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Research Article

A meta-analysis and growth patterns evaluation of the European anchovy, *Engraulis encrasicolus*, in the Mediterranean Sea

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Abstract

European anchovy (*Engraulis encrasicolus*) is one of the most important commercial species in the Mediterranean Sea. 4310 studied records were reported from the Google Scholar database between 1980 and 2022. A search with the keywords "*Engraulis encrasicolus*" or "European anchovy" and "growth" and "sex" and "length" and "length-weight relationship" returned 201 results, of which only research articles were included in the compilation. A total of 20 studies were evaluated in the present study. In the studies on the growth and length-weight relationship of anchovy species, pooled random effect meta-analysis, subgroup analysis, and moderator analysis were carried out. It was found that sex had a significant effect on the mean and standard deviation of length of male and female individuals. The results showed that there was a positive correlation between male and female individuals. The moderator analysis was carried out to examine this high heterogeneity. Accordingly, L_∞ and K values and b coefficients of male and female individuals in different regions of the Mediterranean Sea should not be considered equivalent. The results of the study are generalizable to the reviewed studies except for the b coefficients of males and females.

Introduction

The Engraulidae family is represented by 155 species belonging to 17 genera. Engraulidae is mainly distributed in the Atlantic, Indian, and Pacific Oceans. *Engraulis encrasicolus* is a schooling species, usually found in shallow coastal waters and estuaries of tropical and temperate regions. Many species of this family are filter-feeding animals and feed on zooplankton. Economically important species are used as human food. They are marketed fresh, dried, smoked, canned and frozen; made into fish meal (Froese and Pauly, 2022) (Fig. 1).

Figure 1: A photographic figure of the European anchovy, *Engraulis encrasicolus*.

European anchovy (*Engraulis encrasicolus*) is one of the most important commercial species in the Mediterranean Sea. Its average population reaches up to 595 527 tons/year in the whole basin (FAO, 2022). FAO states that Engraulidae has a substantial contribution to the total global fishery capture worldwide comprising 10%. *E. encrasicolus* is of significance regarding the transfer of energy from lower to higher trophic level organisms, coupling the Mediterranean pelagic and demersal environments (Palomera *et al.*, 2007).

Three main factors substantially influence the fish population dynamics: (1) recruitment, (2) growth and (3) mortality rate (Kilduf *et al.*, 2009). Gebremedhin *et al*. (2021) describes growth as "the increase in length and weight of the individuals of a population in a given period of time." Ricker (1968) have implemented the length-weight (LWR) relationships for elementary uses for valuation of fish stocks and populations (Ricker, 1968). Wootton (1992) and Pauly (1993) also state that "length-weight relationships also facilitate to determine the condition, reproduction history, life history and the general health of fishing species". Standard measures should be necessarily adopted for all the fish populations to obtain more consistent results when comparing the subject populations. Therefore, the information must be gathered on the length-length relations of species under various environmental conditions. The length-length relationship exert huge significance for comparative growth studies (Moutopoulos and Stergiou, 2002).

The articles in the meta-analysis were analyzed in three main regions: the Adriatic Sea, the Eastern Mediterranean, and the Western Mediterranean. The studies carried out in the Adriatic Sea, in chronological order, comprise (Sinovčić, 2000; Sinovčić and Zorica, 2006; Kalayci *et al*., 2007; Đurović *et al*., 2012; Đurović *et al*., 2018; Falsone, 2022). Studies conducted in the Eastern Mediterranean comprise (Erkoyuncu and Özdamar, 1989; Karaçam and Düzgüneş, 1990; Özdamar *et al*., 1991; Samsun *et al*., 2004; Uçkun *et al*., 2005; Bilgin, 2006; Samsun *et al*., 2006; Özdemir *et al.*, 2010; Yankova *et al.*, 2011; Bilgin *et al*., 2013; Sağlam and Sağlam, 2013; Satılmış *et al.*, 2014; Yankova, 2014; Yeşilçiçek *et al*., 2015; Özdemir *et al*., 2018; Bilgin and Solak, 2020; Özdemir *et al*., 2020; Reis, 2020; Solak and Bilgin,

2020; Jemaa *et al*., 2021; Çiloğlu and Şahin, 2022; Gücü *et al*., 2018). Studies conducted in the Western Mediterranean comprise (Giraldez and Abad, 1995; Millán, 1999; Bellido *et al*., 2000; Morey *et al.*, 2003; Basilone *et al*., 2004; Bouaziz and Bennoui, 2004; Basilone *et al.*, 2006; Manzo *et al*., 2013; Brosset *et al*., 2015; Benchikh *et al.*, 2018; Albo-Puigserver *et al*., 2020).

A meta-analysis is a practical approach to bringing together findings from different studies. It reveals the need to integrate and synthesize experimental observations with a quantitative approach (Rosenthal and Dimatteo, 2001; Crombie and Davies, 2009; Borenstein *et al.*, 2021). Therefore, the present study aimed to determine the factors that influence the effect size by examining the mean length and standard deviations of male and female individuals of anchovy species distributed in the Mediterranean Sea by meta-analysis. Accordingly, the results of the studies were analyzed on growth characteristics and length-weight relationship in the period 1980-2022. The aim of this study is to contribute to the future research of the species, about which many studies have been made. As a result, different approaches have been adopted for new research by evaluating the findings obtained from the Mediterranean Sea. Therefore, it is thought that this pioneering study will contribute to future biological studies on the species.

Materials And methods

The low inflow and low precipitation, coupled with high evaporation, make the Mediterranean more saline than the Atlantic Ocean (Robinson *et al*., 2001). To systematically review studies on the growth performance of *Engraulis encrasicolus*, a four-stage literature review following PRISMA guidelines (Moher *et al*., 2009) was applied (Fig. 2). Accordingly, Clarivate Analytics' Web of Science (WoS) and Google Scholar databases were utilized with the keywords '*Engraulis encrasicolus*' or 'European anchovy' for studies conducted between 1980 and 2022. Google Scholar database was used since it was decided to include international and national articles other than SCI to include more literature in the study. A total of 4310 studies were found in the first search. The titles and abstracts of these studies were manually checked, and keywords were elaborated as "*Engraulis encrasicolus*" or "European anchovy" and "growth" and "sex" and "length" and "length-weight relationship" in accordance with the subjects of age, growth and length-weight relationship. This method returned 201 studies. These studies were examined in detail, and books, theses, and reports were excluded. As a result of all these examinations, 20 articles were included in the evaluation. The articles that met these criteria were obtained, and each study was coded and classified according to the characteristics of the meta-analysis. In the coding phase of the studies, after the works of literature were transferred to the Mendeley program, the title and abstract sections were examined and evaluated. Following the preliminary evaluation, the full text of the literature planned to be included in the analysis was accessed. Full-text evaluations were carried out in line with the inclusion and exclusion criteria, and the literature to be included in the analysis was coded. The number of works

of literature to be included in the analysis and the evaluations made is given in Figure 2 with the PRISMA flow diagram (Moher *et al.,* 2015).

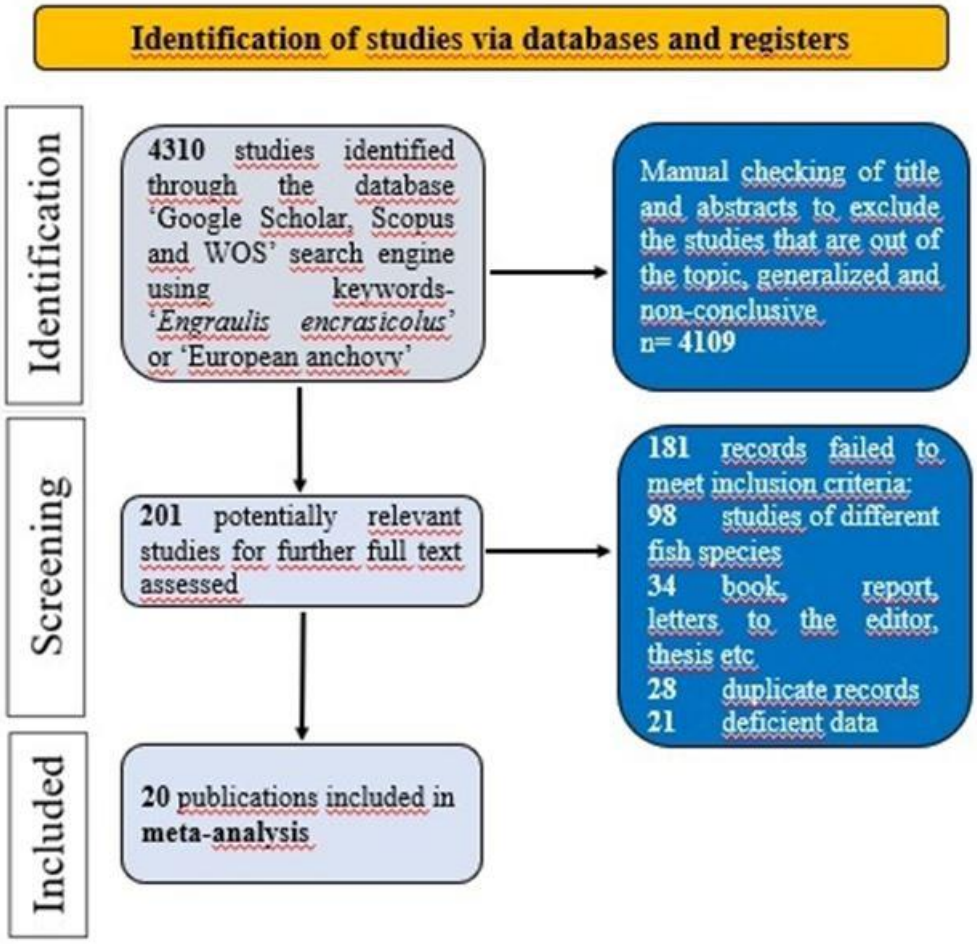


Figure 2: PRISMA flow diagram of systematic literature search.

The relationship between the combined findings and the characteristics of the meta-analysis was established. Finally, the creating a controlled effect study on the outcome measure were examined. Coding of studies, all the information about the species in the studies included in the analysis are shown in Table 1.

Meta-analysis

Effect size in the meta-analysis, measurements (effect sizes) of the outcome variable should be calculated for each of the studies before each study included in the research is numerically combined. In this study, the calculation of effect size was based on "OR" values in the evaluation of the overall effect size in the analyzes performed for the binary data. In evaluating the overall effect, the statistical significance limit OR> 1 means that the risk of the outcome increases (Schechtman, 2002; Dinçer, 2018). The minus (-) sign at the beginning of the effect values indicates that the deformation effect measured in the studies is negative / in favor of the control

group; the plus (+) sign indicates that the effect is positive / in favor of the experimental group. If the effect size is zero (0) or close to zero, it can be stated that there is no result in favor of or against the control and experimental groups.

Table 1: Descriptive data of studies examining anchovy species (*a*: intercept, *b*: slope, r^2: coefficient of determination, L_∞: asymptotic length, *K*: brody growth coefficient).

Authors	Year	Area	Female mean length (TL, cm)	Male mean length (TL, cm)	*A*	*B*	r^2	L_∞	*K*
Samsun *et al.,*	2004	Eastern Mediterranean	11.33	-	0.0083	2.840	-	15.66	0.337
Samsun *et al.,*	2004	Eastern Mediterranean	10.98	-	0.0076	3.055	-	17.07	0.284
Şahin *et al.,*	2008	Eastern Mediterranean	11.25	11.09	0.0101	2.971	-	16.11	0.291
Şahin *et al.,*	2008	Eastern Mediterranean	11.00	10.89	0.0055	3.159	-	15.27	0.284
Millán	1999	Western Mediterranean	13.50	11.00	0.0030	3.318	0.990	-	-
Millán	1999	Western Mediterranean	13.50	12.00	0.0036	3.209	0.990	-	-
Millán	1999	Western Mediterranean	13.50	12.00	0.0030	3.279	0.990	-	-
Sinovčić and Zorica	2006	Adriatic Sea	10.30	10.10	0.0035	3.196	0.998	-	-
Yankova *et al.,*	2011	Eastern Mediterranean	13.39	12.47	0.0240	-	0.990	14.60	0.479
Đurović *et al.,*	2012	Adriatic Sea	-	-	0.0028	-	0.930	10.41	-
Samsun *et al.,*	2006	Eastern Mediterranean	11.21	10.87	0.0118	2.537	0.960	16.84	0.233
Samsun *et al.,*	2006	Eastern Mediterranean	11.67	10.91	0.0051	3.009	0.960	18.46	0.217
Samsun *et al.,*	2006	Eastern Mediterranean	10.55	9.97	0.0075	2.833	0.920	18.73	0.156
Samsun *et al.,*	2006	Eastern Mediterranean	11.04	10.52	0.0080	2.907	0.950	18.91	0.163
Kalaycı *et al.,*	2007	Eastern Mediterranean	12.25	11.10	0.0174	2.559	0.850	-	-
Sağlam and Sağlam	2013	Eastern Mediterranean	11.98	11.39	0.0110	-	-	16.37	0.425
Yankova	2014	Eastern Mediterranean	13.39	12.47	-	-	-	14.60	0.479
Bilgin and Solak	2020	Eastern Mediterranean	10.80	10.10	0.0120	2.876	0.862	-	-
Özdemir *et al.,*	2020	Eastern Mediterranean	10.11	10.72	0.0084	2.867	-	-	-
Solak and Bilgin	2020	Eastern Mediterranean	10.80	10.10	-	-	-	11.10	-

The literatures used in the analysis are indicated with an asterisk in the references.

A combined effect size of 0.80 and above is considered a large effect, and values between 0.50-0.79 as a medium effect and values below 0.50 as no effect (Cohen, 1988). If the distribution is homogeneous, the fixed effect model is used, while the

random effect model is used if the distribution is not homogeneous (Ellis, 2010).

To place or calibrate the results of the studies that meet the criteria on a standard scale, effect sizes were calculated and measured using Hedge's g values. The statistical examinations were implemented using the workbook for meta-essentials version 1.4, licensed under Creative Commons. Data were interpreted using a user guide under the Attribution-Non-Commercial-ShareAlike 4.0 International License (Van Rhee *et al*., 2015) and subsequently improved (Suurmond *et al*., 2017). Sub-group and moderator analyses were conducted when heterogeneity (I^2) was high (Higgins and Green, 2011). This allowed the researchers to investigate the roles of various variables further.

After the effect size values of each study were calculated for the deformation rate in the control and experimental groups, the I^2 statistic was examined. I^2 is the heterogeneity ratio of the total change in the observed effect. Heterogeneity is related to the percentage of variance explained by existing studies. Heterogeneity increases as the explanation percentage increases (Borenstein *et al*., 2021). In the heterogeneity assessment, the heterogeneity ratio (I^2) is evaluated as none if it is below 25%, low if it is 25-50%, medium if it is 51-75%, and high if it is above 75% (Dinçer, 2018). Also, Cochran's *Q* statistic was employed to test heterogeneity between the studies in the present study. This test analyses the null hypothesis that all studies evaluate the same effect. This analysis determines whether there is a statistically significant variance (Higgins and Green, 2011).

A bias for the publication higher than a certain level has an impact on the mean effect size that is the subject of calculation and shows it higher than it should be (Borenstein and Higgins, 2013). Therefore, publication bias is found by calculating Kendall's Tau coefficient to the Begg and Mazumdar rank correlations statistic and the "Funnel Plot" graph. In the absence of publication bias, this coefficient is expected to be close to 1, and the two-tailed p-value is expected to be greater than 0.05 (Dinçer, 2018).

Also, the results were interpreted using Orwin's number and Egger regression analyses to reset the statistically significant effect of the mean and standard deviation values of female and male individuals in the meta-analysis. The mean and standard deviation values of female-male individuals were meta-analyzed over the studies in Table 1. The I^2 statistic was examined for heterogeneity analysis. If this value was above 50% and the heterogeneity test (Q) p-value was significant (<0.05), the analysis was performed using the random effects model. These variables were considered as Adriatic, Eastern, and Western Mediterranean. Publication bias was visualized using a funnel plot and quantified using the Begg-Mazumdar test, which is preferred to Egger regression because it considers smaller samples (Begg and Mazumdar, 1994; Harbord *et al*., 2009). All tests were performed at the 95% confidence level (CI), and all p-values less than 0.05 were considered significant.

Since the species is usually caught monthly with purse seines, sampling

frequency and fishing gear were not considered in the meta-analysis.

Study area

The Mediterranean Basin comprises the Mediterranean, Black, Azov and Marmara Seas and is regarded a single ecosystem (Fig. 3). The linear dimensions of the sea are estimated at 3700- 3750 km from west to east and 1200-1800 km from north to South (Egorov *et al.,* 2021). The average depth the Mediterranean Sea is 1,500 m (max. 5150 m, the southern coasts of Greece). The length of the coastline is 45,000 km. The seas have a semi-enclosed structure and possess only two communication waterways with outside oceans: the 14-km-wide and 300-m-deep Gibraltar Strait to the west and the few-meter-wide artificial Suez Canal to the southeast. The primary source of replenishment is the continuous inflow of surface water from the Atlantic Ocean through the Strait of Gibraltar.

Results

In the studies examined, *a*, *b*, and r^2 values, L_∞, *K* which are the growth values of females, males and all individuals, were determined and meta-analysis was applied. The data on the mean and standard deviations of height revealed by the findings based on regions within the study are given in Table 1 in chronological order. The descriptive data of the studies examining the anchovy species are given in Table 1.

Meta-analysis of the difference between the mean length of male and female individuals

According to the hypothesis that there is a significant relationship between the mean and standard deviation of total lengths of anchovy, female and male individuals according to the three regions (Adriatic Sea, Eastern, and Western Mediterranean) evaluated; since the I^2 value was 98.72% and the heterogeneity test *Q* value was 1485.78 (p=0,000), random effects model was used, and the results of the analysis are shown in Figure 3 with forest plot graph and in Table 2 with meta-analysis. As seen in Figure 4, the effect size of individual studies in the meta-analysis is shown with the blue round symbol, and the overall effect size reflecting the sum of individual studies is shown with the green round at the bottom. The width of the circles is also proportional to the weight of the individual study. In the meta-analysis that calculated the difference between the means, the result was 0.32 [0.04; 0.61] in favor of the control group. The relationship between male and female individuals was significant ($p \leq 0.05$) (Table 2).

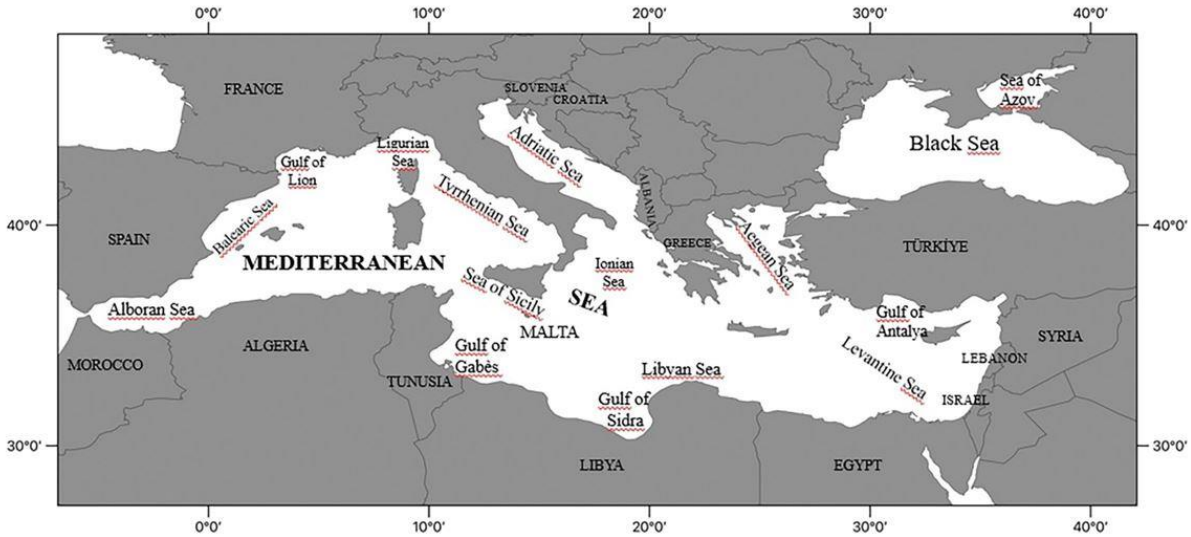


Figure 3: The map of the Mediterranean Basin in the broad sense.

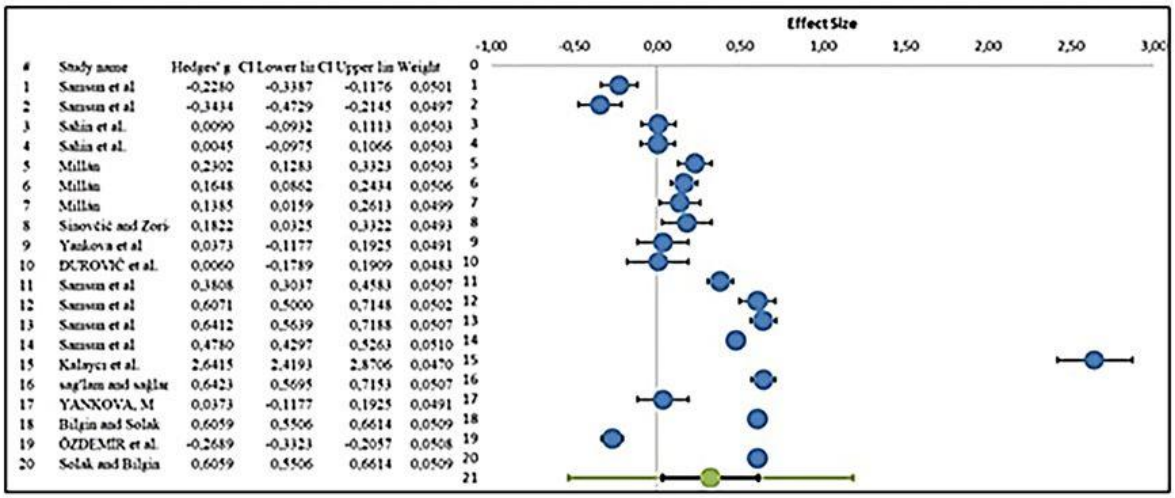


Figure 4: Forest plot of male and female individuals.

Table 2: Meta-analysis results of the mean and deviation values of male and female individuals of the anchovy population given in the compiled studies.

General Effect Size	Standard Error	Z Value	P Value	95% Confidence Interval	
				Lower Limit	Upper Limit
0.32	0.14	2.35	0.009	0.04	0.61

As seen in Figure 5, in the meta-analysis, the effect size of individual studies is shown with the round red symbol, individual studies are shown with the blue round symbol, and the overall effect size reflecting the sum of individual studies is shown with the green color at the bottom. The width of the circles is also proportional to the weight of the individual study. In the meta-analysis that calculated the difference between the means, the result was 0.18 [-1.30; 1.66] in favor of female individuals. The relationship between female and male anchovies in terms of the mean length of individuals was significant ($p \leq 0.05$). In the study, the regions where anchovy was caught were divided into three parts Adriatic Sea, Eastern Mediterranean, and

Western Mediterranean. Accordingly, subgroup analysis was performed to examine the effect of anchovy on the mean and deviation of length in male and female individuals, and the results of subgroup analysis are shown in Figure 5 and Table 3. All subgroups were evaluated according to the random effects model.

According to the results of the combined effect size heterogeneity test to determine the effect of anchovy fish on the mean length of male and female individuals in the publications included in the study, the *p*-value was found to be less than 0.05, and the *Q* (1485.78) value was found to be high, and the I^2 statistic value was calculated as 98.72. As a result of the individual studies included in the analysis, the studies examined according to the mean values of male and female individuals in meta-analysis applications had a heterogeneous structure. Therefore, the distribution of effect sizes as a result of the calculations was evaluated according to the random effects model. The meta-analysis results of the 20 studies that examined the average length of anchovy and included in the study are shown in Figure 5 with the forest plot. According to the random effects model, the effect size was statistically significant with a value of 0.18 (-1.30- 1.66; p<0.000).

Table 3: Meta-analysis results of the mean and standard deviation of anchovy fish length.

Subgroup name	Odds Ratio	CI Lower limit	CI Upper limit	Weight (%)	Q	p_Q	I^2 (%)	T^2	T	PI Lower limit	PI Upper limit
Adriatic Sea	0.10	-0.07	0.27	7.35	2.146	0.146	52.73	0.01	0.09	-1.50	1.70
Eastern Mediterranean	0.38	0.03	0.74	1.70	1423.27	0.000	99.02	0.17	0.42	-0.59	1.36
Western Mediterranean	1.18	0.13	0.23	90.95	1.52	0.469	0.00	0.00	0.00	0.07	0.28
Combined effect size	0.18	-1.30	1.66		1485.78	0.000	98.72	0.15	0.39	-1.39	1.66

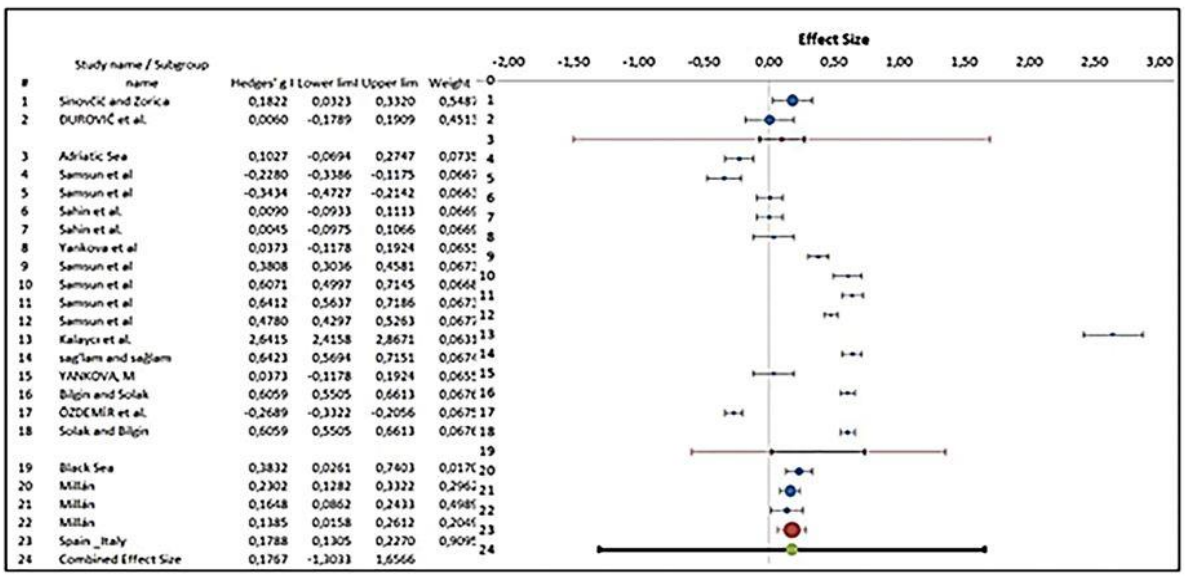


Figure 5: Forest plot graph of the effect of fishing area on male and female individuals of anchovy population.

Examining the results of the meta-analysis of the two groups of mean catches in detail, the heterogeneity found was analyzed between the Adriatic Sea (Q=2.146, p>0.146); there was no risk difference between males and females in terms of mean length 0.10 [-0.07, 0.27]; between the Eastern Mediterranean Sea (Q=1423. 27, p<0.000), the risk difference in terms of mean height was found to be 0.38 [0.03, 0.74] in favor of the group with female individuals. When examined between each other based on the Western Mediterranean (Q=1.52, p>0.469), there was no risk difference between female and male individuals in terms of mean height 1.18 [0.13, 0.23] (Table 3).

Regarding the analysis of publication bias, the funnel scatter plot results, also regarded as a visual summary of the meta-analysis dataset and demonstrates the probability of publication bias, is displayed in Figure 6. Acordingly, most of the 20 studies included are very close to the pooled effect size and are located in the upper parts. According to Figure 5, it can be argued that there is no appearance of publication bias. Consideration of the funnel plot indicates the possibility of publication bias. To verify this finding, the Begg-Mazumdar rank correlation and, according to this value, whether the number of studies considered in the research is safe or not was revealed. Since the value of Kendal's Tau, a coefficient of Begg-Mazumber rank correlation was -0.21 and p= 0.194, no publication bias was observed in the studies included in the meta-analysis according to the calculated values. Therefore, it was found that the number of studies considered was valid for the overall effect size revealed by the meta-analysis. According to this result, the studies conducted according to the mean length of anchovy were the articles that made common conclusions (Fig. 6).

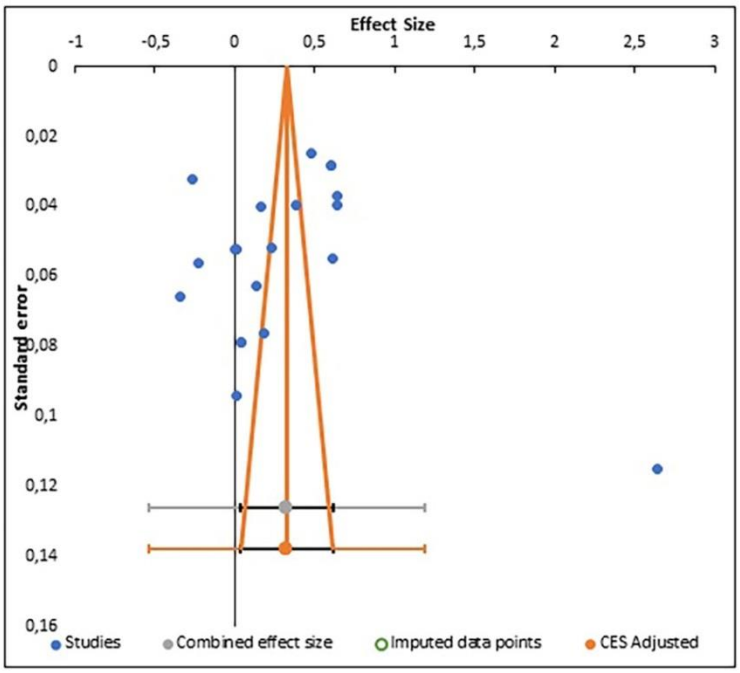


Figure 6: Funnel scatter plot.

As moderators in the studies included in the meta-analysis, the differences between the female *b* coefficient, male *b* coefficient, and L_∞ and *K* values in the model found were revealed according to the mean and deviation of female and male individuals. In the present study, regression graphs and lines can be interpreted according to the line's steepness. As L_∞ and *K* values, a change in the moderator does not affect the effect size. The high p-values supported this result for L_∞ (p=0.581) and *K* values (p=0.386). Therefore, previous publications on the mean length of individuals showed that moderators did not influence the length groups among different subgroups in terms of area fished. A steep downward trend was observed in the *b* coefficients of male and female individuals, indicating that these studies may significantly change effect size in later years (Table 4).

Table 4: Moderator analysis results of the studies with the total length averages and standard deviations of anchovy.

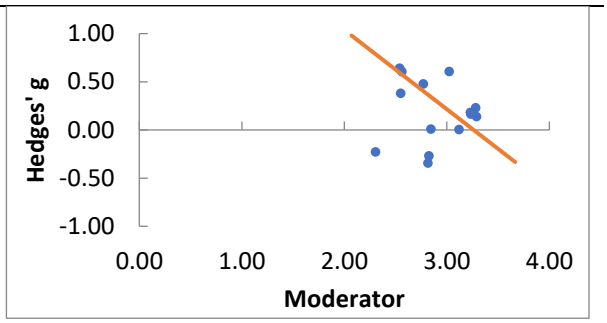
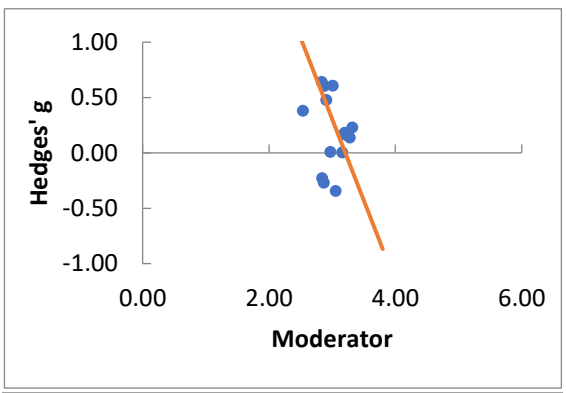
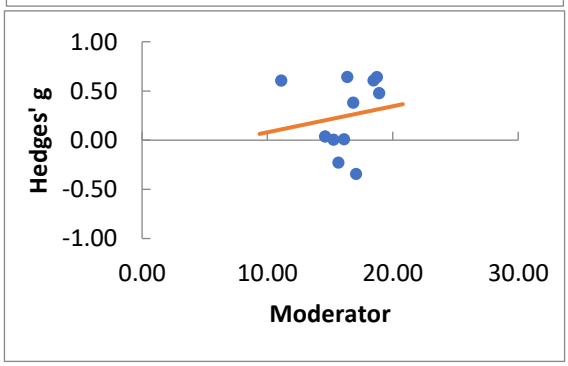
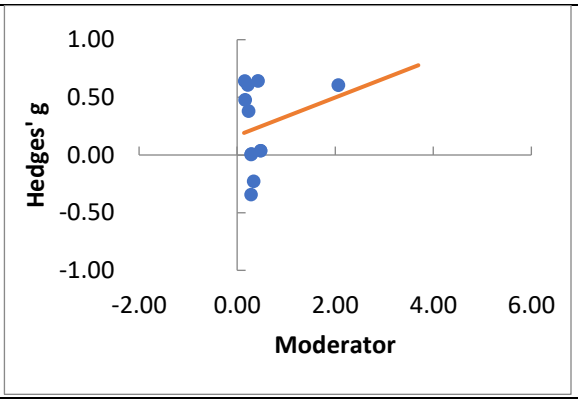
Moderator	B	SE	95% CI	*Z*-value	*p*-value	Regression Model
The *b* coefficient of the female individuals	-0.82	0.32	[-1.51; -0.14]	-2.57	0.010	
The *b* coefficient of the male individuals	-1.47	0.47	[-2.47; -0.46]	-3.12	0.002	
L_∞	0.026	0.05	[-0.08; 0.13]	0.55	0.581	

Table 4 continued:

K values	0.165	0.19	[-0.25; 0.58]	0.87	0.386



Discussion

The increase in the length and weight of fish varies according to the physical, chemical, and biological characteristics of the aquatic ecosystem in which the fish are distributed. In other words, individuals belonging to populations of the same species distributed in colder and more nutrient-rich waters reach larger sizes than individuals distributed in warmer regions. The results of the studies on the growth characteristics of anchovy species also support this case. The highest mean total length value, 14.0 cm, was found in individuals distributed in the Western Mediterranean. The Mediterranean Sea is an oligotrophic sea with a slightly more productive western basin (D'ortenzio and Ribera D'alcalà, 2009). This is related to the upwelling areas such as the Ligurian Sea, the Alboran Sea, and the Strait of Sicily, and in areas characterized by high organic inputs, either natural or artificial, such as the northwestern Adriatic Sea, the Gulf of Lion and the Northern Aegean Sea (Barausse and Palmeri, 2014). Examining the mean total length of individuals by sex, it was found that the female individuals of the population distributed in the Eastern Mediterranean were larger than the male individuals. A similar case was seen in species belonging to Mugulidae, Gadidae, and Psettodidae (Samsun *et al*., 2004). The *b* value used to interpret the condition and body shape of the species varies among individuals of the same species depending on many factors, including region and study period. The *b* values of LWRs have negative allometric growth characteristics ($b<3$) in both females and males ($p<0.05$) of the species sampled after the 2000s in the Eastern Mediterranean . If the *b* value is equal to 3, then all the fish increases in size at the same rate; $b<3$ means that the weight of a fish increases less than the increase in its length; $b>3$ means that the weight of a fish increases more than the increase in its length, i.e., it becomes less elongated or stockier (Froese *et al*., 2011). The differences in *b* values may be due to seasonal variations in water temperature and maturity stage, different sampling sites, biotic factors including age, sex, and other abiotic factors including salinity, competition, food and nutrition, and stomach fullness ratio. Also, overfishing in anchovy stocks distributed in the Eastern Mediterranean resulted in fish growth since

1985, and this period has been expressed as three periods. The first period is 1985, when the fishing pressure has just started (b>3), the second period is the years when the fishing pressure continued to increase (b=3), and the third period is the current years when the stocks are completely affected by overfishing (b<3). In 1985, when the fishing pressure on the stocks had just started, all fish sizes increased at the same rate (b=3) with the effect of overfishing, and in recent years, when the stocks have been completely affected by overfishing, the species (b<3) became even longer (Karaçam and Düzgüneş, 1990; Bilgin, 2006; Bilgin *et al*., 2016). Some differences between growth characters vary annually. The functional regression "b" value refers to body form and is directly related to weight, which is influenced by ecological factors such as temperature, food source, spawning conditions, sex, age, fishing time and area, and fishing vessels (Ricker, 1968; Samsun *et al*., 2006). However, many factors such as gonad maturity, sex, age, diet, stomach fullness, health, sampling methods, sample sizes and preservation techniques, habitat, and environmental conditions affect the condition of the fish and the parameters of length-weight relationships in fish (Adaka *et al.,* 2015). Mediterranean waters are generally warm and oligotrophic and, therefore, have relatively low nutrient concentrations (Estrada, 1996; Stergiou *et al.*, 1997). In light of the knowledge of local and seasonal water properties and hydrodynamics variations, nutrients and primary productivity in the Mediterranean Sea greatly vary locally and seasonally. There is a relationship between zooplankton abundance and distribution in relation to phytoplankton growth, and numerous studies, including that by Alcaraz *et al.* (1988), have reported a relationship between zooplankton biomass and chlorophyll maximums in the western Mediterranean. Sea surface estimates of chlorophyll concentrations have been reported to be good indicators of food availability for anchovy (Basilone *et al*., 2004). Many fish larvae of various species and zooplankton will be consumed by phytoplankton, which is the main food item for small pelagic fish such as anchovy. As a result, anchovy implies a fundamental link between plankton production and predators of the upper trophic levels. All studies on anchovy (larval, juvenile, and adult stages) emphasize the critical role of copepods as the main link between phytoplankton and anchovy production (Tudela and Palomera, 1995; Plounevez and Champalbert, 2000). Economically important fish species have always been target species for fishermen. Therefore, their stocks will inevitably be jeopardized unless permanent management strategies are developed for their conservation (Heral and Bayhan, 2020). *Engraulis encrasicolus* is currently classified as LC (least concern) by the European Red List of Marine Fishes (IUCN, 2022), indicating that it is essential to determine the population's current status and monitor changes over time. Indeed, it has been emphasized that the biomass and average size of small pelagic fish assemblages such as sardines and anchovies, which are now distributed in the northwestern Mediterranean, have decreased significantly (GFCM, 2016). This research findings showed that the

length-weight relationship parameters of the species should be constantly monitored according to the regions where they are distributed.

The present study represents a comprehensive meta-analysis of the growth of European anchovy in the Mediterranean Sea. A difference was found for the Eastern and Western Mediterranean regarding the mean length of males and females in the anchovy population distributed in the Mediterranean. Also, female individuals of the population distributed in the Eastern Mediterranean are represented in larger sizes. Therefore, it is recommended that studies on the length-weight relationship of the species should continue in the future. On the other hand, reliable data that can always be combined in terms of infinite length and *K* values of the species were obtained.

Declarations

Ethical approval No approval of research ethics committees was required to accomplish the goals of this study. Informed consent Informed consent was obtained from all individual participants included in the study.

Financial or non-fnancial interests

None.

Conflict of interest

Manuscirpt single author.

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