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Behavior of some growth performance indexes for exploited Mediterranean hake

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In this paper, some life-history estimates concerning the females of the Mediterranean hake Merluccius merluccius *(L., 1758), i.e. the parameters of the von Bertalanffy growth function (L_∞, K, and t_0), the maximum-ever lengths (L_{mx-e}), and the lengths at full maturity (L_{mst}) were gathered from the pertinent literature and used to derive 5 growth performance indexes (K, φ', $RL=L_{mst}/L_\infty$, $t_{50\%}$ and ω). The original datasets (n= 70) and the corresponding growth performance indexes were organized and analyzed by various geographical units (GFCM's geographical sub-area, GSA; GFCM's statistical division, GD; and biological province, BP).*

The parameter distribution resulted to be normal only for the growth performance indexes K and RL; a significant relationship correlation was detected between K and $t_{50\%}$, between φ' and ω, and between K and ω. The examination of the available historical data showed a scattered and unbalanced geographical distribution by GSA (e.g. 13 of 20 GSAs had less than 5 datasets each), a variability which was higher intra-GSA than inter-GSAs (as evidenced by the box-plots) and no clear geographical trend. GD and BP presented similar patterns, with significant geographical effects only in the RL. Present results suggest that, even if geographical effects are expected, they are obscured by the uncertainty of the original parameters, especially those related to the von Bertalanffy growth function (vBGF). Consequently, growth performance indexes should be used (and interpreted) with caution.

Key words: *Merluccius merluccius*, Mediterranean hake, growth performance index, geographical partition, GSA, Mediterranean Sea

INTRODUCTION

Exploited marine living resources are at present assessed in the Mediterranean by referring to 26 geographical sub-areas (GSA: GFCM, 2009), mainly delimited on the basis of political constraints (LLEONART & MAYNOU, 2003). One of the basic implicit assumptions of such a classification is that, inside each GSA, every fish species (or its sub-groups) has identical ecological properties or at least it is an arbitrary assemblage of populations large enough to be essentially self-reproducing, with members of the assemblage showing similar patterns of growth, migration, and dispersal. From a more practical point of view, the fished units (not necessarily corresponding to a biological or genetic unit) in each GSA are treated as "unit stocks" *sensu* GULLAND (1969).

Whichever the interpretation adopted, comparing present and past life-history traits (especially growth parameters) among GSAs may help in deciding about the correctness of the previously defined basic assumption (i.e. the so-called meta-analysis procedure; HILBORN, 2003), improving the understanding of the underlying phenomena and highlighting the expected inter- and intra-stock response to a variable fishing pattern (ROCHET, 2000; WILLIAMS & SHERTZER, 2005; MARTEINSDOTTIR & PARDOE, 2008). Notwithstanding the relevance of the matter, no standard methodology has been proposed within the GFCM to compare growth performance when raw data and parameters variances are not available, although the φ' (phi-prime;

Table 1. Definition and characterization of the indexes of growth performance applied to the Mediterranean hake females; L_∞ (total length; in cm), K (in 1/yr) and t_0 (in yr) represent the parameters of the von Bertalanffy growth function (vBGF)

Index and main references	Remarks
K FRANCIS, 1996	Growth comparison and index of growth performance. It is the most suitable performance indicator among the 6 methods explored by FRANCIS (1996). The higher the better. Usually considered as a growth rate coefficient (COOKE, 1984 in GFCM glossary), but has not yet been used in the Mediterranean hake fisheries context.
$\varphi' = \log_{10}K + 2*\log_{10}L_\infty$ PAULY, 1981; MUNRO & PAULY, 1983; PAULY & MUNRO, 1984	Growth comparison and index of growth performance. It reflects the growth rate of a fish of unit length. The slope value derives from the unweighed mean of the empirical $\log_{10}$-linerar regressions between K-W_∞ and K-L_∞ and isometric condition (i.e. $W= aL^3$). Considered more useful than other similar methods (SPARRE & VENEMA, 1998); not considered in the FRANCIS (1996) review. The higher the better. Likely the most used in the Mediterranean fisheries context.
$RL= L_m/L_\infty= 0.66$ BEVERTON & HOLT, 1957; CUSHING, 1981; BEVERTON, 1992	Index of growth performance. RL= reproductive load (CUSHING, 1981; a.k.a. the potential growth span, BEVERTON & HOLT, 1957). Usually, the L_m= size at 50% of maturity is employed. In the present case, L_{mst}= length at full maturity stage (75-100% of mature specimens). The value 0.66 is theoretically derived; usually the RL varies between 0.45 and 0.78 in Gadiformes (BEVERTON, 1992). The higher the better. Rarely used in the Mediterranean fisheries context.
$t_{50\%}= t_0 +0.6931/K$ modified from ALLEN, 1966	Growth comparison and index of growth performance. The theoretical age at which the length achieves 50% of L_∞. In the original paper, the expression was suggested to get an initial guesstimate of K. The lower the better. Never used in the Mediterranean hake fisheries context.
$\omega= K*L_\infty$ KNIGHT, 1969; GALLUCCI & QUINN, 1979	Growth comparison and index of growth performance. Rate of growth at L_0 when $t_0\sim 0$. It should be applied to stocks or species with almost equal t_0 and longevity. Similar values of ω may correspond to different growth (KINGSLEY *et al.*, 1980); it may be useful for comparing early growth rates (GULLAND, 1983). Almost never used in the Mediterranean fisheries context.

Table 1) seems the most used criterion (cfr. SAMED, 2002).

The aim of the present contribution consists of reviewing and analyzing the suitability of different growth performance indexes for the specificity of the Mediterranean demersal stocks, living in oligotrophic, warmer and saltier water than their Atlantic counterparts, subject to a generalized and persistent pressure by well established "mature" fisheries (PAPACONSTANTINOU & FARRUGIO, 2000) which have caused a sort of "steady-state overfishing" (LLEONART & MAYNOU, 2003). As a case study, the females of the Mediterranean hake, *Merluccius merluccius*, one of the most investigated and representative stock in the Mediterranean Sea (OLIVER & MASSUTI, 1995; PAPACOSTANTINOU & STERGIOU, 1995; COLLOCA, 1999; RECASENS & LLEONART, 1999; ORSI RELINI *et al.*, 2002), both for its natural history (e.g.: GARCIA-RODRIGUEZ & ESTEBAN, 2002; BIANCHINI *et al.*, 2008) and for its fishery traits (PAPACOSTANTINOU *et al.*, 1992; ALDEBERT & RECASENS, 1996; BIANCHINI *et al.*, 2003), have been used in the analysis.

MATERIAL AND METHODS

The published and the grey literature (cfr. SAMED, 2002) was extensively searched for sets of von Bertalanffy growth function (vBGF) parameters related to the Mediterranean hake, *Merluccius merluccius* L., populations.

The published growth performance indexes allowing the comparison of growth parameters were browsed and five of them - K, φ', RL=L_{mst}/L_∞, $t_{50\%}$ and ω (Table 1) - were selected in order to judge their behavior and performance.

These 5 growth performance indexes were thereafter applied to the data retrieved for hake females; the growth performance indexes were computed using the estimations of the 3 parameters of the classical vBGF (L_∞, total length, in cm; K, in yr^{-1}; and t_0, in yr), the maximum-ever length (L_{mx-e}) and the length at full sexual maturity (L_{mst}, to not be confused with length at 50% of maturity).

Each recovered dataset of parameters was assigned (Table 2) to its specific GFCM (2009) location (geographical sub-area, GSA; and geographical division, GD) and successively to the independent bio-geographic Mediterranean provinces (BP, GARIBALDI & CADDY, 1998) (Fig. 1); two contiguous GSAs (15 and 16) were considered together because many estimates were derived before the area splitting (Strait of Sicily).

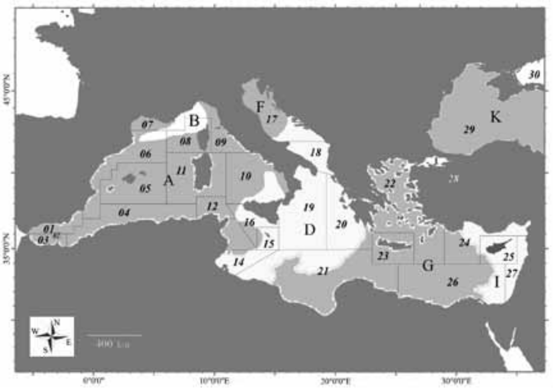

Fig. 1. The Mediterranean Sea geographical sub areas (GSA) according to the General Fisheries Council for the Mediterranean (GFCM), and the biological provinces (BP) according to the classification of GARIBALDI & CADDY (1998). Labels are explained in Table 2

The distributions of each growth performance index were tested for normality according to the Shapiro-Wilk W test and the degree of relationship between each pair of growth performance indexes was assessed using the coefficient r^2_{adj}.

The growth performance indexes were compared by GSA, GD and BP, qualitatively by producing box-plot representations (cfr. MOREAU & PAULY, 1999) and quantitatively by implementing, whenever enough datasets were available, the Kruskal-Wallis non-parametric ANOVA. The level of significance was set at p= 0.05, using the expression "marginally significant" or "marginally not significant" in case of $0.04 < p < 0.05$ and $0.05 < p < 0.06$, respectively. It is worth noting that data were maintained "as it is" throughout the geographical analysis; the presence of anomalous data ("outliers") was only highlighted. The analysis of the residuals was performed to assess their normality, the variance homogeneity and to pinpoint possible outliers.

Table 2. Geographical classification of the datasets by GFCM sub-areas and divisions and by biogeographical provinces; regions without data have been excluded. GARIBALDI & CADDY (1998) merged some older biogeographic provinces as: A=A+C; D=D+E; G=G+H

GFCM geographical sub-area (GSA)	*GFCM division (GD)*	*Biogeographic province (BP)*	*GSA label*	*GD label*	*BP label*	*# of datasets by GSA*
1 Northern Alboran Sea	1.1 Balearic	A Western	a	aa	A	1
3 Southern Alboran Sea	1.1 Balearic	A Western	b	aa	A	1
4 Algeria	1.1 Balearic	A Western	c	aa	A	3
5 Balearic Islands	1.1 Balearic	A Western	d	aa	A	4
6 Northern Spain	1.1 Balearic	A Western	e	aa	A	6
7 Gulf of Lions	1.2 Gulf of Lions	B Gulf of Lions	f	bb	B	10
8 Corsica	1.3 Sardinia	A Western	g	cc	A	2
9 Ligurian & northern Tyrrhenian Sea	1.3 Sardinia	B Gulf of Lions	h	cc	B	8
10 South and central Tyrrhenian Sea	1.3 Sardinia	D Adriatic and Ionian	l	cc	D	6
11 Sardinia	1.3 Sardinia	A Western	i	cc	A	2
12 Northern Tunisian	1.3 Sardinia	A Western	m	cc	A	1
15 & 16 off S and E Sicily and Malta	2.2 Ionian	D Adriatic and Ionian	n	dd	D	5
17 Northern and central Adriatic Sea	2.1 Adriatic	F Upper Adriatic	u	ii	F	2
18 Southern Adriatic Sea	2.1 Adriatic	D Adriatic and Ionian	v	ii	D	4
19 Western Ionian Sea	2.2 Ionian	D Adriatic and Ionian	o	dd	D	6
20 Eastern Ionian Sea	2.2 Ionian	D Adriatic and Ionian	p	dd	D	1
22 Aegean Sea	3.1 Aegean	G Aegean and S Eastern	q	ff	G	5
23 Crete	3.1 Aegean	G Aegean and S Eastern	r	ff	G	1
26 Southern Levant and Egypt	3.2 Levant	G Aegean and S Eastern	s	gg	G	1
28 Marmara Sea	4.1 Marmara Sea	J Marmara	t	hh	J	1

Finally, to evaluate the degree of correlation between L_∞ and K, a common issue when fitting the vBGF, an auximetric plot was computed following MOREAU's (1987) suggestion.

The descriptive statistics, correlation coefficients, ordinary least-square regressions, residuals analyses, and non-parametric ANOVA were obtained using the SYSTAT package (SYSTAT, 2007).

RESULTS

Seventy sets of vBGF parameters were gathered from the literature for hake females (the detailed list is presented in the Appendix with the corresponding growth performance indexes) and assigned to 20 GSAs (area codes and labels are reported in Table 2). The dataset distribution among the GSAs were highly unbalanced (Table 2): the maximum number of datasets (10) concerned the Gulf of Lions (f), whereas 13 GSA showed less than 5 datasets each. Considering the GFCM geographical divisions (GD) and the bio-geographical provinces (BP), the number of datasets becomes (with 2 exceptions) more balanced: in particular, this resulted for the GD as aa (15), bb (10), cc (19), dd (12), ff (6), gg (1), hh (1), ii (6), whereas for the BP resulted in A (20), B (18), D (22), F (2), G (7), and J (1).

Table 3. Descriptive statistics of the growth performance indexes for the Mediterranean hake females

	K	φ’	RL	$t_{50\%}$	ω
N of cases	70	70	70	70	70
Minimum	0.05	2.60	0.25	1.90	5.80
Maximum	0.30	3.50	0.77	12.4	24.2
Range limits ratio	6.00	1.30	3.10	6.50	4.20
Median	0.15	3.00	0.52	4.40	12.0
Arithmetic mean	0.15	2.99	0.51	4.90	12.2
Coefficient of variation	29.0	6.00	23.0	34.0	32.0
Skewness	0.34	0.55	0.12	1.99	1.41
Kurtosis	1.30	1.46	-0.59	5.81	2.41

The overall descriptive statistics for original datasets and related growth performance indexes are presented in Table 3. Considering the original data, the most striking features are the wider range, higher coefficient of variation (CV), lower skewness and kurtosis in the vBGF parameters than in the L_{mx-e} and L_{mst} figures. Speaking of the growth performance indexes, it is worth noting the almost complete correspondence between median and mean, the lowest CV in φ’ and the highest CV, skewness and kurtosis in ω and $t_{50\%}$. The peculiar behavior of these last two growth performance indexes is likely due to the leptokurtic distribution being disturbed by a few outliers at the rightmost side, whereas the other growth performance indexes distributions appear more platikurtic. The normality assumption (Shapiro-Wilk statistic > 0.1) holds only for K and RL; the (expected) correlation among the growth performance indexes was apparent with significant ($p < 0.05$) correlation coefficients between K and $t_{50\%}$ ($r^2 = 0.77$, negative relationship), between φ’ and ω ($r^2 = 0.77$), and between K and ω ($r^2 = 0.59$).

The box-plot analysis of the growth performance indexes at GSA level (Fig. 2, left) evidenced a wide variability (even among adjacent GSAs), an almost graphical equivalence between φ’ and ω and no clear geographical trend, with the exception of the RL (irregular increasing trend in the median from the Balearic Islands [d] to the western Ionian Sea [o]). Some likely outliers are also evident, such as K ~ 0.3 in the Gulf of Lions (f), K ~ 0.05 in the Aegean Sea (q), φ’= 2.6 in the western Ionian Sea (o), ω= 22 in the Ligurian and north Tyrrhenian (h) Seas and $t_{50\%}$= 1.9 yr (i.e. an expected T_{max}~ 4 yr) in the Gulf of Lions (f).

The box-plot analysis by GFCM division (GD) and bio-geographic province (BP) indicated a similar pattern between GD and BP (Fig. 2, center and right), certain homogeneity among the western and Adriatic-Ionian provinces and a scattered and highly irregular pattern in the Aegean-Eastern Basin. The only possible geographical trend is shown by a down-concave pattern of the RL, with higher values in the Gulf of Lions (B) and in the Adriatic-Ionian (D) provinces.

A further quantitative analysis was performed on GD and on BP after the exclusion of zones with less than 3 datasets (gg, hh and J with 1 dataset, and F with 2 datasets). The geographical effects among the GDs resulted as significant for RL and marginally significant for ω; the Balearic (aa) and Aegean (ff) divisions showed RLs significantly lower than the other divisions, whereas the Sardinia (cc) division showed an ω significantly higher than the Gulf of Lions (bb) and the Ionian (dd) divisions.

The geographical effects among the BPs resulted as marginally significant for RL and marginally not significant for φ’ and ω; in particular, the RLs resulted as higher in the Gulf of Lions (B) and the Adriatic-Ionian (D) provinces. The φ’ and ω results were influenced by the presence of a low value (outlier) in the Adriatic-Ionian (D) provinces.

The auximetric plot ($\log_{10}$ K *vs.* $\log_{10} L_\infty$) of the hake females (Fig. 3) denotes a relationship

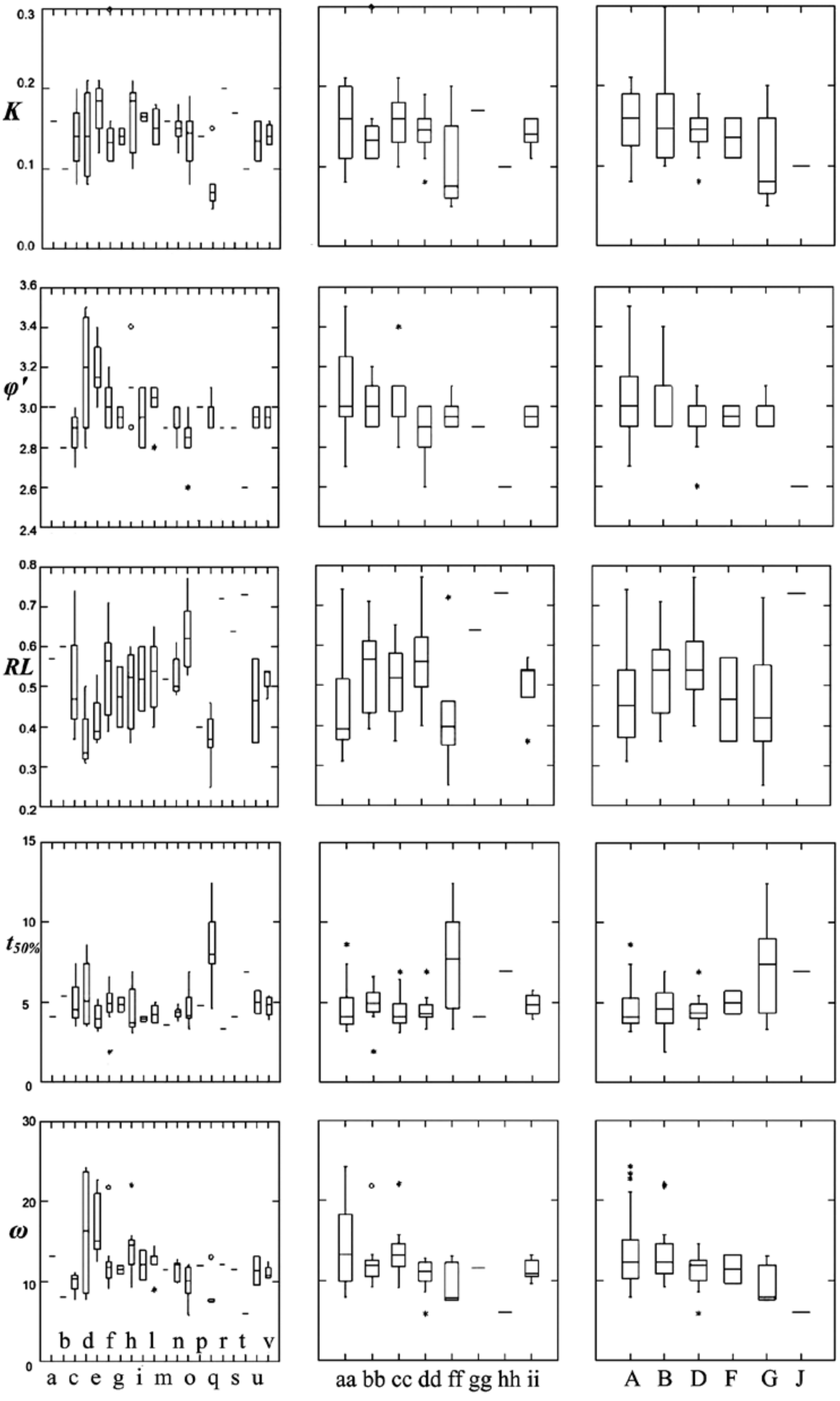

Fig. 2. Box pot representation of growth performance indexes for Mediterranean hake females by GFCM geographical sub areas (GSA), left; by GFCM geographical divisions (GD), center; and by biological provinces (BP), right. Labels are explained in Table 1 and Table 2

(r^2_{adj}= 0.18) and a slope coefficient (b= -0.71 ± 0.174) weaker and lower than the expected $0.4 < r^2 < 0.8$ (PILLING *et al.*, 2002) and b ~ 2 (MUNRO & PAULY, 1983). The figure, however, also indicates the possible negative influence of 9 scattered observations (which are not particularly anomalous on the basis of the residual plot analysis): the elimination of these points greatly improves the relationship (r^2_{adj}= 0.64) as well as increasing the slope coefficient (b= -1.35 ±0.129), although the latter remains significantly lower than the previously said empirical, common value of 2 (t= 5.04 > $t_{n-2;\,0.05}$= 1.67).

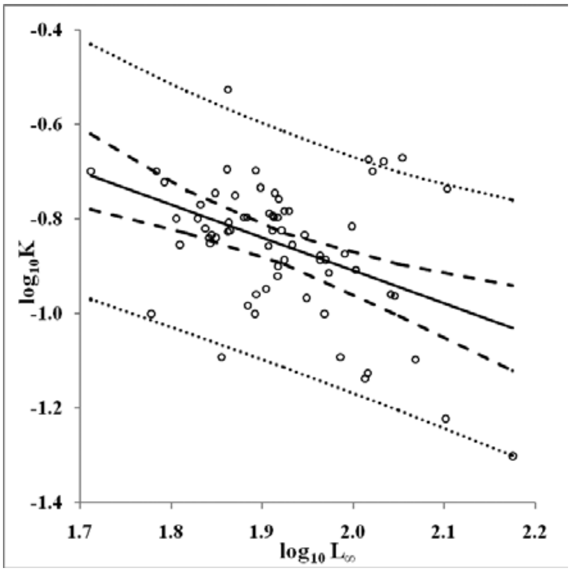

Fig. 3. The auximetric plot (log10L∞ vs. log10K) for the Mediterranean hake females with the linear regression and the corresponding confidence intervals superimposed

DISCUSSION

Assuming that growth is a syn-ecological adaptive property (NIKOLSKY, 1963), growth performance differences in closed genetic populations should reflect adaptations to the synergic interaction between different environments (sea water temperature, JOBLING, 1997; photoperiod, BOEUF & FALCON, 2001; or productivity, CADDY *et al.*, 1995) and fishing (ROCHET, 2000) conditions. A corollary of this conceptual frame is that, bringing back the different populations to the same environment and fishing conditions, their growth differentials would disappear (NIKOLSKY, 1963; ALDRICH & LAWLER, 1996).

However, there is evidence that growth dynamics are more complicated than previously believed; firstly, exploitation might operate a strong “genetic” pressure on the stocks by selective removal of slow-growing and late-maturing “expert-spawner” specimens (LAW, 2007), even after only a few generations (SMITH *et al.*, 1991; KIRKPATRICK, 1993; MARSHAL & MCADAM, 2007). The present growth pattern of heavily fished stocks, consequently, may be substantially different from pristine or lightly-exploited conditions; e.g. all other factors being equal, growth rate increases and length-at-maturity reductions should be expected (TRIPPEL, 1995; ROCHET, 1998). Moreover, distributions of ages and sizes are quantitatively related to the specific catchability of the gear used in different fisheries, and data risk being biased. Nevertheless, even the Mediterranean trawling fishery still catches very large female hake (a.k.a. “big bellies”), providing clues for the assessment of the maturation parameters (RAGONESE, 2009).

Growth pattern variability in a given exploited species might arise from genetic and phenotypic plasticity in response to the interactions between present environmental characteristics and fishing pressure, and caution should therefore be applied when the global patterns are considered. An example of such uncertainty is the contrast of the axiom that growth differences are due to extrinsic factors (ALDRICH & LAWLER, 1996), and are therefore easily removable, with recent evidence that even very similar stocks living in different environments may evolve hidden genetic adaptations, resulting in higher growth performance to overcome a shortened growing phase (JOBLING, 1997; JOBLING, 2002). These findings imply that the temperature-size relationship is just an empirical rule and not a biological law, and that is quite understandable. The relationship could originate from changes caused by temperature in the parameters of the population dynamics, from changes of the mortality rate with temperature, or most likely by these two mechanisms operating together (KOZŁOWSKY *et al.*, 2004). For a more precise comprehension of the auto-ecological "stressor", the hydrology of the water masses, e.g. currents and gyres, should also be taken into account when studying the local stock dynamics (MILLOT, 2005), though the task of integrating these issues in the analysis is extremely complex. In fact, the importance of the environment is underlined almost everywhere in the literature, but seldom included in the assessments (e.g., see STECF, 2011).

Growth studies should take into consideration the temporal evolution of populations and of the fisheries. However, difficulties arise when searching for an initial status (ROCHET *et al.*, 2005), the problem being that, when studies and analyses start, overfishing is already operating (LLEONART & MAYNOU, 2003) and the fact that historical series are often too short, incomplete or lacking altogether.

To further complicate the situation, it is evident that the Mediterranean organisms do not live in homogeneous geographical areas with respect to geomorphology, oceanographic conditions, primary production, bionomic assemblages and fishing pressures strongly different among sea basins (GARIBALDI & CADDY, 1998; BIANCHI, 2007). An example of such a heterogeneity is the dwarfism tendency (a true general nanism was excluded by MAURIN, 1970), and hence low performance, of the eastern demersal stocks living in poorer, warmer and saltier waters and until recently less exploited conditions than their western or Adriatic counterparts (cfr. SONIN *et al.*, 2007).

In addition to the above-mentioned expected differences of geographical origin, the present analysis of growth performances of the Mediterranean hake females raises some doubts (MOREAU, 1987) about the usefulness of univariate growth performance indexes as a tool to compare growth pattern under the actual GSAs partitions. In fact, geographical (or, better, fishing) areas should be defined according to the stock/fisheries distribution and structure (HALIDAY & PINHORN, 1990), and the non-correspondence between geography and unit stock has obviously played a significant although not quantifiable role. However, while it is expected that the politically-defined GSAs reflect the unit stock only weakly, the independent bio-geographic provinces should not encounter a similar ecological error.

Moreover, growth efficiencies should be based on objective criteria (e.g. the fraction of biomass produced by food intake in unit time; GRAINGER, 1973) which are not easily applicable in fisheries science considering the data limitations and the difficulties in defining a growth trajectory. As a consequence, fisheries science has opted for more operational tools like single-parameter (i.e. the φ'; MUNRO & PAULY, 1983; PAULY & MUNRO, 1984) or graphical (i.e. the auximetric grid: PAULY, 1979; PAULY, 1981) evaluations. However, there is evidence that single-parameters have both statistical and interpretational problems (MOREAU, 1987). In particular, ŽIVKOV *et al.* (1999) highlighted that a reason for the inherent difficulties in using the growth performance indexes, and the contrasting opinions of researchers on this subject, lays in the self-regulation of the growth process due to the first-year realizations of length and weight.

Another critical point is the role of t_0 (e.g. it does not describe the growth speed; FRANCIS, 1996) and the general disagreement about the published L_∞ estimates (i.e., $L_\infty > L_{max}$: RICKER, 1975; or $L_\infty \sim L_{max}/0.95$, at least in fish smaller than 50 cm: PAULY, 1984; $L_\infty < L_{max}$: PAULY, 1981; PAULY, 1984; FRANCIS, 1990; FROESE & BINOHLAN, 2000). Of course, the hake females reflect the difficulty in the definition and computation of L_{max} (cfr. L_{mx-e} and different types of L_{max} in PAULY, 1984 and in MATHEWS & SAMUEL, 1990), and the influence of the maximum size in the current samples, which is usually far from the pristine L_{mx-e} (where $L_{max} \sim L_\lambda$, the largest size class still providing enough information for assessment: BEVERTON & HOLT, 1957; HEWITT & HOENIG, 2005). Such a confusion is highlighted by the lack of correlation ($r^2_{adj} < 0.01$) between L_∞ and L_{mx-e}, between L_∞ and L_{mst}, and between L_{mx-e} and L_{mst} of the hake females.

Finally, of the 5 growth performance indexes considered in the casework of hake females, only the RL index resulted as marginally significant in both the GFCM divisions and the bio-geographic provinces, while the estimations of K, φ’, $t_{50\%}$ and ω highlighted an unbalanced datasets distribution by GSA, a higher intra-GSA variability than inter-GSAs and no clear geographical trends.

In conclusion, until both the unit stock-geographical correspondence and the growth curve fitting criteria are well defined, the use and interpretation of a single index of growth performance must be treated with caution.

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*Note: papers ending with a star * are those used and cited in the Appendix only.*

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Kolebanja nekih indeksa rasta gospodarskih iskorištavanog sredozemnog oslića

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SAŽETAK

U ovom radu, iznesene su neke procjene rasta koji se odnosi na ženke sredozemnog oslića (*Merluccius merluccius* L., 1758) tj. parametara rasta von Bertalanffy-eve jednadžbe rasta (L_∞, K, i t_0), maksimalna dužina ikad postignuta (L_{mx-e}), te dužina u punoj zrelosti (L_{mst}), a koji su prikupljeni iz literature i korišteni za dobivanje 5 različitih indeksa rasta (K, φ', $RL=L_{mst}/L_\infty$, $t_{50\%}$ i ω). Originalni setovi (n = 70) i odgovarajući indeksi rasta su organizirani / sistematizirani i analizirani prema različitim geografskim jedinicama (GFCM-a zemljopisno pod-područje, GSA, GFCM-a statistička podjela, GD, te biološka pokrajina, BP). Parametar raspodjele rezultirao je normalno samo za izvedbe rasta indeksa K i RL; značajna korelacija povezanosti je utvrđena između K i $t_{50\%}$,, između φ 'i ω, te između K i ω. Pregled dostupnih povijesnih podataka pokazao je raspršenu i neujednačenu geografsku raspodjelu po GSA (npr. 13 preko 20 GSAs imali su manje od 5 skupova podataka svaki), više varijabilnosti unutar GSA od međudjelovanja GSAs (o čemu svjedoči okvir box-plotova) i nejasan geografski trend. GD i BP prikazuju slične obrasce, sa značajnim geografskim učincima samo u RL. Trenutni rezultati pokazuju da, čak i ako su geografski učinci očekivani, oni su prikriveni nesigurnošću izvornih parametara, posebno onih koje se odnose na rast prikazan von Bertalanffy-evom funkcijom (vBGF), pa stoga performanse rasta indeksa treba koristiti (i interpretirati) s oprezom.

Ključne riječi: *Merluccius merluccius*, sredozemni oslić, indeks rasta, geografska podjela, GSA, Sredozemno more

APPENDIX

Synoptic overview by geographical unit of the original data and the growth performance indexes for the Mediterranean hake females

GSA - locality	label	GSA	L_∞ (cm)	K (1/yr)	t_0 (yr)	L_{mst} (cm)	$L_{mx\text{-}e}$ (cm)	φ'	RL	$t_{50\%}$ (cm)	ω	References
Northern Alboran Sea	a	1	80.9	0.16	-0.20	46.0	80	3.0	0.57	4.1	13.2	SAMED, 2002
Southern Alboran Sea	b	3	76.6	0.104	-1.3	46.0	130	2.8	0.60	5.4	8.0	Zoubi, 1998; SAMED, 2002; Froese & Pauly, 2011
Algeria - Bou Ismail	c	4	51.5	0.20		38.0	65	2.7	0.74	3.5	10.3	Bouaziz, 1992; Bouaziz et al., 1998a; Froese & Pauly, 2010
	c	4	80.6	0.14	-0.44	38.0	66	3.0	0.47	4.5	11.2	Bouaziz et al., 1998b; 1998c
	c	4	96.8	0.08	-1.15	35.7	130	2.9	0.37	7.4	7.8	Zoubi, 1998; 2001
Balearic Islands	d	5	78.0	0.10	-0.66	39.0	93	2.8	0.50	6.3	7.8	Oliver et al., 1990; GFCM, 1986
	d	5	113.2	0.21	0.31	39.0	93	3.4	0.34	3.5	24.2	Alemany et al., 1993
	d	5	117.1	0.08	-0.03	39.0	93	3.0	0.33	8.6	9.4	Oliver et al., 1990
	d	5	126.9	0.18	0.04	39.0	93	3.5	0.31	3.8	23.3	Alemany & Oliver, 1995
Northern Spain - Santa Pola	e	6	72.7	0.20	-0.20	38.6	72	3.0	0.53	3.2	14.7	SAMED, 2002
	e	6	85.0	0.17	-0.25	39.0	72	3.1	0.46	4.0	14.0	Paietta, 1996; Bouaziz et al., 1998c, Fiorentino et al., 2000; Fiorentino, 2000
	e	6	99.7	0.15	0.26	39.0	70	3.2	0.39	4.8	15.3	García-Rodriguez & Esteban, 1998; Orsi Relini et al., 2002
	e	6	100.7	0.12	-0.35	39.0	72	3.1	0.39	5.2	12.5	Farrugio, 1995
	e	6	105.0	0.20	0.39	39.0	70	3.3	0.37	3.9	21.0	García-Rodriguez & Esteban, 1998; Orsi Relini et al., 2002
	e	6	108.0	0.21	0.11	39.0	78	3.4	0.36	3.4	22.7	García-Rodriguez & Esteban, 2002
Gulf of Lions	f	7	68.8	0.15	-0.21	43.0	96	2.9	0.63	4.4	10.4	Aldebert, 1981
	f	7	70.7	0.14	-0.34	43.0	96	2.9	0.61	4.4	10.3	Oliver, 1983; Aldebert, 1978
	f	7	72.8	0.15		43.0	96	2.9	0.59	4.7	10.8	Froese & Pauly, 2011
	f	7	72.8	0.30	-0.38	43.0	96	3.2	0.59	1.9	21.7	STECF, 2008
	f	7	80.2	0.11	-0.52	43.0	96	2.9	0.54	5.6	9.1	Aldebert & Carries, 1989; Aldebert et al., 1993
	f	7	82.6	0.16	-0.20	59.0	88	3.0	0.71	4.1	13.2	SAMED, 2002
	f	7	94.0	0.12	-0.36	43.0	96	3.0	0.46	5.3	11.5	Paietta, 1996; Fiorentino et al., 2000; Fiorentino, 2000
	f	7	100.7	0.12	-0.35	43.0	96	3.1	0.43	5.2	12.5	Farrugio, 1995; Aldebert & Recasens, 1995, 1996
	f	7	110.0	0.11	0.30	43.0	96	3.1	0.39	6.6	12.1	Aldebert et al., 1993
	f	7	110.0	0.11	-0.43	43.0	96	3.1	0.39	5.9	12.1	Recasens, 1992; Cheret et al., 2002
Corsica	g	8	73.2	0.15	-0.20	40.3	70	2.9	0.55	4.4	11.0	SAMED, 2002
	g	8	92.0	0.13		37.0	67	3.0	0.40	5.3	12.0	Dintheer, 1982; Biagi et al., 1998; Orsi Relini et al., 2002
Ligurian and northern Tyrrhenian Sea	h	9	78.1	0.20	-0.31	46.5	91	3.1	0.60	3.1	15.7	Orsi Relini et al., 1992
	h	9	79.1	0.19		43.0	78	3.1	0.54	3.7	14.6	Matta, 1953; Abella et al., 1995
	h	9	79.1	0.19		46.5	78	3.1	0.59	3.7	14.6	Biagi et al., 1995; Froese & Pauly, 2011
	h	9	82.0	0.18	-0.12	46.5	91	3.1	0.57	3.7	14.8	Orsi Relini et al., 1994; Farrugio, 1995
	h	9	92.0	0.13		46.5	78	3.1	0.51	5.2	12.2	Biagi et al., 1998
	h	9	93.0	0.10		40.0	78	2.9	0.43	6.9	9.3	Reale et al., 1995; Relini et al., 1999

	h	9	103.9	0.21	-0.03	37.0		3.4	0.36	3.2	22.0	STECF, 2008
	h	9	111.0	0.11		40.0	78	3.1	0.36	6.4	12.1	Farrugio, 1995
Tyrrhenian Sea	l	10	64.5	0.14	-0.62	38.5		2.8	0.60	4.3	9.0	Greco et al., 1998; Colloca et al., 2000
	l	10	74.2	0.18	-0.20	42.0	66	3.0	0.57	3.7	13.2	SAMED, 2002
	l	10	81.6	0.16	-0.20	53.0	82	3.0	0.65	4.1	13.1	SAMED, 2002
	l	10	82.8	0.17	-0.22	42.0		3.1	0.51	3.7	14.5	Paietta, 1996; Fiorentino et al., 2000
	l	10	93.2	0.13	-0.35	42.0		3.1	0.45	5.0	12.1	Colloca et al., 2000
	l	10	97.9	0.13	-0.39	38.9	61	3.1	0.40	4.8	13.1	STEFC, 2008
Sardinia	i	11	63.9	0.16	-0.55	38.5	60	2.8	0.60	3.8	10.2	Matta, 1953; Relini et al., 1999; Colloca et al., 2000; Fiorentino, 2000
	i	11	84.0	0.17	-0.13	36.7	84	3.1	0.44	4.1	13.9	SAMED, 2002
Northern Tunisia - Gulf of Tunis	m	12	73.0	0.16	-0.80	38.0	60	2.9	0.52	3.6	11.4	Bohual, 1973; Bouhlal, 1975; Bouhlal & Hédi Ktari, 1975
Northern and central Adriatic Sea	u	17	81.8	0.16	-0.06	47.0	82	3.0	0.57	4.3	13.1	SAMED, 2002
	u	17	88.9	0.11	-0.69	32.0	60	2.9	0.36	5.7	9.6	ŽUPANOVIĆ, 1961; ŽUPANOVIĆ, 1968; Relini et al., 1999; VRGOČ et al., 2004
Southern Adriatic Sea	v	18	67.5	0.16	-0.44	32.0		2.9	0.47	3.9	10.7	Marano et al., 1996; Virgoc et al., 2004
	v	18	82.6	0.13	-0.31	44.9	60	2.9	0.54	5.2	10.4	Bello et al., 1986; Ungaro et al., 1992; Relini et al., 1999
	v	18	83.4	0.15	-0.11	44.9	82	3.0	0.54	4.5	12.5	SAMED, 2002
	v	18	84.0	0.13	0.10	44.9		3.0	0.53	5.4	10.9	Marano et al., 1996; Virgoc et al., 2004
Western Ionian Sea	o	19	62.0	0.19	-0.39	43.0	67	2.9	0.69	3.3	11.8	Tursi et al., 1996
	o	19	69.6	0.14	-0.73	43.0	67	2.8	0.62	4.2	9.8	D'Onghia et al., 1995
	o	19	69.9	0.15	-0.72	43.0		2.9	0.62	4.0	10.3	Paietta, 1996; Relini et al., 1999; Fiorentino et al., 2000
	o	19	71.7	0.08	-1.70	38.0		2.6	0.53	6.9	5.8	Paietta, 1996; Fiorentino, 2000
	o	19	75.8	0.16	-0.20	58.7	74	3.0	0.77	4.1	12.1	SAMED, 2002
	o	19	78.2	0.11	-1.03	43.0		2.8	0.55	5.3	8.6	Tursi et al., 1998
Eastern Ionian Sea	p	20	85.7	0.14	-0.20	34.3	88	3.0	0.40	4.8	12.0	SAMED, 2002
Waters off southern and eastern Sicily and Malta - Strait of Sicily	n	15-16	69.4	0.14	-0.35	34.0	67	2.8	0.49	4.4	10.0	Andaloro et al.,1985; Arena, 1985; Paietta, 1996; Fiorentino et al., 2000; Levi et al., 2001
	n	15-16	70.5	0.18	-0.10	43.3	76	3.0	0.61	3.8	12.7	Ragonese et al., 2004
	n	15-16	76.4	0.16	-0.20	43.4	76	3.0	0.57	4.1	12.2	Samed, 2002
	n	15-16	81.5	0.15	-0.08	39.4	88	3.0	0.48	4.5	12.2	STECF, 2008
	n	15-16	82.6	0.12	-0.91	41.4	88	2.9	0.50	4.9	9.9	Gancitano et al., 2007
Aegean Sea	q	22	88.4	0.15	-0.09	40.6	96	3.1	0.46	4.6	13.0	SAMED, 2002
	q	22	103.0	0.07	-1.53	38.0	80	2.9	0.37	8.0	7.5	Tsimenidis et al., 1978
	q	22	103.8	0.08	-1.82	43.7	80	2.9	0.42	7.4	7.8	Papacostantinou et al. 1992; STECF, 2008
	q	22	126.3	0.06	-1.52	43.7	80	3.0	0.35	10.0	7.6	Papacostantinou et al., 1992; Fiorentino et al., 2000; Fiorentino, 2000
	q	22	149.7	0.05	-1.51	38.0	64	3.0	0.25	12.4	7.5	Tsimenidis et al., 1978
Crete	r	23	60.8	0.20	-0.20	43.7	60	2.9	0.72	3.3	12.2	SAMED, 2002; STECF, 2008
Southern Levant and Egypt	s	26	67.9	0.17		43.7	63	2.9	0.64	4.1	11.5	Anonymous, 1984
Marmara Sea	t	28	60.0	0.10		43.7	52	2.6	0.73	6.9	6.0	Froese & Pauly, 2011 (likely using the size-at-age key in Kutaygil, 1967)