Biological Parameters, Body Length-Weight and Length-Height Relationships for Various Species in Greek Waters

K.I. STERGIOU AND C.-Y. POLITOU

Abstract

In the present study, we present biological/fisheries parameters (L_∞, M, F) for four fish species as well as body length-weight and length-height relationships for 11 and 12 fish species, respectively, estimated from trawl samples collected using three different cod-ends (stretched mesh size: 14 mm and 20 mm diamond-shaped and 20 mm square-shaped) during 1993-1994, in the western Aegean and North Euboikos Gulf, Greece. The fisheries parameters, estimated from length-frequencies using the ELEFAN approach and software, are discussed in the light of recent information on the selectivity of the presently used trawl cod-end (14 mm diamond-shaped).

Introduction

In the present work we present: a) biological/fisheries parameters (von Bertalanffy L_∞, instantaneous natural, fishing and total mortalities, M and F, and Z) for four fish species, estimated from length-frequencies using the ELEFAN approach and software; b) length-weight relationships for 11 species; and c) body length-height relationships for 12 fish species. The importance of the knowledge of the relationship between body length and weight for a species in a given geographic region has been stressed elsewhere (e.g., Gulland 1983; Pauly 1993; Petrakis and Stergiou, in press). In addition, Stergiou et al. (1994) have shown that trawl cod-end selectivity parameters are significantly related to body shape, the latter expressed as body length/height ratio: L_{50} selection factor and selection range are all significantly ($P<0.05$) related to body length/height ratio.

Materials and Methods

Sampling took place at five stations in the Trikeri Channel (western Aegean Sea: *st* 1 to 5; Fig. 1) on 1-6 October 1993 and at seven stations in the North Euboikos Gulf (*st* 6 to 12; Fig. 1) on 18-27 March 1994. Sampling was conducted with a chartered professional trawler (length = 26.3 m; two 250 HP-engines). Sampling took place during daylight at depths ranging between 73 and 170 m (*st* 1:84; *st* 2:93 m; *st* 373 m; *st* 4:170 m; *st* 5:101 m) in the Trikeri Channel and between 73 and 210 m (*st* 6:91 m; *st* 7:7 m; *st* 8:80 m; st 9:210 m st 10:174 m; st 11:115 m; st 12:119 m) in the North Euboikos Gulf. The duration of the hauls ranged between 45 and 60 min, on October 1993, and between 60 and 105 min, on March 1994. In all cases, the towing speed was 3 knots.

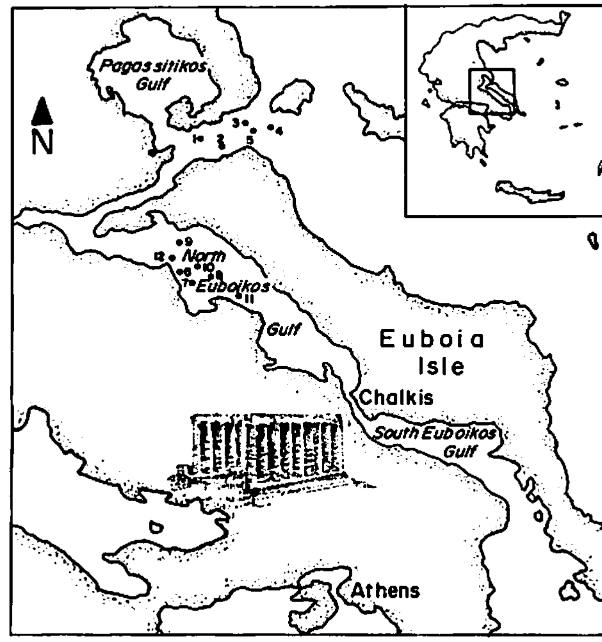

Fig. 1. *Map showing location of sampling stations.*

Sampling was conducted using three different cod-ends, 14 mm (knot-to-knot) diamond-shaped (14D), 20 mm square-shaped (20S) and 20 mm diamond-shaped (20D) mesh size cod-ends. All three cod-ends were covered by multi-monofilament diamond-shaped net of 10 mm (knot-to-knot) mesh size that was used in order to retain the specimens escaping from the three cod-ends. After each haul, the catches of the cod-end and cover were removed and sorted completely into species. The total number and weight per species caught and the individual length (fork length, FL, for *Mullus barbatus*, total length, TL, for the remaining fish species; carapace length, CL, for *Nephrops norvegicus*; all to the nearest mm) and gross weight (W, to the nearest g) of a large subsample of the target species (when the number of individuals was >150) were measured either onboard or in the laboratory. In addition, in March 1994, the maximum body height (H; to the nearest mm) of a subsample for 12 species was also measured onboard (for flatfish and *Lophius* spp., H refers to width).

Results and Discussion

Length-Weight Relationships

Length-weight regressions are presented for nine species caught in the Trikeri Channel in October 1993 and for seven species caught in the North Euboikos Gulf in March 1994 (Table 1). Least-square regressions of weight (g) on length (cm, TL) were derived after log transformation of two variables (log W = log a + b log L).

The sample size (N), and the minimum and maximum lengths used in the analysis for each species as well as the coefficient a and the exponent b of the weight-length relationships ($W = aL^b$), the standard error of the exponent, and the coefficient of determination r^2 are presented in Table 1. In October 1993, the r^2 values ranged from 0.61 for *Symphurus ligulatus* to 0.98 for *Zeus faber*, and all regressions were significant (P<0.01). The values of b ranged from 1.77 for *Cepola macrophthalma*, to 3.45 for *Citharus linguatula*.

In March 1994, r^2 values ranged from 0.82 for *Gadiculus argenteus argenteus* to 0.99 for *Lophius budegassa*, and all regressions were significant (P<0.01). The values of b ranged from 2.16 for *C. macrophthalma*, to 3.29 for *Lepidorhombus boscii*. Limiting the application of these regressions to the length range of the observed values is strongly advised.

Length-Height Relationships

The relationship between length L and H was expressed by a linear regression (H = a+bL; Table 2). The r^2 values of the H-L regressions were high and ranged between 0.76 for *Trachurus mediterraneus*, and 0.98 for *L. budegassa* and *L. boscii*, with the exception of that for *Gaidropsarus mediterraneus* (r^2=0.42). All regressions were significant (P<0.001). The values of the slope ranged between b = 0.03, for *C. macrophthalma*, and b = 0.38, for *L. budegassa*.

One-way ANOVA indicated significant differences (F = 747.7, P<0.0001) in the mean L/H ratio (Fig. 2) between species (Table 3). The homogeneous groups in terms of mean L/H, defined using LSD at the 0.05 level, are shown in Table 3. *C. macrophthalma* is characterized by the highest mean L/H ratio, followed by *G. mediterraneus* (Table 3). *Micromesistius poutassou*, *Merluccius merluccius* and *Eutrigla gurnardus* followed. The mean L/H ratio did not differ significantly (P>0.05) between *Trachurus trachurus*, *G. argenteus* and *Trachurus mediterraneus*, whereas the mean L/H ratio of *Mullus barbatus* did not differ significantly (P>0.05) from that of *Trisopterus minutus*. Finally, *L. budegassa*, followed by *L. boscii*, had the significantly (P<0.05) lowest mean L/H ratios (Table 3 and Fig. 2).

Table 1. Length-weight relationships ($W = aL^b$; g, cm) for various species caught in October 1993 and March 1994. SE (b) = standard error of b; r^2=coefficient of determination; N = number of fish measured.[a]

Species	a	b	SE(b)	r^2	N	L_{min}	L_{max}
October 1994							
Citharus linguatula	0.00074	3.447	0.137	0.82	141	59	220
Cephola macrophthalma	0.98718	1.765	0.036	0.90	256	95	516
Eutrigla gurnardus	0.01670	2.793	0.243	0.69	61	56	161
Gaidropsarus mediterraneus	0.00401	3.078	0.119	0.72	266	53	166
Lophius budegassa	0.03045	2.889	0.097	0.88	117	133	530
Micromesistius poutassou	0.00194	3.223	0.051	0.94	263	123	254
Nephros norvegicus	0.92291	2.913	0.071	0.86	275	11	55
Symphurus ligulatus	0.00296	3.194	0.305	0.61	73	63	108
Zeus faber	0.04187	2.840	0.795	0.98	28	81	492
March 1994							
Cepola macrophthalma	0.0814	2.163	0.077	0.94	49	163	620
Eutrigla gurnardus	0.0044	3.081	0.086	0.95	73	83	258
Gadiculus argenteus	0.0048	3.096	0.099	0.82	209	57	129
Gaidropsarus mediterraneus	0.0028	3.118	0.098	0.87	147	96	182
Lepidorhombus boscii	0.0017	3.285	0.032	0.98	219	57	371
Lophius budegassa	0.0305	2.850	0.046	0.99	38	59	574
Nephros norvegicus	0.4701	3.085	0.055	0.94	221	16	68

[a]FL for *Mullus barbatus*, TL for all remaining fish species; CL for *Nephrops norvegicus*.

Table 2. Length-height relationships (H = a+bL; both in mm) for 12 species caught in March 1994. r^2 = coefficient of determination, N = number of fish measured.[a]

Species	a	b	r^2	N	L_{min}	L_{max}
Cepola macrophthalma	10.78	0.03	0.80	135	149	662
Eutrigla gurnardus	-0.57	0.17	0.94	137	83	258
Gadiculus argenteus	-2.61	0.22	0.91	101	57	129
Gaidropsarus mediterraneus	0.94	0.11	0.42	103	98	180
Lophius budegassa	-1.52	0.38	0.98	43	59	574
Lepidorhombus boscii	-8.79	0.37	0.98	111	60	371
Mullus barbatus	-7.03	0.27	0.89	135	101	212
Merluccius merluccius	-8.02	0.18	0.96	109	81	644
Micromesistius poutassou	-2.35	0.15	0.94	157	66	312
Trisopterus minutus	-10.45	0.31	0.97	103	93	297
Trachurus mediterraneus	-2.69	0.21	0.76	41	73	141
Trachurus trachurus	-3.68	0.23	0.88	44	67	206

[a]FL for *Mullus barbatus*, TL for all remaining fish species; CL for *Nephrops norvegicus*.

Biological/fisheries parameters

The biological/fisheries parameters (von Bertalanffy L_∞ and K instantaneous natural and fishing mortalities, M and F) of *G. argenteus*, *G. mediterraneus*, *S.*

Table 3. Mean length/height ratio (L/H) and standard deviation (SD) for 12 species caught in the study area, March 1994.

Species	*L/H	SD
Cepola macrophthalma[1]	16.56	3.21
Gaidropsarus mediterraneus[2]	8.91	1.26
Micromesistius poutassou[3]	7.52	2.18
Merluccius merluccius[4]	7.04	1.05
Eutrigla gurnardus[5]	6.27	0.43
Trachurus trachurus[6]	5.44	0.71
Gadiculus argenteus[6]	5.37	0.42
Trachurus mediterraneus[6]	5.09	0.35
Mullus barbatus[7]	4.55	0.48
Trisopterus minutus[7]	4.22	0.40
Lepidorhombus boscii[8]	3.24	0.28
Lophius budegassa[8]	2.63	0.18

*The results of the LSD test are also shown: species with the same superscript number do not differ significantly (P>0.05) in terms of mean L/H.

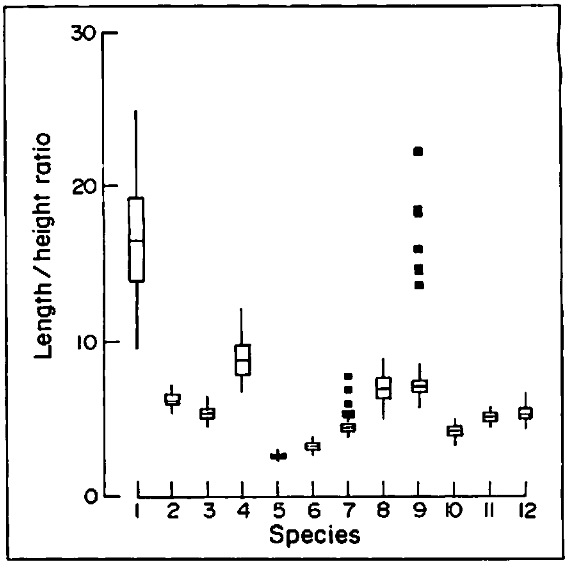

Fig. 2. *Box-Whiskers plots of the length/height ratio for 12 species caught in the North Euboikos Gulf, March 1994. The central box encloses the middle 50% of the values, the horizontal line inside the box shows the median value of the data, the vertical lines extending from each end of the box (i.e., whiskers) enclose 75% of the values, whereas outliers are marked by a small black square.* 1 = Cepola macrophthalma, 2 = Eutrigla gurnardus, 3 = Gadiculus argenteus, 4 = Gaidropsarus mediterraneus, 5 = Lophius budegassa, 6 = Lepidorhombus boscii, 7 = Mullus barbatus, 8 = Merluccius merluccius, 9 = Micromesistius poutassou, 10 = Trisopterus minutus, 11 = Trachurus mediterraneus, *and* 12 = Trachurus trachurus.

Table 4. Summed length-frequency distributions (all cod-ends combined) of the four fish species caught in the study areas, October 1993 (10/93) and/or March 1994 (3/94). ML = midtotal length, in mm.

Symphurus ligulatus		*Gaidropsarus mediterraneus*			*Gadiculus argenteus*			*Lepidorhombus boscii*	
ML	10/93	ML	10/93	3/94	ML	10/93	3/94	ML	10/93
45	1	60	3	0	30	1	1	55	2
50	2	70	19	1	35	2	4	65	8
55	6	80	167	0	40	2	2	75	15
60	7	90	326	0	45	2	5	85	43
65	31	100	232	7	50	16	3	95	53
70	46	110	181	25	55	73	19	105	33
75	111	120	194	91	60	124	44	115	16
80	171	130	173	181	65	132	140	125	4
85	240	140	74	167	70	131	197	135	8
90	189	150	31	109	75	103	198	145	30
95	229	160	6	62	80	19	139	155	50
100	95	170	2	37	85	2	156	165	94
105	85	180		12	90	0	101	175	75
110	18	190		8	95	5	117	185	38
115	6	200		1	100	1	117	195	31
120	1	210		1	105		134	205	17
					110		145	215	21
					115		125	225	6
					120		91	235	13
					125		48	245	4
					130		23	255	3
					135		5	265	2
					140		3	275	4
								285	2
								295	0
								305	2
								315	2
								325	0
								335	1
								345	0
								355	2
								365	0
								375	1
Total	1,238		1,408	701		613	1,817		578

ligulatus and *L. boscii*, estimated from the summed length-frequencies from all cover and test cod-ends (Table 4) using ELEFAN, are shown in Table 5. The total number of individuals caught per species was high and the use of the 10 mm cover resulted in a relatively high number of small individuals caught. These two facts are generally considered essential for the estimation of biological parameters from length data.

There was very good agreement between the results of the various methods and the values of the ELEFAN goodness-of-fit index (R_n) were generally high, ranging from 0.32, for *G. argenteus argenteus*, to 0.67 for *G. mediterraneus* (Table 5). The estimated M values were also generally high (1.18 $year^{-1}$ for *S. ligulatus*, 0.94^{-1} year for *G. mediterraneus*, 0.61 $year^{-1}$ for *G. argenteus*, and 0.48 $year^{-1}$ for *L. boscii*). In addition, all F values estimated (from Z-M) were higher than the corresponding M values (Table 5), a fact indicating that in the study areas the populations of the above-mentioned noncommercial species are overexploited. Experimental trawl surveys undertaken in the same areas in 1987-1988 indicate that the main

Table 5. Biological/fisheries parameters (von Bertalanffy L_∞ in cm, and K, in year^{-1}; instantaneous natural and fishing mortalities (M, F year^{-1}) of four noncommercial species in the study areas, estimated from the summed length-frequencies from all cover and test cod-ends using various routines of ELEFAN i.e., response surface analysis (RSA), automatic search routine (ASR), Wetherall plot (WP), and length-converted catch curve (CC).

Species	RSA			ASR			WP		Z	M	F
	L_∞	K	R_n	L_∞	K	R_n	Z/K	L_∞			
Gadiculus argenteus	162	0.25	0.321	162	0.25	0.321	6.19	162	1.43	0.61	0.82
Gaidropsarus mediterraneus	270	0.60	0.670	270	0.60	0.670	7.98	270	4.82	0.94	3.86
Symphurus ligulatus	129	0.65	0.328	127	0.62	0.425	4.10	129	2.68	1.18	1.50
Lepidorhombus boscii	433	0.26	0.664	430	0.27	0.664	2.90	436	1.47	0.48	0.99

	Wehterall plots[a]		CC regressions[b]	
Gadiculus argenteus argenteus	$\bar{L}$-L' = 22.53-0.139L'	r = -0.93	ln(N/Δt) = 8.52-1.43t'	r = -0.98
Gaidropsarus mediterraneus	$\bar{L}$-L' = 30.10-0.111L'	r = -0.96	ln(N/Δt) = 8.41-4.82t'	r = -0.99
Symphurus ligulatus	$\bar{L}$-L'=25.21-0.199L'	r = -0.98	ln(N/Δt) = 8.66-2.68t'	r = -0.99
Lepidorhombus boscii	$\bar{L}$-L'=111.7-0.256L'	r = -0.93	ln(N/Δt) = 3.93-1.47t'	r = -0.89

[a] $\bar{L}$ is the mean length of individuals with length >L'; L' is the length at which all individuals are fully represented in the sample.
[b] N is the number of individuals with lengths between L_1 and L_2 corresponding to ages t_1 ... t_2, Δt (= t_2-t_1) is the time required for an individual to grow from length L_1 to L_2, and t is the relative age corresponding to length (L_2-L_1)/2.

commercial, demersal stocks are also overfished (Papaconstantinou et al. 1989).

The fact that in the study area the populations of noncommercial species such as *S. ligulatus, G. mediterraneus* and *G. argenteus*, are overfished is not unexpected because of the multispecies nature of the Greek (and the Mediterranean) trawl fishery, the catch of which is composed of many species differing in their body shapes and sizes (e.g., from small 5-6 cm Gobiidae to very large rays), a large part of which is discarded. Indeed, recent estimates indicate that trawlable discards in Greece amount to about 45% of the total trawl catch (Tsimenides et al. 1994). In addition, selectivity experiments in the study area (Stergiou et al. 1994) show that 14D is not selective for all species mentioned here and, in absolute numbers and weights, 14D, when compared with 20D and 20S, is the least efficient; it catches a very large quantity of noncommercial species, whereas the weight of the commercial ones caught is very low. This clearly shows that although the use of a single appropriate mesh size for the Greek trawl fishery as a whole is impossible because of its multispecies nature, the presently used 14D must be urgently increased. It must be pointed out that the replacement of 14D by either 20D or 20S will not be accompanied by any significant commercial loss inasmuch as the majority of the individuals escaping through the meshes of 20D and 20S are undersized (i.e., ≤ minimum legal landing size); yet, the amount of discards will be significantly reduced (Stergiou et al. 1994).

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K.I. STERGIOU *and* **C.-Y. POLITOU** *are from the National Centre for Marine Research, Agios Kosmas, Helleniko, 16604 Athens, Greece.*