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Length-weight relationships for 21 fish species caught in the Argolikos Gulf (central Aegean Sea, eastern Mediterranean)

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Abstract: The length-weight relationship for both sexes of 21 fish species caught in Argolikos Gulf (central Aegean Sea, eastern Mediterranean), using a variety of fishing gear, was estimated for the first time. Fishing took place between August 2007 and August 2008, and the fishing gear used included gill and trammel nets, long lines, and beach seines from 58 inshore fishing vessels. Individuals caught by trammel nets were usually longer and heavier than those collected by other fishing gear. The allometric coefficient (b) for the majority of species (59%) was statistically significantly higher than 3.0, indicating positive allometry between length and weight in most species. The data obtained in the present study could serve as a useful tool in future studies in the wider study area and as a future reference for comparisons of similar parameters estimated in other Mediterranean areas.

Key words: Argolikos Gulf, fishing gear, growth, allometry

Introduction

Length and weight data provide a very useful tool for estimating growth rates, length, and age structures and for the improvement of the knowledge regarding fish population dynamics (Froese, 2006). Length-weight relationships drastically help scientists to convert growth-in-length equations to growth-in-weight in stock assessment models (Stergiou and Moutopoulos, 2001), to estimate biomass from length frequency data, and to estimate fish conditions (Petrakis and Stergiou, 1995). In addition, these relationships contribute to the comparison of life history and morphological aspects of populations among different areas (Stergiou and Moutopoulos, 2001). The present study is based on data collected in the frame of the project “Study of the fishing viability

of the Argolikos Gulf” (Operational Program for Fisheries Sector, 2000-2006). The aim was to estimate the length-weight relationship of 21 fish species caught in the Argolikos Gulf using various fishing gear.

Materials and methods

The Argolikos Gulf is a relatively shallow open gulf located in the central Aegean Sea. The total fishery production of the Argolikos Gulf, including marine fisheries, lagoons, and aquaculture, is around 8500 t annually and has remained relatively constant in the past few years (Source: Prefectural Administration of Argolis). The majority of the registered vessels in the area are small (smaller than 12 m) inshore fishing

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vessels (mainly netters and long-liners); only a very small fraction belong to medium-scale fishery (1.43% purse seines, 1% trawlers).

All data used to evaluate the length-weight relationships in the present study were derived from commercial surveys of the Argolikos Gulf. Fish samples were collected between August 2007 and August 2008, on an almost daily basis, from 58 vessels using gill nets (mesh bar length: 14-32 mm), trammel nets (mesh bar length: 14-34 mm), long lines (hook size: 7-16), and beach seines (mesh bar size at cod-end: 12 mm).

The total length of 2363 specimens was measured using a 0.1-mm class interval and total weight (W) was measured to the nearest 0.01 g. Statistically significant differences between sexes in terms of length and weight were obtained using a t-test. The relationship between length and weight is usually expressed by $W = aL^b$ (Le Cren, 1951), which was logarithmically transformed as follows: $\log W = \log a + b \log L$, where W is the total weight (g), L is the total length (cm), a is the intercept, and b is the slope of the curve. If the coefficient b is larger or smaller than 3.0, there is indication of allometric growth (Bagenal and Tesch, 1978). Specifically, values of b greater than 3 indicate a positive allometric growth and values lower than 3 indicate negative allometric growth. When b equals 3.0, isometric growth is indicated. The t-test was used to account for whether the value of the regression slope (b) was significantly different from 3.0. The nonparametric Mann-Whitney test was performed to test significant differences between sexes. In order to test any statistically significant differences for slopes between different fishing gear, species, and sex, analysis of covariance (ANCOVA) was performed at the significance level of $P = 0.05$.

Results

The total length and weight ranges for the sexes of 21 fish species, both separately and combined and using a variety of fishing gear, are presented in Table 1. The female individuals of *Boops boops*, *Diplodus annularis*, *Engraulis encrasicolus*, *Mullus barbatus*, *Pagellus acarne*, *Scorpaena porcus*, and *Uranoscopus scaber*, caught by trammel nets, were statistically larger and heavier than their male counterparts

(Mann-Whitney test, $P < 0.05$). On the contrary, males of *Pagellus erythrinus* and *Spicara flexuosa* collected by trammel net were statistically larger than the females (Mann-Whitney test, $P < 0.05$). It is worth noting that male *B. boops* caught by gill nets were larger than females (Mann-Whitney test, $P < 0.05$).

The total estimated parameters of the length-weight relationship by sex, independently of gear used, are given in Table 2. Values of the allometric coefficient (b) ranged from 1.81 for *Solea vulgaris* females to 3.69 for *Chromis chromis* and *Diplodus puntazzo* males. The values of the allometric coefficient (b) for all species were in most cases (59%) significantly higher than 3.0, indicating positive allometry in many species and both sexes (Table 2). Negative allometric growth was indicated for females and males separately of *Engraulis encrasicolus*, *Pagellus erythrinus*, and *Solea vulgaris*; females of *Boops boops*, *Chromis chromis*, *Diplodus puntazzo*, *Spicara smaris*, and *Spondyliosoma cantharus*; and males of *Merluccius merluccius*, *Pagellus acarne*, *Sardinella aurita*, and *Spicara cabrilla*. Both sexes of *Spondyliosoma cantharus* presented an isometric growth pattern.

Analysis of covariance indicated that the slopes (b) of the regression lines attributed to the different fishing gear statistically differed for both sexes of *Boops boops* and *Mullus barbatus* and for the females of *Pagellus erythrinus*, 3 of the most commercial species in the Greek seas (ANCOVA, $P < 0.05$) (Table 3).

Discussion

This is the first estimation of the length-weight relationships between sex and fishing gear for 21 fish species caught in the Argolikos Gulf. Since all of the fishes were collected during a 1-year period and were combined, results do not represent the data of a specific season. According to Weatherley and Gill (1987), the annual length-weight relationships could differ between seasons and years and many factors could contribute to these differences, namely maturity, temperature, salinity, food availability, and size. The length-weight relationship may vary seasonally according to the degree of sexual maturity,

Table 1. Total length and weight range for both sexes of 21 fish species caught in the Argolikos Gulf (central Aegean Sea) using a variety of fishing gear. n = number of samples, F = female, M = male, SB = beach seine, GTR = trammel nets, GND = gill nets, LLS = long lines, * indicates statistically significant difference between sexes.

Species	Gear	Sex	n	Range of total length, mm	Range of total weight, g
<i>Boops boops</i>	SB	F	31	40-150	9-30
		M	12	13-107	9-61
	GTR	F	116	121-349*	17-493
		M	77	116-241	22-161
	GND	F	19	140-160*	27-38*
		M	26	142-162	26-41
<i>Chromis chromis</i>	GTR	F	14	81-106	8-18
		M	16	89-99	12-14.8
<i>Diplodus annularis</i>	GTR	F	68	91-241*	11-113*
		M	94	82-192	10-124
<i>Diplodus puntazzo</i>	GTR	F	14	192-239	108-209
		M	15	181-200	82-119
<i>Engraulis encrasicolus</i>	GTR	F	28	105-135*	7-17*
		M	18	107-13	8-14
<i>Merluccius merluccius</i>	SB	F	12	270-305	145-217
		M		No data exist	
	GTR	F	14	198-283	45-167
		M	27	146-283	97-170
<i>Mullus barbatus</i>	SB	F	14	127-153	20-40
		M	17	107-147	13-34
	GTR	F	307	121-195*	20-98*
		M	81	111-164	14-55
<i>Pagellus acarne</i>	GTR	F	12	148-185*	40-88*
		M	29	132-160	32-55
<i>Pagellus erythrinus</i>	SB	F	14	117-223	21-150
		M		No data exist	
	GTR	F	433	71-262*	14-232*
		M	138	105-268	15-235
LLS	F	16	169-208	56-109	
	M		No data exist		
<i>Sardinella aurita</i>	GTR	F	64	150-247	22-137
		M	65	147-228	18-80

Table 1. (Continued).

<i>Scorpaena porcus</i>	GTR	F	30	106-210*	23-243*
		M	15	116-155	31-74
<i>Serranus cabrilla</i>	GTR	F	17	120-175	20-64
		M	14	117-171	21-62
<i>Serranus scriba</i>	GTR	F	52	100-205	13-136
		M	12	112-218	18-153
<i>Solea vulgaris</i>	GTR	F	31	119-280	38-210
		M	44	130-275	21-151
<i>Sphyræna sphyræna</i>	SB	F	17	221-405	47-272
		M		No data exist	
<i>Spicara flexuosa</i>	GTR	F	69	104-164*	11-58*
		M	96	121-184	19-75
<i>Spicara maena</i>	GTR	F		No data exist	
		M	14	135-176	27-58
<i>Spicara smaris</i>	SB	F	47	89-139	7-23
		M		No data exist	
<i>Spondyliosoma cantharus</i>	GTR	F	12	138-171	40-79
		M	24	133-152	37-56
<i>Trachurus mediterraneus</i>	SB	F	17	127-154	15-31
		M		No data exist	
<i>Uranoscopus scaber</i>	GTR	F	28	187-273*	113-409*
		M	33	140-222	40-216

sex, diet, stomach fullness, sample preservation techniques (Wootton, 1990), number of specimens examined, area/season effects, and sampling duration (Moutopoulos and Stergiou, 2002). The majority of the allometric coefficient (b) values calculated in the present study were between 2 and 4, in agreement with the findings of Moutopoulos and Stergiou (2002). The observed differences between allometric coefficient (b) values could be attributed to the different fishing gear used. For example, both sexes

of *B. boops* and *M. barbatus* caught by beach seines and *P. erythrinus* females caught by trammel nets presented significantly lower mean lengths compared to the same fish species caught by other types of fishing gear (Tables 1 and 3). The data obtained in the present study could potentially serve as a useful tool in ongoing fishery studies with regard to fisheries management in the area and as a future reference for comparison of similar parameters estimated in other Greek or Mediterranean areas.

Table 2. Total length-weight relationships by sex (C.S. = combined sexes) of fish species caught in the Argolikos Gulf (central Aegean Sea); a = intercept, b = slope of the relationship, SE = standard error of b, r = correlation coefficient, P.A. = positive allometry, N.A. = negative allometry, F = female, M = male.

Species	Sex	a	b	SE (b)	r	t-test	Allometry
<i>Boops boops</i>	F	0.0002	2.38	0.12	0.85	-14.02	N.A.
	M	0.000001	3.36	0.07	0.98	5.78	P.A.
	C.S.	0.00006	2.61	0.09	0.88	-43.72	N.A.
<i>Chromis chromis</i>	F	0.00003	2.84	0.28	0.99	-26.42	N.A.
	M	0.000006	3.69	0.11	0.99	89.07	P.A.
	C.S.	0.00009	2.60	0.29	0.95	-34.66	N.A.
<i>Diplodus annularis</i>	F	0.00001	3.01	0.14	0.93	8.24	P.A.
	M	0.000005	3.23	0.06	0.98	371.65	P.A.
	C.S.	0.000008	3.13	0.06	0.97	156.77	P.A.
<i>Diplodus puntazzo</i>	F	0.00001	2.99	0.09	0.99	-0.04	N.A.
	M	0.000003	3.69	0.11	0.99	89.07	P.A.
	C.S.	0.00001	3.03	0.21	0.98	23.56	P.A.
<i>Engraulis encrasicolus</i>	F	0.00001	2.82	0.34	0.85	-15.87	N.A.
	M	0.000009	2.92	0.28	0.93	-4.24	N.A.
	C.S.	0.000005	3.02	0.22	0.90	5.08	P.A.
<i>Merluccius merluccius</i>	F	0.0000007	3.42	0.27	0.96	56.78	P.A.
	M	0.000009	2.92	0.28	0.93	4.24	N.A.
	C.S.	0.00005	2.91	0.25	0.94	-13.79	N.A.
<i>Mullus barbatus</i>	F	0.000007	3.1	0.005	0.96	27.59	P.A.
	M	0.000005	3.16	0.01	0.91	16.80	P.A.
	C.S.	0.000005	3.16	0.007	0.96	14.82	P.A.
<i>Pagellus acarne</i>	F	0.000009	3.06	0.18	0.98	19.26	P.A.
	M	0.00004	2.75	0.27	0.96	-6.87	N.A.
	C.S.	0.00002	2.88	0.13	0.98	-9.72	N.A.
<i>Pagellus erythrinus</i>	F	0.00002	2.87	0.02	0.96	-19.75	N.A.
	M	0.00002	2.84	0.04	0.95	-300.2	N.A.
	C.S.	0.00002	2.86	0.03	0.96	-123.65	N.A.
<i>Sardinella aurita</i>	F	0.000001	3.32	0.08	0.98	256	P.A.
	M	0.00003	2.71	0.5	0.91	-233.8	N.A.
	C.S.	0.000005	3.05	0.11	0.92	3.58	P.A.
<i>Scorpaena porcus</i>	F	0.000009	3.15	0.19	0.95	27.38	P.A.
	M	0.00001	3.03	0.18	0.98	2.90	P.A.
	C.S.	0.00001	3.13	0.12	0.97	19.5	P.A.

Table 2. (Continued).

	F	0.000008	3.09	0.3	0.93	5.30	P.A.
<i>Serranus cabrilla</i>	M	0.0002	2.39	0.73	0.88	-3.38	N.A.
	C.S.	0.00005	2.71	0.27	0.91	-15.45	N.A.
	F	0.000008	3.08	0.06	0.99	72.11	P.A.
<i>Serranus scriba</i>	M	0.000007	3.12	0.1	0.99	13.85	P.A.
	C.S.	0.000008	3.09	0.05	0.99	81.44	P.A.
	F	0.005	1.81	0.13	0.93	-331.2	N.A.
<i>Solea vulgaris</i>	M	0.0001	2.42	0.08	0.97	-384.7	N.A.
	C.S.	0.004	1.90	0.16	0.81	-366.78	N.A.
<i>Sphyaena sphyaena</i>	F	0.000001	3.16	0.26	0.98	4.23	P.A.
	F	0.000002	3.33	0.11	0.96	274.11	P.A.
<i>Spicara flexuosa</i>	M	0.000007	3.08	0.06	0.98	130.63	P.A.
	C.S.	0.000005	3.13	0.06	0.97	188.65	P.A.
<i>Spicara smaris</i>	F	0.00001	2.88	0.13	0.96	-27.42	N.A.
	F	0.00002	2.94	0.25	0.96	-2.96	N.A.
<i>Spondyliosoma cantharus</i>	M	0.000005	3.20	0.40	0.98	1.45	P.A.
	C.S.	0.00001	3.00	0.20	0.96		Isometry
<i>Trachurus mediterraneus</i>	F	0.000002	3.24	0.004	0.99	24.75	P.A.
	F	0.000008	3.16	0.30	0.97	7.93	P.A.
<i>Uranoscopus scaber</i>	M	0.0000006	3.64	0.05	0.99	214.17	P.A.
	C.S.	0.0000009	3.56	0.07	0.99	197.23	P.A.

Table 3. Values of F for slopes (b) and associated probability P of ANCOVA test for males and females of different fish species caught using a variety of fishing gear in the Argolikos Gulf (central Aegean Sea); * indicates $P < 0.05$.

Species	Sex	F-value	P
<i>Boops boops</i>	F	6.21	0.002*
	M	21.65	0.00*
<i>Merluccius merluccius</i>	F	2.60	0.109
<i>Mullus barbatus</i>	F	4.90	0.008*
	M	3.59	0.030*
<i>Pagellus erythrinus</i>	F	28.84	0.000*

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