 DOI: 10.3750/AIP2008.38.2.01

MORPHOMETRIC RELATIONS FOR BODY SIZE AND MOUTH DIMENSIONS FOR FOUR FISH SPECIES IN THE STRAIT OF GIBRALTAR

Ivone A. *CZERWINSKI* [1*], Juan C. *GUTIÉRREZ-ESTRADA* [2], Mila C. *SORIGUER* [1], and José A. *HERNANDO* [1]

[1] *Dpto. de Biología, Facultad de Ciencias del Mar y Ambientales, Campus de Puerto Real, Universidad de Cádiz, Cádiz, Spain*

[2] *Dpto. de Ciencias Agroforestales, Escuela Politécnica Superior, Campus Universitario de La Rábida, Universidad de Huelva, Huelva, Spain*

Czerwinski I.A., Gutiérrez-Estrada J.C., Soriguer M.C., Hernando J.A. 2008. Morphometric relations for body size and mouth dimensions for four fish species in the Strait of Gibraltar. Acta Ichthyol. Piscat. 38 (2): 81–90.

Background. The deep-water longline fishery of the blackspot seabream, *Pagellus bogaraveo*, is an economically important fishery in the Strait of Gibraltar, which is a very complex transition ecosystem between the Mediterranean Sea and the Atlantic Ocean with an extreme spatial and temporal variability. This paper presents a series of morphometric relations for the four most important species in this fishery. Some ecological considerations about the results are also discussed.

Materials and Methods. The data were collected during a gear selectivity study, using different sizes of hooks baited with sardine. Relations for weight–length, length–length, and mouth dimensions for blackspot seabream, *Pagellus bogaraveo* (Brünnich, 1768); Atlantic pomfret, *Brama brama* (Bonnaterre, 1788); blackbelly rosefish, *Helicolenus dactylopterus* (Delaroche, 1809); and Mediterranean horse mackerel, *Trachurus mediterraneus* (Steindachner, 1868) were estimated and compared with the ones reported for the same species from other areas.

Results. The sample size varied from 89 for *T. mediterraneus* to 2180 for *P. bogaraveo*. The fitted *L–W* relations explained more than 81% of the variance. For *P. bogaraveo* and *T. mediterraneus*, the estimated allometric coefficient was higher than those reported for other areas, showing a faster increase in weight, in contrast to *H. dactylopterus* and *B. brama* that showed a slower increase in weight. Moreover, linear and highly significant relations between mouth size and fish length were found for *P. bogaraveo*, *H. dactylopterus*, and *T. mediterraneus*.

Conclusions. In this study, the first record for total length–standard length relation for *H. dactylopterus* is reported based on real measurements. There has been no previous studies on the relation between the different mouth size dimensions for the studied species as well as for mouth size and body length relations for *P. bogaraveo* and *H. dactylopterus*. The difference between estimated and reported coefficients might be attributed to different environmental adaptations and to the size ranges used due to the gear-size selectivity.

Keywords: Weight–length, length–length, mouth dimensions, Strait of Gibraltar, *Pagellus bogaraveo*, *Brama brama*, *Helicolenus dactylopterus*, *Trachurus mediterraneus*

INTRODUCTION

Fish size is frequently considered more significant than fish age, mainly because many ecological and physiological factors depend more on the size than the age. Consequently, variability in fish size has important implications for diverse aspects of fisheries science and fish population dynamics (Erzini et al. 1997).

Length and weight data are standard in all fish sampling programs. Its because the knowledge of the length–weight relations is essential for different studies in biology, physiology, and ecology of natural and commercially exploited population of fishes. In this way, in the biological studies of not exploited populations, the analysis of length–weight relations allows to monitor the seasonal variations in the growth and the condition in fish populations. This helps to clarify the functional relations between the growth and the environmental conditions, which allows forecasting the variation of the population dynamics under different environmental scenarios (Gutiérrez-Estrada et al. 2000, Ritcher et al. 2000). On the other hand, in fisheries studies the length–weight relations are fundamental for the estimation of weight-at-age, the

* Correspondence: Dr. Ivone A. Czerwinski, Departamento de Biología, Facultad de Ciencias del Mar y Ambientales, Campus de Puerto Real, Universidad de Cádiz, 11510 Puerto Real, Cádiz, Spain, phone: +34956016017, fax: +34956016019, e-mail: *ivone.czerwinski@uca.es*

calculation of yield and biomass, and are often used to estimate the stock current biomass (Petrakis and Stergiou 1995, Moutopoulos and Stergiou 2002).

However, an inadequate sampling design can result in substantial error in estimated parameters (length, weight) (Safran 1992). This is often due to the fact that most fisheries-based data consist largely of adult fish and smaller sizes and juveniles are poorly represented (Morato et al. 2001).

Several authors have reported different relation between mouth size and body size in marine fishes from mouth size dimensions as vertical and horizontal gapes or mouth area represented as an ellipse (Erzini et al. 1997, Karpouzi and Stergiou 2003) and related them to ecological and/or fisheries aspects.

This paper present a series of morphometric relations for four of the most important commercial species caught in a longline fishery in the Strait of Gibraltar. The Strait of Gibraltar is a very complex transition ecosystem between the Mediterranean Sea and the Atlantic Ocean with an extreme spatial and temporal variability of physical, chemical, and biological characteristics. In this type of systems the analysis of these relations provides very relevant information because changes in morphometric relations can reflect changes in the ecosystem processes, such as productivity, energy pathways, disturbances regimes, abiotic stress, and overfishing.

MATERIAL AND METHODS

Data source. The data were collected during three sampling campaigns carried out in the frames of a gear selectivity study in the Strait of Gibraltar, from December 1999 to July 2005. Three fishing trials were carried out using different hook sizes in a deep-water longline. Each main line consisted of 70 gangions and is attached to a small sinker and a 3.00 mm diameter monofilament line on a hydraulic bobbin. A 20-kg concrete ballast is attached to the end of the longline and is released and left on the bottom when the longline is hauled. The fishing was carried out on rocky bottoms at depths of up to 850 m. Usual fishing practices were observed (setting time, duration of set), using 5 hook sizes. The hooks were baited with standard sized pieces of European pilchard, *Sardina pilchardus* (Walbaum), in all longline sets.

After the longlines were hauled, the fish caught were identified to the species level, and total length (TL), standard length (SL), and fork length (FL) recorded to the nearest mm. The fish were weighed on a 0.01 g precision balance. Mouth size was measured with a 0.01 mm precision gauge, taking the largest vertical and horizontal gape (VG and HG, respectively) with the mouth opened to the maximum.

The four most frequently caught species were used for this study: blackspot seabream, *Pagellus bogaraveo* (Brünnich, 1768); Atlantic pomfret, *Brama brama* (Bonnaterre, 1788); blackbelly rosefish, *Helicolenus dactylopterus* (Delaroche, 1809); and Mediterranean horse mackerel, *Trachurus mediterraneus* (Steindachner, 1868). Data for *B. brama*, *H. dactylopterus* and *T. mediterraneus* are from the three fishing trials.

Length–weight analysis. Following Santos et al. (2002), a power curve (Equation 1) was fitted to the *L*–*W* data:

$$W = aL^b \quad (1)$$

This equation can also be expressed in its logarithmic form (Equation 2):

$$\log W = \log a + b \log L \quad (2)$$

where: W is the total weight [g], L is the total length [mm], a is the intercept (initial growth coefficient or condition factor), and b the slope (growth coefficient, i.e., fish relative growth rate). In equation 1, a is weight × length^b units, and b is a dimensionless constant (Xiao 1998).

Parameters a and b of the *L*–*W* relation were estimated by linear regression analysis (least-squares method). Measures were log-transformed in order to eliminate any effect of 'scale', to keep relations linear and their variances comparable. The degree of association between variables (L and W) was assessed by the coefficient of determination (r^2). Statistical significance level was estimated with a one-way analysis of the variance (ANOVA).

The allometry coefficient is expressed by the slope b of the linear regression equation. In the relations between different types of variables (size and weight), the *L*–*W* relation reflects an isometric growth when $b = 3$, where the relative growth of both variables is perfectly identical (Mayrat 1970).

Statistically significant differences of the estimated values of b from the isometric value were confirmed using Student's *t*-test in which the null hypothesis was that $b = 3$ (Equation 3), with a confidence level of 99% (Sokal and Rohlf 1987):

$$t_s = (b - 3) \times (S_b)^{-1} \quad (3)$$

where: t_s is the value of the Student's *t*-test, b the obtained slope and S_b the standard error for the slope.

Length–length analysis. The relations between the different length measurements were estimated by fitting the data to the following linear model (Equation 4):

$$(\mathrm{FL}, \mathrm{SL}) = a + b\,(\mathrm{TL}, \mathrm{FL}) \quad (4)$$

where: TL is the total length, FL the fork length, SL the standard length (all of them in mm), a is the intercept, and b the slope.

Mouth size dimensions analysis. Fish mouth area was calculated following the ellipse model proposed by Erzini et al. (1997) (Equation 5):

$$\mathrm{MA} = 0.25\pi\,(\mathrm{VG} \times \mathrm{HG}) \quad (5)$$

where: MA [mm^2] is the ellipse area, VG [mm] and HG [mm] are the vertical and horizontal mouth gapes respectively.

The relations between fish mouth dimensions were estimated by the following equation (Equation 6):

$$(\mathrm{VG}, \mathrm{HG}) = a + b\,(\mathrm{HG}, \mathrm{MA}) \quad (6)$$

where: a is the intercept and b the slope.

Mouth size–body length analysis. The relation between mouth size and fish body length was estimated by fitting the following equation (Equation 7) to the data:

$$(\mathrm{VG}, \mathrm{HG}, \mathrm{MA}) = a + b\,(\mathrm{TL}, \mathrm{FL}, \mathrm{SL}) \quad (7)$$

where: VG, HG, and MA are the different measures of mouth size, TL, FL, and SL are the fish lengths, a is the intercept, and b is the slope of the linear regression.

The above relations were estimated when absolute Pearson product-moment correlation coefficient (r) was higher than 0.70. Parameters a and b of the above relations were estimated using linear regression analysis (least-square method) and the degree of association between variables was assessed by the coefficient of determination (r^2). One-way analysis of the variance (ANOVA) was used to evaluate statistical significance. For estimating mouth size and body length relations there were also tested root square and logarithmic transformation of the variables, but in all cases r^2 values estimated without transformation of the variables were equal or higher. Therefore, simple linear relations were selected in favour of the simplicity of the model.

RESULTS

Table 1 shows the results of fits of the *L–W* relation for the four fish species studied (Fig. 1), along with parameters estimated from other studies. The sample size varied from 89 for *T. mediterraneus* to 2180 for *P. bogaraveo*. All the relations were highly significant (ANOVA, $P < 0.001$), with explained variance levels higher than 80%. Slope values varied from 2.843 for *B. brama* to 3.239 for *P. bogaraveo*, whereas the latter was higher than the estimates reported from other areas. The Student's t-test result ($t = 26.55$, $P = 0$) confirmed the positive allometry in this case. Likewise, b values for *T. mediterraneus* in the Strait of Gibraltar (3.146) was higher than other estimated values from other areas (Table 1). In this case, the Student's t-test also confirmed the positive allometry ($t = 3.946$, $P = 0$). On the other hand, for *H. dactylopterus* and *B. brama* the estimated b values were lower compared with other areas, but the Student's t-test showed no significant difference with the isometric value ($t = 2.580$, $P = 0.010$; and $t = 2.437$, $P = 0.015$, respectively).

The parameters of the length–length relations for the four species are shown in Table 2, along with those reported by other authors. All relations were highly significant (ANOVA, $P < 0.001$), with explained variances of more than 90%. Fig. 2 shows the dispersions of the fork- and standard length by total length for all species.

For the mouth size dimensions, only three species (*P. bogaraveo*, *T. mediterraneus*, and *H. dactylopterus*) showed an absolute r^2 values higher than 0.70 between the different dimensions used (VG, HG, MA, TL, FL, and SL).

The estimated linear relations between the different mouth-size dimensions for these three species had, in most cases, explained variances higher than 80%, except for the relations between VG and HG for *T. mediterraneus* and *H. dactylopterus* (r^2 values of 0.78 and 0.69, respectively). All relations were highly significant (ANOVA, $P < 0.01$) (Table 3).

Mouth size and body length estimated relations had explained variances levels lower than 80% only in the VG and body length relation for *T. mediterraneus* and *H. dactylopterus*, and in the MA and body length relation for *H. dactylopterus*. All relations were highly significant (ANOVA, $P < 0.01$). The results are shown in Table 4.

DISCUSSION

The sample of fishes used in this study does not include juveniles or very small individuals, possibly due to the fishing gear size selectivity, or perhaps to the fishing depth and area, and therefore the estimated relations should be limited to the size range used in the estimation of the linear regression parameters (Petrakis and Stergiou 1995, Santos et al. 2002). Several authors have noted that it is particularly dangerous to extrapolate morphometric relations based on adult fish to fish larvae, younger or immature stages (Bagenal and Tesch 1978, Safran 1992). Moreover, given that the samples were collected during four years and seasons, the estimates should therefore be considered as average values (Petrakis and Stergiou 1995, Gonçalves et al. 1997, Santos et al. 2002).

The initial condition factor (a) and allometric coefficient (b) can be related to the ecological process and to the vital history (Stearns and Crandall 1984, Wootton 1990). A high allometric coefficient implies that the species gains weight faster than it grows in length. The fitted *L–W* relations explained more than 81% of the variance. For *P. bogaraveo* and *T. mediterraneus* the b values were higher than those from other areas, showing a faster increase in weight, in contrast, with *H. dactylopterus* and *B. brama* that showed slower increase in weight. In fact, *L–W* relations are not constant, and can vary according to many factors, like temperature, salinity, food availability, sex, gonadal development, spawning season, and feeding rate and coefficients a and b also vary between species, and sometimes between stocks of the same species (Stearns and Crandall 1984, Wootton 1990). During their growth, fishes pass through different stages, and it would be difficult to have *L–W* estimates for all individual stages. There can also exist differences between seasons and/or days (because of changes in the stomach content) (Bagenal and Tesch 1978). However, Mayrat (1970) considered that the coefficient b is characteristic of each species and usually does not vary significantly along years. In this case, the difference between estimated and reported coefficients might be also attributed to the size-ranges used (15–58 cm) due to differences in gear and gear-size selectivity. For *T. mediterraneus*, the range of sizes used in the equation regression, without individuals between 32 and 40 cm of total length, that can also affect the estimated coefficients.

There has been no previous studies on the relation between the different mouth size dimensions (vertical and horizontal gape, and mouth area) for the studied species as well as for mouth size and body length relations for *P. bogaraveo* and *H. dactylopterus*. In the case of *T. mediterraneus*, a linear relation between horizontal gape and total body length was reported by Karpouzi and Stergiou (2003). These authors reported that in Aegean Sea total body length of Mediterranean horse mackerel explained the 58% of the size gape variability (horizontal mouth gape). This contrast with the results of this study in

Table 1

Estimated parameters for the *L–W* relations ($W = a\mathrm{TL}^b$) for *Pagellus bogaraveo*, *Trachurus mediterraneus*, *Helicolenus dactylopterus*, and *Brama brama* in the Strait of Gibraltar (presently reported study and estimates from literature sources); for all cases $P < 0.001$

Species	Source	Locality	*n*	Sex	*a*	*b*	S_b	r^2	*t* test result
P. bogaraveo	Presently reported study		2180	unsexed	0.001	3.239	0.009	0.970	+Allometric
	Alcázar 1987	Cantabrian Sea	360	mixed	0.009	3.158		0.984	
	Coull et al. 1989	UK	6	unsexed	0.008	3.212			
	Krug 1989	ICES VI–VIII		unsexed	0.141	3.079			
	Krug 1989	Azores	872	unsexed	0.149	3.137			
	Campillo 1992	Lyon Gulf		females	0.009	3.138			
	Campillo 1992	Lyon Gulf		males	0.007	3.209			
	Gonçalves et al. 1997	Portugal	57	unsexed	0.021	2.891			
	Stergiou and Moutopoulos 2001	Aegean Sea	649	mixed	0.021	2.926		0.959	
	Mendes et al. 2004	Portugal	30	unsexed	0.014	3.001		0.918	
	Gil 2006	Strait of Gibraltar	1041	unsexed	0.014	3.014		0.990	
T. mediterraneus	Presently reported study		89	unsexed	0.001	3.146	0.037	0.988	+Allometric
	Djabali et al. 1993	Algeria		female	0.014	3.000			
	Djabali et al. 1993	Algeria		male	0.013	3.000			
	Dulcic and Kraljevic 1996	Croatia	17	unsexed	0.015	2.996		0.988	
	Merella et al. 1997	Balearic Islands	232	unsexed	0.014	2.760		0.999	
	Stergiou and Moutopoulos 2001	Cyclades	485	mixed	0.010	2.900		0.979	
	Stergiou and Moutopoulos 2001	Greece	81	mixed	0.020	2.804		0.969	
	Moutopoulos and Stergiou 2002	Cyclades	191	mixed	0.014	2.824	0.063	0.92	–Allometric
	Koutrakis and Tsikliras 2003	Aegean Sea	21	unsexed	0.012	2.908		0.977	
H. dactylopterus	Presently reported study		293	unsexed	0.001	2.871	0.050	0.919	Isometric
	Dorel 1986	Celtic Sea	214	unsexed	0.010	3.091		0.998	
	Merella et al. 1997	Balearic Islands	103	unsexed	0.013	3.040		0.997	
	Monteiro et al. 1991	Azores	105	mixed	0.010	3.144		0.997	
	Massuti et al. 2000	Western Mediterranean	2366	mixed	0.001	3.020		0.990	
	Portela et al. 2002	Uruguay	183	females	0.014	3.064			
	Portela et al. 2002	Uruguay	146	males	0.007	3.256			
	Mendes et al. 2004	Portugal	102	unsexed	0.009	3.216		0.902	
B. brama	Presently reported study		474	unsexed	0.001	2.844	0.064	0.809	Isometric
	Coull et al. 1989	Scotland	11	unsexed	0.052	3.609			
	Lobo and Erzini 2001	Portugal	234	unsexed	0.005	3.185			
	Ayers et al. 2004	New Zeland	932	mixed	0.006	3.289		0.975	Based on FL

n, sample size; *a* and *b* are the parameters of the relation, S_b is the standard error of *b* estimation; r^2 is the coefficient of determination.*n*, sample size; *a* and *b* are the parameters of the relation, *S* is the standard error for the slope *b* ; r^2 is the coefficient of determination.

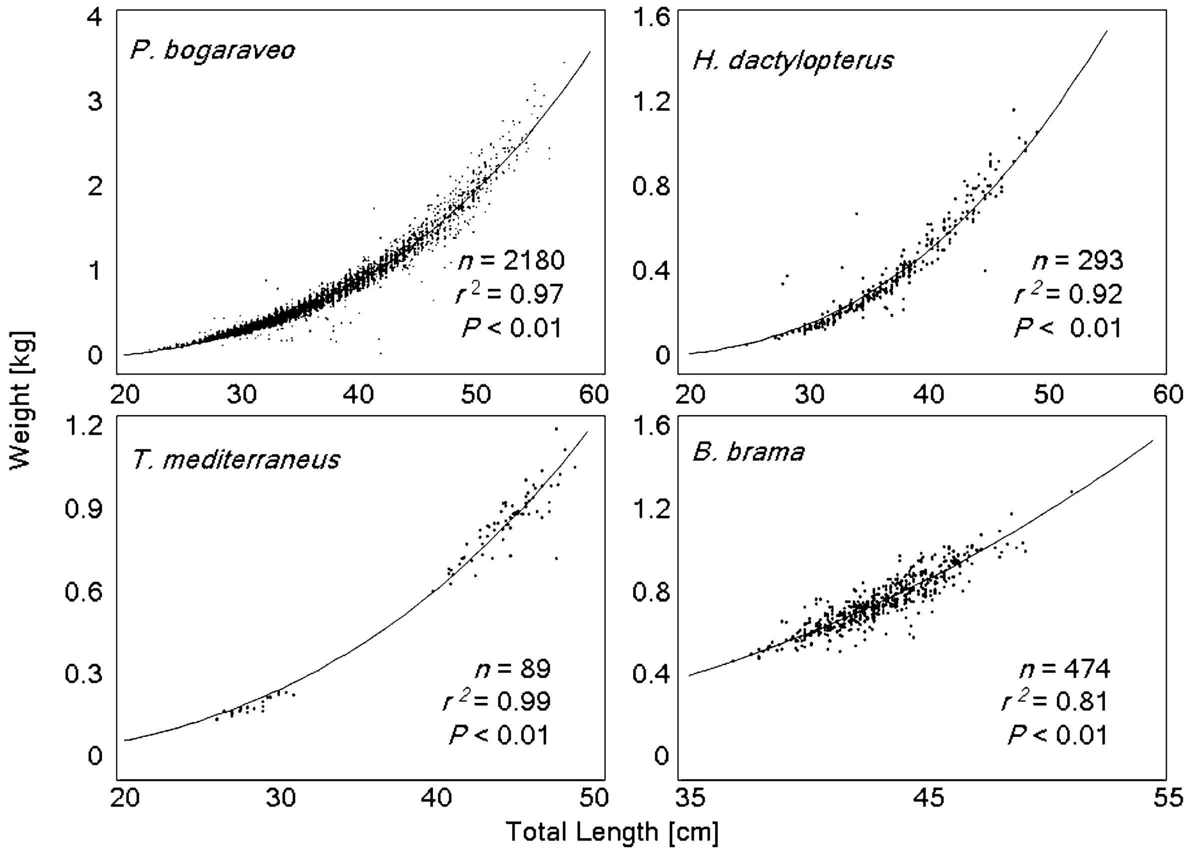

Fig. 1. Length–weight relations ($W = a\mathrm{TL}^b$) for *Pagellus bogaraveo*, *Trachurus mediterraneus*, *Helicolenus dactylopterus*, and *Brama brama*; *n*, sample size; r^2, coefficient of determination; *P*, significance value

which, the body size explained the 83% of mouth size variability. In spite of this, in both cases the size of the gape increased linearly with body length, the slope of the regression line differed between both study areas. In the Strait of Gibraltar the Mediterranean horse mackerel had significantly bigger gapes relative to their body length than in the Aegean Sea.

This pattern is similar to that found in northern pike, *Esox lucius* L. where the mouth size was correlated with body length on different lakes in Sweden (Magnhagen and Heibo 2001). Between different species, the variation in size of the feeding apparatus is commonly explained as an adaptation to the type of prey to enhance the ability of the predator to capture and ingest its prey. Nevertheless, when morphological variations are found within a species, there can be alternatives to the adaptation hypothesis, as discussed by Forsman and Shine (1997). Magnan (1988), Walker (1997), and Svanbäck (2004) indicated that inter-population variation in mouth morphology is usually correlated with differences in the availability of resources either through with other species or by geographical differences in ecological conditions such as water temperature, salinity, and food supply. Similar conclusions have been drawn for other corporal structures and even for the body shape. For example, Ehlinger and Wilson (1998) reported that in bluegill, *Lepomis macrochirus* Rafinesque, 1819, the body shape seemed to be habitat-specific. Also, Karpouzi and Stergiou (2003) indicated that mouth fish morphology plays an important role in determining the type of prey consumed, while morphological variations can lead to changes in foraging ability and subsequently differential exploitation of food resources. In this way, the most probable explanation for the differences in mouth size in relation to body length found between the Mediterranean horse mackerel populations of the Strait of Gibraltar and the Aegean Sea is a combination between adaptations to the prey type and environmental features of each study area.

To compare the results of different authors, the use of different mouth size measurements for different analyses can be confusing, if there are no previous reports on the different mouth size dimensions relation, as occurs with the different body length measurements (total-, fork-, and standard length).

Table 2

Morphometric relations between total- (TL, cm), fork- (FL, cm), and standard (SL, cm) length for *Pagellus bogaraveo*, *Trachurus mediterraneus*, *Helicolenus dactylopterus*, and *Brama brama* in the Strait of Gibraltar (presently reported study and estimates from literature sources)

Species	Source	Locality	n	y	a	b	x	r^2	Sex
	Presently reported study		2180	FL	–0.731	0.910	TL	0.99	unsexed
	Presently reported study		2180	SL	–0.876	0.792	TL	0.93	unsexed
	Presently reported study		2180	SL	–0.322	0.873	FL	0.95	unsexed
	Alcázar 1987	Cantabrian Sea	200	SL	–0.903	0.829	TL	0.99	mixed
P. bogaraveo	Alcázar 1987	Cantabrian Sea	200	SL	–0.227	0.831	TL	0.99	males
	Alcázar 1987	Cantabrian Sea	200	SL	–0.003	0.830	TL	0.99	females
	Krug 1989	Azores		FL	–0.463	0.900	TL		unsexed
	Krug 1989	Azores		SL	–3.180	0.924	TL	0.99	unsexed
	Krug 1989	Azores		TL	–0.043	1.132	FL		unsexed
	Presently reported study		88	FL	0.131	0.894	TL	0.99	unsexed
	Presently reported study		85	SL	–1.037	0.840	TL	0.99	unsexed
	Presently reported study		86	SL	–1.142	0.939	FL	0.99	unsexed
	Moutopoulos and Stergiou 2002	Aegean Sea	154	FL	1.090	0.840	TL	>0.93	unsexed
T. mediterraneus	Moutopoulos and Stergiou 2002	Aegean Sea	154	SL	–0.320	0.960	FL	>0.93	unsexed
	Moutopoulos and Stergiou 2002	Aegean Sea	154	SL	0.460	0.820	TL	>0.93	unsexed
	Smith-Vainz 1986			FL	0.000	0.875	TL		unsexed
	Smith-Vainz 1986			SL	0.000	0.934	FL		unsexed
	Smith-Vainz 1986			SL	0.000	0.817	TL		unsexed
	Presently reported study		293	SL	–0.625	0.834	TL	0.97	unsexed
H. dactylopterus	Froese and Pauly 2007		1	SL	0.000*	0.829*	TL		unsexed
	Froese and Pauly 2007		11	SL	0.045*	0.839*	TL	0.99	unsexed
	Presently reported study		463	FL	2.370	0.764	TL	0.91	unsexed
	Presently reported study		464	SL	0.558	0.695	TL	0.92	unsexed
	Presently reported study		467	SL	–0.805	0.885	FL	0.98	unsexed
	Froese and Pauly 2007		1	FL	0.000*	0.778*	TL		unsexed
B. brama	Froese and Pauly 2007		1	SL	0.000*	0.886*	FL		unsexed
	Froese and Pauly 2007		1	SL	0.000*	0.690*	TL		unsexed
	Froese and Pauly 2007		1	TL	0.000*	1.127*	FL		unsexed
	Froese and Pauly 2007			TL	0.000*	1.212*	SL		unsexed
	Lobo and Erzini 2001	Portugal	234	TL	0.716	1.205	FL	0.97	unsexed

* Based on photo measurements; n, sample size; a and b, parameters of the linear regression analysis; r^2, coefficient of determination.

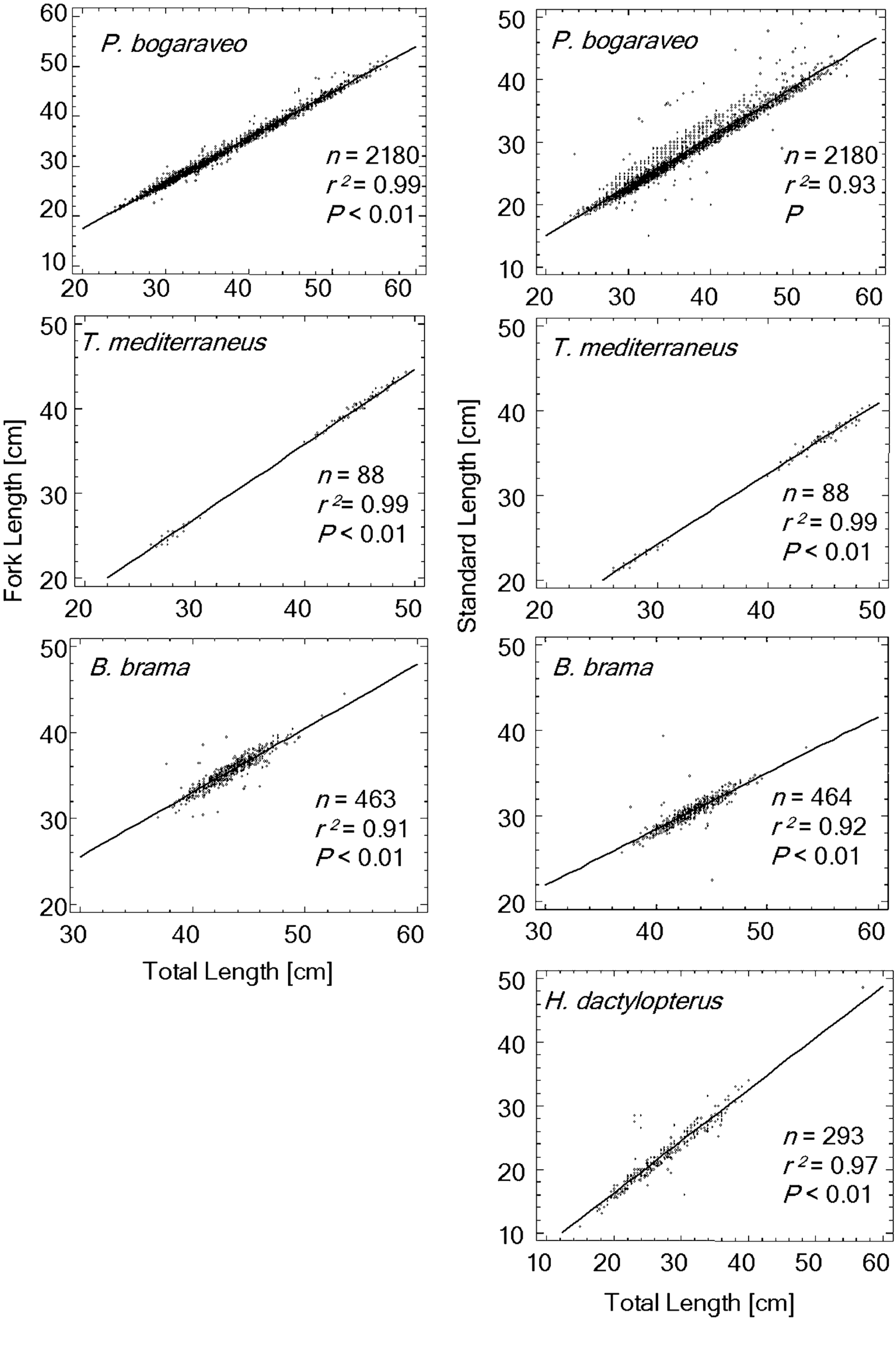

Fig. 2. Length–length relations ($Y = a + bX$) between fork- and standard lengths with total body length for *Pagellus bogaraveo*, *Trachurus mediterraneus*, *Helicolenus dactylopterus*, and *Brama brama*; *n*, sample size; r^2, coefficient of determination; *P*, significance value

Table 3

Relations between different mouth size dimensions of *Pagellus bogaraveo*, *Trachurus mediterraneus*, and *Helicolenus dactylopterus* in the Strait of Gibraltar

Species	*n*	*y*	*a*	*b*	*x*	r^2
P. bogaraveo	1960	VG	1.562	0.864	HG	0.90
		VG	19.330	0.014	MA	0.96
		HG	21.699	0.016	MA	0.97
T. mediterraneus	54	VG	18.930	0.540	HG	0.78
		VG	27.104	0.010	MA	0.92
		HG	21.134	0.016	MA	0.94
H. actylopterus	282	VG	20.977	0.656	HG	0.69
		VG	34.372	0.009	MA	0.86
		HG	25.366	0.012	MA	0.93

n, sample size; *a* and *b,* parameters of the linear regression analysis; r^2, coefficient of determination; VG, vertical mouth gape; HG, horizontal mouth gape; MA, mouth area.

Table 4

Relation between mouth size and total body length for *Pagellus bogaraveo*, *Trachurus mediterraneus*, and *Helicolenus dactylopterus* in the Strait of Gibraltar

Species	*n*	*y*	*a*	*b*	*x*	r^2
P. bogaraveo	2134	VG	1.175	0.101	TL	0.88
		VG	2.357	0.110	FL	0.88
		VG	4.569	0.120	SL	0.84
	1960	HG	1.593	0.110	TL	0.89
		HG	2.866	0.120	FL	0.89
		HG	4.746	0.134	SL	0.89
		MA	–1237.75	7.025	TL	0.90
		MA	–1199.04	7.679	FL	0.91
		MA	–1091.98	8.588	SL	0.88
T. mediterraneus	80	VG	23.726	0.059	TL	0.77
		VG	24.007	0.064	FL	0.75
		VG	24.679	0.069	SL	0.76
	54	HG	15.390	0.092	TL	0.83
		HG	15.297	0.103	FL	0.83
		HG	17.025	0.108	SL	0.82
		MA	–372.255	5.813	TL	0.88
		MA	–379.383	6.496	FL	0.89
		MA	–274.386	6.841	SL	0.87
H. dactylopterus	282	VG	7.222	0.188	TL	0.72
		VG	12.195	0.209	SL	0.65
		HG	0.121	0.254	TL	0.90
		HG	2.173	0.313	SL	0.90
		MA	–2319.35	18.512	TL	0.60
		MA	–1729.37	20.11–	SL	0.50

n, sample size; *a* and *b,* parameters of the linear regression analysis; r^2, coefficient of determination; VG, vertical mouth gape; HG, horizontal mouth gape; MA, mouth area; TL, total length; FL, fork length; SL, standard length.

ACKNOWLEDGMENTS

This work has partly been financed by the Instituto de Formación e Investigación Agraria y Pesquera (IFAPA) (project: C03-007-2003-110), the General Direction of Fishery and Aquaculture of the Council of Andalucía and the Provincial Deputation of Cádiz. We want to express our gratefulness to our colleagues Dr. Cristina Zabala, Dr. Eva Velasco, Mª Carmen Gómez Cama, Remedios Cabrera, Javier Llorente, Noelia Villar, Ramón Bravo, Cesar Vilas, and Jose M. García Rebollo by their disinterested aid during the samplings. We also thank to Dr. Karim Erzini and two anonymous reviewers for their helpful comments and suggestions for improving the manuscript.

REFERENCES

Alcázar J.L. 1987. Aportación al estudio del besugo en el Principado de Asturias. Principado de Asturias: Servicio de Publicaciones.

Ayers D., Francis M.P., Griggs L.H., Baird S.J. 2004. Fish bycatch in New Zealand tuna longline fisheries, 2000–01 and 2001–02. New Zealand Fisheries Assessment Report 2004/46.

Bagenal T.B., Tesch F.W. 1978. Age and growth. Pp. 101–136. *In*: Bagenal T.B. (ed.) Methods for assessment of fish production in fresh waters. 3rd edn. Blackwell Scientific Publications, Oxford.

Campillo A. 1992. Les pêcheries françaises de Médditerranée: synthèse des connaissances. France. Institut Français de Recherche pour l'Exploitation de la Mer.

Coull K.A., Jermyn A.S., Newton A.W., Henderson G.I., Hall W.B. 1989. Length/weight relationships for 88 species of fish encountered in the North Atlantic. Scottish Fishery Research Report **43**.

Djabali F., Mehailia A., Koudil M., Brahmi B. 1993. Empirical equations for the estimation of natural mortality in Mediterranean teleosts. Naga, ICLARM Quart **16:** 35–37.

Dorel D. 1986. Poissons de l'Atlantique nord-est relations taille-poids. Institut Français de Recherche pour l'Exploitation de la Mer.

Dulcic J., Kraljevic M. 1996. Weight–length relationship for 40 species in the eastern Adriatic (Croatian waters). Fisheries Research **28**: 243–251.

Ehlinger T., Wilson D. 1988. Complex foraging polymorphism in bluegill sunfish. Proceedings of the National Academy of Science USA **85**: 1878–1882.

Erzini K., Gonçalves J.M.S., Bentes L., Lino P.G. 1997. Fish mouth dimensions and size selectivity in a Portuguese longline fishery. Journal of Applied Ichthyology **13**: 41–44.

Forsman A., Shine R. 1997. Rejection of non-adaptive hypotheses for intraspecific variation in trophic morphology in gape-limited predators. Biological Journal of the Linnean Society **62**: 209–223.

Froese R., Pauly D. (eds.) 2007. FishBase. version (10/2007) www.fishbase.org

Gil J. 2006. Biología y pesca del voraz (*Pagellus bogaraveo* (Brünich, 1768)) en el estrecho de Gibraltar. Ph.D. Thesis, Universidad de Cádiz, Cádiz, Spain.

Gonçalves J.M.S., Bentes L., Lino P.G., Ribeiro J., Canario A.V.M., Erzini K. 1997. Weight–length relationships for selected fish species of the small-scale demersal fisheries of the south and south-west coast of Portugal. Fisheries Research **30**: 253–256.

Gutiérrez-Estrada J.C., Pulido-Calvo I., Fenández-Delgado C. 2000. Age-structure, growth and reproduction of the introduced pumpkinseed (*Lepomis gibbosa*, L. 1758) in a tributary of the Guadalquivir River (southern Spain). Limnetica **19**: 21–29.

Karpouzi V.S., Stergiou K.I. 2003. The relationships between mouth size and shape and body length for 18 species of marine fishes and their trophic implications. Journal of Fish Biology **62**: 1353–1365.

Koutrakis E.T., Tsikliras A.C. 2003. Length–weight relationships of fishes from three northern Aegean estuarine systems (Greece). Journal of Applied Ichthyology **19**: 258–260.

Krug H.M. 1989. The azorean blackspot seabream, *Pagellus bogaraveo* (Brünnich, 1768) (Teleostei: Sparidae): Age and growth. Cybium **13**: 347–355.

Lobo C., Erzini K. 2001. Age and growth of Ray's bream (*Brama brama*) from the south of Portugal. Fisheries Research **51**: 343–347.

Magnan P. 1988. Interations between brook charr, *Salvelinus fontinalis*, and nonsalmonid species: ecological shift, morphological shift, and their impact on zooplankton communities. Canadian Journal of Fisheries and Aquatic Science **38**: 240–244.

Magnhagen C., Heibo E. 2001. Gape size allometry in pike reflects variation between lakes in prey availability and relative body depth. Functional Ecology **15**: 754–762.

Massuti E., Morales-Nin B., Moranta J. 2000. Age and growth of blue-mouth, *Helicolenus dactylopterus* (Osteichthyes: Scorpaenidae), in the western Mediterranean. Fisheries Research **46**: 165–176.

Mayrat A. 1970. Allometrie et taxinomie. Revue de Statistique Appliquée **18**: 47–58.

Mendes B., Fonseca P., Campos A. 2004. Weight–length relationships for 46 fish species of the Portuguese west coast. Journal of Applied Ichthyology **20**: 355–361.

Merella P., Quetglas A., Alemany F., Carbonell A. 1997. Length–weight relationship of fishes and cephalopods from the Balearic Islands (western Mediterranean). Naga, ICLARM Quart **20**: 66–68.

Monteiro L.R., Isidro E.J., Lopes H.D. 1991. Mercury content in relation to sex, size, age and growth in two scorpionfish (*Helicolenus dactylopterus* and *Pontinus kuhlii*) from Azorean waters. Water, Air and Soil Pollution **56**: 359–367.

Morato T., Afonso P., Lourinho P., Barreiros J.P., Santos R.S., Nash R.D.M. 2001. Length–weight relationships for 21 coastal fish species of the Azores, north-eastern Atlantic. Fisheries Research **50**: 297–302.

Moutopoulos D.K., Stergiou K.I. 2002. Length–weight and length–length relationships of fish species from the Aegean Sea (Greece). Journal of Applied Ichthyology **18**: 200–203.

Petrakis G., Stergiou K.I. 1995. Weight–length relationships for 33 fish species in Greek waters. Fisheries Research **21**: 465–469.

Portela J.M., González M.C., Bellido J.M. 2002. Preliminary results of an exploratory fishing targeting deep-water species of Uruguay. ICES Annual Science Conference, Copenhagen. Session **L: 04**.

Ritcher H., Luckstadt C., Focken U., Becker K. 2000. An improved procedure to assess fish condition on the basis of length–weight relationships. Archive of Fishery and Marine Research **48**: 255–264.

Safran P. 1992. Theoretical analysis of the weight–length relationship in fish juveniles. Marine Biology **112**: 545–551.

Santos M.N., Gaspar M.B., Vasconcelos P., Monteiro C.C. 2002. Weight–length relationships for 50 selected fish species of the Algarve coast (southern Portugal). Fisheries Research **59**: 289–295.

Smith-Vaniz W.F. 1986. Carangidae. Pp. 815–844. *In*: Whitehead P.J.P., Bauchot M.L., Hureau J.C., Nielsen J., Tortonese E. (eds.), Fishes of the north-eastern Atlantic and the Mediterranean (Vol. 2). UNESCO, Paris.

Sokal R.R., Rohlf F.J. 1987. Introduction to Biostatistics. 2 edn. Freeman, New York.

Stearns S.C., Crandall R.E. 1984. Plasticity for age and size at sexual maturity: a life-history response to unavoidable stress in fish reproduction. Pp. 13–33. *In*: Potts G.W., Wootton R.J. (eds.) Fish reproduction: Strategies and tactics. Academic Press, London.

Stergiou K.I., Moutopoulos D.K. 2001. A review of length–weight relationships of fishes from Greek marine waters. Naga, ICLARM Quart **24**: 23–29.

Svanbäck R. 2004. Ecology and evolution of adaptive morphological variation in fish populations. PhD Thesis, Umea University, Sweden.

Walker J.A. 1997. Ecological morphology of lacustrine three-spine stickleback *Gasterosteus aculeatus* L. (Gasterosteidae) body shape. Biological Journal of de Linnean Society **61**: 3–50.

Wootton R.J. 1990. Ecology of teleost fishes. Chapman and Hall, London.

Xiao Y. 1998. What are the units of the parameters in the power function for the length–weight relationship? Fisheries Research **35**: 247–249.

Received: 18 April 2008
Accepted: 10 June 2008
Published electronically: 30 November 2008