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A review of various biological parameters for fish from the Greek Seas

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In this paper, various biological parameters for 142 fish stocks (i.e., maximum observed length and age, L_{max} and t_{max}, for 117 and 57 stocks, respectively; von Bertalanffy growth parameters, K and L_∞, for 72 stocks, and t_o, for 58 fish stocks) from the Greek Seas were collected. These stocks belong to 46 fish species. Significant relationships between the parameters K and L_∞, K and t_{max}, and L_{max} and L_∞ for all Greek stocks for which such data are available, using the original reported length, and after transformation of various types of length to total length, were also identified. These relationships can be used to estimate K and L_∞ from t_{max} and L_{max} respectively, for either rare fish species or for species for which such information is not available, provided that their t_{max} and L_{max} are within the range of these used for the development of the regressions.

Key words: fishes, life history, maximum length, maximum age, growth parameters, Aegean and Ionian Seas.

INTRODUCTION

The global increase of information exchange through the World Wide Web has mediated the development of various online databases, with FishBase (Froese & Pauly, 2005; www.fishbase.org) being the largest one for fish. FishBase, along with other ecological tools also available online (e.g. Ecopath with Ecosim: www.ecopath.org), has greatly contributed to the fisheries science. This is because (i) it transforms available information into knowledge (Stergiou & Karpouzi, 2002), and (ii) it allows testing life history theories and provides the opportunity to obtain preliminary estimates of various parameters from other already available ones (Froese & Binohlan, 2000, 2003). For instance, the von Bertalanffy (1938) K and L_∞ growth parameters as well as the maximum reported length and age, L_{max} and t_{max}, respectively, being essential for the development of a variety of fisheries models and the management of fisheries resources, can also be used for the indirect estimation of other parameters using existing empirical equations (Froese & Pauly, 2000; Froese & Binohlan, 2000, 2003). Examples of indirectly estimated parameters include: (i) natural mortality from growth parameters (Pauly, 1980) or from t_{max} (Hoenig, 1983), (ii) length at first maturity from L_∞ and/or K (Froese & Binohlan, 2000), (iii) age at first maturity from t_{max} (Froese & Binohlan, 2000), (iv) optimum exploitation length from L_∞ or length at first maturity (Froese & Binohlan, 2000), (v) trophic level from L_{max} (Stergiou & Karpouzi, 2002; Froese & Pauly, 2005), (vi) mouth size from L_{max} (Karpouzi & Stergiou, 2003), and (vii) tail area from L_{max} (Karachle & Stergiou, 2005).

In particular, L_{max}, which is the most important demographic parameter, being related with almost every other parameter of the species (e.g. weight, fecundity, girth, mouth area, swimming speed), is known for the vast majority of fish species (Froese & Binohlan, 2003; Froese & Pauly, 2005). In contrast, the von Bertalanffy growth parameters and t_{max} are available for a small percentage of the so far known fish species (Binohlan & Pauly, 2000). Yet, L_{max} varies greatly both spatially and temporally, with the latter mainly reflecting the effect of increased fishing

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pressure with time (e.g. Law, 2000; Conover & Munch, 2002; Stergiou, 2002; Stockwell *et al*., 2003; Williams & Shertzer, 2005). The same might also be true for the von Bertalanffy parameters, which are mainly estimated from length-at-age data, although a fishing-induced bias in the estimates can not be ruled out.

In their review on the available quantitative information on the physics, chemistry, biology and fisheries of the Greek Seas, Stergiou *et al*. (1997) collected data on the growth and longevity for 103 fish stocks, belonging to 40 species out of the about 500 (Ondrias, 1971; Economidis, 1973; Papaconstantinou, 1988; Stergiou *et al*., 1997) known to occur in the Greek Seas. These data were subsequently analysed by Stergiou (2000) within a life-history framework.

In this report, we expanded the data set with information on 142 fish stocks, not included in Stergiou *et al*. (1997). We collected data on L_{max} and t_{max} (for 118 and 57 stocks, respectively), and K and L_∞ (for 72 fish stocks). The stocks presented here belong to 46 species, 19 of which are not included in Stergiou *et al*. (1997). In addition, we computed the L_{max}/L_∞ ratio, whenever possible. This ratio is important for the estimation of L_∞ when L_{max} is available (Froese & Binohlan, 2000, 2003), and for testing the accuracy of L_∞ estimates in cases where the latter deviate largely from L_{max}. Finally, we defined significant relationships between K and L_∞, K and t_{max}, and L_{max} and L_∞.

MATERIALS AND METHODS

We gathered demographic data on Greek marine fish stocks, not included in Stergiou *et al*. (1997), from various sources (i.e., peer-reviewed journals, technical reports, conference proceedings, and unpublished Theses). We tabulated the following data for 142 fish stocks (Table 1): (a) maximum observed length and age, L_{max} and t_{max}, in cm and yr, respectively, and (b) the von Bertalanffy (1938) growth parameters K, L_∞ and t_o, in yr^{-1}, cm and yr respectively, and the parameters C and WP corresponding to the seasonalised von Bertalanffy growth equation (Gayanilo & Pauly, 1997). The word "stock" here indicates species-sex-area-year combinations. Each data set is accompanied by auxiliary information such as area and year of sampling, sample size, method used for age determination, and method used for the estimation of the von Bertalanffy parameters. Finally, we calculated the L_{max}/L_∞ ratio and defined significant relationships between K and L_∞, K and t_{max}, and L_{max} and L_∞ using linear regression. The relationships L_{max}-L_∞ and K-L_∞, were computed based on the original reported length value, as well as after transforming all lengths to total lengths, using the length-length relationships of FishBase or those provided by the original authors. All these relationships are important in the context of life history (Jensen, 1997; Froese & Pauly, 2000; Froese & Binohlan, 2000, 2003).

RESULTS

We summarise the biological parameters for the 142 fish stocks, belonging to 46 species in Table 1. Overall, 16.2% of these data were reported in peer-reviewed journals of the Science Citation Index, whereas the bulk of the information (83.8%) originated from other types of publications (i.e., technical reports, conference proceedings, and unpublished Theses).

The reported parameters were based on samples collected throughout the Greek Seas during 1983-2003 mainly from experimental surveys (i.e., using bottom or mid-water trawls, beach seines, gill and trammel nets, and purse seines) or, less often, from wholesale fish markets [in nine cases only: for European pilchard *Sardina pilchardus* Walbaum, 1792 (Voulgaridou, 1997; Voulgaridou & Stergiou, 2000, 2003) and European anchovy *Engraulis encrasicolus* Linnaeus, 1758 (Loukmidou, 1998; Tsianis *et al*., 2003) in the Thermaikos Gulf; chub mackerel *Scomber japonicus* Houttuyn, 1782 (Kiparissis, 1998; Kiparissis *et al*., 2000) in North Aegean, Cretan Sea and Saronikos Gulf; red mullet *Mullus barbatus* Linnaeus, 1758 (Kalagia & Karlou-Riga, 2003) in the Saronikos Gulf; and swordfish *Xiphias gladius* Linnaeus, 1758 (Tserpes *et al*., 2001) in the Aegean and Ionian Seas]. The reported parameters were based on samples mainly collected on a seasonal basis (85 cases) and, to a lesser extent on monthly (49 cases), biweekly (7 cases) or other basis (15 cases) (Table 1). For the vast majority of the cases (95) demographic parameters referred to sexes combined (Table 1). These studies were based on sample sizes ranging from 47 to 51246 individuals (Table 1). For 63 cases, sample size was less than 1500 individuals, and for 35 cases, more than 5000 individuals (Fig. 1).

Body length measurements referred mainly to fork and total length (74 and 73 cases, respectively). Standard length was used in 7 cases, pre-anal length was used for hollowsnout grenadier *Coelorhynchus coelorhynchus* Risso, 1810 (Ionian Sea, 1996-1997), and lower jaw fork length for *X. gladius* (Aegean and Ionian Seas, 1998). L_{max} was available for 118 cases

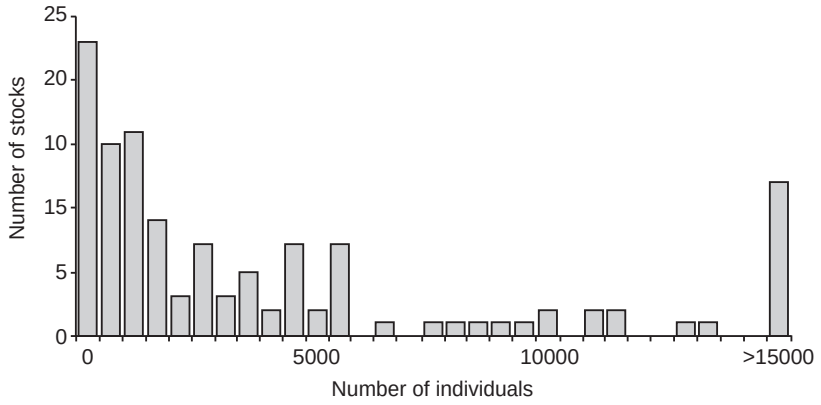

FIG. 1. Frequency distribution of the sample sizes on which the biological parameters presented here were based (see Table 1).

and ranged from 6 to 300 cm (Table 1).

Age and growth estimates were derived either from readings of otoliths and/or scales (otoliths: 38 cases; scales: 11 cases; both: 14 cases) or from length-frequency analysis (14 cases). In three cases, estimates were derived from all three methods (Table 1). Growth in length was described using either the simple or the seasonalised version (Pauly, 1998a) of the von Bertalanffy (1938) growth equation (61 and 11 cases, respectively). Growth parameters were estimated from length-frequencies using FISAT (Gayanilo & Pauly, 1997) in 11 cases, and from the observed or back-calculated length-at-ages, using the non-linear regression method, for 53 cases (Table 1).

Overall, t_{max} was available for 57 cases and ranged from 2 to 12 yr (Table 1). The von Bertalanffy growth parameters K and L_∞ were available for 72 stocks, and t_o for 58 out of the 142 stocks presented here. The von Bertalanffy K ranged from 0.117 to 0.921 yr^{-1}, L_∞ from 7.4 to 94.7 cm, and t_o from –3.522 to 0.238 yr (mean t_o = –1.084 yr, SE = 0.103; median t_o = –0.822 yr) (Table 1).

The L_{max}/L_∞ ratio ranged between 0.657 and 1.233, with a mean value of 0.924 (SE = 0.018; median = 0.93). The relationship between L_∞ and L_{max} (original reported data: equation 1; after transformation to total length: equation 2) for all Greek stocks together, i.e., those included in Stergiou *et al*. (1997) together with those shown in Table 1, were:

$L_\infty = 1.6351 + 1.0574 * L_{max}$ ($r = 0.99$, $n = 123$, $p < 0.05$, SE-slope = 0.016) (eq. 1) (Fig. 2).

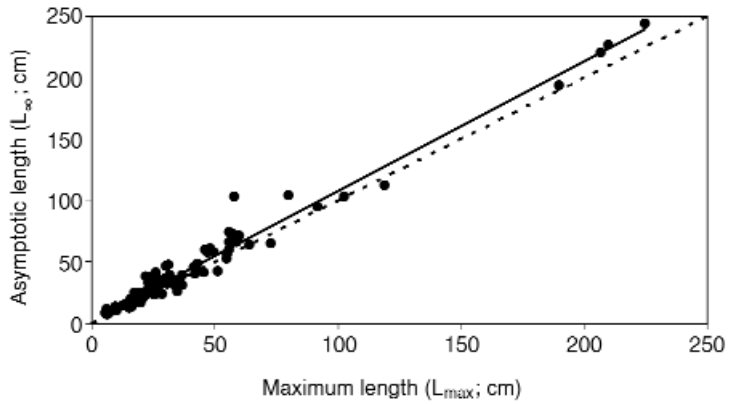

FIG. 2. Relationship between asymptotic length (L_∞) and maximum length (L_{max}) for marine fishes in Greek waters. Dotted line indicates the 1:1 relationship between L_∞ and L_{max}.

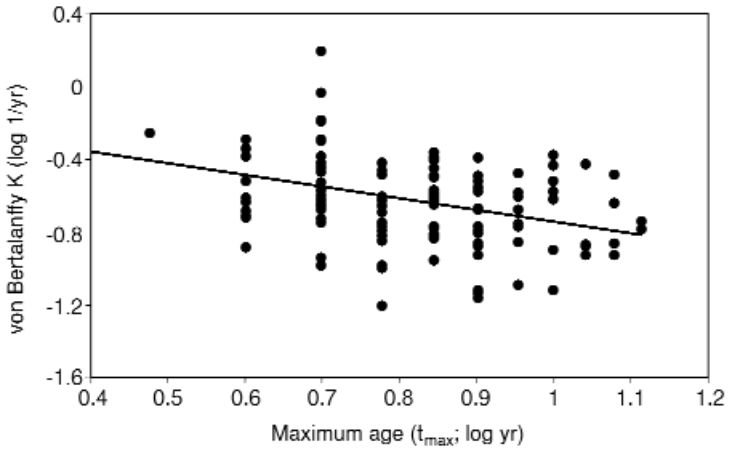

FIG. 3. Relationship between the von Bertalanffy K parameter and the maximum age (t_{max}) for marine fishes in Greek waters.

$L_\infty = 1.6013 + 1.0575 * L_{max}$ (r = 0.99, n = 123, $p < 0.05$, SE-slope = 0.016) (eq. 2).

Analysis of covariance indicated that both the slope and the intercept did not differ significantly ($p > 0.05$).

The relationship between logK and $logt_{max}$ for all Greek stocks together was (Fig. 3):

$LogK = -0.0995 - 0.6421 * Logt_{max}$ (r = –0.37, n = 124, $p < 0.05$, SE-slope = 0.15) (eq. 3).

Finally, the relationship between $logL_\infty$ and logK (original reported data: equation 4; after transformation of L_∞ to total length: equation 5) for all Greek stocks together was:

$LogK = -0.1352 - 0.3006 * LogL_\infty$ (r = –0.34, n = 171, $p < 0.05$, SE-slope = 0.0642) (eq. 4) (Fig. 4).

$LogK = -0.0718 - 0.3094 * LogL_\infty$ (r = –0.34, n = 171, $p < 0.05$, SE-slope = 0.0664) (eq. 5).

Analysis of covariance indicated that both the slope and the intercept did not differ significantly ($p > 0.05$).

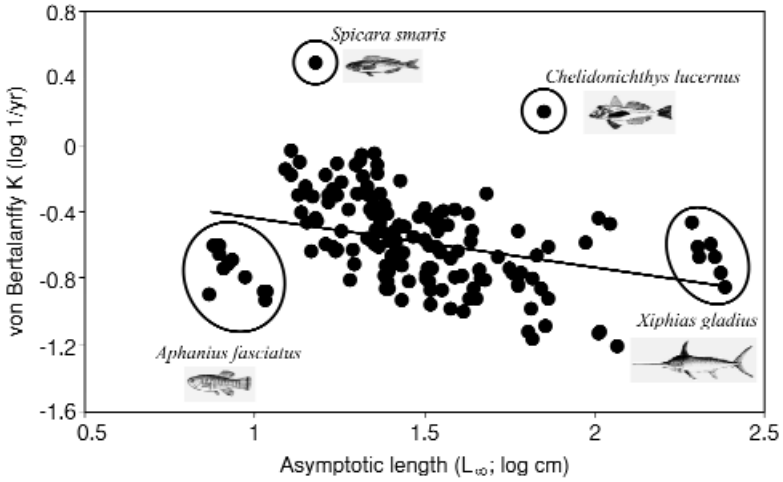

FIG. 4. Relationship between the von Bertalanffy K parameter and the asymptotic length (L_∞) for marine fishes in Greek waters.

TABLE 1. Biological parameters for various fish stocks in Greek Seas [K in yr^{-1}, L_∞ in cm, and t_o in yr; C and WP are the von Bertalanffy (1938) season-related growth parameters. FS denotes sampling frequency (M = monthly, S = seasonal, BW = biweekly, O = other, with number denoting number of samples). Sex (M = males, F = females, C = combined). N denotes the number of individuals used for parameter estimation. MEG denotes the method used for the estimation of growth parameters (FISAT software, routine ELEFAN I; Gayanilo & Pauly, 1997; NL = non-linear regression). L_{max} and t_{max} denote maximum body length, in cm, and maximum age, in yr, respectively. SA denotes element used for ageing (O = otoliths, S = scales, LF = length-frequencies). L denotes type of length used in the original study (TL = total, SL = standard, FL = fork, PAL = pre-anal length, LJFL = lower jaw fork length). M denotes type of L used for the estimation of growth parameters (O = observed, B = back-calculated)]

Species	Area	Year	N	FS	Sex	K	L_∞	t_o	C	WP	MEG	L_{max}	t_{max}	SA	L	M	L_{max}/L_∞	Reference
Aphanius fasciatus	Mesolongi and Etolikon lagoon system	1989-1991	5794	M	C							7.07	6	S	TL	B		Leonardos & Sinis (1999)
Aphanius fasciatus	Mesolongi and Etolikon lagoon system	1989-1991	2026	M	M	0.220	7.92	-1.140			NL	6.81	6	S	TL	B	0.86	Leonardos & Sinis (1999)
Aphanius fasciatus	Mesolongi and Etolikon lagoon system	1989-1991	3768	M	F	0.160	9.44	-1.580			NL	7.07	6	S	TL	B	0.75	Leonardos & Sinis (1999)
*Argentina sphyraena**	Central Aegean Sea	1990-1992	4386	S	C	0.430	22.30		0.60	0.17	FISAT	19.80		LF	FL		0.89	Chatziioannou (1999)
*Argentina sphyraena**	Ionian Sea - Patraikos Gulf	1983-1985	1881	S	C	0.670	23.00		0.40	0.65	FISAT	18.60		LF	FL		0.81	Chatziioannou (1999)
*Argentina sphyraena**	Korinthiakos Gulf	1983-1985	1193	S	C	0.663	23.02		0.59	0.40	FISAT	20.40		LF	FL		0.89	Chatziioannou (1999)
*Argentina sphyraena**	Evvoikos Gulf	1986-1988	47	S	C							20.00			FL			Chatziioannou (1999)
*Arnoglossus laterna**	North Evvoikos Gulf	1983-1984	558	S	C							19.00			TL			Papaconstantinou *et al.* (1985)
Aspitrigla cuculus	North Aegean Sea	1991-1993	1232	S	C							34.00			TL			Papaconstantinou *et al.* (1994)
Aspitrigla cuculus	Central Aegean Sea	1990-1992	3292	S	C							32.40			TL			Papaconstantinou *et al.* (1993)
*Atherina boyeri**	Mesolongi and Etolikon lagoon system	1989-1990	190	M	M							83.10	3	S	TL	B		Leonardos & Sinis (2000)
*Atherina boyeri**	Mesolongi and Etolikon lagoon system	1989-1990	236	M	F							10.30	3	S	TL	B		Leonardos & Sinis (2000)
Boops boops	South Evvoikos Gulf	1992-1993	131	S	C							23.00	4	O	FL	O		Petrakis *et al.* (1993)
Boops boops	Cretan Sea, Heraklion	1989-1991	3190**	S,M	C	0.418	23.70	-0.235			NL	26.20	10	O,S	TL	B	1.11	Kallianiotis (1992)
Boops boops	Cretan Sea, Heraklion	1989-1991		S,M	M	0.407	23.80	-0.421			NL		8	O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Heraklion	1989-1991		S,M	F	0.303	25.80	-0.801			NL		10	O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Ierapetra	1989-1991		S,M	C	0.117	27.20	-2.770			NL			O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Ierapetra	1989-1991		S,M	M	0.135	24.80	-2.219			NL			O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Ierapetra	1989-1991		S,M	F	0.187	27.30	-2.107			NL			O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Kissamos	1989-1991		S,M	C	0.306	22.90	-1.360			NL			O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Kissamos	1989-1991		S,M	C	0.133	32.90	-2.318			NL			O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Tsoutsouras	1989-1991		S,M	C	0.188	24.50	-0.333			NL			O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Chania	1989-1991		S,M	C	0.155	32.10	-0.337			NL			O,S	TL	B		Kallianiotis (1992)
Boops boops	Cretan Sea, Messara	1989-1991		S,M	C	0.164	24.10	-0.349			NL			O,S	TL	B		Kallianiotis (1992)
*Callionymus maculates**	North Evvoikos Gulf	1983-1984	2511	S	C							15.50			TL			Papaconstantinou *et al.* (1985)
*Capros aper**	Ionian Sea-Korinthiakos Gulf	1983-1985	26613	S	C							10.80			SL			Papaconstantinou *et al.* (1987)
Cepola rubescens	North Evvoikos Gulf	1983-1984	1925	S	C							62.00			TL			Papaconstantinou *et al.* (1985)
*Chlorophthalmus agassizi**	Ionian Sea	1983-1985	1452	S	C							13.00			SL			Papaconstantinou *et al.* (1987)
*Coelorhynchus coelorhynchus**	Ionian Sea-Korinthiakos Gulf	1983-1985	2851	S	C							33.00			TL			Papaconstantinou *et al.* (1987)
*Coelorhynchus coelorhynchus**	Ionian Sea	1996-1997	298	M	C	0.132	10.70	-1.535			NL	10.40	11	O	PAL	O	0.97	Labropoulou & Papaconstantinou (2000)

TABLE 1. continued

Species	Area	Year	N	FS	Sex	K	L_∞	t_o	C	WP	MEG	L_{max}	t_{max}	SA	L	M	L_{max}/L_∞	Reference
*Dentex dentex**	Farmed	1996-1997	395	M	C	0.507	48.37	-0.204			NL	43.00	4	O,S	TL	O	0.89	Machias *et al.* (2002)
*Diplodus annularis**	Evvoikos and Pagassitikos Gulfs	1986-1988	39103	S	C							19.00			FL			Papaconstantinou *et al.* (1989)
*Diplodus annularis**	Ionian Sea, Patraikos-Korinthiakos Gulfs	1983-1985	7978	S	C							16.50			FL			Papaconstantinou *et al.* (1987)
*Diplodus annularis**	Eastern-Central Aegean Sea	1990-1992	2379	S	C							18.00			FL			Papaconstantinou *et al.* (1993)
*Engraulis encrasicolus**	Thracian Sea	2000-2001	5654	M	C	0.494	17.63	-1.279			NL	18.00	2	O	TL	O,B	1.02	Kallianiotis *et al.* (2003)
*Engraulis encrasicolus**	Thracian Sea	2000-2002	2901	M	M	0.536	17.00	-1.240			NL				TL	O		Kallianiotis *et al.* (2003)
*Engraulis encrasicolus**	Thracian Sea	2000-2003	2753	M	F	0.587	18.00	-0.846			NL				TL	O		Kallianiotis *et al.* (2003)
*Engraulis encrasicolus**	Thermaikos Gulf	1997-1998	18001	BW	C	0.750	20.00		0.80	0.60	FISAT	16.00		LF	TL		0.80	Loukmidou (1998)
*Engraulis encrasicolus**	Thermaikos Gulf	2000-2003	31760	M	C	0.770	17.50		0.80	0.60	FISAT	16.20		LF	TL		0.93	Tsianis *et al.* (2003)
*Engraulis encrasicolus**	N Aegean, Evvoikos-Saronikos Gulfs	1995-1999	4500	O,4	C	0.487	14.80	-1.500			NL			O	TL	O		Nikoloudakis *et al.* (2000)
*Engraulis encrasicolus**	N Aegean, Evvoikos-Saronikos Gulfs	1995-1999	4500	O,4	M	0.776	13.60	-1.019			NL			O	TL	O		Nikoloudakis *et al.* (2000)
*Engraulis encrasicolus**	N Aegean, Evvoikos-Saronikos Gulfs	1995-1999	4500	O,4	F	0.347	15.30	-2.540			NL			O	TL	O		Nikoloudakis *et al.* (2000)
*Engraulis encrasicolus**	Ionian Sea - Korinthiakos Gulf	1998-1999	4500	O,4	C	0.341	14.30	-2.822			NL			O	TL	O		Nikoloudakis *et al.* (2000)
*Engraulis encrasicolus**	Ionian Sea - Korinthiakos Gulf	1998-1999	4500	O,4	M	0.715	12.30	-1.676			NL			O	TL	O		Nikoloudakis *et al.* (2000)
*Engraulis encrasicolus**	Ionian Sea - Korinthiakos Gulf	1998-1999	4500	O,4	F	0.561	14.20	-1.339			NL			O	TL	O		Nikoloudakis *et al.* (2000)
*Engraulis encrasicolus**	North Aegean Sea	1991-1993	3723	S	C							17.00			FL			Papaconstantinou *et al.* (1994)
*Engraulis encrasicolus**	Ionian Sea - Patraikos Gulf	1983-1984	5996	M	C							17.50	4		TL			Berfotto (1996)
Eutrigla gurnardus	North Evvoikos Gulf	1983-1984	946	S	C							30.00			FL			Papaconstantinou *et al.* (1985)
Gadiculus argenteus argenteus	Evvoikos Gulf	1986-1988	1463	S	C	0.500	16.60		0.55	0.60	FISAT	16.50		LF	FL		0.99	Sotiropoulou (1999)
Gadiculus argenteus argenteus	Korinthiakos - Patraikos Gulfs	1983-1985	2360	S	C	0.520	14.00		0.60	0.60	FISAT	13.00		LF	SL		0.93	Sotiropoulou (1999)
Gadiculus argenteus argenteus	Ionian Sea	1983-1985	902	S	C	0.500	13.50		0.60	0.55	FISAT	9.80		LF	SL		0.73	Sotiropoulou (1999)
Gadiculus argenteus argenteus	North Evvoikos Gulf	1983-1984	1540	S	C							12.00			SL			Papaconstantinou *et al.* (1985)
*Lepidotrigla cavillone**	North Aegean Sea	1991-1993	9199	S	C							17.00			TL			Papaconstantinou *et al.* (1994)
*Lepidotrigla cavillone**	Evvoikos and Pagassitikos Gulfs	1986-1988	17949	S	C							16.50			FL			Papaconstantinou *et al.* (1989)
*Lepidotrigla cavillone**	North Evvoikos Gulf	1983-1984	700	S	C							15.00			FL			Papaconstantinou *et al.* (1985)
*Lepidotrigla cavillone**	Ionian Sea-Patraikos-Korinthiakos Gulfs	1983-1985	11309	S	C							25.00			FL			Papaconstantinou *et al.* (1987)
*Lepidotrigla cavillone**	Central Aegean Sea	1990-1992	9538	S	C							16.50			TL			Papaconstantinou *et al.* (1993)
*Lepidotrigla dieuzeidei**	Ionian Sea	1983-1985	4832	S	C							25.00			FL			Papaconstantinou *et al.* (1987)
*Lithognathus mormyrus**	Cretan Sea	1988-1993	553	S	C	0.650	16.30	-1.330			NL	20.10	5	S	FL	O	1.23	Sterioti (1998)
Liza aurata	Mesolongi and Etolikon lagoon system	1992-1994	1062	M,BW	C	0.136	69.59				NL	59.00	8	S	TL	O,B	0.85	Hotos (1999)
Liza aurata	Mesolongi and Etolikon lagoon system	1992-1994	392	M,BW	F	0.156	66.05				NL	59.00	8	S	TL	O	0.89	Hotos (1999)
Liza aurata	Mesolongi and Etolikon lagoon system	1992-1994	312	M,BW	M	0.169	61.18				NL	48.40	6	S	TL	O	0.79	Hotos (1999)
Liza saliens	Mesolongi and Etolikon lagoon system	1991-1995	537	M	C	0.242	34.31	-0.490			NL	29.10	6	O	TL	B	0.85	Katselis (1996)

TABLE 1. continued

Species	Area	Year	N	FS	Sex	K	L_∞	t_o	C	WP	MEG	L_{max}	t_{max}	SA	L	M	L_{max}/L_∞	Reference
Liza saliens	Mesolongi and Etolikon lagoon system	1991-1995	83	M	M	0.268	31.75	-0.480			NL	28.50	5	O	TL	B	0.92	Katselis (1996)
Liza saliens	Mesolongi and Etolikon lagoon system	1991-1995	143	M	F	0.237	34.56	-0.530			NL	29.10	6	O	TL	B	0.84	Katselis (1996)
Liza ramanda	Mesolongi and Etolikon lagoon system	1990-1995	545	M	C	0.179	56.33	-0.856			NL	54.80	5	O	TL	B	0.97	Minos (1996)
Liza ramanda	Mesolongi and Etolikon lagoon system	1990-1995	58	M	M	0.410	38.80	-0.270			NL	36.86	4	O	TL	B	0.95	Minos (1996)
Liza ramanda	Mesolongi and Etolikon lagoon system	1990-1995	72	M	F	0.211	52.05	-0.727			NL	54.79	5	O	TL	B	1.05	Minos (1996)
Lophius budegassa	North Aegean Sea	1991-1993	5110	S	C							78.00			TL			Papaconstantinou *et al.* (1994)
Lophius budegassa	Western-Central Aegean Sea	1990-1992	944	S	C							64.00			TL			Papaconstantinou *et al.* (1993)
Lophius budegassa	Eastern-Central Aegean Sea	1990-1992	1490	S	C							77.00			TL			Papaconstantinou *et al.* (1993)
Merluccius merluccius	Cretan Sea	1988-1993		S	C							62.50			TL			Tserpes (1996)
Merluccius merluccius	Saronikos Gulf	1989 1992-1993	950	M	C	0.240	73.60	-0.620			NL		10	O	TL	O		Diapouli *et al.* (2000)
Merluccius merluccius	North Evvoikos Gulf	1983-1984	896	S	C							61.00			TL			Papaconstantinou *et al.* (1985)
Micromesistius poutassou	North Aegean Sea	1991-1993	44170	S	C							38.00			TL			Papaconstantinou *et al.* (1994)
Micromesistius poutassou	North Evvoikos Gulf	1983-1984	828	S	C							30.00			TL			Papaconstantinou *et al.* (1985)
Mullus barbatus	Cretan Sea	1988-1993		S	C							26.50			TL			Tserpes (1996)
Mullus barbatus	Saronikos Gulf	1992-1993		M	C	0.380	24.74	-1.020			NL		6	O	TL	O		Kalagia *et al.* (2000)
Mullus barbatus	Saronikos Gulf	1992-1993	5619		M	0.410	21.88	-0.760			NL	21.00	5	O	TL	O	0.96	Kalagia & Karlou-Riga (2003)
Mullus barbatus	Saronikos Gulf	1992-1993	8244		F	0.430	24.29	-0.570			NL	25.00	7	O	TL	O	1.03	Kalagia & Karlou-Riga (2003)
Mullus barbatus	Saronikos Gulf	1998-1999	1966	M	M	0.510	20.13	-0.470			NL	19.00	5	O	TL	O	0.94	Kalagia & Karlou-Riga (2003)
Mullus barbatus	Saronikos Gulf	1998-1999	1765	M	F	0.500	21.78	-0.450			NL	21.00	5	O	TL	O	0.96	Kalagia & Karlou-Riga (2003)
Mullus barbatus	South Evvoikos Gulf	1992-1993	145	S	C							19.50	4	O	FL	O		Petrakis *et al.* (1993)
Mullus barbatus	North Evvoikos Gulf	1983-1984	600	S	C							21.00			FL			Papaconstantinou *et al.* (1985)
Mullus surmuletus	South Evvoikos Gulf	1992-1993	162	S	C							21.50	4	O	FL	O		Petrakis *et al.* (1993)
Mullus surmuletus	Cretan Sea	1988-1991	1526	S	C	0.225	35.40	-1.194			NL	27.50	5	S	TL	O	0.78	Machias *et al.* (1998a)
*Nezumia sclerorhynchus**	Ionian Sea	1996-1997	267	M	C	0.125	7.40	0.238			NL	6.00	10	O	PAL	O	0.81	Labropoulou & Papaconstantinou (2000)
Pagellus acarne	Ionian Sea-Patraikos-Korinthiakos Gulfs	1983-1985	13434	S	C							24.00			FL			Papaconstantinou *et al.* (1987)
Pagellus erythrinus	Cretan Sea	1988-1991	1190	S	C	0.317	27.80	-0.739			NL	23.00	7	S	FL	B	0.83	Somarakis & Machias (2002)
Pagellus erythrinus	South Evvoikos Gulf	1992-1993	163	S	C							22.00	4	O	FL	O		Petrakis *et al.* (1993)
Pagrus pagrus	Cretan Sea	1989-1994	370	S	C	0.137	44.36	-0.961			NL		12	O,S	FL	O		Machias *et al.* (1998b)
Pagrus pagrus	Farmed	1994-1995	1033	S	C	0.303	43.86	-0.540			NL			O,S	FL	O		Machias *et al.* (1998b)
Sardina pilchardus	Thermaikos Gulf	1996-1997	13914	BW	C	0.640	20.98		0.75	0.75	FISAT	20.30	5	LF	TL		0.97	Voulgaridou (1997)
Sardina pilchardus	Thermaikos Gulf	1996-1998	27065	BW	C	0.890	22.50		0.69	0.58	FISAT	21.00		LF	TL		0.93	Voulgaridou & Stergiou (2000)
Sardina pilchardus	North Aegean Sea	1991-1993	5255	S	C							19.50			FL			Papaconstantinou *et al.* (1994)
Sardina pilchardus	Greek Seas	1999	579	O,2	C	0.451	16.50	-0.652			NL	17.00	4	O	TL	O	1.03	Naletaki (1999)
Sardina pilchardus	Thermaikos Gulf	1996-2000	51246	BW	C	0.860	20.80				FISAT	21.00		LF	TL		1.01	Voulgaridou & Stergiou (2003)
Sardina pilchardus	Gulf of Kavala	2000-2001	2700	M	C							17.30	5	LF	TL			Koutrakis *et al.* (2001)

TABLE 1. continued

Species	Area	Year	N	FS	Sex	K	L_∞	t_o	C	WP	MEG	L_{max}	t_{max}	SA	L	M	L_{max}/L_∞	Reference
*Sardinella aurita**	Gulf of Kavala	2000-2001		M	C							24.30		LF	TL			Tsikliras *et al.* (2001)
*Scomber japonicus**	North Aegean Sea	1996	556	M	C							26.60	5	O	FL			Kiparissis (1998), Kiparissis *et al.* (2000)
*Scomber japonicus**	Saronikos Gulf	1996	402	M	C							29.30	2	O	FL			Kiparissis (1998), Kiparissis *et al.* (2000)
*Scomber japonicus**	Cretan Sea	1996	68	O,2	C							31.00	4	O	FL			Kiparissis (1998), Kiparissis *et al.* (2000)
*Scomber japonicus**	Greek Seas	1996		M	M	0.157	46.41	-1.882			NL	30.50		O	FL	B	0.66	Kiparissis (1998), Kiparissis *et al.* (2000)
*Scomber japonicus**	Greek Seas	1996		M	F	0.303	34.55	-1.531			NL	31.50		O	FL	B	0.91	Kiparissis (1998), Kiparissis *et al.* (2000)
*Scomber japonicus**	Greek Seas	1996		M	C	0.154	47.60	-2.177			NL	31.50		O	FL	B	0.66	Kiparissis (1998), Kiparissis *et al.* (2000)
*Scyliorhinus canicula**	Central Aegean Sea	1990-1992	10414	S	C							55.00			TL			Papaconstantinou *et al.* (1993)
Serranus cabrilla	Cretan Sea	1988-1993	1004	S	C	0.340	23.54	-0.700			NL	21.80	5	O	TL	O	0.93	Tserpes (1996)
Serranus cabrilla	Cretan Sea	1990-1992	1004	M	C	0.390	22.29	-0.590			NL	19.70	5	O	TL	B		Tserpes & Tsimenides (2001)
Serranus cabrilla	Cretan Sea	1990-1992	1004	M	C	0.380	22.39	-0.530	1	0.25	NL	19.70	5	O	TL	B		Tserpes & Tsimenides (2001)
*Serranus hepatus**	Cretan Sea	1988-1993	1268	S	C	0.360	15.18	-0.570			NL	14.00	5	S	TL	O	0.92	Tserpes (1996)
*Serranus hepatus**	Thermaikos Gulf	1991-1993	3350	S	C	0.230	14.66	-2.560			NL	14.40	4	O	TL	B	0.98	Wague (1997)
*Serranus hepatus**	North Evvoikos Gulf	1983-1984	3654	S	C							12.00			SL			Papaconstantinou *et al.* (1985)
*Serranus hepatus**	Ionian Sea-Patraikos-Korinthiakos Gulfs	1983-1985	10453	S	C							11.50			SL			Papaconstantinou *et al.* (1987)
*Serranus hepatus**	Heraklion Bay, Crete	1990-1992	1268	M	C	0.360	15.2	-0.570			NL	14.00	5	S	TL	B	0.92	Labropoulou *et al.* (1998)
Spicara flexuosa	North Aegean Sea	1991-1993	19818	S	C							25.00			FL			Papaconstantinou *et al.* (1994)
Spicara flexuosa	Evvoikos and Pagassitikos Gulfs	1986-1988	41259	S	C							20.00			FL			Papaconstantinou *et al.* (1989)
Spicara flexuosa	North Evvoikos Gulf	1983-1984	1365	S	C							20.00			FL			Papaconstantinou *et al.* (1985)
Spicara flexuosa	Ionian Sea-Patraikos-Korinthiakos Gulfs	1983-1985	31385	S	C							19.50			FL			Papaconstantinou *et al.* (1987)
Spicara flexuosa	Western-Central Aegean Sea	1990-1992	3519	S	C							18.00			FL			Papaconstantinou *et al.* (1993)
Spicara flexuosa	Eastern-Central Aegean Sea	1990-1992	2613	S	C							19.00			FL			Papaconstantinou *et al.* (1993)
Spicara smaris	Evvoikos and Pagassitikos Gulfs	1986-1988	5922	S	C							20.00			FL			Papaconstantinou *et al.* (1989)
Spicara smaris	North Evvoikos Gulf	1983-1984	426	S	C							18.00			FL			Papaconstantinou *et al.* (1985)
Spicara smaris	Ionian Sea-Patraikos-Korinthiakos Gulfs	1983-1985	11081	S	C							17.50			FL			Papaconstantinou *et al.* (1987)
Spicara smaris	Cretan Sea	1988-1990	2614	M, S	C	0.393	13.78	-0.678			NL	16.30	7	O,S,LF	FL	O,B	1.18	Vidalis & Tsimenidis (1996)
Spicara smaris	Cretan Sea	1988-1990	658	M, S	M	0.154	19.23	-3.522			NL	16.30	7	O,S,LF	FL	O,B	0.85	Vidalis & Tsimenidis (1996)
Spicara smaris	Cretan Sea	1988-1990	1853	M, S	F	0.921	12.84	-0.215			NL	15.30	5	O,S,LF	FL	O,B	1.19	Vidalis & Tsimenidis (1996)
*Synodus saurus**	Cretan Sea	1988-1993	320	S	C							30.70	8		FL			Sterioti (1998)
Thunnus alalunga	Aegean and Ionian Seas	1989-1993	1136	O,3	C	0.258	94.70	-1.354			NL	92.00	9	S	FL	B	0.97	Megalofonou (2000)
Thunnus alalunga	Aegean Sea	1989-1993	338	O,4	M							89.00			FL			Megalofonou (2000)
Thunnus alalunga	Aegean Sea	1989-1993	154	O,5	F							82.00			FL			Megalofonou (2000)
Trachurus mediterraneus	North Aegean Sea	1991-1993	8759	S	C							27.00			FL			Papaconstantinou *et al.* (1994)
Trachurus mediterraneus	Saronikos Gulf	1989-1992	1611	M	C	0.326	37.20	-0.842			NL	38.90	12	O	TL	O	1.05	Karlou-Riga (2000)

TABLE 1. continued

Species	Area	Year	N	FS	Sex	K	L_∞	t_o	C	WP	MEG	L_{max}	t_{max}	SA	L	M	L_{max}/L_∞	Reference
Trachurus trachurus	Saronikos Gulf	1989-1992	6791	M	C	0.370	30.65	-0.760			NL	33.90	11	O	TL	B	1.11	Karlou-Riga & Sinis (1997)
Trachurus trachurus	North Aegean Sea	1991-1993	11535	S	C							38.00			FL			Papaconstantinou *et al.* (1994)
Trachurus trachurus	Ionian Sea-Patraikos-Korinthiakos Gulfs	1983-1985	4245	S	C							34.00			FL			Papaconstantinou *et al.* (1987)
Trachurus trachurus	Eastern-Central Aegean Sea	1990-1992	11997	S	C							30.00			FL			Papaconstantinou *et al.* (1993)
Trachurus trachurus	Western-Central Aegean Sea	1990-1992	5645	S	C							39.00			FL			Papaconstantinou *et al.* (1993)
Trigloporus lastoviza	Evvoikos and Pagassitikos Gulfs	1986-1988	3542	S	C							29.00			FL			Papaconstantinou *et al.* (1989)
Trisopterus minutus capelanus	North Evvoikos Gulf	1983-1984	5795	S	C							36.00			FL			Papaconstantinou *et al.* (1985)
Trisopterus minutus capelanus	Ionian Sea, Patraikos-Korinthiakos Gulfs	1983-1985	24466	S	C							28.00			FL			Papaconstantinou *et al.* (1987)
Xiphias gladius	Ionian Sea	1998	1372	O	C							300.00	9	LF	LJFL			Tserpes *et al.* (2001)
Xiphias gladius	Aegean Sea	1998	1546	O	C							260.00	9	LF	LJFL			Tserpes *et al.* (2001)

* = species not included in Stergiou *et al.* (1997)
** = this number refers to all records for this author

DISCUSSION

In this study, various biological parameters (i.e., L_{max}, t_{max}, and the von Bertalanffy K, L_∞ and t_o parameters) for 142 fish stocks, belonging to 46 species, from the Greek Seas were collected and analysed. Overall, 19 out of the 46 species presented in Table 1 were not included in Stergiou *et al*. (1997).

As documented earlier (Stergiou *et al*., 1997; Stergiou, 2000), growth estimates of the Greek fish stocks are characterised by large negative t_o values (Table 1). This was reported for the first time for Mediterranean fish by Caddy (1989), who suggested that in this case growth parameters should be computed either from the seasonalised von Bertalanffy equation or by forcing the growth curves to pass through the origin of the axes.

In this work, we also established significant relationships between the parameters K and t_{max}, L_{max} and L_∞ and K and L_∞ for all fish stocks in marine Greek waters for which such data are available [i.e., those included in Stergiou *et al*. (1997) combined with those in Table 1]. The first two relationships can be used for estimating K and L_∞ from the corresponding t_{max} and L_{max} values, which are generally easier to be obtained, for those species for which K and L_∞ are not available from the Greek Seas. The mean L_{max} / L_∞ ratio was 0.924, being similar to that of the 103 stocks reviewed by Stergiou *et al*. (1997). The slope of the relationship between L_{max} and L_∞ was 1.0577, which is similar, when expressed on a log-scale (i.e. 0.95), to that (0.9841) presented by Froese & Binohlan (2000), which was based on a much larger data set (551 cases) than ours.

The mean of the K values smaller and larger than the median K were 0.164 ± 0.006 and 0.448 ± 0.029 (yr^{-1}), respectively, and the corresponding L_{max} / L_∞ mean values for these K ranges were 0.847 ± 0.017 and 0.972 ± 0.016, respectively. The latter differed significantly (t-test: $t = 29.18$, $p < 0.001$). This indicates that the small K values are associated with small L_{max}/L_∞ ratios, whereas high K values are associated with high L_{max}/L_∞ ratios.

In fishes, $\log L_\infty$ and logK values are negatively correlated (Beverton & Holt, 1959; Roff, 1992; Charnov, 1993; Pauly, 1998a, b; Froese & Pauly, 2000). The value of the slope, assuming isometric growth, should equal 0.33 (Jensen, 1997). The updated slope for all Greek stocks, i.e., those reported in Stergiou *et al*. (1997) and those listed in Table 1, was 0.3006 (Fig. 4), close to the theoretical 0.33. The two dots in Fig. 4, corresponding to *Spicara smaris* Linnaeus, 1758 and *Chelidonichthys lucernus* Linnaeus, 1758, that deviate from the regression line, should be considered with caution.

To demonstrate the potential use of compiling such data at small spatial scales, the following example was used. The optimum exploitation length, which is the length corresponding to the mean age at the maximum possible yield/recruit (Froese & Binohlan, 2000) can be estimated from L_∞ using the existing empirical relationship based on 206 stocks (Froese & Binohlan, 2000). For species for which L_∞ is not available, the latter can be estimated from either the global (Froese & Binohlan, 2000) or the region-specific (e.g., the one for Greek Seas) empirical relationships. For instance, the mean $L_\infty \pm$ SE of *M. barbatus* and *E. encrasicolus*, estimated from the reported values in Table 1, are 22.6 ± 0.86 and 15.9 ± 0.70 cm TL respectively, providing optimum exploitation length estimates of 15.4-16.7 and 10.4-11.2 cm, respectively. Indeed, the vast majority of the anchovy purse-seine catches in the northern Aegean Sea are composed of individuals larger than 10-11 cm TL, i.e. larger than the optimum exploitation length (e.g. Loukmidou, 1998; Tsianis *et al*., 2003). The same is also true for the red mullet catches taken with various gears in Cyclades. In the latter area, catches are mainly composed of individuals larger than 14 cm, i.e. larger than the optimum exploitation length (Stergiou *et al*., 2004). In contrast, the purse-seine and trawl catches of bogue *Boops boops* Linnaeus, 1758 and *S. japonicus* in Cyclades are largely (i.e., > 80%) composed of individuals smaller than their optimum exploitation length (Stergiou *et al*., 2004).

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