Age, growth, reproduction and diet of the whiting, Merlangiu merlangus euxinus (Nordmann, 1840), in the southeastern Black Sea

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Age, growth, reproduction and diet of the whiting, *Merlangius merlangus euxinus* (Nordmann, 1840), in the southeastern Black Sea

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Abstract: Age structure, growth, reproduction and diet of the whiting, *Merlangius merlangus euxinus*, were studied on a total of 598 whiting between December 2004 and November 2005 in the southeastern Black Sea. The total length of females was statistically higher than the one of males (t test, $p < 0.001$). The age range estimated was up to 6 years for females and 5 years for males. To obtain reliable estimates of growth parameters, three growth models (von Bertalanffy, Gompertz and Richards) were applied for both sexes. Gompertz (AIC = 1901.46) and von Bertalanffy (AIC = 1853.71) were the most suitable models to fit age-length data for females and von Bertalanffy considered as the most suitable growth model due to goodness of fit for males. Spawning occurred throughout the year with three peaks: firstly end of winter, secondly middle of spring and thirdly end of autumn. Whiting mostly feed on three fish species: anchovy (IRI% = 35.01), whiting (IRI% = 34.07) and sprat (IRI% = 22.81). ANOSIM showed that significant differences in the prey species composition existed between the seasons ($R = 0.1149$, $p < 0.001$) and SIMPER analysis also revealed that the most contributing species to the differences between seasons was anchovy.

Résumé : *Age, croissance, reproduction et régime alimentaire du merlan* Merlangius merlangus euxinus *(Nordmann, 1840) des côtes sud-orientales de la Mer Noire*. 598 individus de merlans du sud-est de la Mer Noire ont été étudiés entre décembre 2004 et novembre 2005. La longueur totale des femelles était supérieure à celle des mâles (test t, $p < 0{,}001$). La durée de vie estimée était de 6 ans pour les femelles et de 5 ans pour les mâles. Afin d'obtenir des estimations fiables des paramètres de croissance, 3 modèles de croissance (von Bertalanffy, Gompertz et Richards) ont été utilisés pour chacun des sexes. Gompertz (AIC = 1901,46) et von Bertalanffy (AIC = 1853,71) se sont révélés les meilleurs modèles pour les femelles et von Bertalanffy pour les mâles. La ponte s'est produite toute l'année avec 3 pics : le premier à la fin de l'hiver, le second au milieu du printemps et le dernier à la fin de l'automne. Le merlan se nourrit principalement de 3 espèces de poissons : l'anchois (IRI% = 35,01), le merlan (IRI% = 34,07) et le sprat (IRI% = 22,81). Une ANOSIM a montré que des différences significatives dans la composition des proies existaient entre les saisons. ($R = 0{,}1149$, $p < 0{,}001$) et une analyse SIMPER a révélé que l'anchois contribuait le plus aux variations saisonnières observées.

Keywords: Merlangius merlangus euxinus ● Age ● Growth model ● Reproduction ● Diet ● Black Sea

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Introduction

Whiting, *Merlangius merlangus* (L., 1758) is a cold water species and the adults prefer water temperature of between 5 and 16ºC. Whiting inhabits inshore waters over muddy grounds and forms shoals at depths between 30-100 m, but generally does not live deeper than 85 m (Whitehead et al., 1986). Whiting make regular vertical migrations; descending during the day above the bottom, and rising during the night to the thermocline or to the upper layers of distribution (Whitehead et al., 1986). *M. merlangus* is a common gadoid fish in the North-eastern Atlantic, the Mediterranean, the Black Sea and adjacent parts of the Azov Sea (Whitehead et al, 1986; Froese & Pauly, 2014). Fricke et al. (2007) reported that populations of whiting in the Black Sea and Aegean Sea are isolated from other populations. Miliić & Kraljević (2011) have recently mentioned that *M. merlangus euxinus* (Nordmann, 1840) from the Black, Marmara and Azov Seas is distinguished from *M. merlangus merlangus* (L., 1758) from the Atlantic, by the presence of a barbel on the chin, the length of the pectoral fin, and the numbers of fin rays, gillrakers and vertebrae.

With respect to ecosystem management, it is essential to understand the role of fish prey and predator interactions within the ecosystem. It is also necessary to determine and contribution the data on feeding habits of the major species. The importance of aggregations of fish in predator and prey interactions is a topic of ecology and especially environments much attention has been given to the schooling behaviors of fish. Whiting is a dominant fish caught among demersal fishes in the Black Sea. An overall increasing trend in landings of this species occurred over the years and reached the maximum in 1988 (28.000 tons which equals 90% of annual landings of whiting caught by all bordering countries of the Black Sea). In the following years, a decrease in catches was observed (GFCM, 1993). High abundance of whiting suggests that it might be an important species in the Black Sea ecosystem. First, whiting is potentially an important predator of fish and crustaceans. Second, whiting may be important food items for fish such as *Psetta maxima* (Linnaeus, 1758), *Squalus acanthias* (Linnaeus, 1758) and small cetaceans especially *Phocoena phocoena* (Linnaeus, 1758), *Delphinus delphis* (Linnaeus, 1758) and *Tursiops truncatus* (Montagu, 1821) (İşmen, 1995; Birkun, 2002; Personal observation). The preferred fish in the diet of whiting appeared to be schooling species such as anchovy *Engraulis encrasicolus* (Linnaeus, 1758) and sprat *Sprattus sprattus phalericus* (Linnaeus, 1758), provided that they are of a suitable size for the whiting to ingest them whole. The other fish, namely whiting and goby, were also important prey in the diet (İşmen, 1995). Moreover, the most important dominant crustaceans prey in the diet of Black Sea whiting were reported as crangonids (e.g. *Crangon crangon* (Linnaeus, 1758)) and cryfish *Upogobia pusilla* (Petagna, 1792) althougth amphipods, isopods, mysidacea and copepods were recorded in the stomach (İşmen, 1995).

In the Black Sea, *M. merlangus euxinus* doesn't perform long migrations. In spring, they move between 15 and 30 m depths for feeding and migrate to greater depths (between 80 and 120 m) for spawning in autumn (İşmen, 1995).

Studies on whiting were carried out their growth and reproduction biology in the Turkish Black Sea coast (Işmen, 1995; Şahin & Akbulut, 1997; Samsun & Erkoyuncu, 1998; Çiloğlu et al., 2001; Sağlam & Sağlam, 2012; Bilgin et al., 2012) and in the western part of the Black Sea (Bradova & Prodanov, 2003; Maximov et al., 2007 & 2011). Feeding ecology of whiting in the Black Sea was also studied by İşmen (1995) and Sağlam & Sağlam (2012).

Growth refers to change in size as the result of a counteraction of anabolism and catabolism of building materials and anabolic activities are always greater than the catabolic activities for fish (Avsar, 2005). Nonlinear growth models such as Richards, Gompertz and von Bertalanffy can be used to describe a particular species' growth pattern. von Bertalanffy growth model mostly used to fisheries sciences. However, in many cases von Bertalanffy growth model is not supported by the data and many species seem to fallow different growth pattern (Katsanevakis & Maravelias, 2008; Liu et al., 2009; Ainsley et al., 2011). Reproduction period of whiting was reported as throughout the whole year (Çiloğlu et al., 2001; Bilgin et al., 2012) and so, gonad development generally continuous during the year. Together with seasonal water temperature changes and food condition, reproductive activity, especially gonadal development of whiting was the some of the major factors influencing the growth. Therefore, three growth models were applied for this species to obtain reliable and suitable growth parameters. Moreover, the objective of the present study was to contribute information on age and growth of this species, also to present some details on the feeding ecology and to assess the differences in these parameters in other studies.

Materials and Methods

A total of 598 whiting specimens (237 males and 361 females) were collected monthly using commercial fisherman whiting gill net with 34, 36, 40 mm mesh size between December 2004 and November 2005 off Rize coast, in South Eastern Black Sea. Sampled specimens were fixed in 70% alcohol and transferred to the laboratory. Total length of each individual was measured to 0.1 cm and wet weight was weighed to the nearest 0.01 g after blotting dry on absorbent paper. The specimens were dissected and sagittal otoliths, stomachs, livers and gonads were removed. Otoliths were cleaned, immersed in glycerol, and examined on black background using reflected light at low magnification to determine age classes.

Monthly size frequency distributions for both sexes were calculated 0.5 cm total length class intervals. Size frequency distributions analyze for female and male were conducted using Kolmogorov-Smirnov two-sample test. Comparison of the mean total length between females and males was performed using t-test.

Age determination

The number of hyaline and opaque zones of sagittal otoliths was counted using a Nikon SMZ1000 mark stereomicroscope at a magnification between ×0.8 and ×8.0 interfaced with a Nikon DSFI1 digital camera connected to a computer using reflected light. Thick otoliths were also a little superficial sanding on sand paper for growth rings to be clearly visible. A total of 598 fish sagittal otoliths rings reading were successfully performed by two separate times.

Growth models

The data was not a good fit with the von Bertalanffy model for female after the preanalysis. Therefore, the other models were applied to analysis growth of whiting. To obtain reliable estimates of whiting growth curve parameters, three growth models (von Bertalanffy, Gompertz and Richards growth models) were applied for both sexes. The formulations of these models were as follows:

$L_t = L_\infty (1 - e^{-K(t-t_0)})$: von Bertalanffy (Bertalanffy, 1938) (1)

$L_t = L_\infty e^{e^{-k(t-1)}}$: Gompertz (Gompertz, 1832) (2)

$L_t = \dfrac{L_\infty}{1 + e^{-k(t-1)}}$: Richards curve (Richards, 1959) (3)

where t is time (age), L_t is length at age t (cm), L_∞ is the upper asymptotic total length to which the garfish growth (cm), K = the growth rate parameter (year^{-1}), t_0 is the nominal age at which the length is zero (year), I is the age at the inflection point.

Analysis of growth models parameters were fitted to age length data using the Growth-II Pisces Conservation Ltd., Lymington, England procedure in the PC-based computer package (Henderson & Seaby, 2006). Using The Akaike Information Criterion (Akaike, 1974), the best model is the one with the lowest AIC results. This criterion takes into account both the closeness of fit of the points to the model and the number of parameters used by the model (Henderson & Seaby, 2006).

Growth performance comparisons were made using the growth performance index (Φ') which is preferred rather than using L_∞ and K individually (Pauly & Munro, 1984) and was computed as:

$\Phi' = \log(K) + 2\log(L_\infty)$ (4)

Reproduction

Sex was recorded and wet weight of the gonads and liver was obtained to the nearest 0.01 g. Monthly values of the gonadosomatic index *GSI*:

$GSI = W_{gonad} / W_{fish} \times 100$ (5)

and hepatosomatic index, *HIS*:

$HIS = W_{liver} / W_{fish} \times 100$ (6)

were calculated for both females and males (Avşar, 2005), where W_{gonad} is gonad weight (g), W_{fish} is fish body weight (g), W_{liver} is liver weight (g), W_{fish} is fish body weight (g).

Food composition

Stomachs were dissected and all prey items were identified to the lowest possible taxonomic level, counted and weighted. Sorted prey items were weighed wet to the nearest 0.001 g. Percentage of prey groups occurrence frequency (*F%*), percentage of prey groups numerical frequency (*N%*), percentage of prey groups weight (*W%*) (Hyslop, 1980) and relative importance index (*IRI*) and percentage of relative importance index (*IRI%*) (Cortes, 1997) were determined as:

$$F(\%) = \frac{n}{N_S} . 100 \quad (7)$$

$$N(\%) = \frac{n^y}{N_p} . 100 \quad (8)$$

$$W(\%) = \frac{w^y}{W_p} . 100 \quad (9)$$

$$IRI = (N\% + W\%). (F\%) \quad (10)$$

$$IRI(\%) = \frac{IRI}{\sum IRI} . 100 \quad (11)$$

where, n is number of fish in which a prey group, N_s is total fish number in which at least one of the food groups, is the total number of a food group, N_p is the total number of all prey groups, is the total weight of a food group, W_p is the total weight of all prey groups, is total relative importance index of all prey groups. Stomach fullness ratio was divided visually into a five point percentage scale as empty (0%), moderately full (25%), half full (50%), quite full (75%) and very full (100%).

One-way analysis of similarity (ANOSIM) (Clarke & Warwick, 1994) was used to determine the differences between seasons in the structure of the stomach contents. The most abundant prey species primarily responsible for an observed difference between seasons were examined using similarity percentages (SIMPER) (Clarke & Warwick, 1994). Multivariate analyses were performed with the software package PAST version 2.14 (Hammer et al., 2001).

Results

Population structure

A total of 598 whiting (361 females and 237 males) were sampled between December 2004 and November 2006. The total length was ranged between 10.6 and 27.4 cm (mean: 16.1 ± 0.08 cm) for all individuals, between 10.6 and 21.2 cm (mean: 15.5 ± 0.10 cm) for males, and between 11.5 and 27.4 cm (mean: 16.5 ± 0.10 cm) for females (Fig. 1).

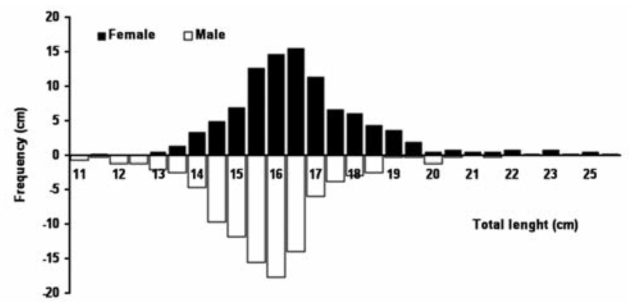

Figure 1. *Merlangius merlangus euxinus*. Total length frequency distribution of females and males sampled between December 2004 and November 2005 off Rize coast in the Black Sea.

Mean total length of females was statistically higher than males (*t* test, $p < 0.001$). Size frequency distribution were also significantly different (Kolmogorov-Smirnov two-sample test: $d = 0.26271$, $p < 0.001$) between female and male. Monthly length frequency distribution showed that female was dominant in higher length groups than male and under minimum allowable catch length (e.g. 13 cm; Anonymous, 2012) percentage was minor level (Fig. 2).

The overall female: male ratio (1.52) of whiting was skewed towards female and the difference between sexes ($\chi^2 = 25.712$, $p < 0.001$).

Age and growth

Age composition and total length at age of whiting showed in table 1. Age ranged between 1 and 6 for females and between 0 and 5 for males. The dominant age group was 3 years old for both females (31.3%) and males (16.7%). Sampling individuals was obtained mostly between 2 and 3 years old age groups for females (46.2%) and males (30.4%). Moreover, mean total length of female at age was greater than male.

Growth parameters estimated by three growth models for both sexes showed in table 2. According to Akaike Information Criterion (*AIC*) the Richards (*AIC* = 1800.60) attained a better fit than Gompertz curve (*AIC* = 1901.46) and von Bertalanffy (*AIC* = 1853.71) models in females, and Gompertz curve model considered as the most suitable growth model due to goodness of fit for females. On the other hand, *AIC* value of von Bertalanffy model for males was lower (*AIC* = 1261.35) than the ones of Gompertz (*AIC* = 1262.47) and Richards (*AIC* = 1262.24) models and von Bertalanffy model considered as the most suitable growth model due to goodness of fit for males.

According to growth models, the asymptotic length (L_∞) of females was estimated higher than the one of males and the L_∞ values estimated as 32.3 cm (Gompertz model), 109.1 cm (Richards model), 158.2 cm (von Bertalanffy model) for females and it was estimated as 22.3 cm (Gompertz model), 23.4 cm (Richards model), 26.9 cm (von Bertalanffy model) for males. Moreover, the growth rate, *K*, of males was estimated higher than the one of females. The *K* values estimated as 0.0143 year^{-1} (von Bertalanffy model), 0.1414 year^{-1} (Richards model), 0.1735 year^{-1} (Gompertz model) for female and it was estimated as 0.1315 year^{-1} (von Bertalanffy model), 0.2668 year^{-1} (Gompertz model) and 0.2878 year^{-1} (Richards model) for male.

Table 1. *Merlangius merlangus euxinus*. Age composition, mean total length (± standard error), minimum and maximum total length at age of whiting in the southeastern Black Sea.

	Female			**Male**			**All**		
Age groups	***Lmean ± SE (Lmin-Lmax)***	**N**	**%**	***Lmean ± SE (Lmin-Lmax)***	**N**	**%**	***Lmean ± SE (Lmin-Lmax)***	**N**	**%**
0				10.60 ±	1	0.2	10.60 ±	1	0.2
1	12.86 ± 0.23 (11.5-13.3)	7	1.2	12.50 ± 0.34 (10.7-14.8)	11	1.8	12.64 ± 0.22 (10.7-14.8)	18	3.0
2	14.75 ± 0.05 (13.4-15.6)	89	14.9	14.53 ± 0.09 (12.2-16.2)	82	13.7	14.64 ± 0.05 (12.2-16.2)	171	28.6
3	16.35 ± 0.04 (15.1-18.0)	187	31.3	15.95 ± 0.08 (14.3-18.2)	100	16.7	16.21 ± 0.04 (14.3-18.2)	287	48.0
4	18.38 ± 0.08 (17.3-19.7)	59	9.9	17.18 ± 0.20 (15.4-20.2)	41	6.9	17.88 ± 0.11 (15.4-20.2)	100	16.7
5	20.96 ± 0.21 (20.0-22.0)	11	1.8	20.55 ± 0.65 (19.9-21.2)	2	0.3	20.90 ± 0.19 (19.9-22.0)	13	2.2
6	23.84 ± 0.61 (22.3-27.4)	8	1.3				23.84 ± 0.61 (22.3-27.4)	8	1.3
All	**16.50 ± 0.10 (11.5-27.4)**	**361**	**60.4**	**15.53 ± 0.10 (10.6-21.2)**	**237**	**39.6**	**16.13 ± 0.08 (10.6-27.4)**	**598**	**100**

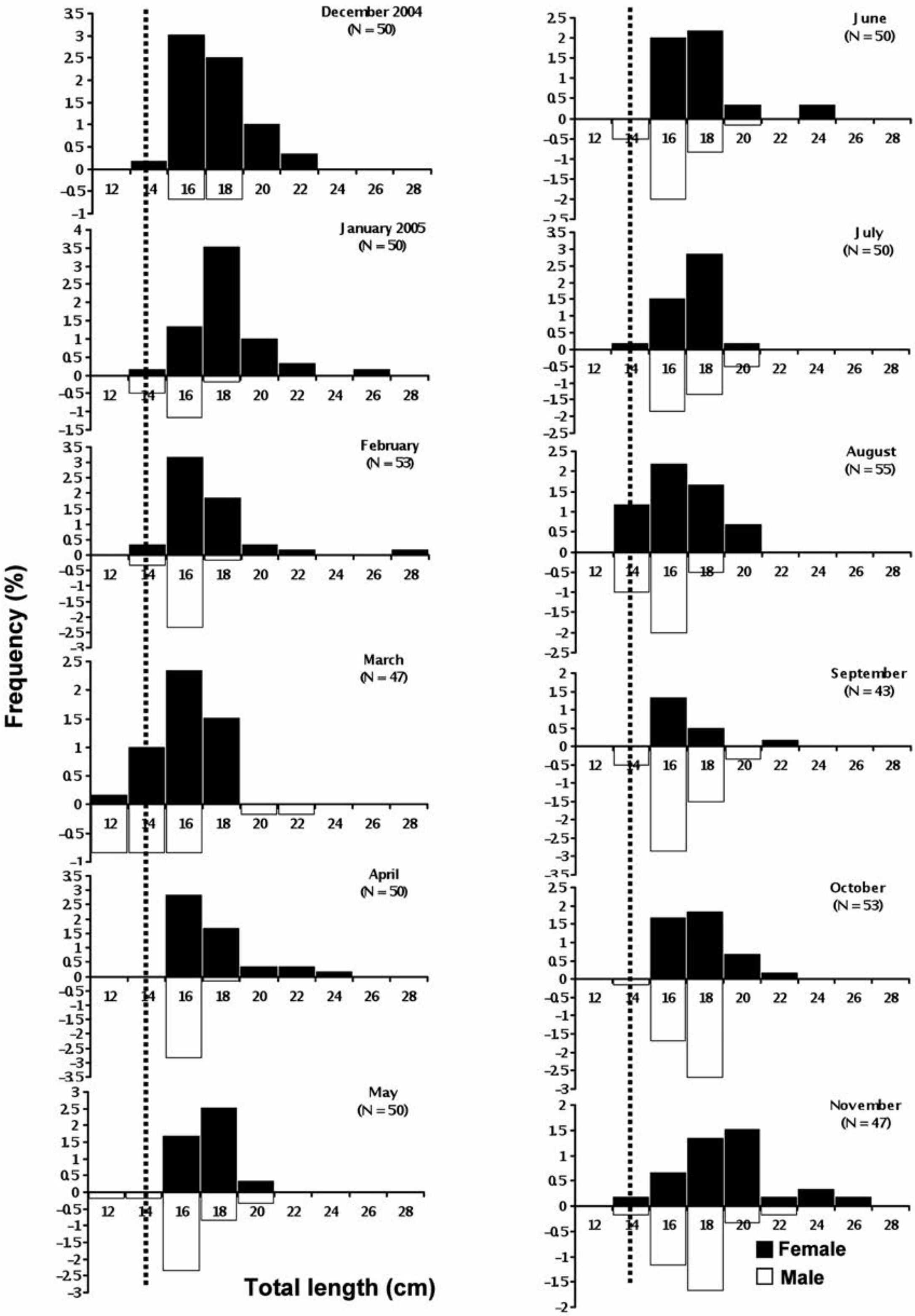

Figure 2. *Merlangius merlangus euxinus*. Monthly total length frequency distribution of females and males sampled between December 2004 and November 2005 off Rize coast in the Black Sea. Dotted line referred to minimum allowable catch size of whiting fisheries in the Black Sea.

Table 2. *Merlangius merlangus euxinus*. Results of von Bertalanffy (VBGF), Gompertz and Richards models parameters, Akaike Information Criterion (AIC) and growth performance index of whiting in the Black Sea. L_∞ = the upper asymptote (cm), K = the growth rate (year^{-1}), t_o = the time when L = 0 (year), I = the age at the inflection point and Φ'= growth performance index.

Growth models	L_∞ (cm)	K (year^{-1})	t_0 (year)	I (year)	*AIC*	Φ'
Females						
VBGF	158.2	0.0143	-4.69		1853.71	2.554
Gompertz	32.3	0.1735		0.68	1901.46	2.258
Richards	109.1	0.1414		15.23	1800.60	3.226
Males						
VBGF	26.9	0.1315	-3.87		1261.35	1.978
Gompertz	22.3	0.2668		-1.13	1262.47	2.123
Richards	23.4	0.2878		0.37	1262.24	2.198

The age at inflection point of the growth curve (I) was estimated the most suitable value in Gompertz model for females and in Richards model for males. The other model values were not suitable results for whiting biology. From all these results, Gompertz and von Bertalanffy growth models selected more biologically suitable models to characterize growth of females and males, respectively.

Growth performance index, Φ', derived from three growth methods was ranged between 2.554 and 3.226 and for female. For male Φ' ranged between 1.978 and 2.198. These results showed that female whiting had a better growth performance than male.

Reproduction

Monthly gonadosomatic index (GSI) fluction of whiting for female, male and all individuals showed in figure 3. The results of monthly GSI values show that spawning occurred throughout the year with three peaks: firstly end of winter (February), secondly middle of spring (April) and thirdly end of autumn (November). Spawning activity of whiting was intensively occurred the warmer time during summer. Moreover, monthly hepatosomatic index fluction (HIS) (Fig. 4) showed similar trends to GSI values.

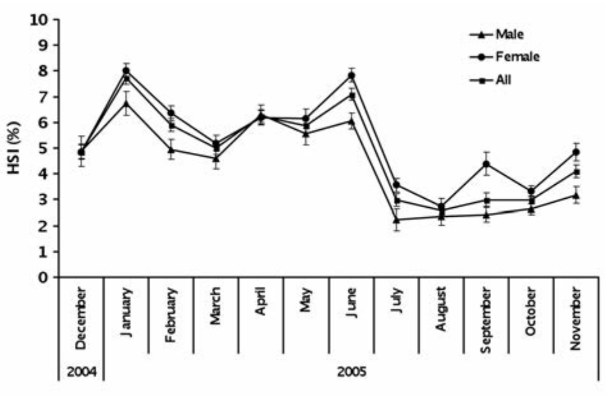

Figure 4. *Merlangius merlangus euxinus*. Monthly Hepatosomatic index (HSI) of females, males and all individuals sampled between December 2004 and November 2005 off Rize coast in the Black Sea.

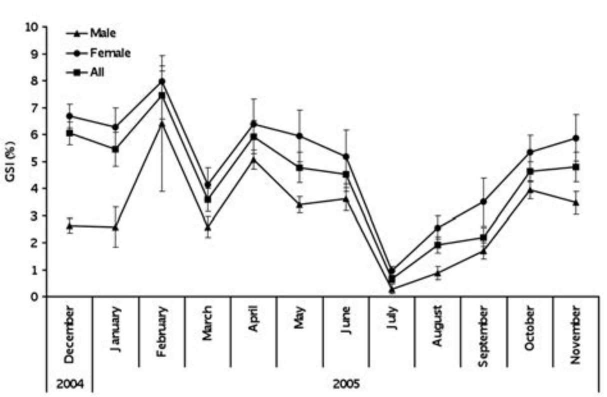

Figure 3. *Merlangius merlangus euxinus*. Monthly Gonadosomatic index (GSI) of females, males and all individuals sampled between December 2004 and November 2005 off Rize coast in the Black Sea.

Diet

All stomach contents of whiting contained Brachyura (N% = 0.77), Crangonidea (N% = 1.03), Gammaridea (N% = 13.85), Gastropoda (N% = 0.26), Bivalvia (N% = 0.51), Gobius sp (N% = 0.51), Trachurus sp (N% = 9.74), *M. m. euxinus* (N% = 25.64), *E. engrasicolus* (N% = 27.18), *Mullus barbatus* (Linnaeus, 1758) (N% = 0.51) and *S. sprattus* (N% = 20). According to percentage of relative importance index, IRI%, whiting generally feed on three fish species: *E. engrasicolus* (IRI% = 35.01), *M. m. euxinus* (IRI% = 34.07) and *S. sprattus* (IRI% = 22.81). Seasonal variations were observed in the diet. Namely, *E. encrasicolus* prevailed frequently (N% = 85.06; IRI% = 99.45) in stomach contents in winter. *Sprattus sprattus* was the dominant species (N% = 61.32;

IRI% = 89.31) in spring. *M. m. euxinus* prevailed frequently (N% = 61.24; IRI% = 94.61) in summer and also both *E. encrasicolus* (N% = 47.06; IRI% = 69.04) and *M. m. euxinus* (N% = 25; IRI% = 20.96) were prevailed frequently in autumn (Table 3). About 50% of examined stomachs were empty and about 20% of stomachs were quite and very full for all seasons (Fig. 5). ANOSIM showed that significant differences in the prey species composition existed between the seasons (R = 0.1149, p < 0.001; Table 4). SIMPER analysis revealed that the most contributing species to the differences between seasons was anchovy in the pairwise comparisons (Table 4).

Table 3. *Merlangius merlangus euxinus*. Seasonal distribution of percentage of prey groups occurrence frequency (*F%*), percentage of prey groups numerical frequency (*N%*), percentage of prey groups weight (*W%*) and percentage of relative importance index (*IRI%*) for the prey groups that were observed in whiting's stomach

	Seasons															
	Winter				Spring				Summer				Autumn			
Prey groups	N%	F %	W%	IRI%	N%	F %	W%	IRI%	N%	F %	W%	IRI%	N%	F %	W%	IRI%
Brachyura	1.15	1.3	0.18	0.01	0	0	0	0	1.55	2.5	0.78	0.06	0	0	0	0
Crangonidea	0	0	0	0	0.94	1.1	0.29	0.01	0.78	1.25	0.34	0.01	2.94	3.57	0.96	0.22
Gammaridea	11.49	6.49	0.76	0.49	17.92	10.99	0.54	2.17	18.6	2.5	0.45	0.48	1.47	1.79	0.02	0.04
Gastropoda	0	0	0	0	0.94	1.1	0.91	0.02	0	0	0	0	0	0	0	0
Bivalvia	1.15	1.3	0.06	0.01	0	0	0	0	0.78	1.25	0.02	0.01	0	0	0	0
Gobius sp	0	0	0	0	0	0	0	0	0	0	0	0	2.94	3.57	1.45	0.25
Trachurus sp	0	0	0	0	16.04	18.68	24.91	8.18	7.75	8.75	9.7	1.53	16.18	16.07	19.72	9.24
M. m. euxinus	1.15	1.3	3.43	0.04	2.83	3.3	5.8	0.3	61.24	70	73.95	94.61	25	23.21	31.37	20.96
E. engrasicolus	85.06	89.61	95.56	99.45	0	0	0	0	0	0	0	0	47.06	48.21	42.34	69.04
M. barbatus	0	0	0	0	0	0	0	0	0	0	0	0	2.94	1.79	2.67	0.16
S. sprattus	0	0	0	0	61.32	64.84	67.55	89.31	9.3	13.75	14.76	3.31	1.47	1.79	1.47	0.08

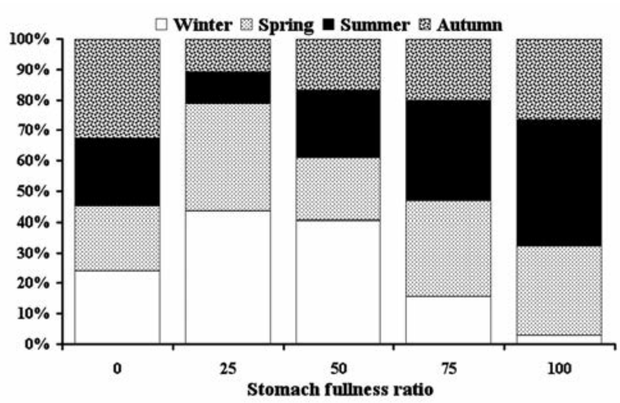

Figure 5. *Merlangius merlangus euxinus*. Seasonal stomach fullness ratio of whiting sampled between December 2004 and November 2005 off Rize coast in the Black Sea.

Discussion

Age and growth

The age range estimated was up to 6 years for females and 5 years for males. In the literature maximum age was reported as 9 years (İşmen, 1995), 7 years (Şahin & Akbulut, 1997; Çiloğlu et al., 2001), 6 years (Samsun & Erkoyuncu, 1998) and 5 years (Sağlam & Sağlam, 2012) for females and it was reported as 6 years (İşmen, 1995; Şahin & Akbulut, 1997; Çiloğlu et al., 2001), 5 years (Samsun & Erkoyuncu, 1998) and 4 years (Sağlam & Sağlam, 2012) for males in the Black Sea whiting stocks (see Table 5). Maximum age of whiting in the Black Sea was estimated different among the studies. This may be due to different fishing pressure, different sampling seasons and depth, different years, length range and biotic and abiotic factors by years (Bowers, 1954). All these factors may affect the length of fish at different ages.

Regarding the growth analyses, there are so large differences growth of whiting between in the Black Sea and the northern areas (e.g. Irish Sea and Celtic Sea). Growth of *M. merlangus* is rapid in both sexes for the first year, and the mean total length at the end of the year is between 15.9 and 27.0 cm in the northern areas (Bowers, 1954; Gerritsen et al., 2003; Hehir, 2003) (see table 5). The range in length of whiting is very great and growth up to 11 years with about 52.5 cm (Bowers, 1954; Hehir, 2003). However, growth of *M. merlangus euxinus* is very lower in both sexes than *M. merlangus*. Namely, whiting total length at the first

Table 4. *Merlangius merlangus euxinus*. One-way ANOSIM results of the stomach content structure for whiting among the seasons (R values and significance level p). Global R = 0.1149, p < 0.001. SIMPER results showing the average dissimilarities (%), the four species contributing most to the dissimilarity and their contribution ratios to the average dissimilarities between seasons.

	One-way ANOSIM		SIMPER					
Groups	***R* value**	***p* value**	**Average Dissimilarity (%)**	**Discriminating species 1**	**Contribution (%)**	**Discriminating species 2**	**Contribution (%)**
Winter-Spring	0.1795	0.0001	74.07	*E. encrasicolus*	33.73	*S. sprattus*	30.12
Winter-Summer	0.166	0.0001	71.90	*E. encrasicolus*	33.32	*M. m. euxinus*	29.98
Winter-Autumn	0.06143	0.0001	54.71	*E. encrasicolus*	44.03	*M. m. euxinus*	6.866
Spring-Summer	0.1062	0.0001	71.50	*S. sprattus*	31.01	*M. m. euxinus*	29.64
Spring-Autumn	0.1121	0.0001	65.12	*S. sprattus*	33.02	*T. trachurus*	12.16
Autumn-Summer	0.07129	0.0001	60.38	*M. m. euxinus*	35.78	*E. encrasicolus*	11.88

Table 5. *Merlangius merlangus euxinus*. Comparison of mean total length at age of whiting obtained from whiting populations of the different locality.

Study	**Locality**	**Sex**	**Mean total length at age (cm)**											
			0	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**
M. merlangus euxinus														
Şahin & Akbulut (1997)	Black Sea	Female		11.3	14.5	17.4	20.2	22.8	24.9	26.7				
		Male		11.0	13.7	16.3	18.9	21.4	22.5					
Samsun & Erkoyuncu (1998)	Black Sea	Female		12.5	15.0	18.0	20.1	22.3	23.8					
		Male		12.2	15.1	18.4	20.5	22.5						
Çiloğlu et al. (2001)	Black Sea	Female		11.0	12.1	16.1	17.9	21.7	24.5	26.5				
		Male		11.0	12.5	16.0	17.5	21.6	25.3					
İşmen (1995)	Black Sea	Female		10.9	14.6	18.1	21.6	24.6	26.2	27.6		30.6		
		Male		10.8	13.9	16.8	21.0		25.8					
Bradova & Prodanov (2003)	Black Sea	All		11.8	14.9	17.0	19.0	20.6	21.8					
Atasoy et al. (2006)	Marmara Sea	Female		8.9	13.2	17.1	20.5	22.6						
		Male		9.1	14.1	18.0	21.3	23.7						
Sağlam & Sağlam (2012)	Black Sea	Female	10.3	14.1	16.1	18.6	21.2	23.1						
		Male	10.4	13.5	15.6	17.5	19.2							
Merlangius merlangus														
Bowers (1954)	Irish Sea	Female		18.9	25.4	30.0	35.2	41.1	46.3	49.8	52.5			
		Male		18.8	24.6	28.1	32.3	34.6	38.3	39.3				
Gerritsen et al. (2003)	W. Irish Sea	Female		16.0	24.1	29.3	32.3							
		Male		15.9	22.7	27.0	29.3	31.5						
Gerritsen et al. (2003)	E. Irish Sea	Female		16.8	24.7	28.1	31.4	33.5						
		Male		17.6	23.4	26.6	29.1	30.2						
Hehir (2003)	Celtic Sea	Female		24.9	30.8	32.2	34.3	35.9	35.4	37.0	35.7	33.0		34.0
		Male		27.0	32.0	34.6	35.9	36.8	36.9		33.0			

year is between 8.9 and 14.1 cm and growth up to 8-9 years with about 30 cm total length in the Black Sea. This large difference in growth is may be explained by the differences of the species (Miliić & Kraljević, 2011), biotic and abiotic factors such as different water temperature, feeding behaviors between geographical areas and differences in reaching sexual maturity length (e.g. Although, size at sexual maturity of whiting was reported as 13.9 cm for male and 14.6 cm for female in the Black Sea by Bilgin et al. (2012), it was reported as 19 cm for male and 22 cm for female by Gerritsen et al. (2003) in the Irish Sea and as 24 cm for male and 25 cm for female by Vallisneri et al., 2006 in the northern Adriatic Sea).

The common practice among researchers who study fish growth is to a priori adopt the von Bertalanffy growth model, which is the most used and common equation in the fisheries sciences. However, in many cases von Bertalanffy growth model is not supported by the age length data and many fish species such as sharptail mola, *Masturus lanceolatus* (Lienard, 1840) (Liu et al., 2009), whitebrow skate, *Bathyraja minispinosa* (Ishiyama & Ishihara, 1977) (Ainsley et al., 2011) seem to fallow different growth pattern (Katsanevakis & Maravelias, 2008). Our results show that growth pattern of whiting was different between both sexes.

von Bertalanffy growth model derived from simple physiological arguments. This model assumes that the rate of growth of an organism declines with size (Bertalanffy, 1938). The Richards curve is a widely used growth model that will fit a wide range of sigmoidal shaped growth curves. The logistic curve is symmetrical about the point of inflection of the curve. To deal with situations where the growth curve is asymmetrical, Richards (1959) added an additional parameter producing the equation (Hendersen & Seaby, 2006). Because organisms generally grow seasonally, a good description of the pattern of growth of an organism that lives for a number of years requires a seasonal adjustment to the growth rate (Hendersen & Seaby, 2006). In the literature, whiting growth has been described with von Bertalanffy model in the Black Sea so far. Among them, only two studies described whiting growth with seasonalized von Bertalanffy growth model (İşmen, 1995; Bilgin et al, 2012). According to *AIC* values, Gompertz (*AIC* = 1901.46) and von Bertalanffy (*AIC* = 1853.71) were suitable models to fit age length data for females. Gompertz model's curve is a sigmoid function and it is a type of mathematical model for a time series, where growth is slowest at the start and end of a time period. Gompertz model was also biologically the most suitable one to characterize growth for females. Namely, the highest total length was measured as 27.4 cm for females, and also in the literature L_∞ values of females were calculated between 20.3 and 52.5 cm (Table 6). Moreover, ovary development of female was one of the major factors influencing the whiting growth and this is the one of the reasons of the seasonal growth pattern of female (Bilgin et al., 2012). So, Gompertz growth model may be considered as biologically suitable candidate model to characterize female's growth. On the other hand, L_∞ values of males were calculated between 22.3 and 26.9 cm by growth models and these results may be considered as suitable values for males. Calculated L_∞ values of males were in accordance with other studies (Table 6). But, the age at the inflection point corresponding to biologically size at sexual maturity was calculated as - 1.13 years by Gompertz growth model. This value was biologically impossible. So, both

Table 6. *Merlangius merlangus euxinus*. Comparison of von Bertalanffy growth parameters and size of whiting in the Black Sea. L_∞, asymptotic total length (cm); K, growth rate (year^{-1}); Φ', growth performance index; L_{min}, minimum total length (cm); L_{max}, maximum total length (cm); L_{mean}, mean total length (cm).

References	L_∞ (cm)	K (year^{-1})	t_o (year)	Φ'	$L_{min-max}$ (L_{mean})	Year
Male						
İşmen, 1995	29.1	0.220	-0.97	2.270	5.0-20	1990-1993
Çiloğlu et al., 2001	37.2	0.114	-2.39	2.198	11-25.3	1996
Şahin & Akbulut, 1997	35.9	0.124	-1.81	2.204	8.8-21.7	1991
Sağlam & Sağlam, 2012	26.3	0.203	-2.51	2.147	10.3-21.0 (14.5 ± 0.06)	2010-2012
Bilgin et al., 2012	19	0.930	-0.26	2.526	10.8-20.4 (15.2 ± 0.04)	2011-2012
Female						
İşmen, 1995	37.3	0.170	-1.05	2.374	5.0-28	1990-1993
Çiloğlu et al., 2001	52.5	0.092	-1.76	2.404	11-30.40	1996
Şahin & Akbulut, 1997	45.4	0.101	-1.81	2.318	9-27.7	1991
Sağlam & Sağlam, 2012	38.2	0.124	-2.58	2.258	10.1-23.1 (15.1 ± 0.05)	2010-2012
Bilgin et al., 2012	20.3	0.801	-0.82	2.519	11.6-30.7 (15.7 ± 0.06)	2011-2012
All						
İşmen, 1995	37.9	0.160	-1.05	2.361		1990-1993
Çiloğlu et al., 2001	38.4	0.136	-1.83	2.302		1996
Samsun & Erkoyuncu, 1998	35.5	0.138	-2.04	2.240	14.53 ± 0.07	1995-1996
Bradova & Prodanov, 2003	26.6	0.223	-1.62	2.198		1983-2000
Maximov et al., 2007	26.3	0.160	-2.19	2.044		2003-2005
Maximov et al., 2011	29.83	0.157	-2.49	2.145		2000-2008
Sağlam & Sağlam, 2012	33.6	0.141	-2.65	2.202	10.1-23.1 (14.9 ± 0.04)	2010-2012

von Bertalanffy and Richards growth models were considered as candidate models for males. Growth performance index is a good tool for averaging growth parameters of a particular species and it was useful for evaluation of growth under a variety of environmental stresses (Sparre & Venema, 1998). Our results of Φ' for females were greater than it was for males, implied that females grew relatively faster and reached a larger asymptotic total length at age compared to males. This result was in accordance with the other studies carried out in the Black Sea (See Table 2).

Reproduction

The monthly changes in GSI values indicate that the spawning time of whiting in the Black Sea occurred throughout the year with three peaks: firstly end of winter (February), secondly middle of spring (April) and thirdly end of autumn (November). This result was in accordance with Bilgin et al. (2012). According to different studies in the Black Sea, reproduction period of whiting was also reported as throughout the whole year (Çiloğlu et al., 2001; Bilgin et al., 2012) with maximum spawning between December and May (Şahin & Akbulut, 1997) and between January and August (Çiloğlu et al., 2001). Moreover, monthly hepatosomatic index fluction (HIS) showed similar trends to GSI values. Similar trends between HIS and GSI for whiting were also reported by Sağlam & Sağlam (2012) in the Black Sea.

Diet

Whiting food intake depends on hunger, the availability of prey and competition among predators (Seyhan & Grove, 1998). It has been also reported that food consumption of whiting is affected by water temperature and seasons. Seyhan & Grove (1998) reported when temperature raised to 18°C the food consumption was about 60-80% higher in summer than winter when decrease in water temperature to 7-8°C. In the Black Sea, food consumption of whiting was intensively during spring and summer seasons (İşmen, 1995). Therefore, in the Black Sea, water temperatures fluctuate about 15°C annually, consequently resulting in a seasonal feed habituation of whiting in this population. Hislop et al. (1991) reported that although *M. merlangus* feed on fish species (Norway pout, sprat, and sandeels), they eat mainly the youngest age classes of herring, cod, haddock, and whiting in the North Sea. Moreover, some geographical and seasonal differences in whiting stomach contents were detected; annelids represented a significant proportion of the food of whiting in the southeastern North Sea, as did cephalopod molluscs in the north, during the first part of the year. It was also reported that whiting is one of the most important piscivorous fish in the North Sea (Hislop et al., 1991). Our results showed that about 50% of examined stomachs were empty and whiting specimens were especially feed on anchovy, sprat and whiting and seasonal variation were observed in the whiting diet.

Opportunistic and cannibalism feeding behaviors were observed for whiting individuals by seasons (İşmen, 1995). Cannibalism commonly occurs among invertebrates and vertebrates, especially under conditions of high density and food limitation (Crump, 1983). Moreover, Singh-Renton & Bromley (1999) and İşmen (1995) were reported that whiting is an opportunistic predator and their diet reflects seasonal changes in the abundance of available food.

In the Black Sea, seasonal occurrence and abundance of prey was the main reason controlling the whiting food habituation. Anchovy was the predominant prey in the stomach contents in winter. After the winter season anchovy began to migrate from the study area to northeast Black Sea coast (Birkun, 2002). Sprats in the diet began to increase after winter, especially in spring. This time sprat was the most abundant pelagic species in the Black Sea and whiting feed on generally sprat (Avsar, 1993). Spawning of sprat can be seen all year round and especially from winter to early spring (Avsar, 1993) and the extended spawning season of the sprat also provide an adequate supply of food in spring to the whiting population. This is may be the reason for the increase in the percentage occurrence of sprat in the diet of whiting in spring. Whiting appeared more frequently in summer. In the summer season the whiting showed generally cannibalism, individual of whiting consuming all or part of another individual of the same species as food may be due to food limitation. In the autumn season, anchovy schools were reached at the Anatolian coast of the Black Sea and similar to the winter season the diets of the whiting were generally composed of anchovy.

In conclusion, the food of Black Sea whiting consisted predominantly of schooling fish species. It shows opportunistic predator and their diet reflects seasonal changes in the abundance of food available. The results of works on age and growth in the whiting showed that there are so large differences in growth between in the Black Sea and the northern areas. It is clear, however, that growth of Black Sea whiting is slower than northern areas whiting stocks especially in both sexes for the first year of their life. To organize sustainable fishery management in the Black Sea whiting population present minimum allowable catch length (13 cm) should be changed as 15 cm total length.

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