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Estimation of growth parameters of the Atlantic chub mackerel (*Scomber colias* Gmelin, 1789) off Gallipoli Peninsula (Northern Aegean Sea, Turkey)

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ABSTRACT

This study was carried out to reveal the age and growth of the atlantic chub mackerel (*Scomber colias* Gmelin, 1789) in Gallipoli Peninsula (northern Aegean Sea, Turkey). The individuals of sampled *S. colias* from commercial fishmongers randomly each month were taken during the period January 2016-December 2016. A total of 348 otoliths were aged successfully. The total length and weight of aged specimens ranged from 16.0 to 28.0 cm and from 31.72 to 222.68 g, with a mean of 22.0 cm and 101.23 g, respectively. The length-weight relationship was estimated as $W = 0.0060TL^{3.20}$ ($R^2 = 0.97$). The von Bertalanffy growth equations were computed to be L_∞ = 32.0 cm, k = 0.30 year^{-1}, t_0 = -1.72 year for all samples. The growth performance index (Φ') was found as 2.49. The present study provides the first information on the growth parameters of the species so as to define the current state *Scomber colias* population for Gallipoli Peninsula (northern Aegean Sea, Turkey).

Keywords: Atlantic chub mackerel, Gallipoli Peninsula, Growth Parameters, *Scomber colias*.

1. INTRODUCTION

The Scombridae is a family of the order Scombriformes and contains 54 species in 15 genera (Froese and Pauly 2021). 10 of them [*Auxis rochei* (Risso, 1810), *Euthynnus alletteratus* (Rafinesque, 1810), *Katsuwonus pelamis* (Linnaeus, 1758), *Orcynopsis unicolor* (Geoffroy Saint-Hilaire, 1817), *Sarda sarda* (Bloch, 1793), *Scomber colias* (Gmelin, 1789), *Scomber scombrus* (Linnaeus, 1758), *Scomberomorus commerson* (Lacepède, 1800), *Thunnus alalunga* (Bonnaterre, 1788), *Thunnus thynnus* (Linnaeus, 1758)] exist in Turkish Seas (Fricke et al., 2007). Originally *Scomber japonicus* (Houttuyn, 1782) was considered the species found in the Atlantic, Indian and Pacific Oceans (Collette and Nauen, 1983). But, high levels of genetic divergence in nuclear and mitochondrial DNA have been reported (Scoles et al., 1998; Infante et al., 2007; Catanese et al., 2010), in which Indo-Pacific fish have remained *Scomber japonicus* and those fish of the Atlantic Ocean and related seas have been designated as *Scomber colias* (Muniz et al., 2018). For this reason, the previous studies from Atlantic and Mediterranean regions have referred to species in question as *Scomber japonicus*.

The atlantic chub mackerel (*Scomber colias* Gmelin, 1789) is a cosmopolitan species inhabiting temperate and subtropical waters worldwide at depths ranging from near the surface

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down to 300 m (Collette, 1986). This species is primarily a coastal pelagic species and, to a lesser extent, epipelagic or mesopelagic over the continental slope. *S. colias* has a very wide distribution in the Atlantic, Mediterranean and Black Sea (Collette and Nauen, 1983). Despite its wide distribution range and commercial importance, there are many studies on population structure (Lorenzo and Pajuelo, 1996; Martins et al., 1983; Martins, 1996; Nespereira and Pajuelo, 1996; Kiparissis et al., 2000; Carvalho et al., 2002; Perrotta et al., 2005; Vasconcelos et al., 2011; Velasco et al., 2011; Čikeš Keč and Zorica, 2012; Daley et al., 2019), as a summary. As for Turkish territoral waters, the data on the biology of this species come from Marmara (Tuggaç, 1957) and Black Seas (Atlı, 1960), Dardanelles (Özekinci et al., 2009), Izmir (Sever et al., 2006; Bayhan, 2007) and Saros Bays (Cengiz, 2012; 2021). In addition, while Cengiz et al. (2013) calculated the determination of hook selectivity for catching the atlantic chub mackerel, Cengiz (2020) reported the maximum size record of species from Northern Aegean Sea. A major proportion of the *S. colias* catch in the Mediterranean and Black Seas is taken by Turkey, but its catch has drastically decreased in the last few years from an annual catch of 10,200 tonnes (t) during 1999 to 1,500 t during 2002 (Sever et al., 2006). Total catches was averagely 2,239,2 t in 2020, for now (TUIK, 2021).

For any exploited fish species, understanding its population biology is critical in the development of sustainable management plans (King, 2007). To determine the age structure of an exploited population is an essential feature in fish stock assessment to estimate growth rates (Haddon, 2001) and the good estimates of age are prerequisites for the estimation of life histories (Bergstad et al. 2021). In this connection, von Bertalanffy (1934) growth parameters (VBGPs) lay at the core of fisheries biology and ecology and are used and/ or required for tasks such as: (a) development of stock assessment models (Hilborn and Walters, 1992); (b) building of ecosystem models (Pauly et al., 2000); (c) testing life history patterns and tradeoffs, both within and between species (Rochet, 2000; Stergiou, 2000); (d) calculating maximum sustainable yield (Beddington and Kirkwood, 2005); (e) estimating vulnerability of fish to overfishing (Cheung et al., 2005); and (f) predicting empirical equations for predicting other biological parameters, such as natural mortality (Pauly, 1980) and length at maturity (Froese and Binohlan, 2000). The existence of accurate VBGP estimates is essential for all of the above to be realized (Apostolidis and Stergiou, 2014). The present paper provides the first information on age structure, lifespan and growth of *Scomber colias* (Gmelin, 1789) collected off Gallipoli Peninsula (northern Aegean Sea, Turkey), which could be an efficacious tool for stakeholders to initiate early management strategies and regulations for the sustainable conservation of the remaining stocks of this species.

2. METHODOLOGY

The Mediterranean Basin has an oligotrophic feature, whereas the eastern Mediterranean exists its highest oligotrophic part (Psarra et al., 2000). There is a trend parallel to the decreasing primary production values along the North-South line of the Aegean Sea (Antoine et al., 1995; Gönülal and Dalyan, 2017). The northern Aegean territories are qualified by an extended continental shelf, smooth muddy/sandy grounds and top nutrient concentrations (Maravelias and Papaconstantinou, 2006) and when compared with the southern Aegean territories, these areas are higher for zooplankton and phytoplankton abundance (Theocharis et al., 1999).

The northern Aegean coasts of Turkey are divided to sub-regions as the Saros Bay, the Gallipoli Peninsula, the Gökceada and Bozcaada Islands and the Edremit Bay (Cengiz and Paruğ, 2020). For the reasons stated above, the Gallipoli Peninsula exhibits the diversity in terms of the species' composition and also considered as an important fishing area (Cengiz et al., 2012) (Fig 1)

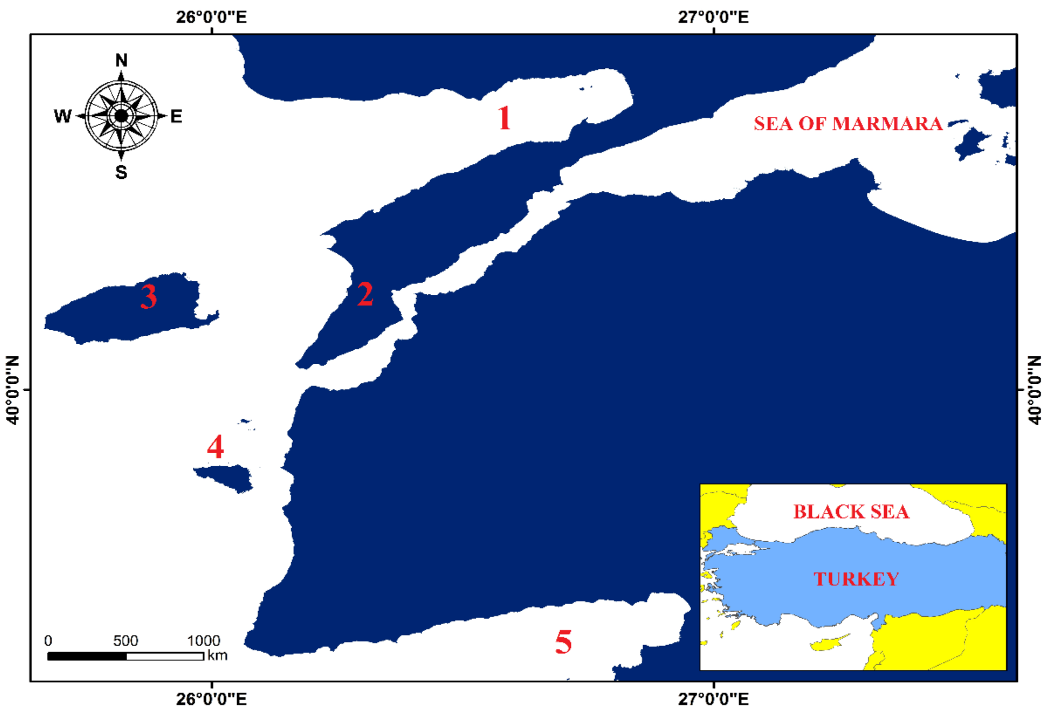

Figure 1. Northern Aegean coasts of Turkey (1: Saros Bay; 2: Gallipoli Peninsula; 3: Gökçeada Isl.; 4: Bozcaada Isl.; 5: Edremit Bay.

The individuals of sampled *S. colias* from commercial fishmongers randomly each month were taken during the period January 2016-December 2016. The samples were measured to the nearest centimeter (total length), weighed to the nearest 0.01 g (total weight). The length-weight relationship was estimated by fitting an exponential curve, $W = aL^b$ (Le Cren, 1951).

Parameters a and b of the exponential curve were estimated by linear regression analysis over log-transformed data log W = log$a$ + $b$logL, where W is the total weight (g), L is the total length (cm), a is the intercept, and b is the slope or allometric coefficient, using the least-squares method. Value $b > 3$ shows a positive allometric growth, while value $b < 3$ indicates a negative allometric growth. It is isometric growth when value b is equal to 3 (Bagenal and Tesch, 1978). The growth type was identified by Student's t-test.

The otoliths were evaluated for age determination. Following removal, the otoliths were read as whole, using a stereoscopic zoom microscope under reflected light against a black background filled with the water. Opaque and transparent zones were counted; one opaque zone together with one transparent zone was assumed to be an age mark (Cengiz, 2012). Growth parameters were estimated by using the von Bertalanffy growth equation: $L_t = L_\infty [1 - e^{-k(t-to)}]$, where L_t is fish length (cm) at age t, L_∞ is the asymptotic fish length (cm), t is the fish age (years), t_0 (years) is the hypothetical time at which the fish length is zero, and k is the growth coefficient (year^{-1}). FAO-ICLARM Stok Assessment Tools FISAT II) were used to estimate growth parameters, which were calculated with the non-linear least-squares method. The growth parameters obtained in this study were compared with the parameters obtained in other studies from various geographical areas using the growth performance index (Φ') (Pauly and Munro, 1984). It was estimated using the formula, $\Phi' = \log(k) + 2 \times \log(L_\infty)$.

3. RESULTS

A total of 348 otoliths were aged successfully. The mean ± standard error (and range) of total length and total weight of aged specimens were 22.0 ± 0.19 (16.0 – 28.0) cm (Fig 2) and 101.23 ± 2.55 (31.72 – 222.68) g, respectively. The length-weight relationship was estimated as $W = 0.0060TL^{3.20}$ ($R^2 = 0.97$) (Fig 3). The b-values and t-test results indicated positive allometric growth.

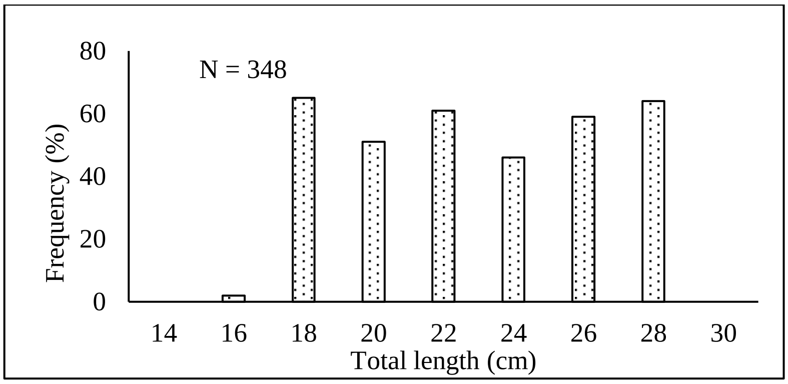

Figure 2. The length-frequency distribution for all samples of *Scomber colias* from Gallipoli Peninsula (Northern Aegean Sea, Turkey).

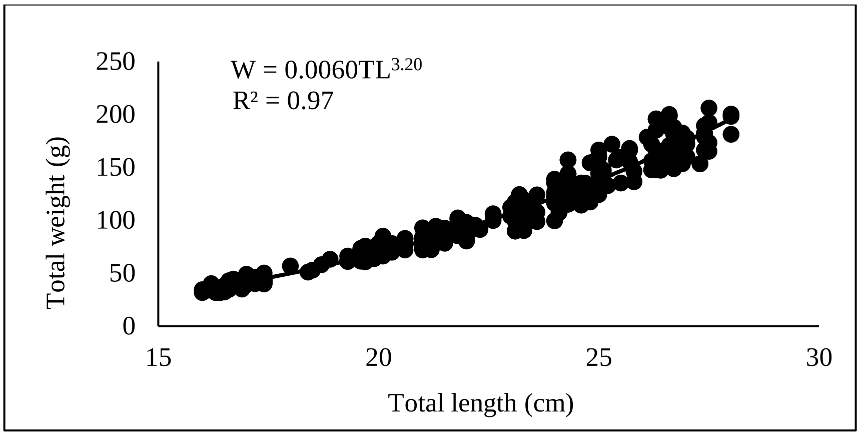

Figure 3. The length-weight relationships for all samples of *Scomber colias* from Gallipoli Peninsula (Northern Aegean Sea, Turkey).

Table 1. The age-length key for all samples of *Scomber colias* from Gallipoli Peninsula (Northern Aegean Sea, Turkey) (N = number of individual, S.E = standard error).

Age	***N***	***Length range (cm)***	L_{mean} **± S.E**
I	105	16.0 – 19.9	17,8 ± 0.13
II	89	19.3 – 23.4	21,2 ± 0.10
III	86	23.1 – 25.0	24,2 ± 0.07
IV	55	24.7 – 27.4	26,5 ± 0.08
V	13	27.2 – 28.0	27,5 ± 0.08

Results obtained from the otolith reading indicated that the ages of the fishes were found to be within the range of 1 to 5 years. Table 1 disclosed the fishes belonging to age groups 1. and 2. were the most dominant. The von Bertalanffy growth equations were computed as L_∞ = 32.0 cm, k = 0.30 year^{-1}, t_0 = -1.72 year for all samples (Fig 4). The growth performance index (Φ') was found as 2.49.

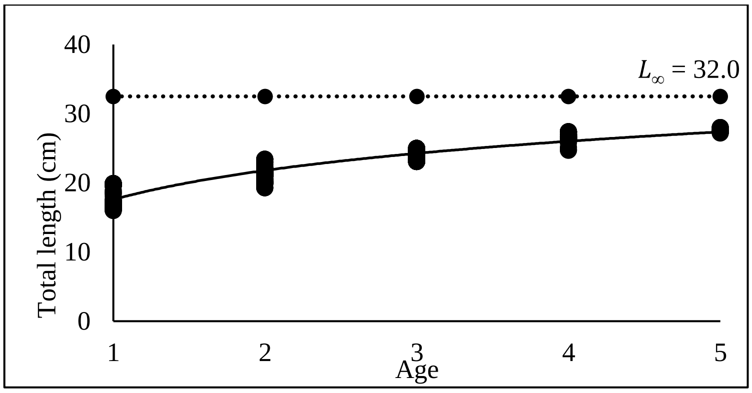

Figure 4. The growth curves for all samples of *Scomber colias* from Gallipoli Peninsula (Northern Aegean Sea, Turkey).

4. DISCUSSION

Table 2 precised the results about the length-weight relationships (LWRs) between the present study to previous ones. The *b* values in LWRs show the change between 2.5 and 3.5 (Froese, 2006) or 2 to 4 (Tesch, 1971). In this study, *b* value of *Scomber colias* correspond to these expected ranges. Many factors, such as gonad maturity, sex, age, diet, stomach fullness, health, sampling methods, sample sizes and preservation techniques as well as season, habitat and environmental conditions could affect parameters of length-weight relationships in fish (Adaka et al., 2015; Cengiz et al., 2019).

Table 2. Length-weight relationships of *Scomber colias* in the previous literatures. N = number of individual; [1] fork length (cm); *a* and *b* = the parameters of the relationships.

References	***Location***	***N***	***Length range (cm)***	***a***	***b***
Lorenzo and Pajuelo (1996)	Canary Islands (Spain)	1142	14.3 – 42.1	0.0030	3.31
Martins (1996)	NE Atlantic (Portugal)	3761	19.0 – 41.0	0.0027	3.33
Carvalho et al. (2002)[1]	NE Atlantic (Portugal)	187	9.1 – 53.0	0.0049	3.26
Bayhan (2007)[1]	Izmir Bay (Turkey)	520	12.5 – 27.2	0.0030	3.40
Vasconcelos et al. (2011)	Madeira Island (Portugal)	2212	13.0 – 41.7	0.0023	3.38
Velasco et al. (2011)	Gulf of Cadiz (Spain)	363	16.4 – 43.0	0.0015	3.52
	Alboran Sea (Spain)	373	17.2 – 40.0	0.0014	3.53
Cengiz (2012)	Saros Bay (Turkey)	402	13.8 – 31.1	0.0066	3.10
Čikeš Keč and Zorica (2012)[1]	Adriatic Sea (Croatia)	4189	10.1 – 39.1	0.0052	3.22
Daley et al. (2019)	NW Atlantic (Usa)	1136	22.4 – 38.6	0.0258	2.72
Abdel Fattah et al. (2021)	Alexandria (Egypt)	511	12.9 – 34.4	0.0056	3.14
Techetach et al. (2021)	M'diq region (Morocco)	845	16.4 – 35.9	0.0019	3.45
This study	**Gallipoli Peninsula (Turkey)**	**348**	**16.0 – 28.0**	**0.0060**	**3.20**

The mean lengths at different ages for *Scomber colias* given by different authors were indicated in Table 3. The maximum ages of the atlantic chub mackerel were reported as 13 years by Carvalho et al. (2002) and 12 years by Martins (1996) from NE Atlantic (Portugal).

Table 4 listed the maximum ages, growth parameters and growth performance indices of *Scomber colias* reported by various authors.

The maximum ages can vary widely among the populations within species especially those that have wide distributions (Gibson, 2005). In this case, the reasons of differences in longevity could be attributed to the effects of temperature, intensities of competition for food, food availability, life history strategies, and fishing efforts (Nash and Geffen, 2005).

Table 3. The mean lengths at different ages for *Scomber colias* estimated in the previous literatures. [1]sampling date 2002, [2]sampling date 2003, [3]fork length (cm).

References	**Location**	**Age (years)**													
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Tuggaç (1957)	Marmara Sea (Turkey)	-	14.8	18.1	20.5	22.2	22.6	26.3	32.6	-	-	-	-	-	-
Atli (1960)	Black Sea (Turkey)	-	14.9	18.9	21.2	23.3	25.1	25.8	27.5	-	-	-	-	-	-
Lorenzo and Pajuelo (1996)	Canary Islands (Spain)	15.8	20.6	25.9	30.8	34.8	37.1	-	-	-	-	-	-	-	-
Martins (1996)	NE Atlantic (Portugal)	21.7	22.2	24.1	29.7	33.1	35.4	36.8	39.2	39.8	39.7	41.3	44.5	40.7	-
Carvalho et al. (2002)	NE Atlantic (Portugal)	9.8	18.9	27.3	32.0	36.6	40.2	43,6	46.3	48.6	50.9	52.2	53.8	55.6	56.5
Perrotta et al. (2005)	NE Mediterranean (Spain)	12.2	23.0	24.8	30.1	33.4	34.8	35.3	36.0	37.1	-	-	-	-	-
	SW Atlantic (Argentina)	16.3	18.7	30.5	33.5	36.2	38.1	40.1	41.2	42.6	-	43.5	-	-	-
Bayhan (2007)[3]	Izmir Bay (Turkey)	-	16.2	18.9	20.4	22.4	-	-	-	-	-	-	-	-	-
Vasconcelos et al. (2011)	Madeira Island (Portugal)[1]	20.1	25.6	32.2	34.2	36.6	-	-	-	-	-	-	-	-	-
	Madeira Island (Portugal)[2]	21.2	22.7	32.5	34.5	36.0	-	-	-	-	-	-	-	-	-
Velasco et al. (2011)	Gulf of Cadiz (Spain)	20.7	21.6	26.7	29.2	36.9	36.4	39.9	43.0	-	-	-	-	-	-
	Alboran Sea (Spain)	22.0	23.6	28.9	29.9	30.1	29.1	40.0	-	-	-	-	-	-	-
Cengiz (2012)	Saros Bay (Turkey)	-	18.3	22.1	25.2	27.5	30.1	-	-	-	-	-	-	-	-
Čikeš Keč and Zorica (2012)[3]	Adriatic Sea (Croatia)	-	17.3	21.6	25.7	28.8	31.7	33.7	35.3	-	38.2	-	-	-	-
Daley et al. (2019)	NW Atlantic (Usa)	10.1	29.9	32.9	33.7	34.4	35.2	35.3	36.7	-	-	-	-	-	-
Abdel Fattah et al. (2021)	Alexandria (Egypt)	-	14.0	19.2	23.8	28.2	31.7	-	-	-	-	-	-	-	-
Techetach et al. (2021)	M'diq region (Morocco)	16.6	22.5	24.5	26.3	28.9	32.1	-	-	-	-	-	-	-	-
This study	**Gallipoli Peninsula (Turkey)**	**-**	**17.8**	**21.2**	**24.4**	**26.5**	**27.5**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Table 4. The maximum ages, growth parameters and growth performance indices of *Scomber colias* reported in the previous literatures. [1] from Vasconcelos et al. (2011), [2] fork length (cm), N = number of individual, L_∞ = theoretical asymptotic length, K = growth rate coefficient, t_0 = theoretical age when fish length is zero, Φ' =growth performance index.

References	Location	Sampling method	N	Ageing method	Ages (years)	Total Length (cm)	L_∞	K	t_0	Φ'
Tuggaç (1957)	Marmara Sea (Turkey)	-	-	otolith	1 - 7	-	33.0	0.47	-	2.71
Martins et al. (1983)[1]	NE Atlantic (Portugal)	-	533	back-calculation	-	-	53.8	0.17	-2.02	2.69
Lorenzo and Pajuelo (1996)	Canary Islands (Spain)	purse-seine	470	otolith	0 - 7	13.7 – 42.1	52.4	0.19	-1.61	2.72
Martins (1996)	NE Atlantic (Portugal)	purse-seine, hook and line, gillnet, trawl	883	otolith	0 - 12	16.0 – 54.0	58.5	0.10	-3.68	2.53
Nespereira and Pajuelo (1996)	Canary Islands (Spain)	commercial catch	3858	length-frequency	0 - 5	13.0 – 48.0	49.5	0.23	-	2.75
Rizkall (1998)	Alexandria (Egypt)	pürse-seine	110	vertebrae	1 - 4	26.0 – 34.0	39.4	0.31	-1.39	2.68
Kiparissis et al. (2000)	Hellenic Seas	commercial catch	1026	otolith	0 - 5	9.1 – 31.0	47.5	0.15	-2.17	2.53
Carvalho et al. (2002)	NE Atlantic (Portugal)	cruise surveys, commercial catch	349	otolith	0 - 13	9.6 – 56.5	57.5	0.20	-1.09	2.82
Perrotta et al. (2005)	NE Mediterranean (Spain)	commercial catch	158	otolith	0 - 8	11.0 – 39.0	39.7	0.29	-1.40	2.66
	SW Atlantic (Argentina)	commercial catch	392	otolith	0 - 10	14.0 – 45.0	44.2	0.32	-1.38	2.80
Bayhan (2007)[2]	Izmir Bay (Turkey)	purse-seine	520	otolith	1 - 4	12.5 – 27.2	29.8	0.20	-0.36	2.25
Vasconcelos et al. (2011)	Madeira Island (Portugal)	purse seine	2115	otolith	0 - 4	17.4 – 41.7	50.0	0.25	-1.33	2.80
Velasco et al. (2011)	Gulf of Cadiz (Spain)	commercial catch	121	otolith	0 - 7	16.4 – 43.0	43.0	0.27	-1.10	2.70
	Alboran Sea (Spain)	commercial catch	98	otolith	0 - 6	17.2 – 40.0	40.0	0.37	-0.91	2.77
Cengiz (2012)	Saros Bay (Turkey)	gillnet, handline, purse-seine	402	otolith	1 - 5	13.8 – 31.1	39.0	0.20	-2.13	2.48
Čikeš Keč and Zorica (2012)[2]	Adriatic Sea (Croatia)	purse-seine	280	otolith	1 - 9	14.1 – 39.1	45.3	0.18	-1.65	2.57
Daley et al. (2019)	NW Atlantic (Usa)	trawl	422	otolith	0 - 7	17.7 – 39.7	37.1	0.41	-2.44	2.75
Abdel Fattah et al. (2021)	Alexandria (Egypt)	purse-seine	511	length-frequency	1 - 5	12.9 – 34.4	38.1	0,18	-	2.68
Techetach et al. (2021)	M'diq region (Morocco)	commercial catch	619	otolith	0 - 5	16.4 – 34.5	37.3	0.26	-2.19	2.56
This study	**Gallipoli Peninsula (Turkey)**	**commercial catch**	**348**	**otolith**	**1 - 5**	**16.0 – 28.0**	**32.0**	**0.30**	**-1.72**	**2.49**

Growth parameters (L_∞, K and t_0) are the basic input data into various models used for managing and assessing the status of the exploited fish stocks and these parameters facilitate the comparison between growth of fishes belonging to different species or to the same species at different times and different localities. The possible differences among the growth parameters may be due to the variations in the ecological parameters or the maximum observed lengths in the catch or the methods used in calculations by different authors or in the different localities (Mehanna et al., 2018).

5. CONCLUSION

Economically important fish species have always been target species for fishermen and thus, their stocks will inevitably be endangered unless continuous management strategies are developed for their conservation. Because of wide distribution range and great commercial exploitation of *Scomber colias* population, the biological information on the growth is required for its stock assessment and management. The results of this study touch upon the age and growth of *Scomber colias* to unearth the growth parameters prediction, which are significant input parameters to stock assessment techniques and provide an insight into the life history of the atlantic chub mackerel. These findings will contribute to future fisheries studies aiming both to determine the current status of the species and to develop management strategies for the species.

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