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New Fisheries-related data from the Mediterranean Sea (April, 2014)

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Abstract

As part of its policy, *Mediterranean Marine Science* started from 2014 to publish a new series of collective article with fisheries-related data from the Mediterranean Sea. In this first collective article we present length frequencies and weight-length relationships for the northern brown shrimp *Farfantepenaeus aztecus* in the Eastern Mediterranean, weight-length relationships for 10 fish species in the North Aegean Sea, the feeding habits for 11 sparid fishes in the North Aegean Sea, a review of the existing literature on the feeding and reproduction of common carp *Cyprinus carpio* in Anatolia (Turkey) and mouth dimensions and the relationships between mouth area and length for seven freshwater fishes from Lake Volvi (Northern Greece).

Keywords: Weight-length relationships, reproduction, feeding, mouth dimension, invertebrates, fishes, Aegean Sea, Eastern Mediterranean.

Introduction

As part of its policy, *Mediterranean Marine Science* started from 2014 to publish a new series of collective article, twice a year, with fisheries-related data from the Mediterranean Sea, notably contributions on topics such as weight-length relationships, length-length relationships, length-frequency distributions, age and growth information, spawning and reproduction, diet, feeding habits and trophic level of fish and other marine animals in the Mediterranean Sea.

This decision was taken because in the last two decades there is a drastic decline in the number of fish and fisheries related journals that consider for publication articles with such basic data. It is worthy to point out that the relative frequencies of occurrence of fish-related 2-word phrases in the corpus of digitized books[1] such as 'fish growth', 'fish feeding', 'fish spawning', 'fish reproduction', 'fish biology', 'fish ecology', 'fish physiology', 'fish genetics' 'fish taxonomy' 'fish biogeography' and 'fish biochemistry' all increase from 1800 to a peak in about 1980-1990 and decline thereafter, with the relative frequencies of 'fish growth', 'fish feeding' and 'fish spawning' being higher than those of the remaining ones (Fig. 1).

Yet, such basic data are essential for fish and fisheries biology and ecology for a plethora of reasons. For instance, such data are useful for: (i) studying patterns and propensities in the life-history of marine animals (e.g. trade-offs); (ii) testing whether life histories change

[1]Michel *et al.* (2010) constructed a corpus of digitized books (nowadays making up about 6% of all books ever printed: Lin *et al.* 2012) and, using the percentage of times a word/phrase appears in the corpus of books, investigated cultural and other trends. The corpus of books is available in eight languages: English, Spanish, German, French, Russian, Italian, Hebrew and Chinese. Michel's *et al.* (2010) computational tool (see also Lin *et al.,* 2012), the Google Ngram viewer, is available online (http://books.google.com/ngrams). This tool estimates the usage of small sets of phrases and produces a graph the y axis of which shows how a phrase occurs in a corpus of books during a particular period relatively to all remaining phrases composed of same number of words (Lin *et al.,* 2012). A detailed account of the Ngram technique is provided in Michel *et al.* (2010) and Lin *et al.* (2012) whereas a step-by-step guide for its application using examples is available online (http://books.google.com/ngrams/info#advanced).

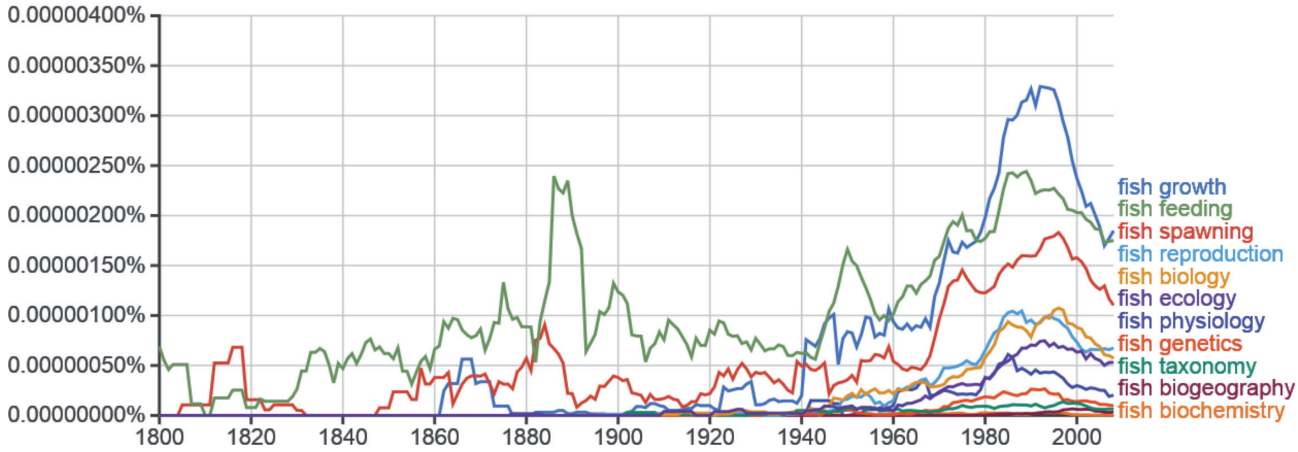

Fig. 1: Relative frequencies of different 2-word phrases in the corpus of digitized books using the Google Ngram viewer tool (see https://books.google.com/ngrams).

spatio-temporally or not (e.g. bigger-deeper hypothesis, shifting baselines, nanism); (iii) estimating the position of marine animals in the ecosystems (i.e. trophic level) as well as other ecological indices (e.g. resilience, vulnerability to fishing); (iv) estimating the productivity of species; (v) estimating year class strength, which can then be used for studying variations in abundance and, thus, recruitment to the fishery; (vi) developing empirical relationships between life-history parameters with maximum length in order to estimate the former for less studied, rare, non-commercial species for which maximum length is available; (vii) stock structure identification (based on life –history traits); (viii) stock assessment; (ix) developing ecological models (e.g. Ecopath with Ecosim); and eventually (x) for management.

In this collective article we present length frequencies and weight-length relationships for the northern brown shrimp *Farfantepenaeus aztecus* in the Eastern Mediterranean, weight-length relationships for 10 fish species in the North Aegean Sea, the feeding habits for 11 sparids in the North Aegean Sea, a review of the existing literature on the feeding and reproduction of common carp *Cyprinus carpio* in Anatolia (Turkey) and mouth dimensions and the relationships between mouth area and length for seven freshwater fishes from Lake Volvi (Northern Greece).

The contributors are co-authors in this collective article, their names appearing in alphabetical order. The contributing authors are cited at the beginning of each section of the collective article.

1. Biological data on northern brown shrimp *Farfantepenaeus aztecus* (Ives, 1891) (Decapoda: Penaeidae) in the Eastern Mediterranean Sea

By Y. Özvarol and M. Gökoğlu

The northern brown shrimp *Farfantepenaeus aztecus* (Ives, 1891) is a Mediterranean penaeid shrimp of Atlantic origin. It reaches sexual maturity at about 14 cm total length and can reach maximum standard length 22 cm (=23.6 cm total length) (Cook and Lindner, 1970; Saoud & Davis, 2003). This study provides biological data on *F. aztecus* in the Eastern Mediterranean. The study was carried out in the Gulf of Finike (36°13.21′N, 33°48.225′E), Antalya (36°50′N, 30°34′E - 36°45′N, 30°55′E), Mersin (36°10′N, 33°55′E) and Adana - İskenderun (36°28’N, 35°23’E - 36°45’N, 35°53’E) during June 2011 - January 2013. Monthly trawling operations (mesh size 22 mm, knot-to-knot) were performed at depths ranging from 25 to 150 m, for 1-3 hours using commercial and research vessels. Female and male individuals were identified by visible thelycum or petesma. All individuals were weighed to the nearest 0.1 g and measured for total length (i.e. from tip of the rostrum to end of the telson).

A total of 1271 individuals were caught of which 834 (65%) were females and 437 (35%) males. The sex ratio differed significantly ($P < 0.05$) from the theroretical 1:1. The mean length was 19.3 ± 1.7 cm (range 11.5-30 cm) for females and 15.6 ± 1.3 cm for males (range: 12.2-20.7 cm) (Fig. 2). The mean length of females was significantly (t test, $P < 0.05$) larger than that of males. The mean weight of females (67.2 ± 19.4 g, range: 12-240 g) was significantly (t test, $P < 0.05$) larger than that of males (30.68 ± 8.7 g range: 14-66 g). The weight-length relationship did not significantly (t test, $P < 0.001$) differ between males and females and thus the weight-length relationship was estimated for sexes combined (Fig. 3).

Holthuis (1980) reports that the maximum observed total length of males and females was 19.5 and 23.6 cm, along the Atlantic coasts of USA and Mexico, respectively, which are both smaller than those found in the present study. Although this species has been recently established off the Mediterranean coasts of Turkey (Deval *et al*., 2010), it appears that it can reach a larger size than in the Atlantic.

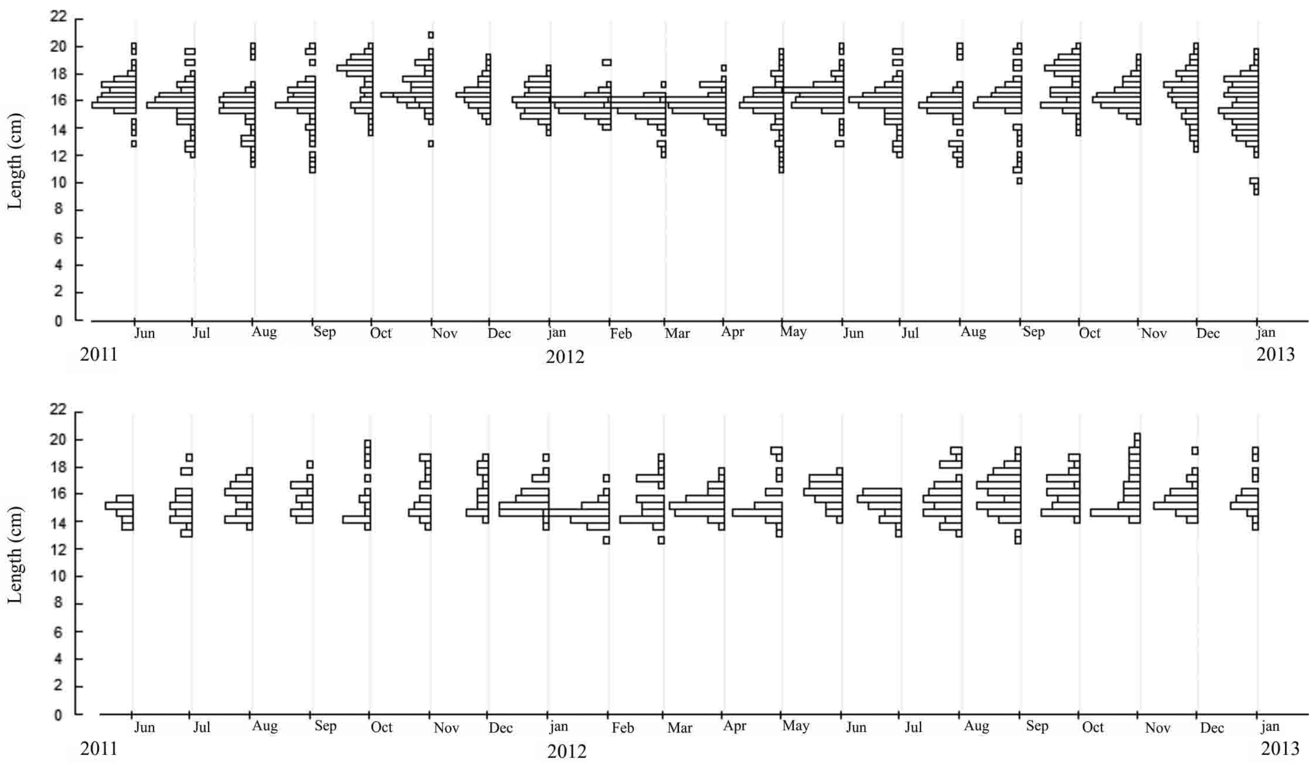

Fig. 2: Monthly length frequency distribution of female (upper, n=437) and male (lower, n=834) *Farfantepenaeus aztecus*, during June 2011 - January 2013.

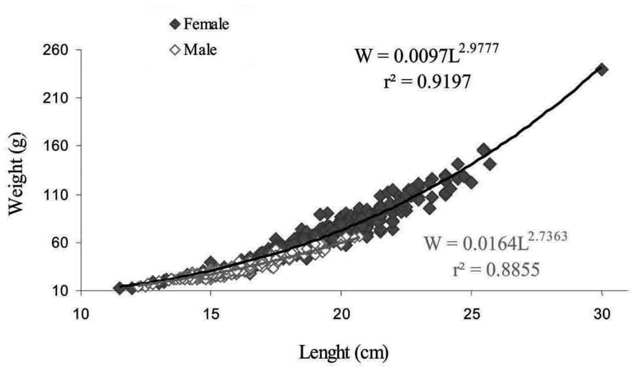

Fig. 3: Weight-length relationship of *Farfantepenaeus aztecus*, sexes combined.

2. Weight-length relationships for ten commercial fish from the North Aegean Sea, Greece

By G. Minos

Weight–length relations are very useful to fisheries biology research since they are used for converting lengths into biomass, determining fish condition and comparing fish growth among areas (Froese *et al.*, 2011). In the present study, weight-length relationships were established for 10 commercial fish in the North Aegean Sea. Samples were collected from one commercial bottom trawler (monthly samples, during October 2004-April 2005) and longlines (for the large pelagics *Thunnus alalunga* and *Thunnus thynnus*; monthly samples, during September 2003 - February 2004). Total length (*TL*), or fork length (*FL*), was measured to the nearest 0.1 cm and total body weight (*W*) to the nearest g. *t*-test was used to identify isometric or allometric growth.

Overall, 2629 individuals were measured for length and weight. The number of individuals ranged from 48 individuals, for *T. thynnus*, to 383, for *Merluccius merluccius*. All r^2 values of the weight-length relationships were greater than 0.90, and all regressions were highly significant (P<0.001). The values of the exponent (b) ranged between 2.53, for *T. alalunga*, to 3.24, for *Micromesistius poutassou.* For *Lophius budegassa* and *Phycis blennoides*, growth was isometric (P>0.05) (Table 1). For all remaining species b values differed significantly (P<0.05) from 3, implying allometric growth (Table 1). It is worthy of mention that the maximum length (52.5 cm TL) recorded in this study for *Lepidorhombus boscii* is higher than that (i.e. 40 cm SL≈ 47.3 cm TL) reported in Fishbase (Froese & Pauly, 2013).

For five species (*L. piscatorius, L. budegassa, M. poutassou, Z. faber* and *T. trachurus*) the parameters b of the weight-length relationships presented here are generally similar with those reported by other authors (Stergiou & Moutopoulos, 2001; Moutopoulos & Stergiou, 2002; Froese & Pauly 2013) for the Aegean Sea.

Table 1. Sample size (n), length range (minimum-maximum) and parameters of the total weight (g) - total length (cm) relationship ($W=aL^b$) for 10 fish species, Northern Aegean Sea. $SE^{(b)}$= Standard error of slope b; r^2= coefficient of determination; Growth= A+, positive allometry; A-, negative allometry; I, isometry; P= P-value.

Species	*n*	Length		*a*	*b*	*SE(b)*	r^2	Growth *(P)*
		min	**max**					
Lepidorhombus boscii	322	16.5	52.5	0.015	2.82	0.053	0.90	A- (<0.05)
Lophius budegassa	121	19.7	66.5	0.0156	2.96	0.047	0.97	I (>0.05)
Lophius piscatorius	179	20.0	47.2	0.026	2.82	0.037	0.97	A- (<0.05)
Merluccius merluccius	383	19.2	81.0	0.016	2.77	0.030	0.96	A- (<0.05)
Micromesistius poutassou	298	15.3	32.0	0.0034	3.24	0.049	0.94	A+ (<0.05)
Phycis blennoides	333	15.8	45.0	0.0087	2.97	0.040	0.94	I (>0.05)
*Thunnus alalunga**	371	70.5	92.4	0.0001	2.52	0.040	0.91	A- (<0.05)
*Thunnus thynnus**	48	72.7	171.0	4.5×10^{-5}	2.80	0.045	0.99	A- (<0.05)
Trachurus trachurus	367	16.0	30.2	0.006	3.11	0.045	0.93	A+ (<0.05)
Zeus faber	207	14.2	59.2	0.023	2.84	0.046	0.95	A- (<0.05)

* Fork length

3. Natural diet of common carp (*Cyprinus carpio* L., 1758) in Anatolia (Turkey): a review

By L. Vilizzi, F.G. Ekmekçi and A.S. Tarkan

Freshwater fish affect several components of the aquatic ecosystems (e.g. nutrients, primary and secondary production; Matthews, 1997). This is especially true of omnivorous species such as the common carp (*Cyprinus carpio* L., 1758), whose 'middle-out' role in the aquatic ecosystems has been widely documented (Weber & Brown, 2009). Herein we provide a review of the natural diet of common carp in Anatolia (Turkey), where the species is widely distributed following translocation for fisheries and aquaculture (Çetinkaya, 2010).

We obtained data from the literature and assigned individual food items into three general taxa (i.e. phytoplankton, zooplankton, benthic invertebrates) and three 'generic' groups (i.e. detritus, plant material, fish eggs and parts). Because of the different reporting formats of the feeding data in the original studies, we present food items in the form of a presence/absence matrix. For the studies providing food items at the genus level, we also tested for any differences in diet composition between waterbody types (details in online Supplement 1), and estimated trophic level following Stergiou & Karpouzi (2002).

In total, 12 studies covering 16 waterbodies were collected (Table S1, in online Supplement 2). Eight out of the 12 studies provided taxon-level data (Table 2) and four studies only summary data (Table S1 in online Supplement 2). Monthly and seasonal diet data were reported in ten and two studies, respectively (Table 2). With the exception of 0+ fish, feeding mainly on zooplankton (Gelingüllü Reservoir: mirror carp), no other age/length-related difference in diet was found in the remaining studies. Diet composition did not differ significantly ($F_{1,7}^{\#}$ = 1.42; $p^{\#}$ = 0.136: $^{\#}$ = permutational value) between waterbody types (Fig. 4). Trophic level was generally similar across waterbody types, ranging from 2.2 to 2.6 (mean 2.39 ± 0.05). Thus, common carp can be characterized as an omnivore with a preference for vegetable material (see Stergiou & Karpouzi, 2002).

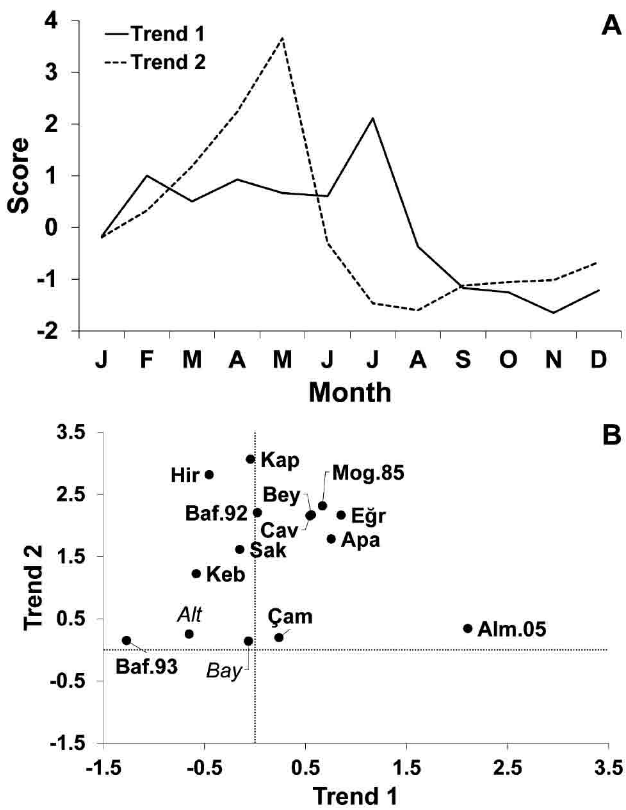

Fig. 4: (a) Non-metric multi-dimensional scaling (NMDS) plot and (b) dendrogram plot showing the waterbodies of Anatolia for which taxon-level data (presence/absence) on common carp natural diet were available. Black dots: man-made reservoirs; open dots: natural lakes (see Table 2). Baf = Bafra Balık Lakes; Gel = Gelingüllü Reservoir (mirror and scale carp); Göl = Lake Gölköy; Hir.95 = Hirfanlı Reservoir (1995); Hir.04 = Hirfanlı Reservoir (2004); Hir.10 = Hirfanlı Reservoir (2010); Keb = Keban Reservoir; Mog.91 = Lake Mogan (1991). Year in parentheses indicate year of source study.

Table 2. Data on the natural diet of common carp in waterbodies of Anatolia (taxon-level studies only). For taxon-level groups, the number of taxa is indicated; for generic groups, presence (+) or absence (−) is provided, along with the source reference (Table S1 in online Supplement 2). Summary data are also provided, i.e. number of fish examined, size and age range, reported monthly (M) or seasonal (S) and ontogenetic differences in diet (Yes = difference; No = no difference) and trophic level (computed after Stergiou & Karpouzi, 2002). n/a = data not available. Taxonomy of groups after http://www.itis.gov (accessed 08/01/2014). Complete list along with source references in Table S1 in online Supplement 2.

	Man-made reservoirs						Natural lakes		
	Gelingüllü Reservoir (mirror)	**Gelingüllü Reservoir (scale)**	**Hirfanlı Reservoir (1995)**	**Hirfanlı Reservoir (2004)**	**Hirfanlı Reservoir (2010)**	**Keban Reservoir**	**Bafra Balık Lakes**	**Lake Gölköy**	**Lake Mogan (1991)**
Number of fish (full gut/total)	167/179	92/97	116/116	174/252	127/206	50/50	122/122	49/60	67/91
Size range (mm)	n/a	n/a	n/a	76–600	138–389	n/a	n/a	150–260	240–690
Age range (years)	0–6	1–7	n/a	0–9	n/a	n/a	0–6	n/a	n/a
Monthly/seasonal variation	M	M	M	M	M	S	S	M	M
Ontogenetic variation	Yes	No	n/a	No	n/a	n/a	No	n/a	n/a
Trophic level (±SE)	2.60 ± 0.19	2.40 ± 0.15	2.30 ± 0.06	2.3 ± 0.18	2.30 ± 0.11	2.30 ± 0.13	2.20 ± 0.15	2.50 ± 0.22	2.60 ± 0.21
Taxon-level groups									
Phytoplankton									
Bacillariophyta	13	12	17	20	14	15	16	5	7
Charophyta	1	2	1	5	3	1	6	3	3
Chlorophyta	3	4	4	7	5	4	6	3	3
Cyanophycota	1	1	3	8	6	10	4	4	2
Euglenophycota	1	1	2	2	1	0	1	1	1
Pyrrhyphycota	0	0	0	2	1	0	1	0	0
Rhodophyta	0	1	0	0	0	0	0	0	0
Xanthophyta	0	0	0	0	0	0	1	0	0
Zooplankton									
Cladocera	5	5	5	4	5	2	1	3	5
Copepoda	2	2	2	2	2	1	0	2	2
Malacostraca	0	0	0	0	0	0	1	3	0
Ostracoda	1	1	1	1	1	0	0	2	1
Rotifera	3	2	0	3	3	9	1	0	4
Benthic invertebrates									
Coleoptera	0	0	0	0	0	0	1	0	0
Diptera	1	1	2	2	2	0	1	1	2
Gastropoda	0	0	0	1	1	0	0	2	0
Nematoda	0	1	0	0	0	0	1	0	0
Oligochaeta	0	0	0	1	1	0	0	0	1
Generic groups									
Detritus	−	−	−	−	+	−	−	+	−
Plant material	+	−	−	−	+	−	−	+	+
Fish	+	+	−	+	−	−	−	−	−
Eggs	+	+	−	−	−	−	+	−	−
Various parts	−	−	−	−	+	−	−	+	−

The present findings confirm the opportunistic feeding of common carp, with spatial variation (i.e. waterbody level) indicating flexible dietary requirements, and temporal variation (i.e. monthly/seasonal) most probably related to overwintering and spawning movements (Numann, 1958). The presence of detritus and plant material reflects its typical bottom-feeding behaviour, i.e. mouthfuls of sediment are sucked into the oral cavity and separated from food in the pharyngeal slits, with food items retained and other particles expelled (Sibbing, 1988). The presence of fish eggs in its diet suggests that common carp indirectly feeds upon other fish when burrowing through the sediment in search for food.

4. Feeding habits for eleven sparids from the N-NWAegean Sea

By P.K. Karachle

Feeding habits of fishes in the Mediterranean Sea have been reviewed by Stergiou & Karpouzi (2002). In this study, information on the feeding habits of 11 species of Sparidae, in N-NW Aegean Sea, are presented. For four species, namely *Diplodus vulgaris*, *Oblada melanura*, *Sarpa salpa* and *Spondyliosoma cantharus*, there is no information on their feeding habits from the Hellenic seas.

Sampling was conducted on a seasonal basis (spring 2001-winter 2006), using professional fishing vessels (see Karachle & Stergiou 2008, for a detailed account on sampling and stomach content analyses).

In total, 960 individuals were examined. The number of individuals ranged from 10, for *Dentex dentex* and *Pagrus pagrus*, to 427 for *Diplodus annularis* (Table 3). The feeding habits and trophic level of *Pagrus pagrus* differed from those previously reported (data from Stergiou & Karpouzi, 2002; Froese & Pauly, 2013), a fact that could be attributed to the smaller lengths of the individuals examined here (Table 3). For *Boops boops*, *Pagellus acarne* and *Pagellus bogaraveo*, the differences found may be attributed the high percentages of fishes as prey of the individuals examined in the present study, compared to those in other studies. In general, no differences were found in the feeding habits of the remaining species with those reported in the literature.

Based on the results presented here, the 11 sparids prey on a great variety of food items and their trophic levels span over a wide range of values, from 2.0 to 4.5 (Karachle & Stergiou, 2008). Indeed, the 11 species prey on algae (herbivores: *S. salpa*) and invertebrates (omnivores: *B. boops, D. annularis, D. vulgaris, O. melanura, Pagellus erythrinus, P. bogaraveo, S. cantharus*), to fish and cephalopods (carnivores: *D. dentex, P. acarne, P. pagrus*) (Table 3), a fact indicating their high adaptability and competent exploitation of resources.

5. Reproductive biology of common carp (*Cyprinus carpio* L., 1758) in Anatolia (Turkey): a review

By L. Vilizzi, A.S. Tarkan and F.G. Ekmekçi

This study provides a synopsis of the reproductive biology of common carp (*Cyprinus carpio* L., 1758) in Anatolia (Turkey). Common carp is a native species to the northernmost areas of the region that was 'naturalised' elsewhere in Turkey following translocation for fisheries and aquaculture (Çetinkaya, 2010).

We obtained data from the literature. We evaluated the relationships of mean age at maturity, spawning period duration, absolute fecundity, relative fecundity and egg diameter with mean annual water temperature using linear regression. We tested for differences in the above mentioned parameters with waterbody types (i.e. manmade reservoirs and natural lakes) using permutational univariate analysis of variance (PERMANOVA). We also evaluated trends in the monthly gonadosomatic index (GSI) data using dynamic factor analysis (DFA) in order to identify the waterbodies where GSI was highest in a certain month (all tests at $\alpha = 0.05$; details in online Supplement 3).

In total, 30 studies covering 26 waterbodies were collected (Table 4). Mean sex ratio was 1.01 ± 0.06 SE and age at maturity ranged between 2 and 4 years. Spawning began between March and June, and the spawning period lasted for 2–7 months. Mean absolute and relative fecundity were 306,124 ± 57,645 eggs/fish and 132,782 ± 10,379 eggs/kg, respectively, and mean egg diameter was 1.151 ± 0.042 mm. No significant relationships were found between mean age at maturity ($n = 24$, $r^2 = 0.001$, $p = 0.934$), spawning period duration ($n = 19$, $r^2 = 0.168$, $p = 0.081$), absolute fecundity ($n = 18$, $r^2 = 0.017$, $p = 0.608$), relative fecundity ($n = 17$, $r^2 = 0.085$, $p = 0.255$) and egg diameter ($n = 25$, $r^2 = 0.066$, $p = 0.214$) with mean annual water temperature. In addition, no significant differences were found in mean age at maturity ($F^{\#}_{1,22} = 0.01$, $p^{\#} = 1.000$: $^{\#}$ = permutational), spawning period duration ($F^{\#}_{1,17} = 0.53$, $p^{\#} = 0.632$), absolute fecundity ($F^{\#}_{1,16} = 0.33$, $p^{\#} = 0.566$), relative fecundity ($F^{\#}_{1,15} = 0.06$, $p^{\#} = 0.810$) and egg diameter ($F^{\#}_{1,23} = 3.44$, $p^{\#} = 0.080$) with waterbody types. However, there was a peak in GSI in July in theAlmus Reservoir (Fig. 5a: Trend 1), and a peak in May in all remaining waterbodies with the exception of Altınkaya, Bayramiç and Çamlıdere Reservoirs as well as Bafra Balık Lakes (1993 study) (Fig. 5b: Trend 2), where GSI remained relatively high also in late summer and/or autumn (Table 4).

The present findings indicate that the reproductive features of common carp are largely homogeneous across Anatolia, as has been found for the condition factor (Vilizzi *et al.*, 2014). Although spawning occurred mainly in late spring, relatively high GSI values in other months indicate potential for protracted spawning (cf. Smith & Walker, 2004).

Table 3. Food items and their contribution (expressed as % wet weight) for eleven sparids in the N-NW Aegean Sea, Greece, spring 2001- winter 2006. Bb=*Boops boops*; Dd=*Dentex dentex*; Da=*Diplodus annularis*; Dv=*Diplodus vulgaris*; Om=*Oblada melanura*; Pa=*Pagellus acarne*; Pb=*Pagellus bogaraveo*; Pe=*Pagellus erythrinus*; Pp=*Pagrus pagrus*; Ss=*Sarpla salpa*; Sc=*Spondyliosoma cantharus*; N.i.=not identified; N=number of individuals; TL=total body length; τ±SE=trophic level ± standard error. Asterisk (*) denotes presence in the diet with % weight contribution < 0.0001.

Taxonomic groups	*Bb*	*Dd*	*Da*	*Dv*	*Om*	*Pa*	*Pb*	*Pe*	*Pp*	*Ss*	*Sc*
Detritus			1.0					0.2		1.2	
Microalgae			0.1								
Macroalgae			13.5		21.5					70.3	*
Cladophora spp.			*			*		3.3			
Cystoseira spp.										*	
Dyctiota spp.			*							*	*
Sphacelaria spp.										*	
Asparagopsis spp.			*								
Asparagopsisarmata			*								
Ceramium spp.			*							*	
Ceramium codii			*								
Chondria spp.			*							*	
Laurencia spp.										*	
Polysiphonia spp.			*							*	
Pterosiphonia spp.			*								
Ageiosperma			3.1					*			
Cymodocea spp.			*					*		25.8	
Posidonia oceanica			*					55.8		2.7	1.5
Cnidaria	1.4		1.7		4.2						
Nematoda			*								
Polychaeta	3.6		8.4	90.2	42.2	12.7	1.3		32.1		4.0
Sipuncula									3.0		
Mollusca											
Polyplacophora			0.8	5.3							
Bivalvia						6.6	0.2				
Gastropoda			2.6	0.9		5.7		7.6			0.5
Cephalopoda						19.6	6.8				
n.i.			6.8				0.8				
Crustacea											
Ostracoda			0.3							*	0.5
Cypridina mediterranea											
Cladocera	*										
Evadne spp.	*										
Podon spp.	*										
Copepoda			0.1	*	0.6	*					
Candacia spp.	*										*
Centropages spp.	*										
Onceaspp.	*										

(continued)

Table 3 (continued)

Taxonomic groups	*Bb*	*Dd*	*Da*	*Dv*	*Om*	*Pa*	*Pb*	*Pe*	*Pp*	*Ss*	*Sc*
Pleuromama spp.	*										
Sapphirina spp.											
n.i. Copepoda	0.3										2.0
Euphasiacea	55.2				0.1						9.7
larvae											*
Stomatopoda											
Squilla spp. larvae	0.1										
Decapoda											8.7
Natantia			*			2.1	*	17.5	0.6		15.2
Macroura reptantia								13.6			
Brachyura			1.4		0.4	9.4					
Metazoa											
Portunus puber metazoa	0.1										
Decapoda larvae	0.2				*	*		*			
Mysidacea					1.3			0.2			0.3
larvae	*		0.1								
n.i.	2.6								2.7		
Cumacea					*						
Amphipoda	0.6		*	*	1.3	7.5	0.2				2.5
Anisopoda			*								
Isopoda			0.8				0.3	*			0.5
Sphaeroma spp.											0.5
n.i. Crustacea	5.1	1.2	47.0	0.9	13.3	11.0	2.9	1.8			37.3
Chaetognatha	2.8										
Echinodermata, Ophiuroidea				0.9		1.8					
Chordata –Urochordata											
Appendicularia			1.0								2.7
Ascidiacea			1.3	1.8							12.4
Thaliacea	3.6										
Chordata –Vertebrata											
fish eggs	*										*
fish larvae	0.1	52.4				23.5					
Hippocampus spp.					7.9						
n.i. fish	22.4	46.4	1.2		5.6		86.8				
Others											
eggs	1.8		7.6		1.5	0.2			61.5		1.2
n.i.			1.3		0.1		0.7				
N	106	10	427	50	56	63	72	59	10	25	82
TL range (mm)	112–199	117–153	61–175	90–167	126–227	105–192	93–231	84–164	102–155	117–195	97–140
τ±SE (from Karachle & Stergiou, 2008)	3.52±0.52	4.49±0.80	3.20±0.43	3.08±0.28	3.11±0.42	3.84±0.55	4.43±0.76	3.30±0.39	3.36±0.34	2.00±0.00	3.39±0.46
τ±SE from FishBase	3.00±0.12	4.50±0.70	3.40±0.40	3.20±0.40	3.00±0.1	3.50±0.5	3.70±0.56	3.40±0.5	3.70±0.6	2.00±0.00	3.30±0.4

Table 4. Review of data on the reproductive biology of common carp in Anatolia. The following parameters are provided for each waterbody: water temperature (Tw), sample size (n), male to female ratio (M/F), age class at maturity (M, F, in years), spawning period (monthly range), monthly female gonado-somatic index (GSI), fecundity and egg diameter. Water temperature was estimated from the relationship Tw = 3.47 + 0.898Ta (after Erickson & Stephan, 1996), where Ta is the mean annual air temperature (taken from Meteorologisk Institutt: www.yr.no: accessed 30/11/2013). Values in italics indicate estimated mean of the reported monthly values.

				Maturity			GSI												Fecundity		
Waterbody	T_w (°C)	*n*	M/F	M	F	Period	J	F	M	A	M	J	J	A	S	O	N	D	Absolute (no. eggs)	Relative (eggs kg^{-1})	Egg Ø (mm)
Man-made reservoirs																					
Almus Reservoir[1]	11.5	156	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	85,850	–
Almus Reservoir[2]	11.5	313	0.71	III	IV	Jun–Aug	5.01	5.71	6.62	7.74	8.06	9.01	10.97	1.61	1.88	2.09	3.32	4.51	*54,747*	148,617	*0.978*
Altınkaya Reservoir[3]	16.3	592	0.85	II	II	Apr–Oct	0.60	1.15	1.35	2.45	3.30	1.35	1.15	1.90	3.15	3.83	3.00	2.40	156,197	–	*0.908*
Apa Reservoir[4]	13.9	251	1.03	III	IV	Jun–Jul	4.82	6.85	7.51	10.82	11.93	18.78	1.23	1.64	2.02	2.73	3.31	3.95	29,427	–	*0.905*
Bayramiç Reservoir[5]	16.9	351	0.86	IV	IV	May–Jul	2.61	2.65	2.17	2.89	2.52	2.12	1.65	2.49	1.62	2.44	1.92	2.70	138,194	89,167	–
Çamlıdere Reservoir[6]	14.0	123	1.76	III	IV	May–Jun	9.56	6.54	8.56	10.80	15.08	9.26	13.10	12.82	12.08	11.19	8.26	9.17	–	–	0.916
Gelingüllü Reservoir[7a]	13.0	572	0.76	III	III	Apr–Jul	–	–	10.96	12.02	9.03	8.59	8.23	1.25	3.10	1.63	1.19	–	522,712	–	*1.054*
Gelingüllü Reservoir[7b]	13.0	248	0.97	II	III	Apr–Jul	–	–	11.03	9.17	8.68	2.95	0.53	0.82	1.90	3.60	0.77	–	208,528	–	*1.092*
Hirfanlı Reservoir[8]	14.0	456	1.08	III	III	May–Jul	8.92	9.85	12.48	15.26	19.37	8.26	4.29	5.04	6.74	6.97	7.26	8.04	658,596	155,603	1.201
Kapulukaya Reservoir[9]	14.0	353	1.01	–	–	May–Aug	10.36	11.28	14.69	17.18	20.46	7.56	5.02	5.58	7.25	7.95	4.00	9.12	602,872	154,431	1.236
Karacaören I Reservoir[10]	14.2	169	0.87	IV	IV	Apr–May	8.89	12.87	18.27	17.59	4.81	2.30	–	–	–	–	–	–	*408,790*	141,300	1.318
Keban Reservoir[11]	15.6	253	1.14	II	III	–	1.87	0.81	0.40	11.25	4.77	0.83	0.55	0.85	0.61	4.53	2.53	3.26	582,082	–	1.006
Kemer Reservoir[12]	16.9	92	1.14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Natural lakes																					
Lake Akşhehir[13]	13.3	788	0.86	III	IV	May–Jul	–	6.55	7.22	–	9.18	–	2.43	–	–	4.33	–	5.31	25,083	58,993	1.186
Lake Akşhehir[14]	11.0	–	–	III	IV	Apr–Jun	–	–	14.07	16.32	15.02	4.86	5.55	6.49	8.42	12.98	14.51	14.68	–	108,000	1.337
Bafra Balık Lakes[15]	16.3	360	0.86	II	III	Apr–Jun	7.15	7.80	10.05	15.15	13.70	5.80	4.50	3.60	2.90	5.23	6.25	7.00	–	–	1.260
Bafra Balık Lakes[16]	16.3	618	0.97	II	III	Apr–Jul	11.70	9.91	15.70	8.62	8.79	9.67	8.82	7.60	9.49	13.32	14.42	14.29	211,443	–	1.048
Lake Beyşehir[17]	14.2	–	–	III	III	–	7.89	9.63	11.05	12.92	15.30	7.92	5.37	2.76	4.15	5.23	4.26	6.16	*367,783*	191,200	1.315
Lake Cavuşcu[18]	13.9	–	–	IV	V	–	7.17	8.14	9.64	12.01	15.58	5.68	5.23	3.97	2.92	4.01	3.75	5.52	*38,750*	186,330	1.503
Lake Çıldır[19]	7.7	–	–	–	–	–	–	–	–	–	2.86	7.51	3.24	3.23	6.10	–	–	–	–	–	*0.645*
Lake Eber[20]	13.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	188,760	1.472
Lake Eğridir[21]	14.2	–	–	III	III	–	6.89	9.02	10.44	13.09	15.94	7.32	6.07	3.67	4.02	4.10	3.84	4.96	*305,825*	177,110	1.356
Lake Kazan[22]	8.9	–	–	III	IV	–	–	–	–	–	–	–	–	–	–	–	–	–	–	75,860	–
Lake Kazova Kaz[23]	11.5	799	0.84	II	II	Mar–Apr	5.81	7.41	9.08	9.36	1.99	3.04	–	–	–	–	–	5.22	*159,193*	*80,313*	1.193
Lake Köyceğiz[24]	16.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.005
Lake Mogan[25]	14.0	820	0.97	III	IV	May–Jul	–	–	–	–	–	–	–	–	–	–	–	–	208,035	–	*1.307*
Lake Mogan[26]	14.0	916	0.95	III	III	May–Aug	6.32	8.86	11.13	14.64	16.24	6.65	6.19	4.03	4.23	4.50	4.66	5.84	–	127,356	*1.343*
Lake Nazik[27]	11.3	418	1.68	II	III	Jun–Jul	–	–	–	–	–	–	–	–	–	–	–	–	831,978	153,169	0.919
Lake Tödürge[28]	11.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	135,233	1.285
Lake Yeniçağa[29]	15.7	–	–	IV	IV	May–Jul	–	–	4.97	8.71	13.33	7.00	4.94	4.92	5.92	5.72	5.78	–	–	–	–
Watercourses																					
Sakarya River[30]	–	354	0.81	III	IV	May–Jul	5.94	6.29	7.23	9.36	12.33	6.12	3.35	3.92	4.18	4.29	4.86	5.27	–	–	–

[1] Akyurt (1987a); [2] Karataş & Sezer (2005); [3] Bircan & Erdem (1997); [4] Mert *et al.* (2008); [5] Çolakoğlu & Akyurt (2013); [6] Doğan (2001); [7a] Kırankaya (2007; mirror carp) (GSI data courtesy Ş.G. Kırankaya); [7b] Kırankaya (2007; scale carp) (GSI data courtesy Ş.G. Kırankaya); [8] Yılmaz & Gül (2002); [9] Yılmaz (1994); [10] Balık & Çubuk (2001); [11] Güç (2006); [12] Özcan & Balık (2007); [13] Çetinkaya (1992); [14] Alp *et al.* (1999); [15] Demirkalp (1992); [16] Bircan (1993); [17] Erdem (1982a); [18] Erdem (1982a); [19] Yerli & Zengin (1998); [20] Erdem (1982b); [21] Erdem (1982a); [22] Akyurt (1987b); [23] Karataş (2000); [24] Yerli (1989); [25] Karabatak (1973); [26] Düzgüneş (1985); [27] Şen (2001); [28] Erdem (1988); [29] Kılıç (2003); [30] Ölmez (1992). See online Supplement 4 for full references.

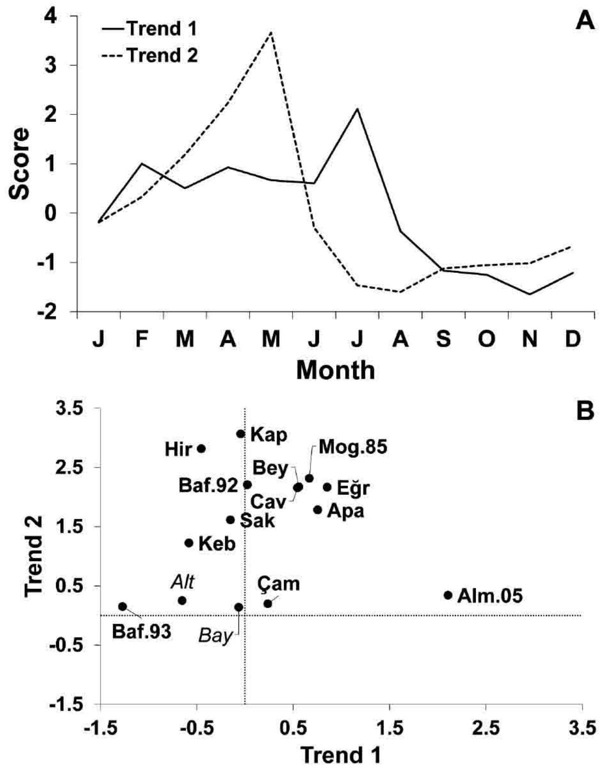

Fig. 5: Dynamic factor analysis (DFA) trends (A) and factor loadings (B) for gonado-somatic index (GSI) monthly values of female common carp in 14 waterbodies of Anatolia. Alm = Almus Reservoir; Alt = Altınkaya Reservoir; Apa = Apa Reservoir; Baf.92 = Bafra Balık Lakes (1992); Baf.93 = Bafra Balık Lakes (1993); Bay = Bayramiç Reservoir; Bey = Lake Beyşehir; Çam = Çamlıdere Reservoir; Cav = Lake Çavuşcu; Eğr = Lake Eğridir; Hir = Hirfanlı Reservoir; Kap = Kapulukaya Reservoir; Keb = Keban Reservoir; Mog = Lake Mogan; Sak = Sakarya River. Factor loadings for Altınkaya and Bayramiç Reservoirs are in italics because they are averages also including non-mature individuals.

6. Mouth dimensions for seven freshwater fishes

By P.K. Karachle, I. Salvarina and D. C. Bobori

Feeding habits, diet composition and food consumption in fishes have been related to various morphological characteristics, with mouth being of primary importance for understanding predator-prey interactions (e.g. Karpouzi & Stergiou, 2003; Karachle & Stergiou, 2011; and references therein). In this report, we present relationships of horizontal (HMO) and vertical (VMO) mouth opening, and mouth area (MA) with total length (TL) for seven freshwater species, two of which, *Alburnus volviticus* Freyhof & Kottelat, 2007 and *Vimba melanops* (Heckel, 1837) are endemics to Greece and the Balkan Peninsula, respectively.

Samples were collected seasonally (summer 2005-summer 2006) in Lake Volvi (Northern Greece), by deploying gillnets (mesh sizes 12-60 mm; knot-to-knot) at sunset until next sunrise. Specimens were directly preserved in 10% formalin solution. All individuals were identified and total body length (TL, in cm), horizontal (HMO, in cm) and vertical (VMO, in cm) mouth openings were measured. Consequently HMO and VMO were used for estimating mouth area (MA, in cm^2), based on the assumption that MA shape could be that of an ellipse (Erzini *et al.,* 1997):

$$MA = \pi \left(\frac{HMO}{2}\right)\left(\frac{VMO}{2}\right), \text{ where } \pi = 3.14.$$

The relationships of HMO, VMO and MA with TL were described using power regression ($Y=a X^b$), which is appropriate for describing morphometry relationships (Lleonart *et al.*, 2000).

Overall, 754 individuals were examined, covering, per species, a wide length range (Table 5). Sample size ranged from 16, for the Greek endemic *A. volviticus*, to 203 for *Perca fluviatilis* Linnaeus, 1758 (Table 5). All relationships were significant ($p < 0.01$; Table 5). For the same TL, MA was higher for *P. fluviatilis*, which is a piscivorous species (Bobori *et al.,* 2013). The remaining six species that generally have an omnivorous diet (Bobori *et al.,* 2013) showed similar MA for the same TL and lower than that of *P. fluviatilis* (Fig. 6). This agrees with the findings of Karachle & Stergiou (2011), who report that for the same TL piscivores have bigger MA than omnivores, and the latter bigger MA than herbivorous species. For the species examined here no such information is available, as is generally the case for freshwater species for which such relationships are generally scarce. Mouth area relationships will contribute to the quantification of prey-size related feeding patterns and interpretation of the high interspecific and intraspecific dietary diversity observed in Lake Volvi (Bobori *et al.,* 2013)

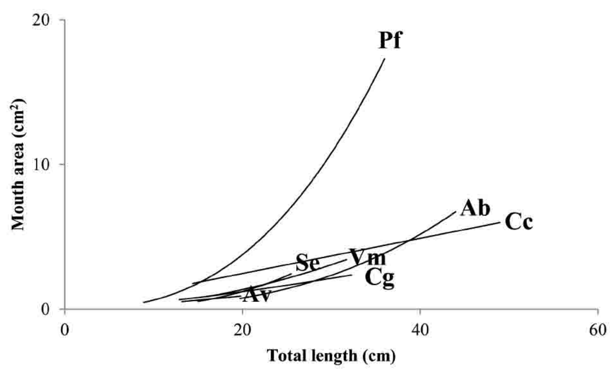

Fig. 6: Regressions between total length (cm) and mouth area (cm^2) for seven fish species from Lake Volvi, Greece. Equations are given in Table 1. Ab: *Abramis brama*; Av: *Alburnus volviticus*; Cg: *Carassius gibelio*; Cc: *Cyprinus carpio*; Pf: *Perca fluviatilis*; Se: *Scardinius erythrophthalmus*; Vm: *Vimba melanops*.

Table 5. Relations between horizontal mouth opening (HMO), vertical mouth opening (VMO) and mouth area (MA) with total body length (TL) for seven fishes from the Lake Volvi (North Greece). n = number of individuals; SE_b = standard error of slope b; r^2 = coefficient of determination. All relationships were highly significant ($p<0.01$).

Species	TL range (cm)	n	HMO=aTL^b	SE_b	r^2	VMO=aTL^b	SE_b	R^2	MA=aTL^b	SE_b	r^2
Abramis brama	19.7-44.0	174	$y = 0.0112x^{1.4676}$	0.069	0.73	$y = 0.0224x^{1.2925}$	0.089	0.55	$y = 0.0002x^{2.7601}$	0.141	0.69
Alburnus volviticus	13.2-19.8	16	$y = 0.1793x^{0.5435}$	0.193	0.36	$y = 0.1104x^{0.8158}$	0.436	0.20	$y = 0.0155x^{1.3593}$	0.603	0.27
Carassius gibelio	12.9-32.3	141	$y = 0.0956x^{0.8399}$	0.059	0.60	$y = 0.2405x^{0.5629}$	0.093	0.21	$y = 0.018x^{1.4027}$	0.140	0.42
Cyprinus carpio	14.4-49.0	23	$y = 0.3543x^{0.5271}$	0.170	0.32	$y = 0.3951x^{0.5117}$	0.162	0.32	$y = 0.1099x^{1.0387}$	0.322	0.33
Perca fluviatilis	8.9-36.0	203	$y = 0.0253x^{1.4936}$	0.046	0.84	$y = 0.0796x^{1.1022}$	0.044	0.76	$y = 0.0016x^{2.5958}$	0.083	0.83
Scardinius erythrophthalmus	15.0-25.5	56	$y = 0.0183x^{1.365}$	0.131	0.67	$y = 0.0153x^{1.5108}$	0.276	0.36	$y = 0.0002x^{2.8758}$	0.370	0.53
Vimba melanops	16.0-29.6	141	$y = 0.0425x^{1.1132}$	0.080	0.58	$y = 0.0962x^{0.9039}$	0.138	0.23	$y = 0.0032x^{2.0171}$	0.196	0.43

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