznik in Anatolia) (Ketmaier et al. 2008; Larmuseau et al. 2009), haplotypes of *R. r. caspicus* have been found to be highly similar to those of *R. rutilus* from Lake Volvi in Northern Greece, which is considered to be the home of the west-European and Ponto-Caspian *R. rutilus* clades (Tsoumani et al. 2014). This finding therefore supports historical evidence for the existence of a subspecies at most (www.briancoad.com/Species%20Accounts/FFI%20Complete.htm accessed 15/06/2015]).

For comparative purposes and consistency with other studies (e.g. Hickley and Dexter 1979; Britton 2007), fork length (*FL*) was the reference length measurement employed across the reviewed studies. Consequently, whenever required mean LAA values were expressed as *FL* (mm; converted from cm or inches, if originally reported as such) using the following species-specific conversion factors from *SL* (standard length) or *TL* (total length) (Froese and Pauly 2015):

$FL = 1.152\ SL$

$FL = 0.802\ TL$

Notably, for those studies (mainly from former USSR countries) providing no indication of the length measurement employed, this was taken to be *SL* (see Vilizzi et al. 2015b). On the contrary, for those studies (8% in total) where no indication of the length used was reported, this was taken to be *FL*, which represented the nearest-accurate and 'judicious' choice given possible conversion from *SL* or *TL*.

Growth Index

The GI (%) is computed as the mean value of the growth in length of fish in each age class of a certain population and with reference to an age class-specific global growth value for the species under study:

$$GI = \Sigma\ FL_{oi}/FL_{ri} \cdot 100$$

where FL_{oi} and FL_{ri} are the observed (*o*) and reference (*r*) mean *FL*, respectively, and *i* is the (estimated) age of the fish. Notably, the age class-specific global growth value for the species is estimated from a global von Bertalanffy growth function (VBGF) fitted to the LAA values from a sample of populations (n = 14 in Hickley and Dexter 1979). For the present purposes, the GI was used to assess the extent of growth in roach over the entire life span of each of the reviewed populations.

Statistical analyses

The mean LAA reference values for roach originally provided by Hickley and Dexter (1979) were updated after fitting a global VBGF to the entire collection of available mean LAA data points in the present review. The VBGF was fitted as (Ricker 1975):

$$FL = FL_{\infty}\ (1 - e^{(-K\ (age - t0))})$$

where FL_{∞} is the asymptotic *FL*, *K* the Brody growth coefficient (years^{-1}), and t_0 the age of the fish at 0 mm *FL*. Fitting the VBGF was in R x64 v3.0.3 (R Core Team 2014) using package 'FSA' (Ogle 2014) with 1000 bootstrap confidence interval estimates of the parameters.

Statistical comparison between Hickley and Dexter's (1979) reference values (up to age class 15+) and those obtained upon fitting the global VBGF was by permutational univariate analysis of variance (PERANOVA). This employed a Euclidean dissimilarity measure on the normalised data and 9999 permutations (raw data), with tests of significance at α = 0.05 (PERMANOVA+ v1.0.1 for PRIMER v6: Anderson et al. 2008). Briefly, the advantage of PERANOVA over traditional parametric ANOVA is that the stringent assumptions of normality and homoscedasticity, which prove very often unrealistic when dealing with real-world ecological datasets (and especially so in case of small sample sizes), are consistently relaxed (Anderson 2001; Anderson and Robinson 2001).

Because GI values were also computed for the 75 *R. rutilus* populations reviewed in Zivkov and Raikova-Petrova (2001) and therein categorised as 'low', 'average' and 'high' growth, a comparison was made to assess the consistency of the findings between that study and the present one. Comparison was by PERANOVA (as above) followed by computation of quartiles under Excel® 2013 (min, 25th, 50th, 75th and max). Also, because of overlap between the upper and lower quartiles for the 'low' and 'average' growth categories, receiver operating characteristic (ROC) curve analysis was performed to identify the best GI value threshold to distinguish between Zivkov and Raikova-Petrova's (2001) low/average/high categories and, ultimately, re-define Hickley and Dexter's (1979) slow/average/fast categories. This was achieved using a combination of Youden's J statistic and the point closest to the top-left part of the plot with perfect sensitivity or specificity, and using the mean area under the ROC curve (AUC) as a measure of the accuracy of the calibration analysis (Bewick et al. 2004). The threshold value between 'average' and 'high' growth categories was similarly identified. Analyses were carried out in R with package 'pROC' (Robin et al. 2011) using 2000 bootstrap replicates for the confidence intervals. Notably, no additional comparison with the quantitative growth categories identified in Kas'yanov et al. (1995) was conducted because of the comparatively larges sample of populations reviewed in Zivkov and Raikova-Petrova (2001) also coming from a wider range of distribution.

Results

Data were obtained for 299 roach populations from 209 Eurasian water bodies (Figure 1; Appendix Table S1). In total, there were 2211 mean LAA data points (i.e. *FL* values) in 18 age classes (Appendix Table S1). The mean LAA reference values (ages 1 to 15) for roach estimated from the global VBGF fitted to the entire collection of mean LAA data points did not differ significantly from those originally provided by Hickley and Dexter (1979) ($F^{\#}$ = 1,28 = 0.076, $P^{\#}$ = 0.787: $^{\#}$ = permutational; Table 1). Regardless, because of the much larger sample size the estimated mean LAA reference values from the present study were used for all subsequent GI-based computations.

Mean GI values differed significantly amongst the three semi-quantitative growth categories identified by Zivkov and Raikova-Petrova (2001) ($F^{\#}_{2,72}$ = 130.77, $P^{\#}$ < 0.001). Also, quartile analysis indicated an overlap between 'low' and 'average' growth populations at 100–125% GI, but complete separation for 'high' growth populations (Table 2). Based on ROC curve analysis, a threshold value of 114% GI was identified to distinguish between 'slow' from 'average' growth populations (mean AUC = 0.9525, 0.9081–0.9969 95% CI), and a threshold value of 155% GI between 'average' and 'fast' growth populations (mean AUC = 1).

By plotting GI values vs. latitude, 'fast' growth populations were found up to ≈55ºN and 'average' growth up to ≈59ºN (Figure 2). Conversely, 'slow' growth populations spanned the entire latitudinal range of the species distribution and were the only ones present above ≈59ºN. Conversely, below ≈37ºN all types of growth were encountered. Also, at similar low latitudes *R. rutilus* in Seyhan Reservoir (Turkey) and from the South Caspian Sea showed 'fast' growth, similar to *R. r. caspicus* from Gomishan and Anzali wetlands (Iran).

Discussion

The validity of the GI as a robust descriptor of growth rate in *R. rutilus* was evidenced by the overall concordance with the growth categorisation (i.e. 'low', 'average' and 'high') proposed by Zivkov and Raikova-Petrova (2001). This indicates that the GI can be used reliably as a comparative measure of growth for the species, even though conditional upon calibration. In the present study, this was achieved by ROC analysis using the above three *a priori* categories. These were originally based on a growth measure named 'average absolute (real)' growth rate (at age 4, in that study), which has been recommended as one of the most reliable indices for growth comparisons in fish (Živkov et al. 1999). However, it is noteworthy that, following calibration, the threshold values of 114% GI and 155% GI to distinguish between 'slow', 'average' and 'fast' growing populations proved to be consistently higher compared to Hickley and Dexter's (1979) reference values above and below 100%.

Table 1. Mean length-at-age (LAA) reference values for *Rutilus rutilus* used for computation of the Growth Index (GI).

Age	Present data			Original
	Mean	LCI	UCI	
1	62.5	60.5	63.8	50.0
2	97.6	89.7	105.9	91.9
3	127.5	115.1	141.0	127.0
4	153.0	137.2	170.3	156.4
5	174.7	156.4	194.8	181.1
6	193.3	173.0	215.3	201.7
7	209.0	187.5	232.3	219.0
8	222.5	200.2	246.6	233.5
9	233.9	211.1	258.5	245.6
10	243.7	220.7	268.5	255.7
11	252.0	228.9	276.8	264.3
12	259.1	236.1	283.8	271.4
13	265.1	242.4	289.6	277.4
14	270.3	247.9	294.4	282.4
15	274.7	252.6	298.5	286.6
16	278.4	256.7	301.9	–
17	281.6	260.3	304.7	–
18	284.3	263.4	307.0	–

LCI and UCI: lower and upper confidence intervals, respectively. LAA reference values estimated from a global VBGF fitted to the LAA data for 299 Eurasian roach populations (Appendix Table S1). The values originally provided in Hickley and Dexter (1979) are also given.

Table 2. Summary statistics for the GI in *R. rutilus* based on the semi-quantitative growth categories for roach identified by Zivkov and Raikova-Petrova (2001).

Category	*n*	Mean	SE	Quartile				
				0	25	50	75	100
Low	39	96.73	1.97	73.7	88.4	95.0	**103.3**	**125.1**
Average	27	127.72	2.57	**100.2**	**121.2**	129.1	136.4	151.1
High	9	180.96	8.32	158.5	162.8	177.7	183.3	229.1

SE = standard errors. In bold, overlapping quartiles for 'low' and 'average' categories.

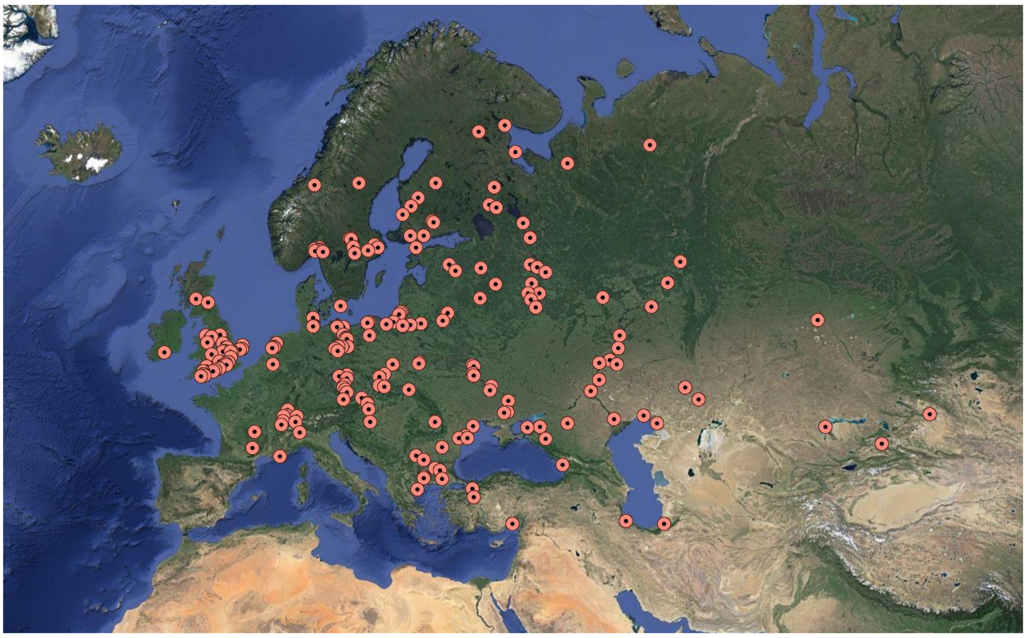

Figure 1. Water bodies for which length-at-age (LAA) data for roach *Rutilus rutilus* were reviewed. See also Appendix Table S1.

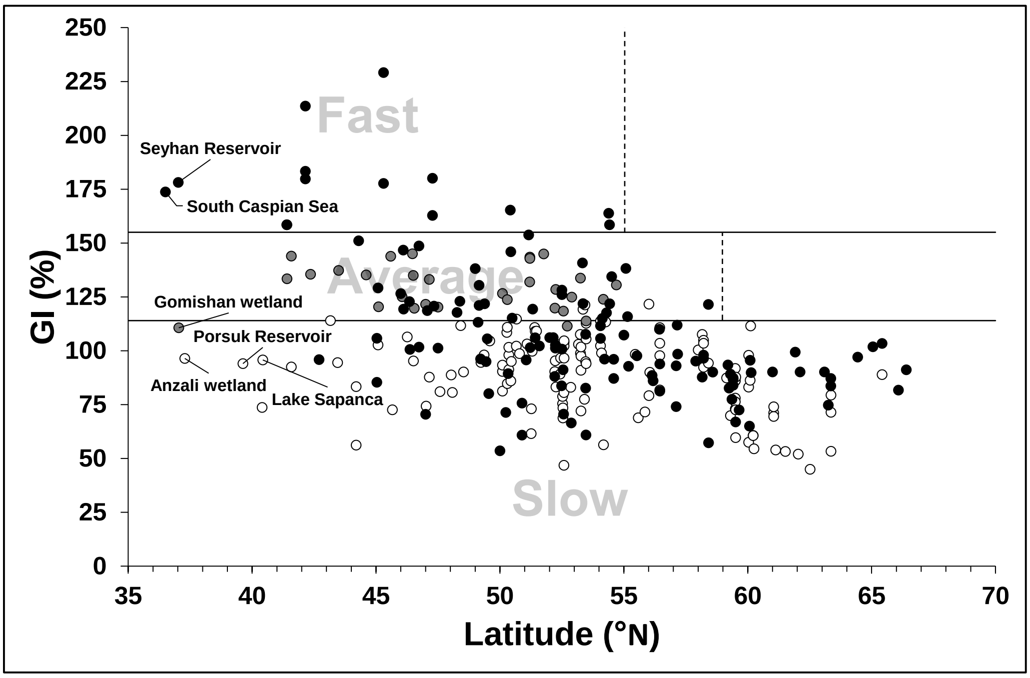

Figure 2. Growth Index (GI) values for 283 *R. rutilus* populations plotted against latitude and categorised according to 'slow' (white dots), 'average' (gray dots) and 'fast' (black dots). Key populations at the southern limits of the species' latitudinal range of distribution are highlighted. See also Appendix Table S1.

The lack of significant differences between Hickley and Dexter's (1979) original (UK-based) mean LAA reference values and those estimated globally in the present study indicates that the former did already provide for a representative sample size. However, it is recommended that the updated reference values provided here be used in future studies. This is because of the much larger number of populations reviewed and the inclusion of three additional age classes (i.e. 16+ to 18+) that have allowed for higher accuracy, objectivity and ease of applicability of the estimated values. Also, by defining a percentage-based interval to quantify the 'average' growth rate of a species (i.e. 114–155% GI for *R. rutilus,* based on the current findings) the problem of arbitrarily determining by how many percentage points a fish population/stock should be categorised as either 'slow' or 'fast' growing is overcome.

By combining the GI-based growth categorisation with information on latitude, a distinct picture of global growth patterns in *R. rutilus* emerged (Figure 2). Accordingly, slow growth rates were identified across the entire latitudinal range of distribution, pointing to the influence not only of latitude (hence, temperature) but also of water body-specific a/biotic factors upon the species' 'genetically programmed' growth capacity template. This was evidenced by the slow growth rates observed for several populations at the lower latitudes of the species' distributional range. These populations appeared as 'outliers' where a plateau in the cline occurred and reflected a decrease in growth capacity as suggested by Lappalainen et al. (2008). This was the case for Caspian roach in Anzali and Gomishan wetlands (Iran), the former water body being characterised by a temperate climate type but high levels of pollution, and the latter by an arid climate leading to more extreme summer temperatures in conjunction with local high salinity conditions (Naddafi et al. 2005). In Anatolia, the translocated population from Porsuk Reservoir had similar growth rate to that from Lake Sapanca, which is characterised by low productivity levels (Tarkan 2006); but the similarly translocated population from Seyhan Reservoir was characterised by considerably faster growth, suggesting again the influence of water body-related factors. Finally, the population of Caspian roach from the South Caspian Sea (Sedaghat and Hoseini 2012) and the Anatolian populations from Seyhan Reservoir (Ergüden et al. 2008) and Porsuk Reservoir deserve attention. In the former case, the observed fast growth rates as opposed to the populations from Anzali and Gomishan wetlands would rule out taxon-specific differences (i.e. *R. rutilus* vs. *R. r. caspicus*) in growth rate. In the latter case, translocated roach in Seyhan Reservoir may have benefited from locally available resources leading to successful establishment and growth, contrary to Porsuk Reservoir.

In conclusion, given the relatively widespread usage of the GI in the literature, species-specific calibrations leading to improved definition of corresponding growth bands (similar to what achieved in the present study) are recommended. This would apply not only to the other three species originally evaluated by Hickley and Dexter (1979), i.e. common bream *Abramis brama*, European chub *Leuciscus cephalus* and common dace *Leuciscus leuciscus*, but also to other cosmopolitan species such as the common carp *Cyprinus carpio*, which has been receiving increasing attention by scientists, environmental managers and stakeholders alike due to its economic value but also ecological threats (e.g. Vilizzi 2012; Vilizzi and Tarkan 2015; Vilizzi et al. 2015a).

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Appendix Table S1. Roach *Rutilus rutilus* populations for which mean LAA data (fork length: FL, mm) were reviewed for Growth Index (GI) computations.

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Alderfen Broad Lake[1]	52°72'N	01°48'E	111.5	–	S	87	113	138	157	168	200													Cryer et al. (1986)
Anzali wetland[1,2]	37°28'N	49°27'E	96.4	–	S	64	105	123	140	156	175	191	219											Naddafi et al. (2005)
Batak Reservoir (1966–1976)	41°58'N	24°11'E	92.5	L	S	73	115	128	130	143	162	166	177	203	215	234	236	250						Zivkov and Raikova-Petrova (2001)
Batak Reservoir (1977–1992)	41°58'N	24°11'E	144.0	A	A	84	147	180	219	255	279													Zivkov and Raikova-Petrova (2001)
Bay of Greifswald	54°13'N	13°32'E	115.0	–	A		96	136	170	203	227	250	270	294										*fide* Więsky and Załachowsky (2000)
Bay of Greifswald (Dänische Wiek)	54°06'N	13°28'E	111.6	–	S		98	138	170	197	219	242	256	263										*fide* Więsky and Załachowsky (2000)
Bay of Pomerania (a)	54°06'N	14°08'E	113.7	–	S	67	103	136	172	199	226	250	263	278										*fide* Więsky and Załachowsky (2000)
Bay of Pomerania (b)	54°06'N	14°08'E	102.3	–	S	65	91	119	149	170	196	222	247	264										Więsky and Załachowsky (2000)
Belaya River (middle course)	45°03'N	39°25'E	85.3	–	S				127	142	162	192												Kas'yanov et al. (1995)
Belaya River (mouth)	45°03'N	39°25'E	105.8	–	S				172	183			220											Kas'yanov et al. (1995)
Berounka River	49°59'N	14°24'E	104.5	–	S	48	89	130	165	194	219	240	257											Hanel (1991)
Bolshoy Irgiz River	51°59'N	47°31'E	102.2	–	S			106	143	187	210		260											Kas'yanov et al. (1995)
Bridgewater Canal	51°06'N	02°99'W	95.7	–	S			117	137	157	188	196	244											Hartley (1947)
Canal de la Thielle	47°02'N	07°02'E	74.3	–	S	38	62	76	103	143	161	173	180	201										Zaugg (1987)
Caspian Sea[2]	50°00'N	46°00'E	53.6	–	S			74	79	88														*fide* Kas'yanov et al. (1995)
Cheboksary Reservoir	56°18'N	46°42'E	86.1	–	S			109	128	146	174													Kas'yanov et al. (1995)
Chernobyl Nuclear Power Station cooling pond	51°16'N	30°13'E	153.8	–	A				230	266	295	318	343	369										Kas'yanov et al. (1995)
Crapina-Jijila pools (Danube Delta)	45°08'N	29°50'E	129.1	A	A	71	135	170																*fide* Zivkov and Raikova-Petrova (2001)
Danube River (Lom)	43°49'N	23°14'E	137.3	A	A	92	134	167	200															*fide* Zivkov and Raikova-Petrova (2001)
Danube River (Rusovce)	48°03'N	17°08'E	88.8	–	S	56	85	112	134	153	168	187	202											*fide* Chitravadivelu (1974)
Danube River (Tutrakan)	44°30'N	26°37'E	151.1	A	A	100	142	185																*fide* Zivkov and Raikova-Petrova (2001)
Danube River (Vlčie hrdlo)	48°08'N	17°06'E	80.6	–	S	53	82	103	121	141	152	154												*fide* Chitravadivelu (1974)
Danube River (Vojka arm complex)	47°58'N	17°22'E	81.0	L	S	48	74	97	120	139	158	175	207											Chitravadivelu (1974)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Darent (gravel pit lake)	51°42'N	00°26'W	109.1	–	S	53	88	135	175	223	248													Gee (1978)
Dneprovsk Reservoir	47°34'N	34°58'E	120.7	L	F		135	144	181	194														*fide* Zivkov and Raikova-Petrova (2001)
Dnieper River (a)	–	–	97.2	L	S	41	83	114	144	170	196	220	240	264	265									*fide* Zivkov and Raikova-Petrova (2001)
Dnieper River (b)	–	–	100.4	L	S	48	89	123	151	177	203	237	259											*fide* Zivkov and Raikova-Petrova (2001)
Dnieper River (Dnipropetrovsk)	48°27'N	34°59'E	117.8	–	A				190	205	222	236												*fide* Kas'yanov et al. (1995)
Dnieper River (upper)	–	–	86.9	–	S			108	120	147	162	195	211											Kas'yanov et al. (1995)
Dnistrovskyi Reservoir	46°11'N	30°20'E	119.3	–	A					211	226													Kas'yanov et al. (1995)
Don River	–	–	131.2	A	A	76	129	172	204															*fide* Zivkov and Raikova-Petrova (2001)
Don River (upper)	–	–	89.3	–	S				134	144	173	184		227										Kas'yanov et al. (1995)
Dospat Reservoir	41°41'N	24°05'E	133.5	A	F	76	136	183	212	234	238	271												Zivkov and Raikova-Petrova (2001)
Elbe region (1951–1956)	50°10'N	14°46'E	93.3	–	S	48	91	120	151	173	184													Frank (1962)
Elbe region (Malá and Velká)	50°10'N	14°46'E	126.6	–	A	53	114	184	218	238	257	260												Frank (1962)
Elbe region (Poltruba – 1955)	50°10'N	14°46'E	81.2	L	S	50	84	101	121	134	153	168	192											*fide* Zivkov and Raikova-Petrova (2001)
Elbe region (Poltruba – 1956)	50°10'N	14°46'E	90.4	–	S	50	83	113	139	184														Frank (1962)
Ellesmere	52°90'N	02°89'W	124.9	–	A	45	120	160	220	240	260	270	280	300										*fide* Goldspink (1978)
Emba River	46°37'N	53°19'E	100.6	–	S			124	154	179														Kas'yanov et al. (1995)
Exeter Canal	50°66'N	03°46'W	102.1	–	S	56	92	120	145	186	206	222	241	252	266									*fide* Cowx (1988)
Filipoin channel (Danube Delta)	45°08'N	29°50'E	102.7	A	S	50	100	139	179															*fide* Zivkov and Raikova-Petrova (2001)
Fosterudbekken stream[1,2]	59°41'N	10°44'E	87.3	–	S				127	149	165	175	187	198	213	215	237	238	238	266				Vøllestad and L'Abée-Lund (1990)
G. Dimitrov Reservoir (1964–1968)	41°40'N	26°34'E	158.5	H	F	91	152	199	265															*fide* Zivkov and Raikova-Petrova (2001)
G. Dimitrov Reservoir (1973–1977)	41°40'N	26°34'E	158.5	H	A	79	156	210	257	296														*fide* Zivkov and Raikova-Petrova (2001)
Goczałkowickie Reservoir	49°55'N	18°52'E	80.1	–	S		64	96	120	144	168	176	184	188	201									*fide* Epler et al. (2005)
Gomishan wetland	37°04'N	54°04'E	110.7	–	S	77	116	139	161	182	194													Naddafi et al. (2005)
Gorjkovsk Reservoir	54°59'N	73°22'E	87.1	L	S		62	99	134	175	190	195												*fide* Zivkov and Raikova-Petrova (2001)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Grantham Canal	52°86'N	00°98'W	83.0	–	S	66	61	104	124	142	157	178												Hartley (1947)
Grey Mist Mere (1969)	50°89'N	01°38'W	60.8	–	S		93	101	106	109	114	113	117	118	121	119	122							*fide* Linfield (1979)
Grey Mist Mere (1971)	50°89'N	01°38'W	75.7	–	S		89	110	152		155	157	147	157	154	167	191	161						Linfield (1979)
Grimnitzsee	52°58'N	13°47'E	80.6	–	S	66	79	102	114	124	145	155												*fide* Hartley (1947)
Groote Brekken Lake	52°88'N	05°70'E	66.5	A	S	74	121	159	200	222	264	285	305	309	325	328								*fide* Zivkov and Raikova-Petrova (2001)
Großer Plöner See	54°70'N	10°24'E	130.6	–	A		58	92	102	112	118	132	159	168										Goldspink (1979)
Hamr pond[1]	50°42'N	14°50'E	165.3	H	A	75	161	232	280	301														*fide* Zivkov and Raikova-Petrova (2001)
Heegermeer[1]	52°57'N	05°35'E	70.6	–	S		79	95	110	118	126	129												Goldspink (1979)
Humbie Reservoir[1]	55°85'N	02°85'W	71.6	–	S	26	60	93	120	140	152	164	169	173										*fide* Goldspink (1978)
IJsselmeer	52°49'N	05°15'E	83.8	–	S				142	156	166	178	173	185	181									Goldspink (1979)
Irtysh River	54°59'N	73°22'E	96.1	–	S							196	207	235										Kas'yanov et al. (1995)
Ivankovskoye Reservoir	56°44'N	37°10'E	109.9	L	S		107	130	151	172	197	226	251	287	320									Baranova (1984)
Kakhovka Reservoir (a)	47°28'N	34°10'E	180.1	–	F				250	304	343	385	416	429	455									Spivak et al. (1979)
Kakhovka Reservoir (b)	47°28'N	34°10'E	162.8	H	A			180	248	295	341													*fide* Zivkov and Raikova-Petrova (2001)
Kama Reservoir	58°59'N	56°10'E	90.1	–	S			128	138	151	170	182	192											*fide* Kas'yanov et al. (1995)
Kanevsk Reservoir	46°05'N	38°57'E	125.1	L	A	69	107	146	184	217	249	272	295	309	321	332	334							*fide* Zivkov and Raikova-Petrova (2001)
Khutorskoye (Solovetsky Islands)	65°05'N	35°53'E	101.9	–	S				151	173	206													*fide* Kas'yanov et al. (1995)
Kiev Reservoir	50°49'N	30°27'E	115.1	–	A			106			238	260	285											Kas'yanov et al. (1995)
Klíčava Reservoir (a)	50°30'N	13°56'E	110.9	–	S	44	66	144	189	220	243	258	274	283										Holčík (1967a)
Klíčava Reservoir (b)	50°30'N	13°56'E	123.8	L	A	66	139	181	200	221	238	249	259	267	274									*fide* Zivkov and Raikova-Petrova (2001)
Kozłowa Góra Reservoir	50°24'N	18°56'E	71.3	–	S				96	124	136	148	160	172	180	188								*fide* Epler et al. (2005)
Kremenchuk Reservoir (a)	49°16'N	32°38'E	121.1	A	A			158	185	206	230	242	267	296										*fide* Zivkov and Raikova-Petrova (2001)
Kremenchuk Reservoir (b)	49°16'N	32°38'E	130.4	A	A		138	161	202	214	238	263	288	302	340									*fide* Zivkov and Raikova-Petrova (2001)
Kuban River[3]	–	–	140.4	A	A	85	139	179	214															*fide* Zivkov and Raikova-Petrova (2001)

Population	Lat	Long	GI	Z-RP	GT	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Source
Kurshskiy Zaliv Lagoon	55°00'N	21°00'E	107.3	–	S					190	204	222	238											Kas'yanov et al. (1995)
Kuybyshev Reservoir (a)	53°46'N	48°55'E	95.0	L	S	47	78	105	131	157	181	206	232	252	271	283								*fide* Zivkov and Raikova-Petrova (2001)
Kuybyshev Reservoir (b)	53°46'N	48°55'E	82.6	L	S		47	78	105	131	157	181	206	232	252	271								*fide* Zivkov and Raikova-Petrova (2001)
Kuybyshev Reservoir (c)	53°46'N	48°55'E	107.6	–	S			106	134	149	180	229	273	297	305	332								*fide* Kas'yanov et al. (1995)
Lac de Pareloup (after refilling)	44°20'N	02°76'E	83.4	–	S	58	82	103	123	134														Angèlibert et al. (1999)
Lac de Pareloup (before draining)	44°20'N	02°76'E	56.2	–	S	33	51	70	89	107														Angèlibert et al. (1999)
Lac des Quatre-Cantons	47°00'N	08°24'E	121.6	–	A	95	134	175	184	201		245	257	262	257			261						Zaugg (1987)
Lac du Loclat	47°00'N	06°59'E	70.5	–	S			87	102	132														Zaugg (1987)
Lake Balaton	46°50'N	17°44'E	135.0	–	A	96	135	174	205	234	257	272	279	291										Specziár et al. (1997)
Lake Balkhash	46°10'N	74°20'E	146.8	–	A					274	287	294	309											*fide* Kas'yanov et al. (1995)
Lake Beloye (a)	60°10'N	37°38'E	86.3	L	S	50	74	105	135	153	179	198												*fide* Zivkov and Raikova-Petrova (2001)
Lake Beloye (b)	60°10'N	37°38'E	95.6	–	S			122	141			204												Kas'yanov et al. (1995)
Lake Biel (a)	47°50'N	07°10'E	101.3	–	S				164	176	192	201												Büsser and Schumi (1987)
Lake Biel (b)	47°50'N	07°10'E	120.3	–	A	95	119	164	186		225	248	253	256	268	265								Zaugg (1987)
Lake Biserovo	55°46'N	38°07'E	98.4	L	S	60	97	128	149	170	187	205												*fide* Zivkov and Raikova-Petrova (2001)
Lake Charkhal	51°32'N	46°00'E	119.4	–	A					205	232	245	263	285										Kas'yanov et al. (1995)
Lake Charzykowy	53°43'N	17°30'E	121.3	A	A	62	93	143	183	233	259	282	306											*fide* Zivkov and Raikova-Petrova (2001)
Lake Cherven[1]	43°16'N	24°06'E	114.0	A	A	53	98	136	167	196	222	252	279	301	324									*fide* Zivkov and Raikova-Petrova (2001)
Lake Dąbie (a)	53°27'N	14°39'E	101.8	–	S	59	91	121	149	173	197	223	250	262										*fide* Więsky and Załachowsky (2000)
Lake Dąbie (b)	53°27'N	14°39'E	72.1	–	S	39	61	81	99	115	132	147	164	175	187	199	209	217	219					Załachowsky and Krzykawska (1995)
Lake Dąbie (c)	53°27'N	14°39'E	97.5	–	S	58	89	121	151	173	188	204	221	241										Więsky and Załachowsky (2000)
Lake Dąbie (Kwiecińska 1984)	53°27'N	14°39'E	90.9	–	S	36	73	109	142	167	182	210	233	256										Więsky and Załachowsky (2000)
Lake d'Aydat	45°66'N	02°98'E	72.6	–	S	48	72	92	109	124	136	147												Jamet and Desmolles (1994)
Lake Dusya	54°30'N	23°70'E	117.6	–	A				147	206	233			314										Kas'yanov et al. (1995)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Lake Erken (location 1)	59°50'N	18°35'E	76.3	–	S	60	80	100	112	128	132	148	156	168										Putkis and Batsianiou (2005)
Lake Erken (location 2)	59°50'N	18°35'E	86.0	–	S	72	84	96	116	132														Putkis and Batsianiou (2005)
Lake Erken (location 3)	59°50'N	18°35'E	86.1	–	S	84	96	108	116	128	140	152	164											Putkis and Batsianiou (2005)
Lake Erken (location 4)	59°50'N	18°35'E	73.0	–	S	56	72	88	108	120	136	148	152											Putkis and Batsianiou (2005)
Lake Erken (location 5)	59°50'N	18°35'E	78.0	–	S	64	84	92	108	128	136	148	168											Putkis and Batsianiou (2005)
Lake Erken (location 6)	59°50'N	18°35'E	91.8	–	S	88	108	112	124	132	140	148												Putkis and Batsianiou (2005)
Lake Gardno	54°39'N	17°06'E	163.8	–	A		162	196	235	275	323	369	374	381										Hornatkiewicz-Żbik (2003)
Lake Geneva[1]	46°26'N	06°33'E	106.4	–	S	66	104	137	166	192	195	221	229											Ponton and Gerdeaux (1987)
Lake Glaningen	60°12'N	15°04'E	111.5	–	S	51	99	140	164	206	229	248	264	273	282	292								Kempe (1962)
Lake Haarajärvi[1]	62°52'N	23°37'E	45.0	–	S	28	44	56	68	76	88	92	104											Estlander et al. (2010)
Lake Halmsjön	59°65'N	17°97'E	72.5	–	S	51	75		87	116	137	150	161	168	171	170	182	207	229					Kempe (1962)
Lake Haukijärvi	61°52'N	21°41'E	53.2	–	S	40	56	68	76	84	92	108	116											Estlander et al. (2010)
Lake Hiidenvesi (deep basin)	60°22'N	24°11'E	60.6	–	S	36	60	84	100	104	116	120	128	136										Vinni et al. (2000)
Lake Hiidenvesi (shallow basins)	60°22'N	24°11'E	60.7	–	S	44	64	84	96	100	112	116	120	128										Vinni et al. (2000)
Lake Hjälmaren	59°15'N	15°45'E	87.4	–	S	58	79	107	130	150	168	183	203	208										*fide* Hartley (1947)
Lake Hokajärvi	61°13'N	25°12'E	54.0	–	S	36	56	72	80	88	100	108	116											Estlander et al. (2010)
Lake Ilmen (a)	58°16'N	31°17'E	87.8	L	S		66	85	115	143	173	184	218	228	243	247	259							*fide* Zivkov and Raikova-Petrova (2001)
Lake Ilmen (b)	58°16'N	31°17'E	107.6	L	S	67	104	138	165	185	206													*fide* Zivkov and Raikova-Petrova (2001)
Lake Kamyshovoye	54°22'N	22°42'E	96.2	–	S					170	180	194		223	245									Kas'yanov et al. (1995)
Lake Kloten	59°52'N	15°27'E	87.8	–	S	53	81	109	132	147	170	191	201	218										*fide* Hartley (1947)
Lake Kyvann	63°25'N	10°50'E	74.7	–	S					138		161	176	181	177	153	206		191					Vøllestad and L'Abée-Lund (1990)
Lake Łebsko	54°42'N	17°24'E	158.5	–	F		149	180	230	259	293	359	380	369	418		422							Hornatkiewicz-Żbik (2003)
Lake Lebyazh'ye	64°44'N	42°00'E	97.0	–	S				152	169	181	192	204	233	253									Kas'yanov et al. (1995)
Lake Libiszowskie	51°26'N	20°18'E	61.5	–	S	36	60	72	88	112	128	136												*fide* Epler et al. (2005)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Lake Lugano	45°59'N	08°58'E	143.9	–	F	89	143	183	223	240														Guthruf (2002)
Lake Lukom	49°49'N	32°53'E	105.5	L	S			146	154	173	205													*fide* Zivkov and Raikova-Petrova (2001)
Lake Majajärvi	62°04'N	22°53'E	52.0	–	S	40	56	68	76	84	88	100	108											Estlander et al. (2010)
Lake Mälaren	59°30'N	17°12'E	69.9	–	S	34	61	89	112	129	143	153	160	165	171	176	184	188						Kempe (1962)
Lake Miedwie	53°17'N	14°54'E	103.0	–	S	69	97	119	147	183	201	229												*fide* Hartley (1947)
Lake Morotskoye	58°42'N	37°39'E	57.3	–	S				84	91	106	113	121	143	166									Kas'yanov et al. (1995)
Lake Myadelka	55°08'N	27°10'E	138.2	A	A		138	175	194	232	263	295	329											*fide* Zivkov and Raikova-Petrova (2001)
Lake Myatyalis	55°15'N	21°18'E	115.9	–	A				177	194	222	237		286										Kas'yanov et al. (1995)
Lake Narach	54°51'N	26°44'E	134.4	A	A		128	161	209	241	265													*fide* Zivkov and Raikova-Petrova (2001)
Lake Nero	57°90'N	39°26'E	95.2	–	S			93	122	150	177	207	236	259	275									*fide* Kas'yanov et al. (1995)
Lake Neuchâtel	46°54'N	06°51'E	119.7	–	A	89	134	168	185	212	232	237	249	265	273	277	279	287						Zaugg (1987)
Lake Norra Hörken	60°07'N	14°89'E	65.0	–	S				112	116	124	128	136	156	147	164								Kempe (1962)
Lake of Sainte-Croix	43°45'N	06°11'E	94.5	–	S	48	93	126	153	171	185	196												*fide* Angèlibert et al. (1999)
Lake Oltush	51°42'N	23°58'E	106.0	L	S		116	142	153	166	198													*fide* Zivkov and Raikova-Petrova (2001)
Lake Øyeren	59°51'N	11°09'E	72.6	–	S	56	72	96	112	120	136	140	144	160	164	180	196	201	205	196	201	196		*fide* Naddafi et al. (2005)
Lake Paliastomi	42°70'N	41°43'E	95.9	–	S				149	166	182													*fide* Kas'yanov et al. (1995)
Lake Peipus (a)	58°41'N	27°29'E	94.3	L	S	28	76	118	145	166	182	194	210	225	234	253	271	305	316					*fide* Zivkov and Raikova-Petrova (2001)
Lake Peipus (b)	58°41'N	27°29'E	121.5	–	A			173	185	195	220	238	267	276	276	319		364						Mitrofanova (1976)
Lake Pleshcheyevo (1930)	56°45'N	38°47'E	110.8	–	S	59	99	138	175	203	228	249												*fide* Kas'yanov and Izyumov (1995)
Lake Pleshcheyevo (1960)	56°45'N	38°47'E	97.7	–	S	60	92	120	147	173	191	206	226											*fide* Kas'yanov and Izyumov (1995)
Lake Pleshcheyevo (1979–1980)	56°45'N	38°47'E	81.8	–	S	55	78	101	122	138	156	173	183											Kas'yanov and Izyumov (1995)
Lake Pleshcheyevo (1980)	56°45'N	38°47'E	81.2	–	S				115	144	157	168	190											*fide* Kas'yanov et al. (1995)
Lake Pleshcheyevo (1991a)	56°45'N	38°47'E	103.5	–	S	78	106	130	151	170	189	205	219	232	257									Kas'yanov and Izyumov (1995)
Lake Pleshcheyevo (1991b)	56°45'N	38°47'E	93.9	–	S			105	132	157	180	199	215	240	249									Kas'yanov et al. (1995)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Lake Pskov	58°00'N	28°00'E	100.4	L	S	55	70	106	138	160	177	194	213	230	266	291	309	323	357					*fide* Zivkov and Raikova-Petrova (2001)
Lake Pyaozero	66°08'N	30°97'E	81.7	–	S				130	141	149	173												Kas'yanov et al. (1995)
Lake Pyhäjärvi (Finnish zone)	63°35'N	25°57'E	83.6	–	S				136	148	164	172	188	192	196		217	209						Auvinen (1987)
Lake Pyhäjärvi (Soviet zone)	63°35'N	25°57'E	87.2	–	S					172	172	184	192	201	209	213	221	209						Auvinen (1987)
Lake Royk-Navolokskoye	63°10'N	32°90'E	90.1	–	S			109	139	152	170		217											Kas'yanov et al. (1995)
Lake Sæbyvannet[1]	59°25'N	10°59'E	82.6	–	S				138	144	153	176	184	198	195	190								Vøllestad and L'Abée-Lund (1990)
Lake Sapanca	40°43'N	30°15'E	95.7	–	S	56	88	131	149	160	173	193	218	249										Okgerman et al. (2009)
Lake Sarnen	46°51'N	08°12'E	95.2	–	S	55	84	114	145	170	188	203	217	222	245	246	254							Müller and Meng (1986)
Lake Sayram	44°60'N	81°20'E	135.2	–	A	95	140	178	189	222	235													Wenlin et al. (1992)
Lake Seliger (a)	57°11'N	33°04'E	74.1	–	S			92	105	130	144	158	172											*fide* Kas'yanov et al. (1995)
Lake Seliger (b)	57°11'N	33°04'E	93.1	L	S		76	121	143	161	179	200	214	223		242								Baranova (1984)
Lake Shivchey[1]	–	–	95.2	–	S					162	176	195	217	233										Kas'yanov et al. (1995)
Lake Södra Hörken (fast)	60°04'N	15°03'E	97.9	–	S	46	90	128	155	190	209													Kempe (1962)
Lake Södra Hörken (immigrants)	60°04'N	15°03'E	83.1	–	S	34	55	74	91	104	161	213	226	253	276	289								Kempe (1962)
Lake Södra Hörken (slow)	60°04'N	15°03'E	57.5	–	S	31	50	83	98	105	109	119	122											Kempe (1962)
Lake Somova	45°10'N	28°45'E	120.4	–	A	70	129	131	202															*fide* Chitravadivelu (1974)
Lake Sövdeborgssjön	55°58'N	13°70'E	68.9	–	S	44	64	88	101	125														*fide* Angèlibert et al. (1999)
Lake Stor-Finnsjön (type A)	63°36'N	16°01'E	53.4	–	S	31	47	65	81	96	107	125												Kempe (1962)
Lake Stor-Finnsjön (type B)	63°36'N	16°01'E	79.4	–	S	35	67	98	124	144	160	176	189	204	211									Kempe (1962)
Lake Stor-Finnsjön (type C)	63°36'N	16°01'E	71.4	–	S	41	72	94	110	124	133	152												Kempe (1962)
Lake Suoyarvi	62°11'N	32°23'E	90.1	–	S			109	138	153	170		217											Kas'yanov et al. (1995)
Lake Svitiaz	51°30'N	23°50'E	99.8	L	S	50	82	119	147	175	205	240	267											*fide* Zivkov and Raikova-Petrova (2001)
Lake Syamozero[1]	61°92'N	33°17'E	99.3	–	S				157	170	194	199	213	240										*fide* Kas'yanov et al. (1995)
Lake Vesijärvi[1]	61°05'N	25°30'E	74.0	–	S	48	76	100	120	128	140	148	152	156										Horppila (1994)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Lake Vesijärvi (Enonselkä Basin)	61°05'N	25°30'E	69.5	–	S	51	79	98	108	119	124	128	132	140										Horppila (2000)
Lake Vesijärvi (Laitialanselkä Basin)	61°05'N	25°30'E	71.1	–	S	49	77	99	113	124	130	136	140	145										Horppila (2000)
Lake Volvi	40°40'N	23°28'E	73.7	L	S	61	91	99	111	121	128	138	145	155	164	175	181							Papageorgiou (1979)
Lake Vyshtenetskoye	54°43'N	20°31'E	121.8	–	F				194	203	217	228	263	302	336									*fide* Kas'yanov et al. (1995)
Lake Węgorzewskie	54°18'N	21°45'E	56.3	–	S	36	56	68	80	96	112	120	128											*fide* Epler et al. (2005)
Lake Zhizhitskoye	56°14'N	31°15'E	88.6	–	S			97	142	167														Kas'yanov et al. (1995)
Leeds and Liverpool Canal	53°47'N	01°31'W	60.9	–	S		50	70	80	95	110	130	150	170	180									*fide* Goldspink (1978)
Lena River (a)	–	–	76.7	L	S		46	92	104	138	150	173	184	207	219									*fide* Zivkov and Raikova-Petrova (2001)
Lena River (b)	–	–	95.5	–	S					167	183													*fide* Kas'yanov et al. (1995)
Lipno Reservoir	48°42'N	14°04'E	111.7	A	S	51	96	136	175	206	235	263	274											*fide* Zivkov and Raikova-Petrova (2001)
Loch Lomond	56°05'N	04°34'W	90.0	–	S	32	66	104	143	176	199	217	228	240										*fide* Goldspink (1978)
Lower Don River	–	–	100.2	A	S	61	71	137	185															*fide* Zivkov and Raikova-Petrova (2001)
Madingley (upper pond)	52°22'N	00°04'E	119.8	–	A	90	101	142	180															Hartley (1947)
Maly Uzen River	51°22'N	48°19'E	101.5	–	S			119	137	164	204	223	235		275									Kas'yanov et al. (1995)
Müggelsee	52°26'N	13°39'E	83.2	–	S	61	84	104	122	137	147	168												*fide* Hartley (1947)
Mušov Reservoir	48°53'N	16°36'E	90.1	L	S	46	75	111	145	180	199													*fide* Zivkov and Raikova-Petrova (2001)
Neman River[2]	–	–	107.1	A	S	39	79	118	153	182	211	234	251	271	294	328	363							*fide* Zivkov and Raikova-Petrova (2001)
Nizhnekamsk Reservoir	55°53'N	52°45'E	97.7	–	S			119	149	172	185	198	218	223	257									Kas'yanov et al. (1995)
Norfolk Broads	52°43'N	01°38'E	89.1	–	S	69	91	118	127	135	152	172	198	216										Hartley (1947)
North Caspian Sea (a)	–	–	138.2	–	A				206	244	272	283												*fide* Kas'yanov et al. (1995)
North Caspian Sea (b)	–	–	120.9	–	A				184	204	229	253	279											*fide* Kas'yanov et al. (1995)
Ob River	–	–	98.6	–	S						184	202	222	237										Kas'yanov et al. (1995)
Odra River Mouth (Międzyodrze)	53°24'N	14°34'E	107.6	–	S	67	96	124	151	180	210	240	258	281										Więsky and Załachowsky (2000)
Old West River	52°21'N	00°01'E	90.3	–	S	66	91	118	124	142	165													Hartley (1947)

Population	Lat	Long	GI	Z-RP	GT	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Source
Orava Reservoir	50°30'N	13°56'E	84.8	L	S	48	67	83	97	114	121	145	167	179	207	230	249	268	280	285	291	300	304	Holčík (1967b)
Orlík Reservoir	49°36'N	14°10'E	98.0	L	S	54	79	109	143	177	199	222	244	262										*fide* Zivkov and Raikova-Petrova (2001)
Ovcharitsa Reservoir (1976–1985)	42°15'N	26°13'E	179.8	H	F	120	192	241	267	288	302													Zivkov and Raikova-Petrova (2001)
Ovcharitsa Reservoir (1976–1989)	42°15'N	26°13'E	183.3	H	F	127	197	243	272	288	302													Zivkov and Raikova-Petrova (2001)
Ovcharitsa Reservoir (1986–1989)	42°15'N	26°13'E	213.6	H	A	145	215	256	301															Zivkov and Raikova-Petrova (2001)
Paimionjoki River	60°25'N	22°40'E	54.5	–	S	30	48	64	79	93	109	127	144											Kännö (1969)
Pechora River (a)	65°42'N	52°28'E	103.4	–	S						200	215	229	244	248									*fide* Kas'yanov et al. (1995)
Pechora River (b)	65°42'N	52°28'E	88.9	L	S	46	77	111	146	169	192													*fide* Zivkov and Raikova-Petrova (2001)
Plußsee	54°10'N	10°26'E	99.0	–	S	49	80	128	149	165	174	204	228	235	257	261	279	323						Arzbach (1997)
Pond Velký Tisý	49°00'N	14°46'E	138.2	–	A	75	142	187																Frank (1962)
Ponds at Valkenswaard (1958)	51°21'N	05°28'E	142.9	–	A	77	161	197	221	237	252													Hofstede (1974)
Ponds at Valkenswaard (1959)	51°21'N	05°28'E	143.5	–	A	83	160	195	206	226														Hofstede (1974)
Porsuk Reservoir	39°63'N	30°28'E	94.1	–	S	65	102	124	139	148	155													Başkurt et al. (2015)
Pripyat River	51°09'N	30°29'E	103.2	L	S	43	100	126	159	181	199	229	259	276										*fide* Zivkov and Raikova-Petrova (2001)
Proletarskoye Reservoir	46°35'N	42°00'E	122.8	–	A				196	211	228													*fide* Kas'yanov et al. (1995)
Przeczyce Reservoir	50°44'N	19°17'E	146.0	–	F				212	238	279	313	333	355	359	370	378	384						Skóra (1972)
Puiu Lake (a)	45°30'N	29°29'E	177.7	H	F	101	191	220	271															*fide* Zivkov and Raikova-Petrova (2001)
Puiu Lake (b)	45°30'N	29°29'E	229.1	H	A	172	217	237																*fide* Zivkov and Raikova-Petrova (2001)
Red Lake (Lacu Roșu)[2]	46°47'N	25°47'E	145.1	A	A	86	141	192	221															*fide* Zivkov and Raikova-Petrova (2001)
Regalica River (a)	53°25'N	14°33'E	133.7	–	A	89	124	147	193	231	259	287	310	338										*fide* Hartley (1947)
Regalica River (b)	53°25'N	14°33'E	98.8	–	S	56	84	114	145	174	203	228	252											*fide* Więsky and Załachowsky (2000)
River Birket[1]	53°41'N	03°12'W	77.5	–	S	73	81	94	109	125	130	136	152											*fide* Linfield (1979)
River Cam (Barrington)	51°48'N	01°42'W	109.1	–	S	69	107	130	160	180	216	241	231	274										Hartley (1947)
River Creedy[1]	50°44'N	03°33'W	86.0	–	S	56	79	105	125	140	157	174	198	211	220	236								Cowx (1988)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
River Culm	50°46'N	03°30'W	95.0	–	S	51	88	126	158	176	192	202	206	212	226	237	247							Cowx (1988)
River Desna[1]	50°33'N	30°32'E	89.4	–	S				130	141	161			251										Kas'yanov et al. (1995)
River Exe (Cowley Bridge)[1]	50°36'N	03°25'W	91.3	–	S	51	85	116	140	162	176	194	207	216	225	238								Cowx (1988)
River Exe (Fortesque)[1]	50°36'N	03°25'W	101.6	–	S	51	92	141	161	190	201	216												Cowx (1988)
River Exe (Trew's weir)	50°36'N	03°25'W	98.0	–	S	55	97	123	146	168	184	200	214	228	239	246	301							Cowx (1988)
River Frome	50°67'N	02°18'W	114.7	A	A	50	90	131	164	194	221	246	271	293	311	324	334	341						Mann (1973)
River Funshion	52°15'N	08°24'W	106.1	–	S			150	166	183	188	199	240	235	278									*fide* Linfield (1979)
River Glomma (Glengshølen)	59°30'N	11°13'E	89.2	–	S			104	119	149	167	179	200	196	231	229	225	263	283					Vøllestad and L'Abée-Lund (1990)
River Glomma (Langnes)[1]	59°36'N	11°07'E	77.4	–	S				119	120	133	143	154	182	189	202	216	217	236	235				Vøllestad and L'Abée-Lund (1990)
River Glomma (Vestvannet)	59°20'N	11°50'E	93.4	–	S				149	155	172	198	209	204	224	222	249	253		280				Vøllestad and L'Abée-Lund (1990)
River Granta	52°21'N	00°16'E	88.0	–	S		89	117	130	142	165	191												Hartley (1947)
River Lugg	52°01'N	02°38'W	106.1	–	S			159	169	177	215	228	235	245	258	263	262	225						Hellawell (1972)
River Nene (Cogenhoe) (above sluice)	52°24'N	00°79'W	102.6	–	S		105	140	165	180	190	205	210	230										Hart (1971)
River Nene (Cogenhoe) (below sluice)	52°24'N	00°79'W	101.2	–	S		105	130	150	180	190	210	220	235	240									Hart (1971)
River Nene (Kislingbury)	52°23'N	00°98'W	95.3	–	S	55	95	130	150	160	180	205	215	215	245	220								Hart (1971)
River Nene (Wollaston)	52°25'N	00°66'W	128.5	–	A	105	150	180	190	220	230	245	250	255	265									Hart (1971)
River Nene (Yarwell)	52°56'N	00°43'W	118.4	–	A	75	125	150	175	190														Hart (1971)
River Ryck	54°06'N	13°28'E	105.7	–	S		104	136	154	187														*fide* Więsky and Załachowsky (2000)
River Stour	50°79'N	01°92'W	98.7	L	S	46	84	119	154	177	192	206	219	229	239	274	285	298						Mann (1973)
River Thames (Reading)	51°27'N	00°58'W	73.0	–	S	43	79	95	113	129	138	147	156	167	176									Williams (1967)
River Uil	49°38'N	56°72'E	121.8	–	A			150	189	214	235													Kas'yanov et al. (1995)
River Wensum	52°38'N	01°16'E	102.9	–	S	40	75	125	160	195	225	255	280											Beardsley and Britton (2012)
Rostherne Mere (Banks 1970)	53°35'N	02°39'W	119.3	–	A	48	104	165	198	228	246	267	270	280										Banks (1970)
Rostherne Mere (Mills 1969)	53°35'N	02°39'W	121.9	–	A		100	160	189	209	232	264	294											*fide* Goldspink (1978)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Rybinsk Reservoir	58°22'N	38°26'E	103.4	L	S	37	75	103	137	167	198	229	257	282	302	324	348							*fide* Zivkov and Raikova-Petrova (2001)
Rybinsk Reservoir (herbivors)	58°22'N	38°26'E	96.5	–	S				143	167	184	204	217	228										*fide* Kas'yanov et al. (1995)
Rybinsk Reservoir (mollusk-eating form)	58°22'N	38°26'E	104.8	–	S	71	96	122	151	175	199	219	238	258	274									Kas'yanov and Izyumov (1995)
Rybinsk Reservoir (omnivors)	58°22'N	38°26'E	98.0	–	S			99	132	161	187	218	235	249	272									*fide* Kas'yanov et al. (1995)
Rybinsk Reservoir (phytophagous form)	58°22'N	38°26'E	92.3	–	S	85	99	114	127	139	150	159												Kas'yanov and Izyumov (1995)
Rye Meads Lagoons	51°77'N	00°01'E	145.0	–	A	75	145	190	240	260	275													White and Williams (1978)
Sagyz River	47°07'N	51°53'E	118.7	–	A				188	204	222													Kas'yanov et al. (1995)
Sakrower See	52°45'N	13°05'E	96.6	–	S	74	91	114	135	157	178	213												*fide* Hartley (1947)
Saratov Reservoir (a)	52°50'N	48°30'E	128.1	A	A		115	132	190	209	245	281	308	327	351									*fide* Zivkov and Raikova-Petrova (2001)
Saratov Reservoir (b)	52°50'N	48°30'E	126.1	A	A		109	126	174	198	227	262	308	327	346	392								*fide* Zivkov and Raikova-Petrova (2001)
Saratov Reservoir (c)	52°50'N	48°30'E	100.8	–	S			121	147	173	192	206	228		274									Kas'yanov et al. (1995)
Sea of Azov	46°00'N	37°00'E	126.5	A	A			139	179	214	245	273	310	321										*fide* Zivkov and Raikova-Petrova (2001)
Seyhan Reservoir	37°02'N	35°19'E	178.1	–	F	147	174	193	220															Ergüden et al. (2008)
Sheksna Reservoir[1]	60°14'N	37°35'E	89.8	–	S			107	138	156	168	187	207	219										Kas'yanov et al. (1995)
Shetirgiz River	48°38'N	58°32'E	123.0	–	A			144	190	218	240	264												Kas'yanov et al. (1995)
Skirvite Stream[2]	55°19'N	21°34'E	92.8	–	S					164	174	189	205		234									Kas'yanov et al. (1995)
Slapton Ley Lake	50°28'N	03°65'W	108.5	–	S	59	107	142	167	199	214	226	238											Burrough and Kennedy (1979)
Slapy Reservoir	49°23'N	14°36'E	94.6	L	S	45	77	112	149	179	203	217	236											*fide* Zivkov and Raikova-Petrova (2001)
Solina Reservoir	49°22'N	22°27'E	96.2	–	S			127	160	171	179	188	201											Epler et al. (2005)
South Caspian Sea	36°50'N	54°26'E	173.7	–	A	143	183	217	240	260	280													Sedaghat and Hoseini (2012)
Straussee	52°58'N	13°87'E	46.9	–	S	33	41	58	71	81														*fide* Hartley (1947)
Sutton-at-Hone (gravel pit lake)	51°40'N	00°23'W	110.8	–	S	68	108	122	182	208	214	226												Gee (1978)
Szczecin Lagoon[1]	53°48'N	14°08'E	105.5	–	S	60	98	136	169	195	212	222	229	237										Więsky and Załachowsky (2000)
Szczecin Lagoon (Hajdus 1985)[1]	53°48'N	14°08'E	112.7	–	S	63	101	135	168	202	230	247	263	279										Więsky and Załachowsky (2000)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Szczecin Lagoon (Novak 1980)	53°48'N	14°08'E	113.8	–	S	73	114	151	182	199	210	222	237											Więsky and Załachowsky (2000)
Szczecin Lagoon (Stasia 1984)	53°48'N	14°08'E	94.0	–	S	63	86	112	134	156	179	199	219	240										Więsky and Załachowsky (2000)
Tatton Mere	53°33'N	02°38'W	140.8	–	A		107	173	218	268	290	313												Goldspink (1978)
Tjeukemeer	52°54'N	05°48'E	68.8	–	S	41	67	87	103	116	128	138	153	163	191									Goldspink (1979)
Trammer See	54°17'N	10°41'E	123.9	A	A	78	119	157	183	206	248	267												*fide* Zivkov and Raikova-Petrova (2001)
Tresna Reservoir	49°44'N	19°12'E	94.9	–	S		85	108	141	168	188	206	217	229	237	245								Epler et al. (2005)
Tvärminne Archipelago (1975)	59°51'N	23°15'E	66.9	–	S		53	74	92	108	129	146	163	180	192									Lappalainen et al. (2001)
Tvärminne Archipelago (1997)	59°51'N	23°15'E	59.7	–	S	38	55	70	84	98	112	126	139	150	162									Lappalainen et al. (2001)
Uchinsk Reservoir (a)	56°01'N	37°45'E	79.2	L	S	36	63	100	130	158	187													*fide* Zivkov and Raikova-Petrova (2001)
Uchinsk Reservoir (b)	56°01'N	37°45'E	121.6	A	A	53	103	153	202	243	280													*fide* Zivkov and Raikova-Petrova (2001)
Uglich Reservoir	57°15'N	37°50'E	111.9	L	S		103	130	159	179	202	215	242	282	288	326		340						Baranova (1984)
Ulungur Lake (1995–1996)	47°15'N	87°15'E	133.1	–	A	56	124	192	225	249	269	281	289											*fide* Li et al. (2009)
Ulungur Lake (2007–2008)	47°15'N	87°15'E	87.7	–	S	60	89	111	129	145	159													Li et al. (2009)
Umba River	66°40'N	34°18'E	91.2	–	S					143	165	183	211	227	240									Kas'yanov et al. (1995)
Various lakes (Lithuania)	–	–	91.7	L	S			86	108	129	152	180	204	228	252	272	293	306						*fide* Zivkov and Raikova-Petrova (2001)
Vilyuy River	–	–	93.5	L	S		81	104	138	150	161	196	230	253	265									*fide* Zivkov and Raikova-Petrova (2001)
Vistula Lagoon	54°27'N	19°45'E	113.4	–	S	56	101	141	179	220	252													Frank (1962)
Volga River[1]	–	–	94.8	L	S	39	67	92	122	158	185	240	260	282	230	311								*fide* Zivkov and Raikova-Petrova (2001)
Volga River Delta (a)	46°73'N	47°85'E	101.7	–	S			116	162	183	200													*fide* Kas'yanov et al. (1995)
Volga River Delta (b)	46°73'N	47°85'E	148.7	A	A		182	204	225	241	260	283	300											*fide* Zivkov and Raikova-Petrova (2001)
Volgograd Reservoir	49°12'N	44°93'E	113.2	L	S			121	167	202	220	248	265	276										*fide* Zivkov and Raikova-Petrova (2001)
Vollebekken stream (1987)	59°41'N	10°44'E	84.0	–	S		86	109	128	143	161	167	182	198	202	214								Vøllestad and L'Abée-Lund (1987)
Vollebekken stream (1990)	59°41'N	10°44'E	86.7	–	S			120	135	150	167	176	189	198	203	211	237	245	227	221				Vøllestad and L'Abée-Lund (1990)
Votkinskoye Reservoir	57°17'N	54°47'E	98.4	–	S			128	144	168	184	202		240	247									Kas'yanov et al. (1995)

Population	Lat	Long	GI	Z-RP	GT	Age																		Source
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Vytegorsk Reservoir	61°00'N	36°50'E	90.2	–	S			114	131	153	177	198												Kas'yanov et al. (1995)
Warta River (zone A)	52°59'N	14°61'E	104.6	–	S	45	90	125	150	180	205	220	230	245	280	295	310	320						Przybylski (1996)
Warta River (zone B)[1]	52°59'N	14°61'E	102.2	–	S	45	90	125	150	180	205	230	245	270	275									Przybylski (1996)
Warta River (zone C)[1]	52°59'N	14°61'E	103.9	–	S	40	95	130	160	185	215	230	245	260	270	280								Przybylski (1996)
Warta River (zone D)[1]	52°59'N	14°61'E	96.6	–	S	45	80	125	150	180	200	220	225	240										Przybylski (1996)
Western Dvina River	–	–	100.3	L	S	39	81	120	157	187	213	238	252	264										*fide* Zivkov and Raikova-Petrova (2001)
Willow Brook (Apethorpe)	52°55'N	00°49'W	91.1	–	S				141	162	172	188	200	213										Cragg-Hine and Jones (1969)
Willow Brook (Elton)	52°53'N	00°40'W	78.8	–	S	49	70	93	120	131	150	172	179	194	206									Cragg-Hine and Jones (1969)
Willow Brook (Fotheringhay)	52°53'N	00°45'W	75.5	–	S	30	64	108	116	133	142	166	168	229										Cragg-Hine and Jones (1969)
Willow Brook (Woodnewton)	52°54'N	00°47'W	73.4	–	S	33	83	100	110	123	130	179												Cragg-Hine and Jones (1969)
Yateley (gravel pit lake)	51°20'N	00°49'W	131.9	–	A	66	118	183	216	248	260													Gee (1978)
Zhrebchevo Reservoir	42°36'N	25°53'E	135.5	A	F	101	130	159	183															*fide* Zivkov and Raikova-Petrova (2001)

[1] Mean LAA values averaged over males and females.
[2] Caspian roach *R. rutilus caspicus*.
For each population, the latitude and longitude of the corresponding water body, the GI (Hickley and Dexter 1979), indication of the semi-quantitative classification (Z-RP: after Zivkov and Raikova-Petrova 2001) into 'low' (L), 'average' (A) and 'high' (H) growth, and the resulting growth type (GT) are provided. Secondary source studies are indicated as *fide*. A dash '–' indicates.