

LENGTH–WEIGHT RELATIONS FOR 29 DEMERSAL FISHES CAUGHT BY SMALL OTTER TRAWL ON THE SOUTH-EASTERN COAST OF KOREA

Joo Myun PARK^{1*} and Sung Hoi HUH²

¹Department of Biological Sciences, Macquarie University, Sydney, Australia

²Department of Oceanography, Pukyong National University, Busan, Korea

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Abstract. We present herewith the relations between total length and weight (LWRs) for 29 fish species from the southern coast of the East Sea (=Sea of Japan), Korea: *Conger myriaster* (Brevoort, 1856); *Coilia nasus* Temminck et Schlegel, 1846; *Engraulis japonicus* Temminck et Schlegel, 1846; *Clupea pallasii pallasii* Valenciennes, 1847; *Coelorinchus multispinulosus* Katayama, 1942; *Lophius litulon* (Jordan, 1902); *Zeus faber* Linnaeus, 1758; *Paracentropogon rubripinnis* (Temminck et Schlegel, 1843); *Lepidotrigla guentheri* Hilgendorf, 1879; *Liparis tanakae* (Gilbert et Burke, 1912); *Acropoma japonicum* Günther, 1859; *Doederleinia berycoides* (Hilgendorf, 1879); *Jaydia lineata* (Temminck et Schlegel, 1842); *Ostorhinchus semilineatus* (Temminck et Schlegel, 1842); *Sillago sihama* (Forsskål, 1775); *Trachurus japonicus* (Temminck et Schlegel, 1844); *Pagrus major* (Temminck et Schlegel, 1843); *Pennahia argentata* (Houttuyn, 1782); *Zoarces gillii* Jordan et Starks, 1905; *Callionymus lunatus* Temminck et Schlegel, 1845; *Callionymus valenciennei* Temminck et Schlegel, 1845; *Amblychaeturichthys hexanema* (Bleeker, 1853); *Amblychaeturichthys sciistius* (Jordan et Snyder, 1901); *Sphyræna pinguis* Günther, 1874; *Trichiurus lepturus* Linnaeus, 1758; *Psenopsis anomala* (Temminck et Schlegel, 1844); *Pseudorhombus pentophthalmus* Günther, 1862; *Pseudopleuronectes yokohamae* (Günther, 1877); and *Cynoglossus robustus* Günther, 1873. The LWRs for 12 species are estimated for the first time and new maximum lengths for six species are reported herewith. All of the relations between total length and weight were significant (all $r^2 > 0.938$). The values of exponent b , estimated using simple linear least squares of log-transformed weight and length data, ranged from 2.730 to 3.440.

Keywords: marine fish, fisheries management, East Sea, Sea of Japan, LWR

The fishes examined in the presently reported study were collected off the south-eastern coast of Korea. The study area, in terms of its environmental and geographical characteristics, differs generally from other coastal marine ecosystems in the east and south seas of Korea (Suh et al. 2001). It is a habitat for many commercially important demersal fish species and has been renowned for being abundant in prey organisms (Kim unpublished**). However, little is known on the ecology of the fishes living in the area.

Length–weight relation (LWR) parameters (a , b) are useful in the assessment of fish stocks and populations (Ricker 1968, Froese 2006). LWRs are used to estimate the mean weight for a given length group and convert length observations into weights to provide a measure of biomass (Froese 2006, Froese et al. 2011). LWRs also allow for life history and morphological comparisons between different fish species or between fish populations from different

habitats and/or regions (Gonçalves et al. 1997). Although LWRs of scorpionfishes and righteye flounders inhabiting south-eastern coast of Korea have been reported (Baeck et al. 2012, 2014), there are still insufficient information of LWR parameters for Korean fishes. This study reports LWRs for 29 fish species collected by demersal trawl from the south-eastern coast of Korea: *Conger myriaster* (Brevoort, 1856); *Coilia nasus* Temminck et Schlegel, 1846; *Engraulis japonicus* Temminck et Schlegel, 1846; *Clupea pallasii pallasii* Valenciennes, 1847; *Coelorinchus multispinulosus* Katayama, 1942; *Lophius litulon* (Jordan, 1902); *Zeus faber* Linnaeus, 1758; *Paracentropogon rubripinnis* (Temminck et Schlegel, 1843); *Lepidotrigla guentheri* Hilgendorf, 1879; *Liparis tanakae* (Gilbert et Burke, 1912); *Acropoma japonicum* Günther, 1859; *Doederleinia berycoides* (Hilgendorf, 1879); *Jaydia lineata* (Temminck et Schlegel, 1842); *Ostorhinchus semilineatus* (Temminck et Schlegel, 1842);

* Correspondence: Dr Joo Myun Park, Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia; phone: +61 2 9850 8234; e-mail: (JMP) joomyun@gmail.com or joomyun.park@mq.edu.au, (SHH) shhuh@pnu.ac.kr

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Sillago sihama (Forsskål, 1775); *Trachurus japonicus* (Temminck et Schlegel, 1844); *Pagrus major* (Temminck et Schlegel, 1843); *Pennahia argentata* (Houttuyn, 1782); *Zoarces gillii* Jordan et Starks, 1905; *Callionymus lunatus* Temminck et Schlegel, 1845; *Callionymus valenciennesi* Temminck et Schlegel, 1845; *Amblychaeturichthys hexanema* (Bleeker, 1853); *Amblychaeturichthys sciistius* (Jordan et Snyder, 1901); *Sphyræna pinguis* Günther, 1874; *Trichiurus lepturus* Linnaeus, 1758; *Psenopsis anomala* (Temminck et Schlegel, 1844); *Pseudorhombus pentopthalmus* Günther, 1862; *Pseudopleuronectes yokohamae* (Günther, 1877); and *Cynoglossus robustus* Günther, 1873.

Fish specimens were collected monthly from January to December 2006 off the south-eastern coast of Korea (35°15'–35°17'N, 129°18'–129°21'E) from depths between 30 and 60 m using a small otter trawl. Fish samples were immediately packed with ice and taken to the laboratory for measurement of total length (TL) and wet weight to the nearest millimetre and gram, respectively. All scientific names were verified following FishBase (Froese and Pauly 2015).

For each species, the weight–length relation was determined based on the formula:

$$W = aL^b$$

where W is the wet weight [g], L is total length [cm], and a and b are the intercept and allometric coefficient, respectively. Parameters a and b were estimated using a simple linear regression analysis of log-transformed data. Extreme outliers were removed before fitting the linear regression (Froese et al. 2011). The 95% confidence intervals (CIs) of parameters a and b and the statistical significance level of r^2 were estimated using SYSTAT software (Systat, version 12. SPSS, USA). LWRs were summarized over all months. Seasonal LWRs, each spring (March–May), summer (June–August), autumn (September–November), and winter (December–February), were also estimated for species where more than 30 specimens were collected for each season. Analysis of covariance (ANCOVA) was used to determine significant differences in the slopes of length–weight regressions between seasons.

Length–weight regressions were applied to 16 456 specimens of the 29 species from 24 families. Comparing with information in FishBase (Froese and Pauly 2015), our results provide new maximum lengths for 6 species: *Amblychaeturichthys hexanema* (15.6 cm TL), *A. sciistius* (9.2 cm TL), *Jaydia lineata* (10.2 cm TL), *Liparis tanakae* (56.3 cm TL or 51.1 cm SL), *Pseudorhombus pentopthalmus* (26.8 cm TL), and *Zoarces gillii* (45.1 cm TL).

The estimated parameters for the LWRs, along with the descriptive statistics by species, are given in Table 1. All LWRs were highly significant ($P < 0.001$), with r^2 values > 0.938 . The r^2 values ranged from 0.938 for *Acropoma japonicum* to 0.993 for *Liparis tanakae*. The estimated b values ranged from 2.730 for *Amblychaeturichthys hexanema* to 3.440 for *Sillago si-*

hama. All of b values were within the expected range of 2.5 to 3.5 (Froese 2006). The mean value of b (\pm standard deviation) was 3.117 ± 0.184 indicating a tendency towards positive allometry, which is followed by the majority of fish species (Froese 2006). The LWRs for 12 of the 29 species determined in the course of the presently reported study are first reports of LWRs for those species. For remaining 17 species, LWRs of 8 species, *Amblychaeturichthys hexanema*, *Jaydia lineata*, *Conger myriaster*, *Engraulis japonicus*, *Liparis tanakae*, *Lophius litulon*, *Pseudopleuronectes yokohamae*, and *S. sihama* have been reported from the Yellow Sea (Xue et al. 2011, Wang et al. 2013) and the southern coast of Korea (Baeck et al. 2014). The LWRs of 15 species also were available in FishBase (Froese and Pauly 2015), and 2 species, *A. hexanema* and *L. litulon* were only listed in the literature (Xue et al. 2011, Wang et al. 2013).

The seasonal LWRs for 10 of the 29 species are presented in Table 2. The parameter b did not differ significantly (ANCOVA; $P > 0.05$) with seasons for *Jaydia lineata*, *Coelorinchus multispinulosus*, *Lophius litulon*, *Trachurus japonicus*, *Callionymus lunatus*, and *Pseudopleuronectes yokohamae*, whereas it differed significantly (ANCOVA; $P < 0.05$) for *Acropoma japonicum*, *Clupea pallasii pallasii*, *Liparis tanakae*, and *Pseudorhombus pentopthalmus*. Lower b values were recorded in winter for *C. pallasii pallasii*, while *A. japonicum* in summer and winter, and *P. pentopthalmus* were in summer. For *L. tanakae*, the b value was lower in autumn than other seasons. Seasonal differences in length–weight relations may be due to seasonal difference in the condition and/or sexual maturing of the specimens (Moutopoulos and Stergiou 2002, Froese 2006).

Our LWR estimates were compared with the Bayesian estimates of LWRs in fishes (Froese et al. 2014) and were found to fall within the ranges expected for each species or the genus and body shape where they belong. Thus, our results represent the reasonable estimates of the LWRs for the 29 species. The estimated parameters of LWRs in this work should be used with some caution as the length ranges of the specimens available was limited by the selective characteristics of fishing gear used. The majority of the samples did not include the full size ranges of specimens in the study area, especially early juveniles. Petrakis and Stergiou (1995) suggested the use of LWRs only for specimens of lengths within the length ranges used in the estimation of the parameters.

In conclusion, this study provides LWRs of 29 fishes caught off the south-eastern coast of Korea. Our results can be useful for sustainable utilization and management of fishery resources in the study area, and also for fishery biologists/managers in Korea.

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Table 1

Parameters of length–weight regression (LWR) for 29 fish species on the south-eastern coast of East Sea, Korea during 2006

Order	Family	Species	n	Length [cm]		Weight [g]		$W = aL^b$			r^2	
				Min.	Max.	Min.	Max.	a	95% CIs of a	b		95% CIs of b
Anguilliformes	Congridae	<i>Conger myriaster</i>	101	14.9	49.5	4.4	212.1	0.0006	0.0004–0.0009	3.273	3.170–3.376	0.976
	Engraulidae	<i>Coilia nasus</i>	54	11.7	28.5	2.7	67.9	0.0009	0.0005–0.0014	3.346	3.179–3.507	0.970
Clupeiformes		<i>Engraulis japonicus</i>	164	7.7	15.9	2.0	24.5	0.0029	0.0021–0.0040	3.215	3.087–3.343	0.938
	Clupeidae	<i>Clupea pallasii pallasii</i>	3947	6.7	28.7	1.7	171.4	0.0026	0.0025–0.0028	3.283	3.255–3.311	0.989
Gadiformes	Macrouridae	<i>Coelorrinchus multispinulosus</i> ¹	393	7.4	30.4	1.4	107.3	0.0047	0.0057–0.0057	2.857	2.783–2.931	0.956
	Lophiidae	<i>Lophius litulon</i>	472	5.0	57.4	1.1	3201.5	0.0199	0.0161–0.0245	2.955	2.892–3.019	0.970
Zeiformes	Zeidae	<i>Zeus faber</i>	112	9.3	34.2	13.5	772.5	0.0236	0.0178–0.0311	2.884	2.795–2.973	0.974
	Scorpaenidae	<i>Paracentropogon rubripinnis</i> ¹	56	4.8	10.5	2.1	21.8	0.0137	0.0108–0.0193	3.116	2.964–3.267	0.973
Perciformes	Triglidae	<i>Lepidotrigla guentheri</i> ¹	117	5.7	18.1	1.9	75.9	0.0067	0.0057–0.0078	3.210	3.146–3.274	0.983
	Liparidae	<i>Liparis tanakae</i> ²	406	6.0	56.3	2.2	1742.8	0.0098	0.0089–0.0108	3.065	3.033–3.097	0.993
Perciformes	Acropomatidae	<i>Acropoma japonicum</i> ¹	3368	3.6	13.6	0.8	32.3	0.0129	0.0117–0.0141	3.036	2.990–3.083	0.982
	Apogonidae	<i>Doederleinia berycooides</i> ¹	832	9.1	29.1	11.0	346.1	0.0208	0.0192–0.0241	2.871	2.818–2.925	0.986
Sillaginidae		<i>Jaydia lineata</i> ²	3981	3.5	10.2	0.5	17.5	0.0072	0.0063–0.0082	3.414	3.345–3.483	0.974
		<i>Ostorhinchus semilineatus</i> ¹	54	4.5	10.7	0.7	12.3	0.0067	0.0050–0.0090	3.174	3.021–3.326	0.971
Carangidae		<i>Sillago sihama</i>	36	9.8	20.6	5.3	74.3	0.0021	0.0014–0.0033	3.440	3.285–3.596	0.983
		<i>Trachurus japonicus</i>	397	7.1	34.5	2.6	362.9	0.0050	0.0045–0.0055	3.205	3.171–3.239	0.990
Sparidae		<i>Pagrus major</i>	30	15.2	42.2	49.5	1279.9	0.0135	0.0075–0.0242	3.073	2.897–3.249	0.985
		<i>Pennahia argentata</i>	72	7.2	26.4	3.1	256.3	0.0044	0.0036–0.0054	3.338	3.256–3.419	0.990
Zoarcidae		<i>Zoarces gillii</i> ^{1,2}	49	11.3	45.1	5.4	395.0	0.0040	0.0029–0.0054	3.038	2.949–3.127	0.990
		<i>Callionymus lunatus</i> ¹	282	6.2	18.7	1.3	36.4	0.0071	0.0065–0.0078	2.912	2.874–2.950	0.990
Gobiidae		<i>Callionymus valenciennesi</i> ¹	151	6.2	17.4	1.5	26.8	0.0082	0.0067–0.0102	2.830	2.740–2.919	0.963
		<i>Amblychaeturichthys hexanema</i> ²	94	6.9	15.6	2.5	23.8	0.0116	0.0085–0.0160	2.730	2.598–2.862	0.951
Sphyracidae		<i>Amblychaeturichthys sciaenoides</i> ^{1,2}	73	4.1	9.2	0.5	7.5	0.0061	0.0046–0.008	3.115	2.976–3.253	0.967
		<i>Sphyracna pinguis</i>	31	13.1	35.9	11.4	244.0	0.0048	0.0032–0.0071	3.044	2.915–3.172	0.988
Pleuronectiformes	Trichiuridae	<i>Trichiurus lepturus</i>	241	26.2	62.6	6.3	122.3	0.0001	0.0001–0.0002	3.357	3.247–3.468	0.978
	Centrolophidae	<i>Psenopsis anomala</i> ¹	173	10.5	20.6	21.6	161.9	0.0140	0.0115–0.0169	3.086	3.014–3.157	0.981
Pleuronectidae	Paralichthyidae	<i>Pseudorhombus pentophthalmus</i> ^{1,2}	404	10.2	26.8	9.8	208.7	0.0055	0.0045–0.0068	3.207	3.140–3.275	0.960
		<i>Pseudopleuronectes yokohamae</i>	231	9.5	44.5	8.7	958.1	0.0078	0.0069–0.0097	3.136	3.092–3.180	0.987
Cynoglossidae		<i>Cynoglossus robustus</i>	135	8.0	19.7	3.3	50.9	0.0043	0.0027–0.0066	3.175	3.009–3.341	0.961

n = number of individuals studied, a = intercept, b = slope, r² = coefficient of determination, CIs = confidence intervals; ¹ first records of LWR for the species; ² new records of maximum length.

Table 2

Parameters of seasonal length-weight regression (LWR) for 10 fish species which were abundant in the south-eastern coast of East Sea, Korea during 2006

Species	Season	n	Length [cm]		Weight [g]		a	95% CI of a	b	95% CI of b	r ²
			Min.	Max.	Min.	Max.					
<i>Clupea pallasii pallasi</i>	Sp	112	13.8	28.7	12.2	132.1	0.0031	0.0017-0.0057	3.235	3.021-3.448	0.920
	Su	3710	6.7	28.0	1.7	171.4	0.0025	0.0023-0.0028	3.305	3.262-3.349	0.983
	Wi	104	12.8	25.9	11.4	121.5	0.0038	0.0029-0.0051	3.141	3.040-3.242	0.982
<i>Coelorinchus multispinulosus</i>	Sp	160	7.4	29.3	1.4	101.6	0.0054	0.0037-0.0079	2.803	2.658-2.948	0.932
	Su	51	7.7	28.6	1.9	84.1	0.0060	0.0035-0.0102	2.790	2.595-2.985	0.944
	Wi	174	7.4	30.4	1.8	107.3	0.0049	0.0034-0.0071	2.836	2.705-2.967	0.943
<i>Lophius litulon</i>	Sp	64	5.0	57.4	1.1	3201.5	0.0074	0.0064-0.0086	3.219	3.172-3.265	0.996
	Au	14	16.7	47.1	58.8	2330.0	0.0147	0.0092-0.0236	3.018	2.877-3.159	0.975
	Wi	51	21.3	49.3	193.4	1563.4	0.0174	0.0085-0.0360	3.003	2.790-3.217	0.928
<i>Liparis tanakae</i>	Sp	245	6.0	56.3	2.2	1742.8	0.0100	0.0086-0.0116	3.050	2.999-3.101	0.991
	Su	104	13.7	40.6	24.5	786.9	0.0094	0.0070-0.0127	3.091	2.998-3.184	0.987
	Au	57	23.1	41.8	167.2	941.6	0.0158	0.0101-0.0248	2.938	2.809-3.067	0.984
<i>Acropoma japonicum</i>	Sp	979	3.6	10.5	0.8	16.8	0.0142	0.0122-0.0166	3.008	2.977-3.088	0.985
	Su	544	5.1	12.4	1.6	21.4	0.0156	0.0104-0.0234	2.912	2.772-3.103	0.960
	Au	669	4.4	13.6	1.1	32.3	0.0132	0.0112-0.0154	3.022	2.946-3.097	0.985
<i>Jaydia lineata</i>	Wi	1176	4.6	10.6	1.1	19.9	0.0082	0.0070-0.0096	3.278	3.191-3.364	0.987
	Sp	1648	4.1	10.0	0.9	17.5	0.0055	0.0044-0.0068	3.526	3.408-3.644	0.972
	Su	34	6.2	9.0	3.6	12.8	0.0072	0.0037-0.0139	3.371	3.049-3.693	0.934
<i>Trachurus japonicus</i>	Au	743	4.0	10.2	1.0	17.6	0.0090	0.0068-0.0119	3.276	3.120-3.433	0.974
	Wi	1556	4.3	9.2	1.0	14.3	0.0100	0.0078-0.0129	3.216	3.070-3.362	0.968
	Sp	97	8.0	34.5	3.9	362.9	0.0058	0.0047-0.0072	3.146	3.068-3.223	0.986
<i>Callionymus lunatus</i>	Su	35	11.0	29.5	11.4	271.3	0.0047	0.0035-0.0062	3.224	3.133-3.316	0.994
	Au	115	10.4	30.5	9.3	285.6	0.0048	0.0039-0.0061	3.225	3.144-3.305	0.982
	Wi	150	7.1	19.3	2.6	60.7	0.0058	0.0048-0.0070	3.136	3.063-3.209	0.988
<i>Pseudorhombus pentophthalmus</i>	Sp	143	6.2	15.5	1.3	22.4	0.0070	0.0060-0.0082	2.918	2.845-2.991	0.975
	Su	26	9.4	18.7	4.9	36.4	0.0069	0.0033-0.0146	2.954	2.675-3.234	0.960
	Wi	102	9.3	18.3	5.0	35.0	0.0083	0.0053-0.0135	2.843	2.664-3.023	0.961
<i>Pseudopleuronectes yokohamae</i>	Sp	120	12.0	26.8	15.1	208.7	0.0064	0.0045-0.0092	3.169	3.053-3.285	0.957
	Su	59	14.4	25.3	24.1	166.1	0.0081	0.0037-0.0178	3.077	2.822-3.332	0.912
	Au	152	10.2	24.4	9.8	145.5	0.0052	0.0039-0.0068	3.218	3.122-3.314	0.975
<i>Pseudopleuronectes yokohamae</i>	Wi	73	14.8	25.1	28.4	173.2	0.0097	0.0058-0.0163	3.023	2.851-3.195	0.945
	Sp	99	9.5	32.1	8.7	399.5	0.0085	0.0070-0.0101	3.103	3.040-3.167	0.987
	Su	42	13.0	35.0	27.4	557.7	0.0091	0.0063-0.0132	3.095	2.970-3.220	0.984
<i>Pseudopleuronectes yokohamae</i>	Au	52	14.1	35.2	32.1	497.1	0.0076	0.0052-0.0111	3.157	3.032-3.237	0.979
	Wi	38	11.6	44.5	16.3	958.1	0.0078	0.0057-0.0107	3.130	3.022-3.237	0.989

Sp = spring, Su = summer, Au = autumn, Wi = winter.

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