ELSEVIER
Fisheries Research 50 (2001) 297–302
FISHERIES RESEARCH
www.elsevier.com/locate/fishres

Short communication

Length–weight relationships for 21 coastal fish species of the Azores, north-eastern Atlantic

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Received 24 January 2000; received in revised form 9 May 2000; accepted 21 May 2000

Abstract

Length–weight relationships were estimated for 21 coastal fish species of the Azores, namely *Abudefduf luridus, Bothus podas, Chromis limbata, Coris julis, Diplodus sargus, Echiichthys vipera, Gaidropsarus guttatus, Labrus bergylta, Mullus surmuletus, Phycis phycis, Pomatomus saltator, Sarda sarda, Scorpaena maderensis, Scorpaena notata, Seriola rivoliana, Serranus atricauda, Sparisoma cretense, Sphyraena viridensis, Synodus saurus, Thalassoma pavo* and *Trachinotus ovatus*. Significant length–weight relationships were found for all species. Sexual dimorphism did not affect the length–weight relationships, except in the cases of *S. cretense* and *C. julis*. Length–length equations for converting size measurements (standard length (SL) and fork length (FL) to total length (TL)) are also presented for all fish species.

Keywords: Length–weight relationships; Length–length relationships; Azores; Coastal fishes

1. Introduction

Length and weight data are useful and standard results of fish sampling programs. Such data are essential for a wide number of studies, for example estimating growth rates, age structure, and other aspects of fish population dynamics (Kolher et al., 1995). Length–weight regressions have been extensively used to estimate weight from length because of technical difficulties and the amount of time required to record weight in the field. These relationships are often used to calculate the standing stock biomass (e.g. Martin-Smith, 1996), condition indices, in the analysis of ontogenetic changes (Safran, 1992) and several other aspects of fish population dynamics. However, estimated growth parameters (length and weight) can deviate substantially from true estimates of the population parameters due to inadequacies in the sampling design (Safran, 1992). For example, because nearly all fishery surveys are focused on commercial or recreational species, the resulting parameters are based on adults and the juvenile phase is often missing from the data sets.

In the Azores, the northern-most archipelago of the Atlantic, coastal fish have been poorly studied and very little biological information is available, includ-

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0165-7836/01/$ – see front matter
PII: S0165-7836(00)00215-0

ing most of the commercially important species. Moreover, there is an urgent need to manage and regulate the small-scale coastal fishery in the region, and this requires basic population dynamics information for the target species (Santos et al., 1995). The present paper describes the length–weight relationships for 21 coastal fish species in the Azores using data collected during a baseline survey aimed to study the coastal fish community of the archipelago. We include the most common and representative coastal species of both soft and hard substrata (Patzner et al., 1991), and also most of the species targeted by local artisanal fisheries: *Abudefduf luridus*, *Bothus podas*, *Chromis limbata*, *Coris julis*, *Diplodus sargus*, *Echiichthys vipera*, *Gaidropsarus guttatus*, *Labrus bergylta*, *Mullus surmuletus*, *Phycis phycis*, *Pomatomus saltator*, *Sarda sarda*, *Scorpaena maderensis*, *Scorpaena notata*, *Seriola rivoliana*, *Serranus atricauda*, *Sparisoma cretense*, *Sphyraena viridensis*, *Synodus saurus*, *Thalassoma pavo* and *Trachinotus ovatus*. With the exception of *P. phycis* (Silva, 1985) and *B. podas* (Nash et al., 1991), our results constitute the first information for 19 of the 21 species regarding Azorean populations.

2. Materials and methods

Length and weight data (n=6709, see Table 1) were collected from a number of fish species throughout the

Table 1
Weight–length relationships for 21 coastal fish species from the Azores[a]

Species	Sex	Length characteristics					Parameters of the relationship				P
		n	Mean	S.E.	Minimum	Maximum	*a*	*b*	S.E. (*b*)	r^2	
A. luridus	Both	89	10.3	0.52	2.7	17.4	0.0344	2.813	0.064	0.956	0.8578
	Males	32	15.1	0.33	11.9	17.4	0.0064	3.444	0.116	0.967	
	Females	16	12.8	0.48	10.3	15.8	0.0081	3.410	0.154	0.970	
B. podas	Both	511	10.5	0.24	2.7	23.4	0.0082	3.124	0.014	0.991	0.1658
	Males	136	16.0	0.22	10.6	23.4	0.0104	3.035	0.046	0.970	
	Females	65	16.6	0.35	10.2	22.1	0.0141	2.919	0.076	0.959	
C. limbata	Both	147	10.7	0.33	1.8	16.4	0.0142	3.058	0.020	0.994	0.3030
	Males	77	13.2	0.15	10.1	16.4	0.0461	2.605	0.109	0.884	
	Females	31	12.7	0.17	10.0	13.8	0.0229	2.878	0.267	0.800	
C. julis	Both*	421	15.6	0.17	7.4	24.2	0.0058	3.175	0.018	0.987	0.0006
	Males	129	19.3	0.19	10.3	24.2	0.0049	3.242	0.063	0.954	
	Females	244	14.0	0.14	8.1	20.1	0.0087	3.011	0.030	0.977	
D. sargus	Both	1178	18.2	0.33	1.7	41.1	0.0111	3.181	0.005	0.997	0.6155
	Males	231	24.5	0.45	9.2	39.8	0.0180	3.032	0.040	0.961	
	Females	446	27.1	0.30	12.2	41.1	0.0166	3.054	0.025	0.970	
E. vipera	Both[b]	49	7.8	0.37	2.6	14.3	0.0084	3.171	0.039	0.993	
G. guttatus	Both	124	20.1	0.32	12.5	32.6	0.0052	3.141	0.063	0.953	0.1669
	Males	15	19.4	0.57	15.7	24.1	0.0169	2.744	0.362	0.815	
	Females	95	20.5	0.39	12.5	32.6	0.0049	3.162	0.066	0.961	
L. bergylta	Both	355	34.1	0.41	17.9	50.0	0.0141	3.039	0.024	0.979	0.1472
	Males	28	41.3	1.33	20.4	49.0	0.0197	2.929	0.066	0.974	
	Females	306	33.6	0.43	17.9	50.0	0.0126	3.074	0.026	0.978	
M. surmuletus	Both	1149	14.4	0.23	4.6	34.4	0.0069	3.219	0.008	0.992	0.1728
	Males	90	19.6	0.33	12.8	27.2	0.0125	3.002	0.086	0.933	
	Females	374	23.0	0.27	8.5	34.4	0.0097	3.111	0.023	0.974	
P. phycis	Both[b]	42	43.3	1.54	11.1	59.5	0.0069	3.135	0.044	0.992	
P. saltator	Both	58	42.8	3.20	8.6	91.0	0.0091	3.012	0.019	0.998	0.5172

Table 1 (*Continued*)

Species	Sex	Length characteristics					Parameters of the relationship				P
		n	Mean	S.E.	Minimum	Maximum	a	b	S.E. (b)	r^2	
	Males	14	60.2	2.89	46.3	86.0	0.0289	2.725	0.194	0.943	
	Females	22	58.4	2.80	20.1	91.0	0.0538	2.580	0.127	0.953	
S. sarda	Both[b]	31	60.4	2.80	22.0	83.5	0.0176	2.877	0.084	0.976	
S. maderensis	Both	525	11.9	0.09	5.4	17.8	0.0140	3.065	0.024	0.969	0.0562
	Males	184	13.3	0.14	8.4	17.8	0.0161	3.013	0.056	0.941	
	Females	151	11.8	0.14	6.9	15.6	0.0230	2.863	0.053	0.951	
S. notata	Both	225	15.7	0.20	5.1	22.8	0.0153	3.051	0.027	0.982	0.5764
	Males	105	16.9	0.26	10.1	22.8	0.0163	3.035	0.055	0.967	
	Females	106	15.2	0.24	5.1	20.7	0.0175	2.997	0.041	0.981	
S. rivoliana	Both	101	57.4	2.32	10.5	122.8	0.0108	3.058	0.039	0.984	0.2489
	Males	35	62.1	3.30	33.0	98.0	0.0160	2.963	0.059	0.987	
	Females	55	57.6	3.48	29.0	122.8	0.0096	3.086	0.065	0.977	
S. atricauda		385	28.9	0.30	11.6	41.2	0.0076	3.175	0.023	0.980	
S. cretense	Both*	647	34.3	0.37	3.1	52.2	0.0107	3.129	0.010	0.994	0.0026
	Males	273	26.1	0.52	16.1	52.2	0.0127	3.079	0.019	0.990	
	Females	340	34.4	0.47	12.6	49.5	0.0095	3.162	0.019	0.988	
S. viridensis	Both	125	78.5	1.58	19.7	119.0	0.0036	3.016	0.044	0.975	0.1079
	Males	35	75.2	1.72	54.5	98.0	0.0119	2.745	0.173	0.884	
	Females	66	84.8	1.72	66.3	119.0	0.0025	3.096	0.118	0.915	
S. saurus	Both[b]	40	7.4	0.48	5.4	17.8	0.0034	3.332	0.045	0.993	
T. pavo	Both	292	8.8	0.23	1.7	17.9	0.0092	3.111	0.016	0.992	0.0772
	Males	42	12.3	0.43	7.6	17.9	0.0183	2.835	0.060	0.983	
	Females	82	10.6	0.24	7.5	17.1	0.0131	2.967	0.047	0.980	
T. ovatus	Both[b]	221	8.3	0.32	2.6	36.2	0.0122	2.832	0.021	0.988	

* Significant differences ($P<0.05$) between males and females.

[a] All regressions are highly significant (ANOVA for H_0: $\beta=0$ against H_A: $\beta\neq0$; $P<0.001$). *n* is the sample size, mean, standard error, minimum and maximum total length in centimetre, *a* and *b* are the parameters of the equation ($W=a\mathrm{TL}^b$), where W is the total weight (g) and TL is the total length (cm), and r^2 is the coefficient of determination. *P* is the *P*-value for Student's *t*-test comparing the slopes of the regressions for males and females.

[b] Sex not recorded.

year from June 1997 to December 1999. Fish were caught by spear fishing, line and hook and SCUBA hand netting at the islands of Corvo, Santa Maria, Faial and Terceira (Fig. 1). Particular effort was made to collect juveniles, which were obtained from a complementary monthly beach seining program undertaken at Porto Pim Bay, Faial.

Fork length (FL), standard length (SL) and total length (TL) were measured to the nearest millimetre. Individual total weight (*W*) was recorded to the nearest milligram. Weights and lengths were log transformed and the resulting linear relationship fitted by the least squares regression using *W* as the dependent variable. The significance of the regression was assessed by analysis of variance (ANOVA) testing the hypothesis H_0: $\beta=0$ against H_A: $\beta\neq0$ (Zar, 1996). To test for possible significant differences between sexes ($P<0.05$) we used Student's *t*-test for comparison of two slopes (Zar, 1996). *S. atricauda* was excluded from this analysis because it is a simultaneous hermaphrodite. We used analysis of covariance (ANCOVA) to compare more than two slopes (Zar, 1996) when testing for differences in length–weight relationship of fishes caught at Corvo (the north-western island), Faial and Terceira (central islands), and Santa Maria (south-eastern island). All analyses

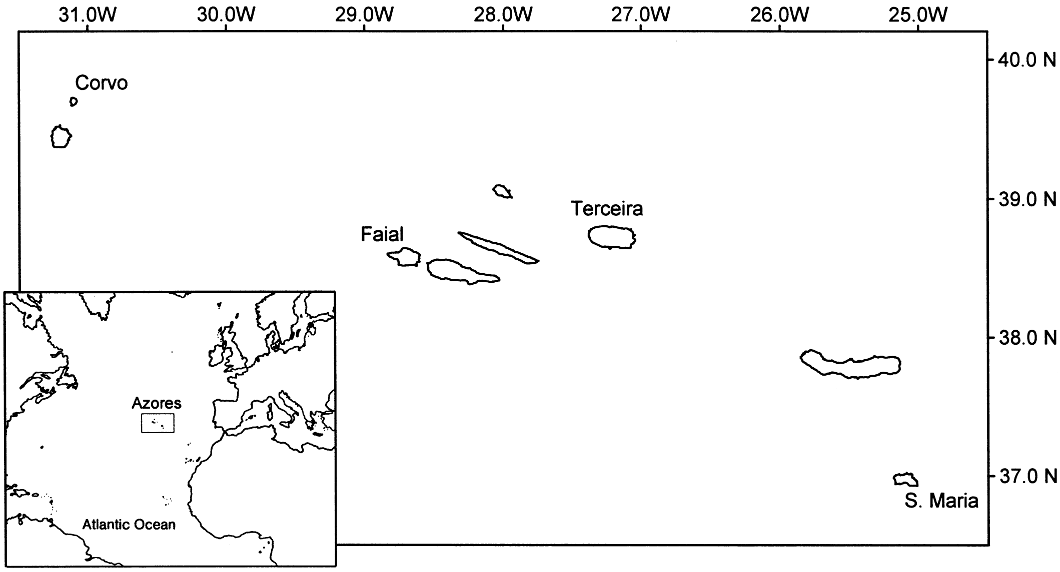

Fig. 1. Location of the Azores archipelago in the north-eastern Atlantic. Sampling was carried out around the islands of Corvo, Santa Maria, Faial and Terceira.

were undertaken using similar size ranges of individuals for each species.

Conversions among length measures can generally be accomplished with simple linear regression models. Therefore, length–length relationships were determined by the method of least squares to fit a simple linear regression model. The significance of the regression was assessed by ANOVA testing the hypothesis H_0: $\beta=0$ against H_A: $\beta\neq0$ (Zar, 1996).

3. Results and discussion

Length statistics obtained for each species are given, along with the estimated parameters of the length–weight relationship and the coefficient of determination r^2 (Table 1). Linear regressions were significant for all species ($P<0.001$), with 43 of 51 r^2 values greater than 0.95. The other eight r^2 values were greater than 0.80. The estimates of the parameter b ranged from 2.58 to 3.44, with a mean b value of 3.03 (S.D.=0.18). Conversions among length measurements are given in Table 2. The length–length regressions were significant ($P<0.001$) for all species, with all r^2 values greater than 0.96.

Pronounced sexual dimorphism in length–weight relationship was observed for *S. cretense* and *C. julis* with significant differences in the slopes of length–weight relationships between males and females. There were no significant differences in slopes

Table 2
Estimated parameters for the conversion between the length measurements (TL, FL and SL in cm) for 21 coastal species of the Azores[a]

Species	Equation	n	r^2	Constant a	Slope b
A. luridus	TL=a+bFL	67	0.9960	0.0239	1.1141
	TL=a+bSL	88	0.9925	−0.4001	1.3513
B. podas	TL=a+bSL	508	0.9972	−0.1641	1.2775
C. limbata	TL=a+bFL	144	0.9880	−0.4374	1.2749
	TL=a+bSL	147	0.9898	−0.3341	1.4948
C. julis	TL=a+bSL	421	0.9883	0.2096	1.2015

Table 2 (*Continued*)

Species	Equation	n	r^2	Constant a	Slope b
E. vipera	TL=a+bSL	49	0.9852	0.0298	1.2055
D. sargus	TL=a+bFL	1109	0.9963	0.1981	1.0935
	TL=a+bSL	1171	0.9978	0.2024	1.2828
G. guttatus	TL=a+bSL	124	0.9787	0.3408	1.1341
L. bergylta	TL=a+bSL	355	0.9802	0.5802	1.2234
M. surmuletus	TL=a+bFL	1126	0.9974	0.0270	1.1155
	TL=a+bSL	1142	0.9964	−0.0103	1.2723
P. phycis	TL=a+bSL	42	0.9964	0.9523	1.1231
P. saltator	TL=a+bFL	58	0.9964	−0.1873	1.0975
	TL=a+bSL	56	0.9962	0.5740	1.2274
S. sarda	TL=a+bFL	23	0.9916	3.3484	1.0288
	TL=a+bSL	31	0.9917	4.4716	1.0936
S. maderensis	TL=a+bSL	525	0.9703	0.5572	1.1992
S. notata	TL=a+bSL	225	0.9851	0.0305	1.3058
S. rivoliana	TL=a+bFL	33	0.9971	0.3970	1.1090
	TL=a+bSL	101	0.9741	4.4872	1.1477
S. atricauda	TL=a+bSL	381	0.9863	0.7592	1.1686
S. cretense	TL=a+bSL	639	0.9902	0.1756	1.2439
S. viridensis	TL=a+bFL	44	0.9614	1.0467	1.0733
	TL=a+bSL	125	0.9767	2.0862	1.1437
S. saurus	TL=a+bFL	39	0.9975	0.0225	1.0631
	TL=a+bSL	40	0.9932	0.1821	1.1284
T. pavo	TL=a+bFL	213	0.9916	−0.9687	1.1138
	TL=a+bSL	291	0.9885	−0.1065	1.2724
T. ovatus	TL=a+bFL	219	0.9960	−0.4750	1.2306
	TL=a+bSL	221	0.9955	−0.3597	1.3910

[a] All regressions are highly significant (ANOVA for H_0: $\beta=0$ against H_A: $\beta\neq0$; $P<0.001$), n is the sample size and r^2 the coefficient of determination.

Table 3
Test for differences in slopes of the length–weight relationship for fish species caught at different islands[a]

Species	Santa Maria		Faial		Corvo		Covariance analysis	
	n	b_1	n	b_2	n	b_3	F	P
D. sargus	141	3.026	537	3.067	153	3.094	1.143	0.319482
L. bergylta	39	2.959	281	3.046	34	2.748	2.379	0.094175
M. surmuletus	118	3.174	1012	3.221	19	3.041	1.378	0.252559
S. maderensis	102	3.125	314	3.031	109	3.004	1.150	0.317570
S. atricauda	106	3.103	247	3.134	32	3.048	0.379	0.684994
S. cretense	204	3.077	321	3.201	115	3.058	13.163	0.000003

[a] n is the sample size, b the regression slope. Covariance analysis for H_0: $\beta_1 = \beta_2 = \beta_3$.

between males and females in any of the other species.

Significant differences in length–weight relationships between islands were found only for *S. cretense* (Table 3). The observed difference could be due to the sampling procedure, namely sample size and length range. However, the sample of *S. cretense* was relatively large and covered a reasonable size range, suggesting that the differences in slope could reflect the influence of differences in environmental or habitat factors. For example, differences in the water thermal regime are known to influence fish growth (Jobling, 1997). If this is true, differences in length–weight relationship among different islands could also be expected for the other five species, which does not appear to be the case. However, a conclusive comparative analysis requires information on growth rates and length-at-age in the different sub-samples, as well as data on mean water temperature in the different islands. Furthermore, such analysis should be placed in the broader context of each species distribution range, benefiting from the comparison with similar studies from other geographical areas (e.g. Pérez and Contreras, 1995; Petrakis and Stergiou, 1995; Gonçalves et al., 1997). This aspect does warrant further study.

Acknowledgements

Financial support was given by the Fundação da Ciência e Tecnologia through the PRAXIS/3/3.2/EMG/1957/95 project, and PRAXIS grants GGPXXI/BIC/1938/96 to TM and GGPXXI/BIC/1930/96 to PA. We wish to thank several volunteers for their help in data collection, namely Jorge Fontes, Miguel Machete, Fernando Tempera, Frederico Cardigos, Octávio Melo, Ana Fernandes, Filipa Gomes, José Branco, Carmelina Leal, Fátima Mendes, Victor Rosa, Paulo Martins, Noberto Serpa and Marco Rosa.

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