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AGE AND GROWTH OF THE GOLDEN GREY MULLET *LIZA AURATA* (ACTINOPTERYGII: MUGILIFORMES: MUGILIDAE), IN THE MESSOLONGHI-ETOLIKO LAGOON AND THE ADJACENT GULF OF PATRAIKOS, WESTERN GREECE

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Background. The fisheries of the Greek lagoons is based on the seasonal fish migration from coastal areas to the lagoon and the summer-to-winter offshore fish migration. The knowledge of the age and growth of the species in the two connected regions is essential for the proper management of the resources. The aim of this study was to estimate the age and growth of *Liza aurata* in the Messolonghi-Etoliko Lagoon system and the neighbouring coastal waters of the Gulf of Patraikos (Western Greece).
Materials and methods. From December 1992 to February 1994, a total of 1146 individuals of *Liza aurata* were caught in the Klisova Lagoon (part of the lagoon complex of Messolonghi-Etoliko) and their adjacent sea coastal area, using barrier fish traps, seine, and trammel nets. The fish age was determined from scale readings. Back calculated lengths at age, as derived using scales readings, were used to estimate the growth parameters of von Bertalanffy equation. The length–weight relation was estimated by the equation: $W = a \cdot L^b$.
Results. The total length (L) of examined specimens ranged from 9.7 to 59 cm. The scale readings revealed nine age classes in the Gulf of Patraikos (0 to VIII) and seven (0 to VI) in the lagoon. Maximum age was found to be 8 and 6 years for females and males, respectively. The analysis of the residuals sum of squares showed that the VBGF curves of sexes between the Patraikos sea area and the lagoon were not significantly different (sexes: $F = 0.51$, $P > 0.05$ and regions: $F = 0.46$, $P > 0.05$, respectively). The estimated values of VBGF for all samples were $L_\infty = 65.08 \pm 2.61$ cm; $k = 0.149 \pm 0.017$ year^{-1} and $t_o = -1.15 \pm 0.063$ year. No significant difference on the length–weight relations among the sexes was found ($F = 3.15$, $P > 0.05$) while a significant difference on the length–weight relations among the regions (sea: $W = 0.0036L^{3.26}$; lagoon: $W = 0.0057L^{3.13}$) was found ($F = 21.1$, $P < 0.05$) which reproduced a rather low difference (<±5%) along the size (weight) of species. The length–weight relations exhibited allometry.
Conclusion. The age and growth in length and weight of *Liza aurata* in the lagoon system of Messolonghi-Etoliko and the neighbouring seawaters of Gulf of Patraikos were not significantly different. This could be explained by the fact that the relative high salinity situation of the lagoon may rebut their high trophic advantage for the fish and/or alternatively, by a scenario that is based on the seasonal migrations of species between sea and lagoon.

Keywords: Golden grey mullet, *Liza aurata*, age, growth, western Greece, von Bertalnaffy estimates

INTRODUCTION

Grey mullets (Mugilidae) and mullet products have considerable economic importance at a regional level around the Mediterranean. In 1999, 48 188 t of grey mullets were produced by aquaculture in marine, brackish and inland waters of countries bordering the Mediterranean and the Black Sea (Anonymous 2002). Around the Mediterranean, an area of at least 6500 km^2 of coastal lagoons (Pearce and Crivelli 1994) is exploited as fishing grounds (Ananiades 1984, Kapetsky 1984, Ardizzone et al. 1988, Peja et al. 1996, Anonymous 2001). Coastal lagoons and estuaries are key ecosystems and local fishers intensively exploit the increased natural productivity of these ecosystems (Kapetsky 1984).

The Greek lagoons cover an area of about 350 km^2 and their exploitation is a common extensive culture, based on the seasonal migration from neighbouring coastal waters and entrance in the lagoons and the summer-to-winter offshore fish migration. The recorded annual fishery produc-

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tion of 50 Greek lagoons was estimated to about 1000 t, while 56% of this production consists of five species (*Liza aurata*, *Liza saliens*, *Liza ramada*, *Chelon labrosus*, and *Mugil cephalus*) (Anonymous 2001).

One of the most important types of lagoon exploitation is the use of barrier traps to catch fish during their seasonal or ontogenic offshore migration. The fish traps operate from July to December. Before July, the traps are open allowing the entrance of fish into the lagoon. Also, other gear types such as gill nets and dip nets are also used in the lagoon all year long (Anonymous 2001). Thus, the knowledge of the biology and the behaviour of species in the two connected regions (sea and lagoon) are essential for their proper management.

The golden grey mullet, *Liza aurata* (Risso, 1810), is distributed around the Mediterranean, the Black Sea coast, along the Atlantic coast from Senegal to the southern coasts of Norway and Sweden, the British Isles (but not Baltic Sea), and the Caspian Sea where it has been introduced. Schools of the golden grey mullet occur mostly in shallow waters, especially in coastal lagoons of varying salinity while they enter rivers and estuaries for feeding. *L. aurata* spawns in the sea (Thomson 1990).

Information on golden grey mullet biology comes mainly from studies carried out in- and around the Mediterranean, Black and Caspian Sea and eastern Atlantic coasts (Brusle 1981, Quignard and Farrugio 1981). The information, however, on the biology of the golden grey mullet in the central and eastern Mediterranean—particularly in the Ionian and Aegean coasts (Greek and Turkish)—is limited to a number of papers (age, growth and sex ratio: İlkyaz et al. 2006; morphological characters of fry: Minos et al. 2002; seasonal occurrence of fry, spawning period: Katselis et al. 1994, Koutrakis et al. 1994, Hotos et al. 2000; description of seaward migration: Katselis et al. 2003, 2007; population dynamic: Katselis et al. 2010; scales suitability for age determination: Hotos 2003). Also, some studies presented information on the age and growth of this fish in the Ionian coasts (Giatnisi 1985, Konides et al. 1992) and the Gulf of Saronikos (Velentza unpublished*), but the estimates were of low accuracy.

The aim of this work was to determine the age and growth of the golden grey mullet in the Messolonghi-Etoliko lagoons and the neighbouring shallow waters of the Gulf of Patraikos (Western Greece). The exploitation of the lagoonal system is based on the seasonal migration from the Gulf of Patraikos to the lagoons and the summer-to-winter offshore fish migration. The fishes are captured by barrier traps, gill and dip nets (Katselis et al. 2003). The estimated total annual fish catches decreased from 1500–2000 t in the 1960s to 1300–1500 t in recent years (Kotsonias 1984, Dimitriou et al. 1994) and are derived from about 200 fishermen working at the barrier traps and 700 fishermen operating in the lagoon. The golden grey mullet consists of about 14.3% of the recorded annual fishery production (Katselis et al. 2003) with a rather great commercial value in the local market (4–6 € per kg, as of 2009). In view of the above, the knowledge of the age and growth of the species in two connected regions is essential for the proper management of the resources (Katselis et al. 2010).

MATERIALS AND METHODS

The lagoon system of Messolonghi-Etoliko is located in western Greece between lat 38º18′N to 38º30′N and long 21º08′E to 21º29′E and covers an area of approximately 150 km^2 and is one of the largest lagoon systems in the Mediterranean (Fig. 1). Based on the topography, hydrology and fish species composition, six sub-areas can be defined (Dimitriou et al. 2000, Katselis et al. 2003). The largest portion (R3) is the Kentriki limnothalassa (Central lagoon) a shallow sea separated from the Gulf of Patraikos and the Ionian Sea by a chain of sand islands. To the north, the Etoliko Lagoon (R6) is connected to the Messolonghi Lagoon by a narrow “neck” and resembles a deep lake rather than a lagoon. The Klisova Lagoon (Fig. 1, R2), is a shallow, closed type lagoon communicating with the sea through 4 long canals. The temperature ranged from 11ºC in February to 35.4ºC in mid July, salinity fluctuated around 40 (‰) while in isolated parts ranged from 2–3 (‰) (on April after a rainfall) to 95 (‰) in summer (Hotos and Avramidou 1997).

Sample: In total, 1146 individuals were examined. From these, 1065 specimens were caught monthly during December 1992–February 1994 in Klisova Lagoon using the barrier fish traps, seine and trammel nets. Also, 81 specimens were caught during January–September 1993 in the adjacent sea (Table 1) using seine and trammel nets with a rough selectivity for fish size over to 8 cm. All golden grey mullets were iced-transferred to the laboratory where individuals were measured to the nearest mm for total length (L), standard length (L_s), fork length (L_f), weighed (total weight) to the nearest 0.01 g, and sexed. The sex and gonadal development were determined macroscopically using an eight stage key adapted from Kesteven (1960) and Hotos et al. (2000): I, immature; II, maturing; III, developing early; IV, developing late; V, gravid; VI, spawning; VII, Partial spent; VIII, spent.

The length–weight relation was estimated based on the equation: $W = a \cdot L^b$ where total weight (W) is expressed in g, and L in cm. Analysis of covariance (ANCOVA) was used for testing for statistically significant differences in length–weight relations between sexes and biotopes. Additionally, the Student’s t-test (Zar 1984) was used to test for difference of the parameter b from the theoretical value of 3. Moreover, in order to assess the quantity of weight–length growth differences between the sexes, biotopes, as well as among the weight–length growth of species in the study area and other areas, the percentage difference in weight (%DW) was estimated:

$$\%\mathrm{DW}_i = 100 \cdot \frac{(\mathrm{W}_i - \mathrm{W}_{all})}{\mathrm{W}_{all}} = 100 \cdot \frac{(a_i L^{bi} - aL^b)}{aL^b}$$

where W_{all} is the estimated weight at length L from all specimens in the present study, W_i the estimated weight at length L of sample i (i = sex, biotopes, or regions) and a, b the parameters of length–weight relation.

* Velentza A. 1992. Ilikia ke afxisi ton ixthion tis oikogeneias Mugilidae. [Age and growth of Mugilidae species.] BSc. Thesis, Aristotle University of Thessaloniki. [In Greek.]

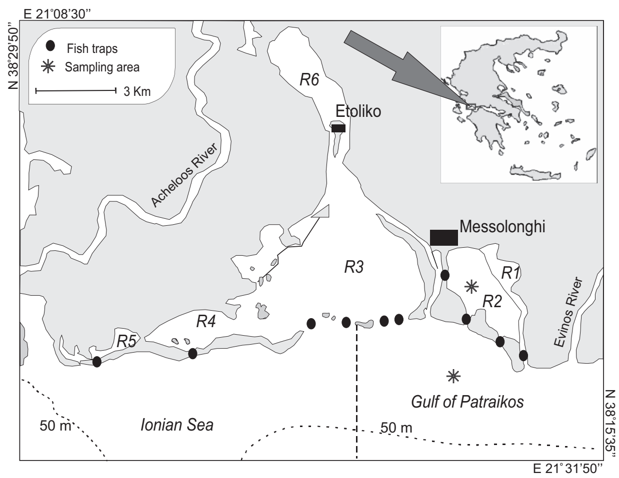

Fig. 1. Map of the Messolonghi Lagoon and the adjacent areas; (R1= Anatoliki Klisova; R2 = Ditiki Klisova; R3 = Kentriki limnothalassa; R4 = Tholi; R5 = Paleopotamos; R6 = Etoliko Lagoon)

Scales were used for age determinations. The scales were removed from the second and third row just under the base of the first dorsal fin of the left side of fish. The scales were interpreted by use of standard criteria (Bagenal and Tesch 1978). Annual marks were distinct in both the anterior and lateral scale's field and displaced cutting-over of circuli in one or both lateral fields. The scales were examined two times by the same reader with a minimum of three weeks between examinations. When the readings of the same fish were different, the scales were considered unreadable.

In a previous study (Hotos 2003) the scales and scales' marks of the golden grey mullet have been described in much detail and they are generally clear and closely related to fish length and easily interpretable. Additionally, a strong linear relation between the scale size and the fish length was found as well as one mark was formed per year.

Back calculation of total lengths at annulus formation was done with Lee's method (Bagenal and Tesch 1978) which is a modified version of the direct proportion formula:

$$L_t = L_\infty\,(1 - e^{-k(t - t_0)})$$

where R_i is the radius of the annulus i, R_c is the total scale radius at time of capture, L_c is the total length of the specimen at time of capture, L_i is the estimated total length at the assigned age i^{th} and a is the intercept on length axis from linear regression of length on scale radius.

Analysis of variance (ANOVA) was used to test for differences in the mean back-calculated total lengths-at-annulus formation among ages, sexes and regions (lagoon, sea). Furthermore, the Tukey test was applied, to check which factors (ages, sexes, biotopes, fishing gears), differ from each other.

Estimates of theoretical growth in length were obtained by fitting the von Bertalanffy growth function (VBGF) to the mean back calculated total length-at age data. The VBGF is expressed as:

$$L_i = a + (L_c - a)\,R_i R_c^{-1}$$

in which L_t is length at age t, L_∞ is the asymptotic length, k is the growth coefficient, and t_0 is the age at which length is zero. Growth parameters were estimated iteratively by the nonlinear least squares estimation procedure, using the program SPSS ver.10. Growth curves were estimated separately for females and males and region and compared with the analysis of the residuals sum of squares (Chen et al. 1992).

Overall growth performance was estimated with the index $\varphi' = \ln k + 2\ln L_\infty$, which allows the comparison of the overall growth performance between regions (study area and for other locations from the literature) (Pauly and Munro 1994).

RESULTS

During the study period a total of 1065 golden grey mullets were collected in the Klisova Lagoon and 81 in the Gulf of Patraikos (total 1146 individuals). The total length ranged from 9.7 to 59 cm (mean = 25.9 cm; SD = 7.2 cm) while the total weight ranged from 7.4 to 1850 g (mean = 198.7 g; SD = 203.3 g). The regression equations between L and L_S as well as L and L_f had slopes that did not differ significantly between the sexes (P > 0.05). The relations for sexes combined were: $L = 0.098 + 1.262L_S$ ($R^2 = 0.98$, $n = 1058$, SEest (standard error of estimate) = 0.28) and $L = -0.523 + 1.144L_f$ ($R^2 = 0.99$, $n = 1035$, SEest = 0.32), respectively.

In the lagoon, 317 individuals were identified as male, 382 as female, and 366 as immature individuals (sex ratio males : females = 1 : 1.20; $\chi^2 = 6.02$; df = 1; $P < 0.05$). In the Gulf of Patraikos, 28 individuals were identified as male, 41 as female, and 12 as immature individuals (sex ratio males : females = 1 : 1.46; $\chi^2 = 2.1$; df = 1; $P > 0.05$) (Table 1). Fig. 2 shows the distribution of the gonadal development. The specimens caught in the Gulf of Patraikos were at an earlier maturity stage than those caught in the lagoon ($\chi^2 = 34.8$; df = 7; $P < 0.05$).

Table 1

Monthly samples of *Liza aurata* from Klisova Lagoon and Gulf of Patraikos

Year	Month	Lagoon			Gulf			Total
		IM	F	M	IM	F	M	
1992	Dec	10	4	3				17
1993	Jan	4	7	2	2		4	19
	Feb		9	3		4	3	19
	Mar	4						4
	Apr	29	8	8	6	6	3	60
	May	19	12	6	4			41
	Jun	54	32	8		7	7	108
	Jul	23	36	14		5	4	82
	Aug	76	12	10		12	3	113
	Sep		25	60		7	4	96
	Oct	67	148	155				370
	Nov	59	67	31				157
	Dec	18	14	13				45
1994	Jan	3	3	2				8
	Feb		5	2				7
	Total	366	382	317	12	41	28	1146
Grand total*			1065			81		1146

IM = immature, F = females, M = males; *(IM + F + M).

The parameter b of length–weight relations was significantly different from 3 ($P < 0.05$) indicating allometry. ANCOVA on the log transformed values of length and weight showed no significant difference in the length–weight relations with sex ($F = 3.15$, $P > 0.05$). However, ANCOVA showed a significant difference ($F = 21.1$, $P < 0.05$) in length–weight relations with region (sea: $W = 0.0036\ L^{3.26}$; lagoon: $W = 0.0057\ L^{3.13}$). The length–weight relation for all specimens was $W = 0.0054L^{3.15}$ ($R^2 = 0.99$; SEest = 0.086). Moreover, the percentage difference in weight (%DW) at weight range from 150 to 1600 g was ± 5% (Fig. 3).

From the total sample the scales were easy readable in 1066 (93.02%) specimens while in 80 (6.98%) specimens were considered unreadable (Table 2).

Scale readings showed nine age classes of which the first three (0, I, and II) were dominant and the last two (VII and VIII) were represented by very few female specimens (Table 2).

There were nine age classes of golden grey mullet in the Gulf of Patraikos while in the Klisova Lagoon only seven (0–VI). The longest and oldest individual (59 cm, more of 8 years old) was caught in the sea while in the lagoon the longest and oldest individual was 47.1 cm and six years old.

The analysis of covariance showed no significant difference between male and female $Lc \div Rc$ relations ($F = 4 \cdot 10^{-6}$, $P > 0.05$). Thus, a pooled equation was estimated for the total sample: $L_c = 4.17 + 6.063R_c$, $R^2 = 0.96$, SEest = 1.54 (SEest is the standard error of estimation or of the slope).

Analysis of variance confirmed that for age groups I to IV there are significant differences on the back-calculated length at annulus formation among age groups ($P < 0.05$) while these differences (Tukey test) distributed rather randomly to the ages groups without any particular pattern (Table 3). On the other hand, no significant differences ($P > 0.05$) were found between the mean back-calculated length at annulus formation for males and females, for lagoon and sea as well as between the fishing gear types (Table 3).

Table 4 shows the parameters of the VBGF estimated by fitting the mean back-calculated length at annulus formation. The analysis of the residuals sum of squares showed that growth curves did not differ with sex and region (sexes: $F = 0.51$, $P > 0.05$; region: $F = 0.46$, $P > 0.05$ respectively). Thus, the VBGF parameters for all

Table 2

The sample used for growth analysis of *Liza aurata* from Klisova Lagoon and Gulf of Patraikos

Length	Age group (years)																	Total				
	IM			F								M										
	0	I	II	I	II	III	IV	V	VI	VII	VIII	I	II	III	IV	V	VI	IM	F	M	Aged	*n*
9–11	27																	27			27	27
11–13	16																	16			16	18
13–15	5																	5			5	5
15–17	71																	71			71	75
17–19	73																	73			73	73
19–21	46	1										3						47		3	52	54
21–23	31	25		4								21						56	4	21	81	83
23–25	6	31		23	2							34	2					37	25	36	98	107
25–27		17	1	64	34							35	20					18	98	55	171	179
27–29		1		35	57	2						57	37	2				1	94	96	191	202
29–31				13	19	25	1					10	9	14					58	33	91	101
31–33				2	3	25	6					1	3	12	4				36	20	56	63
33–35					1	4	16							4	18				21	22	43	51
35–37						3	13	1							12	1			17	13	30	40
37–39							6	2	2						3	3			10	6	16	20
39–41								3	2							2			5	2	7	8
41–43								4	2							2	1		6	3	9	10
43–45									2								3		2	3	5	5
45–47									7								4		7	4	11	12
47–49									1	1							3		2	3	5	5
49–51									1	3									4		4	4
51–53										3									3		3	3
53–55																						
55–57																						
57–59																						
59–61											1								1		1	1
Lagoon	266	72	1	143	115	49	34	8	7			157	70	25	31	7	6	339	356	296	991	1065
Gulf	9	3			1	10	8	2	10	7	1	4	1	7	6	1	5	12	39	24	75	81
Total	275	75	1	143	116	59	42	10	17	7	1	160	71	32	37	8	11	351	395	320	1066	1146

IM = immature, F = females, M = males, *n*, number of specimens used in scales ageing, 0 = no annulus present on the scale.

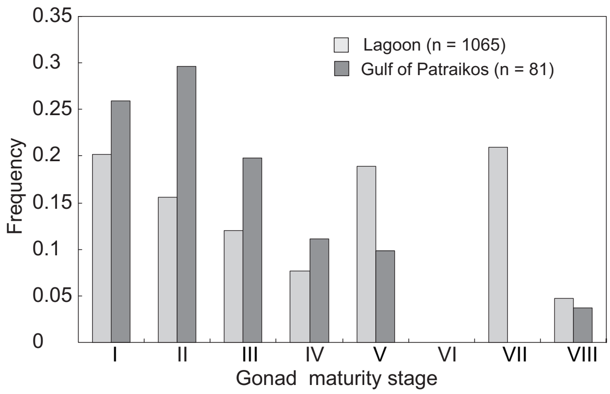

Fig. 2. Frequency distribution of gonad stage maturity (according to Kesteven 1960 and Hotos et al. 2000) of the males and females of *Liza aurata* from the Klisova Lagoon and the Gulf of Patraikos

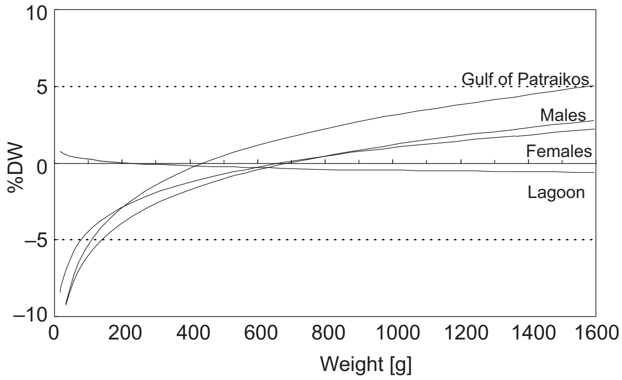

Fig. 3. Weight percentage difference (%DW) of sexes and biotopes of *Liza aurata* from the Klisova Lagoon and the Gulf of Patraikos, estimated by length–weight models in relation to the weight estimated from the corresponding model of pooled total sample

samples combined (L_∞ = 65.08 ± 2.61 cm; k = 0.149 ± 0.017 year^{-1} and t_o = –1.15 ± 0.063 years) were used to describe golden grey mullet's growth (Fig. 4). Back-calculated lengths at age were characterised by a large spread and overlapping among age groups.

The ratio of $L_{obs} \div L_\infty$ (L_{obs} is the maximum observed total length in the sample) was 0.72 in the lagoon and 0.90 in the sea. The estimation of φ' from the VBGF parameters from all samples combined was φ' = 2.80.

DISCUSSION

Various methods are used to determine the age in Mugilidae. Some authors using length frequency analysis (Albertini-Berhaut 1978, Drake et al. 1984a, Konides et al. 1992), but Quignard and Farrugio (1981) claim that these methods are useless for mullets because of the difficulties in obtaining samples and because spawning takes place over several months.

Both scales and otoliths are used for the age determination of Mugilidae. To use scales, otoliths or any other structure, for age determination, the deposition of regular detectable age marks is essential. Otolith age determination is supposed to be more accurate because otoliths have a higher priority in utilization of calcium (Carlander 1987). In mullet the otoliths have rarely been used because of the difficulty in reading the rings in the region near the focus of the otolith. Quignard and Farrugio (1981) indicated that only 67%, 66% and 64% of the otoliths of *L. ramada*, *C. labrosus*, and *L. aurata* respectively were readable. However, this difficulty can be overcome by smoothing the bezel side during the preparation of the otolith, increasing the percentage of reliability of readings up to 92.1% (Katselis et al. 2002) but with an increase in the otolith preparation cost.

The suitability of the scales for ageing of golden grey mullet has been reported. The scales and scale's marks of the golden grey mullet were generally clear and closely related to fish length, easily interpretable and a mark formed per year (February), while the first mark on the scales was formed on fishes about 17 months old (Hotos 2003). Furthermore, they were generally clear and closely related to fish length (R^2 = 0.96), easily interpretable with a high readability (93%).

The oldest specimen of golden grey mullet in the Gulf of Patraikos was 8 years while in the lagoon it was 6 years. The golden grey mullet cannot be easily typified as a short-lived species, because in the present study several specimens older than 6 years were recorded. Indeed, Reay (1987) reports 14-year-old specimens from the Great Britain waters, while the oldest specimen was caught in Caspian Sea aged in 11-year-old (Fazli et al. 2008). On the other hand, the sea water preference of the oldest specimens of golden grey mullet is in agreement with the findings in other regions (Caspian Sea: Nikolskii 1954*; Black Sea, Bay of Biscay: Quignard and Farrugio 1981; Caspian Sea: Fazli et al. 2008; Adriatic Sea: Kraljević and Dulčić 1996), while the species has a shorter life span in internal waters (about 3–6 years) (Table 5).

The length overlapping between successive age classes is expected for species with an extended reproductive period. The golden grey mullet belongs to this group of species (Hotos et al. 2000). Moreover, the population of golden grey mullet caught in the lagoon system of Messolonghi-Etoliko consists of individuals of different ages, which inhabit several biotopes with various levels of trophic importance for fishes in adjacent areas of the Ionian Sea and the Gulf of Patraikos and enter into the lagoons each spring. This mechanism could explain a part of the variability of back calculated length at annulus formation among the ages (Table 3) and the length overlapping between successive age classes.

The equation of von Bertalanffy in the present study exhibited an excellent fit of the data (R^2 = 0.92) and appeared to be an accurate description of growth in length of golden grey mullet for all stages of its life (fry, juveniles and adults). Indeed, the high values $L_{obs} \div L_\infty$ (L_{obs} is the maximum observed length in the sample) (0.72 in the lagoon and 0.90 in the sea) indicated that the von Bertalanffy

* quoted after Quignard and Farrugio 1981.

equation described a major part of species life. The $Lc \div Rc$ relation, also, exhibited an excellent fit of the data ($R^2 = 0.96$), while the intercept of their relationship was 4.17 cm close to the length that appeared the scales on body of species (Quignard and Farrugio 1981). Finally, the estimated value of t_0 was –1.14 ± 0.063 years (12.2–15.2 months) and can be considered, as the time needed to form the first ring in scales (about 17 months) (Hotos 2003), indicated that the von Bertalanffy equation described, also, the growth of the young stages of species. These finding are in agreement with the corresponding value estimated for the *L. saliens* ($L_{obs} \div L_\infty = 0.88$) in the Messolonghi–Etoliko Lagoon (Katselis et al. 2002).

A lot of variation in the values of the growth parameters of the golden grey mullet is evident from the published literature (Table 5). The overall growth performance index φ' ranged from 2.52 to 2.99. In the present study the index φ' was estimated at 2.81, but considered the confidence interval 95% of VBGF parameters estimations (±1.96 SE) (Table 4), can be estimated that the index φ' in the present study ranged from 2.66 to 2.92. In Table 5 seems that the most of index φ' records (63%: 14 from 22 records) included in this range which it revealed a rather similar growth performance of species in study area compared to other regions. However, some differences in the index φ' as well as in the back-calculated values of the total length at age from the present study, may be attributed either to different biology of the species in those areas or to possible false age estimation. Indeed, in some studies the younger age groups were not collected (Kraljević and

Table 3

Mean back calculated total lengths (cm) at annulus formation of *Liza aurata* from Klisova Lagoon and Gulf of Patraikos

Age group (yr)	Age group I	II	III	IV	V	VI	VII	VIII	*n*
0	—								275
I	18.51[a]								378
II	17.53[b]	24.59[d]							188
III	15.80[c]	24.27[d]	29.88[f]						91
IV	17.43[b]	24.67[d]	29.35[f]	33.24[i]					79
V	17.96[a,b]	26.85[e]	33.86[h]	37.02[k]	39.67[l]				18
VI	19.34[a]	24.86[d]	31.05[g,f]	34.66[j]	39.37[m]	41.95[n]			28
VII	18.93[a,b]	24.02[d]	30.00[f]	36.05[j]	40.76[l]	43.44[o]	46.24		7
VIII	21.25	27.20	34.42	40.60	45.51	48.37	51.46	53.51	1
mean	17.86	24.69	30.23	34.26	39.77	42.42	46.90	53.51	
SD	2.02	2.11	2.66	2.82	2.13	2.20	2.14		
n_r	683	412	224	133	54	36	8	1	
F	15.5	5.19	22.7	20.8	7.01	13.3			
P	0.00	0.00	0.00	0.00	0.00	0.00			
				Per sex					
Females	17.79	24.86	30.38	34.37	39.60	42.25	46.90	53.51	
n_r	300	272	207	116	60	35	8	1	
Males	17.92	24.49	30.07	34.11	40.04	42.79			
n_r	355	313	229	124	49	11			
F	0.65	2.99	0.87	0.39	0.54	0.45			
P	0.42	0.08	0.35	0.54	0.46	0.51			
				Per region					
Gulf (sea)	17.82	24.68	30.13	34.31	39.83	42.53	46.90	53.51	
n_r	63	61	52	41	26	20	8	1	
Lagoon	17.83	24.67	30.12	34.30	39.82	42.44			
n_r	727	351	172	92	28	16			
F	0.07	0.08	0.02	0.02	0.04	0.01			
P	0.81	0.78	0.87	0.96	0.84	0.91			
				Per fishing gear					
Barrier traps	17.83	24.68	30.10	34.30	39.85	42.45			
n_r	651	281	107	55	9	4			
Net Lagoon	17.80	24.65	30.15	34.29	39.80	42.43			
n_r	76	70	65	37	19	12			
Net Sea	17.81	24.68	30.18	34.31	39.83	42.53	46.90	53.51	
n_r	63	61	52	41	26	20	8	1	
F	0.01	0.11	0.02	0.04	0.03	0.04			
P	0.99	0.89	0.98	0.95	0.96	0.95			

n = number of specimens, n_r = number of scales readings, SD = standard deviation, *F* = *F*-ratio; *P* = significance level; The same superscript letters mark back-calculated lengths showing non significant differences between the age groups.

Table 4

Parameters of the von Bertalanffy equation for *Liza aurata* from Klisova Lagoon and Gulf of Patraikos (with standard error in the brackets)

	F	M	Lagoon	Gulf (sea)	All
L_∞ [cm]	63.12 (2.86)	64.98 (3.7)	64.12 (3.8)	66.15 (4.16)	65.08 (2.61)
k [year^{-1}]	–0.159 (0.013)	–0.149 (0.019)	–0.152 (0.016)	–0.145 (0.017)	–0.149 (0.010)
t_o [year]	–1.094 (0.081)	–1.148 (0.100)	–1.140 (0.080)	–1.170 (0.013)	–1.141 (0.063)
SEest	4.66	4.51	4.6	3.65	4.55
R^2	0.92	0.91	0.89	0.95	0.92
	$F = 0.51$; $P = 0.66$		$F = 0.46$; $P = 0.70$		

F = females, M = males, All = pooled sample; L_∞ = asymptotic length; k = growth coefficient; t_o = age at which length is zero; SEest = Standard Error of Estimation; R^2 = Coefficient of determination; F = F-ratio, P = significance level.

Dulčić 1996: $\varphi' = 2.52$) and in some others fish older than two or three years were not recorded (Serbetis[*] 1939: $\varphi' = 2.99$ and Heldt[*] 1948: $\varphi' = 2.89$; Arruda et al. 1991: $\varphi' = 2.71$). Also, in previous studies in western Greece coastal waters (Konides et al. 1992, Giatnisi unpublished[**]) the φ' values (2.64 and 2.65 respectively) were close to the lower limit of estimated φ' in the present study. This fact may be a result of the low accuracy of age estimation and can be attributed on the unsuitability of length frequency as an age estimation method for mullet as used by Konides et al. (1991) and on the fact that the age has been estimated from a sample of young specimens (0–3 age groups) (Giatnisi unpublished[**]).

Certainly, different growth rates of golden grey mullet in different locations are probably due to local differences on important factors influencing growth, like water temperature. This is because grey mullets spent most of their time

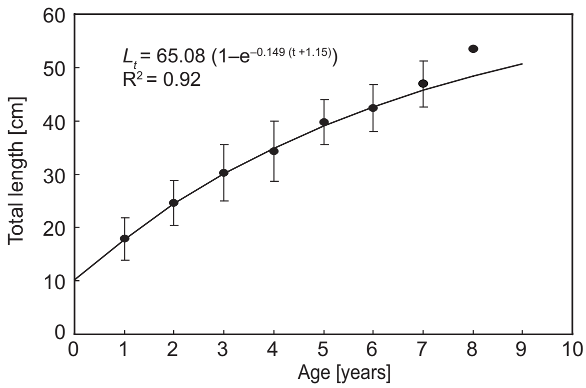

Fig. 4. Von Bertalanffy growth curve for both sexes of *Liza aurata* from the Klisova Lagoon and the Gulf of Patraikos (combined data); Solid dots are the mean back calculated lengths at annulus formation and bars indicate two folds of the SD

in shallow inshore waters, where the temperature is influenced more by local conditions (with noticeable fluctuations from location to location) than by temperature of the open sea, which is more stable (Kennedy and Fitzmaurice 1969). However, the different growth rates of golden grey mullet in different locations can be related to other factors apart from temperature, such as food availability and/or density-dependent relations (El Zarka et al. 1970, Drake et al. 1984 b).

Growth in length was similar for males and females, even though females were predominant in the older age groups (Table 3). Although it is not clear if differences in the growth between the sexes in mullet species are existing, when these are noticeable the females grow faster than males while these appear only after the second year of life (Quignard and Farrugio 1981). However, the findings for other Mugilidae species in the Greek lagoons (Messolonghi-Etoliko Lagoon: *L. ramada*: Minos unpublished[***]; *L. saliens*: Katselis et al. 2002; Porto Lagos Lagoon and Vistonis Lake: *L. ramada*, *L. saliens* and *C. labrosus*: Koutrakis and Sinis 1994) supported the similarity of growth in length between sexes.

The parameters b of the length–weight relation show that golden grey mullet in the study area grew allometrically while it was greater than in other regions (Table 6). Variability on L–W estimates could be attributed to a number of other factors including season, habitat, gonad maturity, sex, diet and stomach fullness, health, preservation techniques and differences in the observed length ranges of the specimen caught (Froese 2006). Thus, in the present study the differences on the parameters of length–weight relation between the sea and lagoon samples can be attributed to the corresponding differences on the stage maturity of samples (Fig. 2), as well as to the season of samples collected. Indeed, the sea sample was collected during the period from January to September while more than of 50% of specimens of lagoon sample were collected during the period October to December (Table 1). However, the percentage differences on weight between the sea and the lagoon, in the range of weight 150–1600 g, are low (about ±5%) (Fig. 3). In contrast, the corresponding differences on weight between the present study and other regions (Fig. 5) are ranged from ±5% (Aveiro Lagoon: Arruda et al. 1991; Homa Lagoon: İlkyaz et al. 2006; Coasts of W. Greece: Konides et al. 1992) to –60% (Brittany, France: Quignard and Farrugio 1981) and to 80% (Étang de Berre, France: Quignard and Farrugio 1981).

In conclusion, the results of the present study revealed that the age and growth in length and weight of golden grey mullet in the Klisova Lagoon and in the adjacent coastal waters of the Gulf of Patraikos were not significantly different. Taking into account that, the trophic level of the Klisova Lagoon is higher than that of the sea (Hotos and Avramidou 1997), it would be expected to see differences in the growth of the grey mullet between the two biotopes. However, the growth performance and the osmotic adjustment effort of golden grey mullet are opti-

[*] quoted after Quignard and Farrugio 1981.

[**] Giatnisi M.E. 1985. Sigritiki meleti ton viologikon parametron tou genus *Mugil* (Family: Mugilidae). [Comparative study of biological parameters of genus *Mugil* (Family: Mugilidae).] MSc Thesis, University of Athens. [In Greek.]

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Table 5

Growth rate of *Liza aurata* in different geographic localities

[Author] Area	MTH	n	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_∞	k	t_o	φ'
Lagoons and estuaries																	
[1] Klisova Lagoon (F)	S	393	17.8	24.9	30.4	34.4	39.6	42.3						63.1	0.159	–1.09	2.80
[1] Klisova Lagoon (M)	S	312	17.9	24.5	30.1	34.1	40	42.8						64.9	0.152	–1.14	2.81
[1] Klisova Lagoon (M + F)	S	991	17.8	24.7	30.2	34.3	40	42.4						64.1	0.152	–1.14	2.80
[2] Krka River estuary														51	0.3	–0.4	2.89
[3] Stagnone Lagoon (Sicily)	S	423	10.5	17.4	19.8	21.7	22.6	24						24.3	0.63	–0.11	2.57
[4] Cádiz estuaries (Spain)	LF	3012		18.7	26.2	30.7	34.5							41.7	0.382	–0.54	2.82
[5] Aveiro Lagoon (Portugal)	S	3689	10.5	16.5	21.9	26.8								68.5	0.11	–0.51	2.71
[6] Étang de Thau (France)	S		12.5	17.6	21.6	31.9											
[7] Homa Lagoon (Izmir, Turkey)	S	342	12.19	21.6	26.9	32.6	39.45							43.2	0.33	–0.30	2.79
[22] Étang de Berre (France) (F)	S		13.1	20.1	26.6	32.5	36.9	41						68.6	0.14	–0.5	2.82
[22] Étang de Berre (France) (M)	S	1055	12.7	18.8	25.4	30.3	34							57.8	0.16	–0.5	2.73
Coastal areas and sea																	
[1] Gulf of Patraikos (Greece)	S	75	17.8	24.7	30.2	34.3	39.8	42.5	46.9	53.5				66.2	0.145	–1.17	2.80
[4] Bahía de Cádiz (Spain)	LF		13.5	19.5	25.5	30.7	34.5							63.7	0.135	–0.75	2.74
[8] Ionian coast of Greece	LF, S	645												76.9	0.074	–0.2	2.64
[9] Epirus (NW Greece)	Ot	117	9	14.2	20.5	22.9								40	0.28	–0.96	2.65
[10] Gulf of Saronikos (Greece)	?													26.6	0.55	–0.46	2.59
[11] Luka Mirna (Croatia)	S	1073			22.8	26.5	28.5	30.7	32.4	34.5				39.8	0.21	–1.14	2.52
[12] Bay of Marseille (France)	LF	4800	17.9											45	0.2	–0.49	2.61
[13] Rome area (Italy)	S	40	13.5	25	33.5	39.2								53.7	0.34	0.15	2.99
[14] Brittany (France)	S	127	10.9	19.7	27.2	31.4	35.8	39.9	43.9					61.3	0.173	–0.08	2.81
[15] Morbihan (France)	S	127	9.1	20.9	26.2	31.3	34.5	38.3						58.2	0.156	—	2.72
[16] Bay of Biscay (France)	S		11.2	17.3	27.1	31.1	34.9							51.1	0.224	–0.02	2.77
[17] Isles of Scilly (UK)	S, LF		5	10.7	18.7	24.2	26.5	34.3						116	0.061	0.24	2.91
[18] Black Sea	?		12	21	26	30	36							51.6	0.229	–0.21	2.79
[18] Caspian Sea	?			21	28	33	36	41	43	46				60	0.177	–1.56	2.80
[19] Caspian Sea	?		13	24	32.7	37.5	41.5	45	48					54.1	0.311	0.12	2.96
[20] Caspian Sea	s	3502	12	20	27	30	35	40	45	49	53	54.6	55.8	68.8	0.15	–0.23	2.85
[21] Tunisia (Tunis)	S		18.8	27	32									39.8	0.495	–0.29	2.89

MTH = method, F = female, M = male, Ot = otolith, S = scales, LF = length-frequency analysis n = No. of fish; $L_1, L_2 \ldots L_n$ = the length at age 1, 2…n years; L_∞ = asymptotic length; k = growth coefficient; t_o = age at which length is zero; φ' = Overall growth performance;1 = presently reported study, 2 = Modrusan et al. 1988, 3 = Andaloro 1983, 4 = Drake et al. 1984a, 5 = Arruda et al. 1991, 6 = Coutelan 1953†, 7 = İlkyaz et al. 2006, 8 = Konides et al. 1992, 9 = Giatnisi unpublished* 1985, 10 = Velentza unpublished**, 11 = Kraljević and Dulčić 1996, 12 = Albertini-Berhaut 1978, 13 = Serbetis 1939†, 14 = Thong 1969†, 15 = Thong 1971†, 16 = Arne 1938†, 17 = Hickling 1970†, 18 = Nikolskii 1954†, 19 = Alexandrova 1964†, 20 = Fazli et al. 2006, 21 = Heldt 1948†, 22 = Ezzat 1965†; † quoted after Quignard and Farrugio 1981.

* see footnote (**) on page 153.
** see footnote on page 148.

Table 6

Length–weight relation (a, b) of *Liza aurata* in this study and in studies reported by other authors

Area	Author(s)	Type of length	Length [cm]	*n*	a	b
Ionian coast of Greece	Konides et al. 1992	L_f	6–26	645	$2.8\cdot10^{-2}$	2.78
Gulf of Patraikos (M + F)	Present study	L	18–59	81	$3.6\cdot10^{-3}$	3.26
Klisova Lagoon (M + F)	Present study	L	9.7–47	1065	$5.7\cdot10^{-3}$	3.13
Epirus (NW Greece)	Giatnisi unpublished[1*]	L	9–25	117	$3.8\cdot10^{-3}$	3.20
Gulf of Saronikos (Greece)	Velentza unpublished[2]	L_s	15.5–21		$7.8\cdot10^{-3}$	3.23
Luka Mirna (Croatia)	Dulčić and Kraljević 1997		15–39		$9.1\cdot10^{-3}$	2.95
Bay of Marseille (France)	Albertini-Berhaut 1978	L	1–19	4800	$4.6\cdot10^{-3}$	3.31
Étang de Berre (France) (F)	Ezzat 1965†	L	9–42		$1.5\cdot10^{-2}$	2.49
Étang de Berre (France) (M)	Ezzat 1965†	L	9–42		$6.4\cdot10^{-3}$	2.62
Homa Lagoon (Izmir, Turkey)	İlkyaz et al. 2006	L	7.5–39.5	342	$1.1\cdot10^{-2}$	2.93
Stagnone Lagoon (Sicily)	Andaloro 1983	L	10–25	423	$2.0\cdot10^{-2}$	3.01
Rome area (Italy)	Serbetis 1939†	L	14–43	40	$4.9\cdot10^{-3}$	2.69
Brittany (France)	Thong 1969†	L	8.1 – 41.4	127	$4.2\cdot10^{-3}$	3.04
Aveiro Lagoon (Portugal)	Arruda et al. 1991	L	2–29	3689	$1.2\cdot10^{-2}$	2.93
Strymon River estuary, (NW Aegean)	Koutrakis and Tsikliras 2003	L	1.7–8.4		$1.0\cdot10^{-2}$	2.99
Rihios River estuary, (NW Aegean)	Koutrakis and Tsikliras 2003	L	2–17.5		$1.2\cdot10^{-2}$	2.83

L_f = fork length, Ls = standard length, L = total length, F = females; M = males, *n* = No. of fish; † quoted after Quignard and Farrugio 1981.

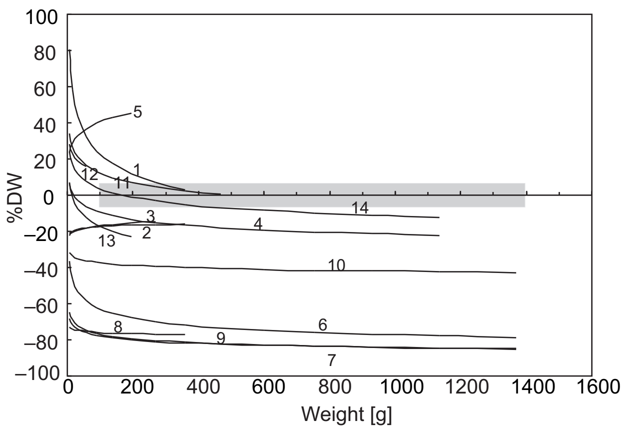

Fig. 5. Comparison of weight percentage difference (%DW) of *Liza aurata* from other localities (determined by other authors) with the presently reported study, estimated by length–weight models; The shadowed area indicating the differences which noted in the present study among the sexes and biotopes; F = females, M = males, 1 = Konides et al. 1992, 2 = Giantisi 1985, 3 = Velentza unpublished*, 4 = Dulčić and Kraljević 1997, 5 = Albertini-Berhaut 1978, 6 = Ezzat 1965† (M), 7 = Ezzat 1965† (F), 8 = Andaloro 1983, 9 = Serbetis 1939†, 10 = Thong 1971†, 11 = Arruda et al. 1991, 12 = Koutrakis and Tsikliras 2003 (Strymon estuary), 13 = Koutrakis and Tsikliras 2003 (Rihios estuary), 14 = İlkyaz et al. 2006; † quoted after Quignard and Farrugio 1981

mized within the salinity range from 15‰ to 30‰ (Shusmin 1990) and it seems that the optimum salinity is the key factor of habitat preference of this species (Cardona 2006). These data support that the relatively high salinity environment of the studied lagoon (Hotos and Avramidou 1997: about 40‰) may rebut their high trophic advantage for golden grey mullet. Alternatively, this paradox could be explained by a scenario based on the seasonal migrations of this fish between sea and lagoon (Katselis et al. 2003, 2007). Based to this the lagoon population of species is part of the sea population which migrates in the lagoon during the spring and after short-term residence in lagoon (some months), returns to sea.

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* see footnote on page 148.

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