Aspects on the demography of Chub Mackerel (*Scomber japonicus* Houttuyn, 1782) in the Hellenic Seas

Sotiris Kiparissis[1], **George Tserpes**[2] **and Nikolaos Tsimenidis**[3]

[1] **Aristoteleion University of Thessaloniki, School of Biology, Laboratory of Ichthyology, Box 134, 54006 Thessaloniki, Hellas**
[2] **Institute of Marine Biology of Crete, PO Box 2214, 71003 Heraklion, Hellas**
[3] **University of Crete, Department of Biology, PO Box 1470, 71110 Heraklion, Hellas**

ABSTRACT. The main features of the demography of *Scomber japonicus* in the Hellenic seas were studied during 1996. The dominant size class in the length frequencies of all catches was 190-200 mm, whereas the dominant age class in the samples from the Northern Aegean and Saronikos Gulf was the age class 1, and from the Cretan Sea the age class 3. The formation of the new annulus commences in April for age classes 1 and 2 and in July for the age class 3. The sex ratio in all samples was found to be 1:1. The von Bertalanffy growth functions showed no statistically significant difference between males and females. The growth parameters from the pooled data were estimated as: L_∞ = 475.96 mm, K = 0.154 yr^{-1} and t_0 = -2.177. Scomber japonicus in the Hellenic seas exhibits slower growth rate than that observed in other Mediterranean regions.

KEY WORDS: *Scomber*, Aegean, Saronikos, Cretan Sea.

INTRODUCTION

Chub mackerel (*Scomber japonicus* Houttuyn, 1782), is a cosmopolitan middle-sized pelagic species with a very wide distribution over the continental shelf of the tropical and subtropical regions of the Atlantic, Indian, Pacific Oceans and adjacent seas. It is a primarily coastal species, found from the surface down to 300 m depth (COLLETE & NAUEN, 1983). Along its distribution, the species is found in isolated populations with complex intraspecific structure, which has been studied little (KOTLYAR & ABRAMOV, 1982). Five subspecies have been identified so far, which form discrete populations with different spawning and feeding areas along the species distribution (KOTLYAR & ABRAMOV, 1982; BELYAEV & RYABOV, 1987). In the Mediterranean sea and in the west African waters, the subspecies found is the *Scomber japonicus colias* (MORAITOPOULOU, 1963; KOTLYAR & ABRAMOV, 1982).

Scomber japonicus is a species of high commercial interest in Hellas. According to the bulletins of the Hellenic National Statistical Service, during the last decade the annual production in the Hellenic seas was about 10000 mt. Despite its important commercial value, virtually nothing is known about its stocks in this region and generally in the Eastern Mediterranean. Information regarding the biology and population dynamics of this species comes mainly from studies conducted in other parts of the world, mainly from the Pacific Ocean (SCHAEFER, 1980). The objective of the present work is to elucidate the main features of the demography of this species in the Hellenic seas.

MATERIAL AND METHODS

Fish sampling

Samples were collected monthly during the year 1996 from the landings at the auction sites of Kavala and Thessaloniki (Northern Aegean), Pereus (Saronikos Gulf) and Heraklion and Chania (Cretan Sea). A total of 1138 fish was collected from all sampling regions. From the Cretan Sea samples were found only during June and August because of the seasonal appearance of this species in this area. All fish were caught with purse seines and after landing were refrigerated at -20°C until further work. Sampling was not conducted during January and

Corresponding author: Sotiris Kiparissis. e-mail: tholi @ bio.auth.gr

December 1996 because of the prohibition of purse seine fishing during these months. The total weight of each fish was weighed to the nearest centigram and its fork length was measured to the nearest millimeter. Sex was determined through gonadal inspection. The proper interval for the length frequency distribution was estimated by the Goulden method (Cansela da Fonseca, 1965).

Age determination

The age of each fish was assigned by otolith reading. The otoliths (sagittae) of each fish were removed, cleaned and preserved dry. The readings were conducted by a stereoscopic microscope under a 50x magnification, using reflected light against a dark background. Under reflected light the bands formed during periods of fast growth have a white appearance (opaque), while those formed during the periods of slow growth have a dark appearance (translucent). In order to enhance their transparency during reading, the otoliths were kept submerged in 90° alcohol. Each otolith was read twice, with a two month interval between each reading. Whenever there was a discrepancy between the two readings, the age data were excluded from the study. Besides the number of annuli on each otolith, the otolith radius (distance from the focus to the otolith posterior end), the width of each annulus as well as the type of marginal formation were recorded.

Statistical analysis

The time of the annulus formation and the periodicity of the opaque and translucent bands were estimated by the marginal increment ratio (MIR), which gives a measure of the relative width of the otolith edge and is described by the ratio:

$$MIR = (R - r_n) / R$$

where R = the total otolith radius and
r_n = the radius of the most recent annulus.

The MIR was calculated for each month and age separately. Marginal increment analysis was not conducted for ages above 3 due to the lack of sufficient samples.

The sex composition of the samples from all three sampling regions was examined for each age class independently and significant deviations from the expected 1:1 sex ratio were tested using the χ^2 goodness of fit test (Zar, 1996). The correction factor of Yates was applied on the test.

The theoretical rate of growth was obtained by fitting the assigned ages and the corresponding lengths to the von Bertalanffy growth model. The parameters of the model were estimated iteratively using the Simplex minimization algorithm (Wilkinson, 1987). The measure of goodness of fit was the coefficient of determination (r^2). The 1st of June was assigned as the birth date for all fish. During this month, the largest concentration of *S. japonicus* larvae has been detected in the Northern Aegean (Somarakis, personal communication). The growth parameters were estimated for each sex separately and for both sexes combined. The difference in growth of males and females was tested by an analysis of the residual sum of squares using the Ratkowsky method as suggested by Chen et al. (1992).

The length-weight relationship was estimated from the regression of the total weight to the fork length. For this calculation the logarithmic values of weights and lengths were used.

RESULTS

Length frequencies

The dominant size class in the length frequency distribution from the catches of all three regions together was the 190-200 mm size class. For each region seperately, the dominant size classes were: 155-165 and 240-250 mm for the Northern Aegean catches, 190-200 mm for the Saronikos Gulf catches and 275-285 mm for the Cretan Sea catches (Fig. 1). The range of the total lengths and the mean length of the fish caught in each study area were: a) for the Northern Aegean Sea 91-266 mm (mean length=184 mm, sd=28 mm) b) for the Saronikos Gulf 138-293 mm (mean length=206 mm, sd=38 mm) and c) for the Cretan Sea 239-310 mm (mean length=279 mm, sd=15 mm).

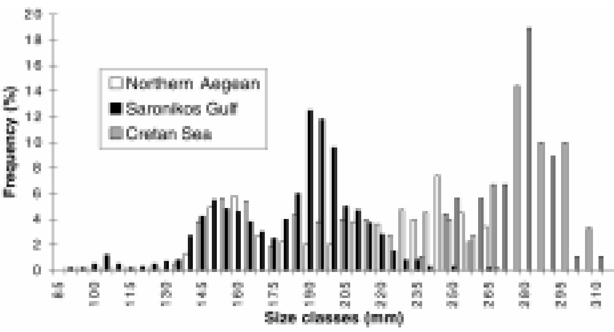

Fig. 1. – Length frequency distributions of chub mackerel caught at the three sampling areas.

Marginal Increment Analysis

Translucent edges on the otoliths were observed in all months, while opaque edges were observed from March

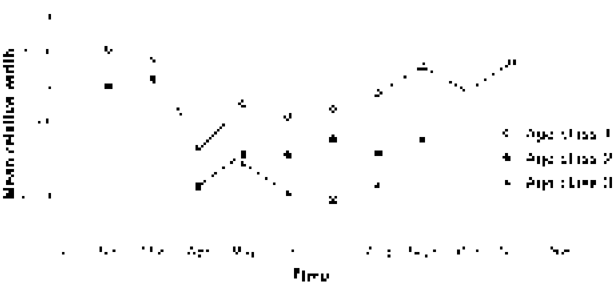

Fig. 2. – Mean monthly relative marginal width on the otoliths of chub mackerel belonging to the age classes 1, 2 and 3.

to September, with highest percentage (59%) on April. Analysis of the Marginal Increment Ratio, showed a distinct fall of the relative marginal width on April for the age classes 1 and 2 and on July for the age class 3 (Fig. 2). During one year period there was only one distinct fall, which proves that one translucent and one opaque band are formed each year constituting one annulus.

Age composition

Conformity in both age readings was found for 1026 otoliths which corresponds to 90,3% of the readings. From the three sampling areas the allocated age classes were: a) for the Northern Aegean the age classes 0 to 5 with dominant the age class 1, b) for the Saronikos Gulf the age classes 0 to 2 with also dominant the age class 1 and c) for the Cretan Sea the age classes 1 to 4 with dominant the age class 3 (Table 1).

TABLE 1

Percentage of each age class of chub mackerel in the three sampling areas

Age class	Sampling area			Total
	Northern Aegean	***Saronikos Gulf***	***Cretan Sea***	
0	34.5	30.8	0	30.1
1	52.7	43.5	4.4	45.9
2	11.7	25.6	41.2	19.1
3	0.7	0	52.9	3.9
4	0.1	0	0	0.2
5	0.1	0	0	0.1

Sex composition

The χ^2 test for heterogeneity performed for each sample separately in all sampling areas, revealed that the ratio males: females was not significantly different from 1:1 for all cases. The χ^2 test for heterogeneity performed for each age class from each sampling area also showed the ratio males: females to be not significantly different from 1:1 (Table 2).

Finally, the χ^2 test for goodness of fit for all samples combined, verified the former analogy (for all tests performed, it was p>0,05).

Growth rate

By the iterative method the parameters of the von Bertalanffy equation for males and females were estimated as:

males: L_∞ = 46.406 cm, K = 0.157 and t_0 = -1.882
females: L_∞ = 34.548 cm, K = 0.303 and t_0 = -1.531
with coefficients of determination r^2 = 0.989 for the males and r^2 = 0.987 for the females respectively. The comparison of the these two growth curves by the Ratkowsky method (CHEN et al., 1992), displayed no statistically significant difference between the two curves (F = 0.7390558, $F_{(0.05,\ 3,\ 1017)}$ = 2.61), thus we cannot reject the null hypothesis of similarity.

The parameters of the Bertalanffy function as they were estimated from the pooled data of both sexes, were: L_∞ = 47.596 cm, K = 0.154 y^{-1} and t_0 = -2.177 (r^2 = 0.988).

Weight - Length relationship

From the regression of the total weight on the fork length of each fish the relationship derived, was: logW = 3.462 logL - 6.0151 $\Rightarrow$ W = 9.65 * 10^{-7} $L^{3.5}$.

DISCUSSION

In natural populations the younger an age class is the more abundant it is expected to be, unless extraordinary environmental conditions have preceded. An unbiased sampling device is expected to show this age abundance sequence in the samples it collects. In the samples coming from the Northern Aegean and Saronikos Gulf (Table 1), the age class 0 is underrepresented, which shows that there is a sampling bias originating either from the preference of the fishermen to the larger fish, or from the ability of smaller fish to escape from the seines. Either way, the 0 age class specimens caught must be the largest ones

TABLE 2

Sex composition of chub mackerel in the three sampling areas, tested for each age class in each area seperarely as well as for all sampling areas combined. The H0 tested was the 1 male : 1 female sex ratio (m = number of males, f = number of females, ÷*c2* = ÷*2* test value corrected for continuity, * = no fish were caught).

Sampling area	Age class											
	0			1			2			3		
	m	f	χ_c^2	m	f	χ_c^2	m	f	χ_c^2	m	f	χ_c^2
Northern Aegean	58	44	1.66	157	149	0.16	19	19	0.00	3	1	0.13
Saronikos Gulf	70	64	0.19	79	68	0.68	4	9	1.23	*	*	*
Cretan Sea	*	*	*	30	22	0.94	12	14	0.04	8	10	0.06
Total	128	108	1.53	266	239	1.34	35	42	0.64	11	11	0.00

of this class, which leads to the conclusion that selective fishing is exerted towards the largest specimens of this class. The remaining age classes in these regions follow the expected pattern which also shows that fishes of the age class 1 and older are fully fished. In the Cretan Sea the complete lack of the age class 0, the very low presence of the age class 1 and the high abundance of larger sexually mature classes (age classes 2 and 3) along with the highly seasonal appearance of this species in this area – the species appears in the area during the summer months (Moraitopoulou, 1963) – lead us to the conclusion that its presence there is related with its spawning migratory routine. The migratory pattern of this fish – whether it comes from the Aegean Sea stock or from other Eastern Mediterranean stocks – is a matter for further investigation.

Due to their annual periodicity opaque and translucent bands are appropriate for assigning age. The time of the onset of the new annulus formation for the age classes 1 and 2 was April, whereas that for the age class 3, was July. This is in agreement with Williams & Bedford (1974) who state that generally, within each stock, younger fish begin to lay down the opaque band before older ones. Analysis of the marginal type has shown that the period of rapid growth (when opaque edges are observed) is from March to August. The same period of fast growth (March to September) has been observed in the Canary Islands, where the same subspecies is found (Lorenzo et al., 1995).

The sex ratio of 1 male: 1 female found in the Hellenic seas was also found for chub mackerel in the Pacific Ocean (Schaefer, 1980). According to Watanabe (1970) during wintering and spawning periods the sex ratio varies among *S. japonicus* schools, but is assumed to be 1:1 for the population as a whole.

Scomber japonicus growth rates are similar in both sexes, as has also been observed in other regions of the species distribution (Gagliardi & Cousseau, 1970; Perrotta & Forciniti, 1989). From studies conducted in most regions of the species distribution, it was shown that *S. japonicus* exhibits a very high growth rate during its first year of life (Schaefer, 1980; Perrotta, 1992). In the Hellenic seas this growth rate reached 38.7% of its asymptotic length (L_{∞}). During the second and third year of life the growth rate dropped, reaching 47.5% and 55% of its asymptotic length respectively, a phenomenon that can be attributed to sexual maturity (Lorenzo et al., 1995). The growth rate observed in the Hellenic seas was slightly lower than that observed in the Canary Islands, where the species reached 40% of its asymptotic length during the first year of life (Lorenzo et al., 1995). The von Bertalanffy parameters as estimated for the Hellenic seas were very close to those estimated for Mauritania (L_{∞} = 48.8 cm, K = 0.20) and Morocco (L_{∞} = 51.2 cm, K = 0.32) by Martins & Gordo (1984). We can conclude that the growth and demographic characteristics of *S. japonicus colias* in the Hellenic seas are similar to those in the rest of the subspecies distribution (Mediterranean Sea and NW Africa), yet show a trend towards a slower growth rate. However, differences exist in the growth rates exhibited by the other subspecies. In Argentine waters *S. japonicus marplatensis* reached 50% of its asymptotic length within the first year of life (Perrotta, 1992). Comparative studies have shown that the subspecies of the Pacific Ocean (*S. japonicus peruanus*, *S. japonicus diego and S. japonicus japonicus*) exhibited faster growth rates than *S. japonicus colias* and *S. japonicus marplatensis* (Rodriguez-Roda, 1982; Morales-Nin, 1988). This makes *S. japonicus colias* the slowest growing of all subspecies.

REFERENCES

Belyaev, A. & S. Ryabov (1987). Population structure of Chub Mackerel, *Scomber japonicus*, in the Northwestern Pacific Ocean. *J. Ichthyol.* 27 (3): 73-79.

Cancela da Fonseca, J.P. (1965). L'outil statistique en biologie du sol: I. Distributions de frequences et tests de signification. *Rev. Ecol. Biol. Sol. T.* II (3): 299-332.

Chen, Y., A. Jackson & H. Harvey (1992). A comparison of von Bertalanffy and polynomial functions in modeling fish growth data. *Can. J. Fish. Aquat. Sci.* 49: 1228-1235.

Collete, B. & E. Nauen (1983). FAO Species Catalogue: Vol. 2 Scombrids of the World. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. *FAO Fish. Synop.*, (125) vol. 2: 137 pp.

Gagliardi, R. & B. Cousseau (1970). Estudios biologios y pesqueros sobre la caballa (Scombridae, *Scomber japonicus marplatensis*). *Infs. Tec. Prog. Des. Pesq., Mar del Plata*, 28: 1-33.

Kotlyar, A. & A. Abramov (1982). Some biological properties of Peruvian Mackerel, *Scomber japonicus peruanus* (Scombridae*). J. Ichthyol.* 22 (6): 91-101.

Lorenzo, J., G. Pajuelo & G. Ramos (1995). Growth of the chub mackerel *Scomber japonicus* (Pisces:Scombridae) off the Canary Islands. *Sci. Mar.* 59 (3-4): 287-291.

Martins, M. & S. Gordo (1984). On the comparison of spanish mackerel (*Scomber japonicus* Houttuyn, 1782) from Corringe Bank and Peniche. *I.C.E.S. C.M.* 1984/H:50, 14 pp.

Moraitopoulou, E. (1963). Contribution to the study of *Scomber japonicus colias* in Aegean sea (in Greek). *Praktika of the Hellenic Hydrobiological Institute*, vol VIII, no 1, 56 pp.

Morales-Nin, B. (1988). Crecimiento de *Scomber japonicus* (Houttuyn, 1782) (Pisces: Scombridae) y *Sardinops sagax* (Jenyns, 1923) (Pisces: Clupeidae) en aguas ecuatorianas. *Inv. Pesq.* 52 (4): 483-500.

Perrotta, R. (1992). Growth of Mackerel (*Scomber japonicus* Houttuyn, 1782) from the Buenos Aires-north patagonian region (Argentine Sea). *Sci. Mar.* 56 (1): 7-16.

Perrotta, R. & L. Forciniti (1989). Un analisis del crecimiento de la caballa (*Scomber japonicus*) en dos areas de su distribution. *Sexto Simposio CTMFM, entre el 4 y 6 de diciembre de 1989, Montevideo.* Contribucion del INIDEP No 667.

RODRIGUEZ-RODA, J. (1982). Biologia de la caballa (o estornino), *Scomber (Pneumatophorus) japonicus* Houttuyn (1782) del golfo de Cadiz. *Inv. Pesq.* 46 (1): 143-159.

SCHAEFER, K. (1980). Synopsis of biological data on the chub mackerel, *Scomber japonicus* Houttuyn, 1782, in the Pacific Ocean. *Spec. Rep. Inter-Am. trop. Tuna Commn* 2: 395-446.

WATANABE, T. (1970). Morphology and ecology of early stages of life in Japanese common mackerel, *Scomber japonicus* Houttuyn, with special reference to fluctuation of population. *Bull. Tokai Reg. Fish. Res. Lab.* 62: 283 pp.

WILKINSON, L. (1987). SYSTAT: The system for statistics. Evanston, IL: SYSTAT, Inc., 1987.

WILLIAMS, T. & B. BEDFORD (1974). The use of otoliths for age determination. In: Bagenal, T. (ed), The ageing of fish, Unwin Bros. Ltd., Surrey, England: 114-123.

ZAR, J. (1996). Biostatistical Analysis, Third Edition. Prentice-Hall Inc., USA, 662 pp.