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Growth and exploitation of Salema *Sarpa salpa* (Linnaeus, 1758) (Sparidae) in the North Aegean Sea, Türkiye

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Abstract

Salema, Sarpa salpa (Linnaeus, 1758), is a herbivorous fish species of the family Sparidae. It is an important predator of benthic algae, especially seagrass Posidonia oceanica. Due to excessive herbivorous behaviour, ecological importance becomes more significant than economical value. Thus, the aim of this study was to contribute scientific knowledge of Salema stock distributed around North Aegean Sea, Turkey with reveal age structure, growth, mortality, and exploitation rates. For this purpose, a total of 412 specimens, varied between 10.2 cm and 38.0 cm TL in length were obtained by commercial gill net fisheries monthly. The length-weight relationship (LWRs) was calculated as $W=0.01898*TL^{2.883}$ ($r^2=0.97$)*, and growth type was determined as negative allometric in all sexes. The von Bertalanffy growth parameters were calculated as* $L_\infty=41.6$ *cm,* $K=0.21$ y^{-1}*, and* $t_0=-1.50$ *y, and the total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) were calculated as 2.04, 0.44, 0.81, and 0.65, respectively. The fishing mortality optimum reference point (Fopt), fishing mortality limit reference point (Flim), optimum exploitation rate (Eopt) and the length where the maximum yield can be obtained (Lopt) were calculated as Fopt=1.02, Flim=1.36, Eopt=0.44, and Lopt=28.6, respectively.*

Keywords: *Age, growth, mortality, reference points, Salema, North Aegean Sea*

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Kuzey Ege Denizi'nde (Türkiye) Sarpa (*Sarpa salpa*, Linnaeus, 1758) (Sparidae) balığının büyümesi ve sömürülmesi

Öz

Sarpa, Sarpa salpa (Linnaeus, 1758), Sparidae familyasının otçul bir türü olup, özellikle deniz çayırlarından Posidonia oceanica türünün önemli bir predatörüdür. Aşırı otçul davranışından dolayı türün ekolojik önemi ekonomik değerini aşmaktadır. Bu yüzden, bu çalışmanın amacı Kuzey Ege Denizi'nde dağılım gösteren Sarpa türünün populasyon dinamikleri konusundaki bilimsel bilgilere yaş dağılımı, büyüme, ölüm ve sömürülme oranlarını ortaya koyarak katkı sağlamaktır. Bu amaçla, 10.2 cm ile 38.0 cm TL boy aralığında değişen 412 birey ticari uzatma ağı ile avlanan balıkçılardan aylık olarak temin edilmiştir. Boy-ağırlık ilişkisi $W=0.01898*TL^{2.883}$ ($r^2=0.97$) *şeklinde ve büyüme tipi ise negatif allometrik olarak tespit edilmiştir. von Bertalanffy büyüme parametreleri* $L_\infty=41.6$ *cm,* $K=0.21$ y^{-1}*, ve* $t_0=-1.50$ *y olarak belirlenmiştir. Toplam ölüm (Z),doğal ölüm (M), balıkçılık ölümü (F) ve sömürülme oranı (E) ise sırasıyla 2.04, 0.44, 0.81 ve 0.65 belirlenmiştir. Balıkçılık ölümü optimum referans noktası (Fopt), balıkçılık ölümü limit referans noktası (Flim), optimum sömürülme oranı (Eopt) ve maksimum verimin sağlanabileceği boy (Lopt) sırasıyla 1.02, 1.36, 0.44 ve 28.6 olarak belirlenmiştir.*

Anahtar kelimeler: *Yaş, büyüme, ölüm, referans noktaları, Sarpa, Kuzey Ege Denizi*

1. Introduction

In the scientific literature, different numbers are stated regarding the species number of the family Sparidae such as 166 species [1] and 164 species [2] belonging to 39 genus. In marine fish checklists of Türkiye, the family Sparidae was represented with 10 genus and 21 species [3, 4], 13 genus and 24 species [5, 6, 7] and 13 genus and 25 species [8]. Whereas, Sarpa genus is represented by with a single species *Sarpa salpa* (Linnaeus, 1758) in all these sources.

The salema, is an important representative of the family Sparidae, mainly distributed in shallow marine and brackish waters (5-70 m) of subtropical areas. It has a wide geographical distribution from the Bay of Biscay to South Africa, including Mediterranean [9]. Similarly, it is distributed in all seas of Turkey [4]. Herbivorous feeding and therefore distribution on vegetative areas of adults are known [10]. Due to the salema is one of the main predators of seagrass beds, the ecological impact becomes more important. [11] Salema is responsible for the 40% of herbivory of *Posidonia oceanica* oneself [12]. Thus, the population structure and stock status should become more important and challenging in the near future.

S. sarpa has a medium-low commercial interest in Turkey. It is caught with gill nets and mostly target for small-scale fisheries in coastal waters. According to Turkish fisheries statistics, the quantity of landed fish has been varied between 150 and 200 tonnes/year for last 10 years and it was a 167.4 tonnes for the last year. Unfortunatelly, the reconstructed catch of Turkish fisheries landings were estimated 63% higher than reported data [13].

Due to the ratio of unreported landings of small-scale fishery is high, the number of landings of Salema in Turkey might be bigger than reported. The Aegean coasts and Çanakkale Strait area are important fishing areas of salema for Turkey.

Due to its herbivory on seagrass beds, the previous studies mostly concentrate on feeding habits [14], [15], [16], [17], and [18]. Also, some published literature on toxicity [19], [20], [21], and [22] and reproductive biology [23], [24], and [25] were realised. The published literature on population dynamics and growth of Salema restricted some areas around South Africa [26], Italy coasts of the Mediterranean [27], Atlantic coasts [28], [29], and the Adriatic Sea [30]. As well as the maximum length record [6] and length-weight relationship [43], information on the population biology of salema is restricted to a single study in the Aegean Sea and Turkish waters [31]. The aim of this study was to contribute scientific knowledge of salema stock distributed around the North Aegean Sea, Türkiye with reveal age structure, growth, mortality and exploitation rates.

2. Material and methods

Salema individuals were obtained from commercial catches of gill net fisheries around the North Aegean coasts of Türkiye between August 2020 and July 2021 (Fig. 1). Beside, for understanding length at first capture, the specimens of salema caught with nylon gill nets were obtained by simultaneous trial in the same area and the same time. Minimum 30 specimens was selected random from the total commercial catch for each month during the study period. Sub-sampled fish individuals were transported from the vessel to the laboratuary inside an icebox, immediately. In the laboratory, all specimens were measured to the lowest millimeter and weighed to the lowest 0.1 g. The length-weight relationship parameters were calculated by the exponential regression $W=a*TL^b$, where W is the total weight (g) and TL is the total length (cm) [32] To determine the growth type, the student t-test was applied for b value to find out if it was different from the three. [33; 34]. Sex was determined using macroscopic observation of male and female gonads.

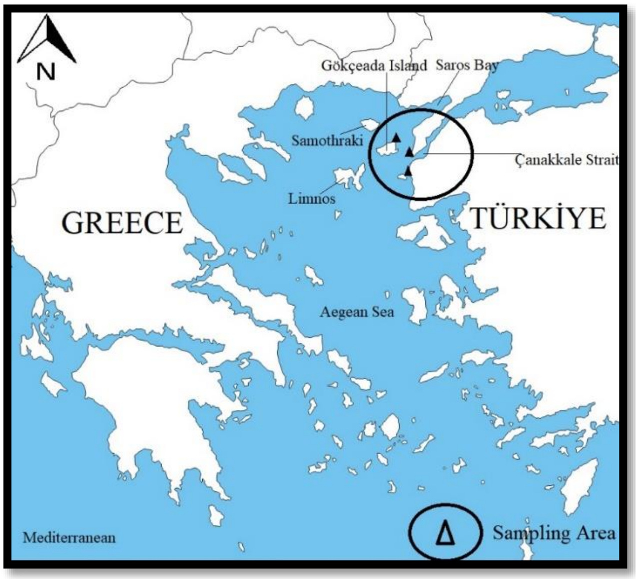

Figure 1. The study area (North Aegean Sea coasts of Türkiye; commercial catches obtained from Gökçeada Kaleköy, Seddülbahir, and Babakale fishing ports)

Age was determined by interpreting annual growth rings on otoliths of 412 adult salema individuals according to Iglesias and Dery's method [48]. To increase the visibility of annual age rings, first glycerin was dripped and then otolith rings were counted under reflected light by placing the concave side against the glass surface. For daily age determination of six juvenile individuals, the sagittal otoliths were removed and the right otoliths were sticked on glass slide with thermoplastic glue. After grounding and polishing, increment rings were counted from the first visible check mark succeeding the primordium to the outer edge along the maximum diameter axis as stated by Brothers [49]. von Bertalanffy growth function [46] was used to determine growth parameters, $L_t = L_\infty$ [1-exp(k(t-t_0)) where L(t) is the length at time, L_∞ is the asymptotic length- the mean length the fish of a given stock would reach if they were to grow indefinitely, K is the growth rate parameter, and t_0 the age of the fish at zero length. FISAT II was used to calculate the growth parameters [35]. The ϕ growth performance index was calculated as follows to compare the growth parameters between the studies and areas.

Instantaneous total mortality (Z) was calculated with a length-converted catch curve lnNt=a+bt where Z is estimated from the slope b of the descending right arm of the plot. [36]. Natural mortality (M) was determined using Pauly's empirical [37] formula, Log (M)= (-0.0066) – 0.279 * log(L) + 0.6543 * log(K) + 0.4634 * log(T), which contain mean annual sea water temperature (15.7 °C) [47]. Fishing mortality (F) was found with the deduction of natural mortality (M) from total mortality (Z) and the exploitation rate (E) was calculated as the fraction of F with Z.

Optimum fishing mortality (Fopt), fishing mortality limit reference point (Flim) and optimum exploitation rate (Eopt) reference points were calculated due to evaluate mortality and exploitation of stock.

The reference points were used according to the given formula by [38], [39], and [40], respectively.

$Fopt = 0.5M$

$Flim = (2M)3^{-1}$ [38]

$Eopt = F_{opt} . (M + F_{opt})^{-1}$ [39]

Besides, the maximum possible yield per recruit is obtained at an intermediate length (Lopt) was calculated;

$Lopt = 3L_\infty . (3 + (M.K^{-1}))^{-1}$ [40]

where K is the growth rate and M is natural mortality.

3. Results

A total of 418 specimens of *S.salpa* were obtained from the commercial catches of gillnet fishery around the North Aegean coasts of Türkiye. The individuals ranged from 10.2 cm to 38.0 cm in total length (TL), with a mean of 26.4 ± 0.2 cm TL and ranged between 9.2 cm and 34.0 cm fork length (FL), with a mean of 23.60 ± 0.18 cm FL. The total weight of individuals ranged from 15.9 g to 752.4 g, with a mean of 225.5 ± 5.5 g. 6 of 418 individual were not sexed due to immature gonads. Between the remaining 412 individuals, 185 individuals were determined as female, and 227 were male. Females ranged from 22.5 cm to 38 cm at TL, whereas males were ranged between 16.9 cm to 34.2 cm TL. The mean TL of females and males were 28.5 ± 0.3 cm and 25.1 ± 0.3 cm TL, respectively. Besides, the females ranged from 135.4 g to 757.4 g at weight, whereas males were ranged between 59.9 g and 523.9 g. The mean weight of females and males was 311.1 ± 7.9 g and 213.4 ± 7.6 g, respectively. The length and weight values did not differ significantly (Anova, $p>0,05$) between the sexes.

In total, 54% of the stock was consisted of individuals distributed at lengths between 24 cm and 28 cm TL. The most abundant length group was found as 27 cm TL. Due to the selectivity of commercial gillnets, the individuals that had lengths lower than 16 cm TL did not involved length data set (Fig. 2). The smallest six individuals were obtained from scientific trial nets for understanding recruitment size. Hence, the smallest individuals were seen in July for the first time, and the recruitment size was determined as 10.2 cm TL. According to the temporal variation of length-frequency distribution, it was found that the recruitment took place between June and September.

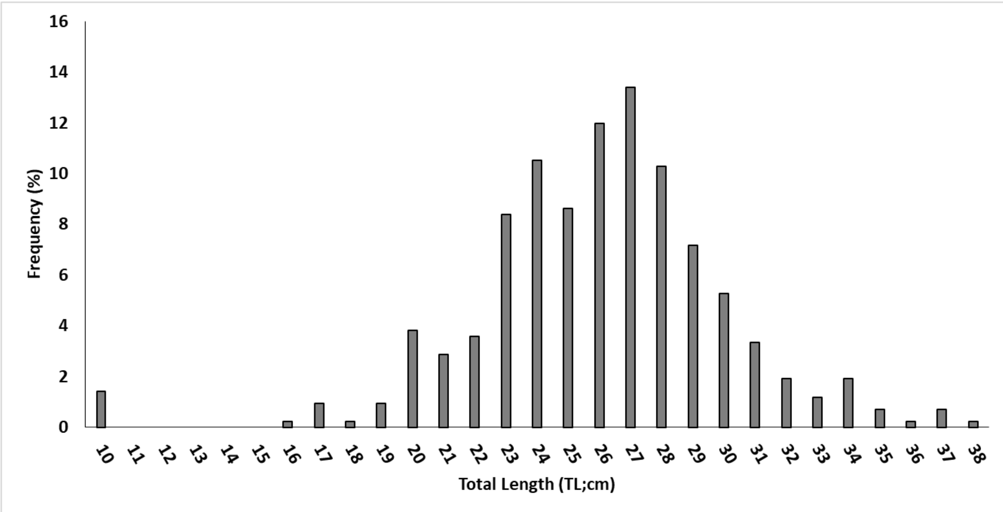

Figure 2. The length-frequency distribution of salema stock around the North Aegean Sea, Türkiye

The highest length individuals (37 cm and 38 cm TL) were seen in June, whereas the highest mean length (29.6 cm TL) was found in October, when the spawning peaked. The strong linear relationship (r^2=0.99) between total length (TL) and standard length (SL) was found within the given formula FL= 0.8948TL-0.0404. The length-weight relationship of males, females, and all sexes was given in Fig. 2. The length-weight relationship (LWRs) were calculated as $W=0,01898*TL^{2,883}$ (r^2=0.97), and growth type was determined as negative allometric in all sexes. For males, the LWRs were found as $W=0,02430*TL^{2,8054}$ (r^2=0.95), and growth type was determined negative allometric as in all sexes. For females, the LWRs were calculated as $W=0,01392*TL^{2,9773}$ (r^2=0.93), and the growth type was determined as isometric (Fig. 3).

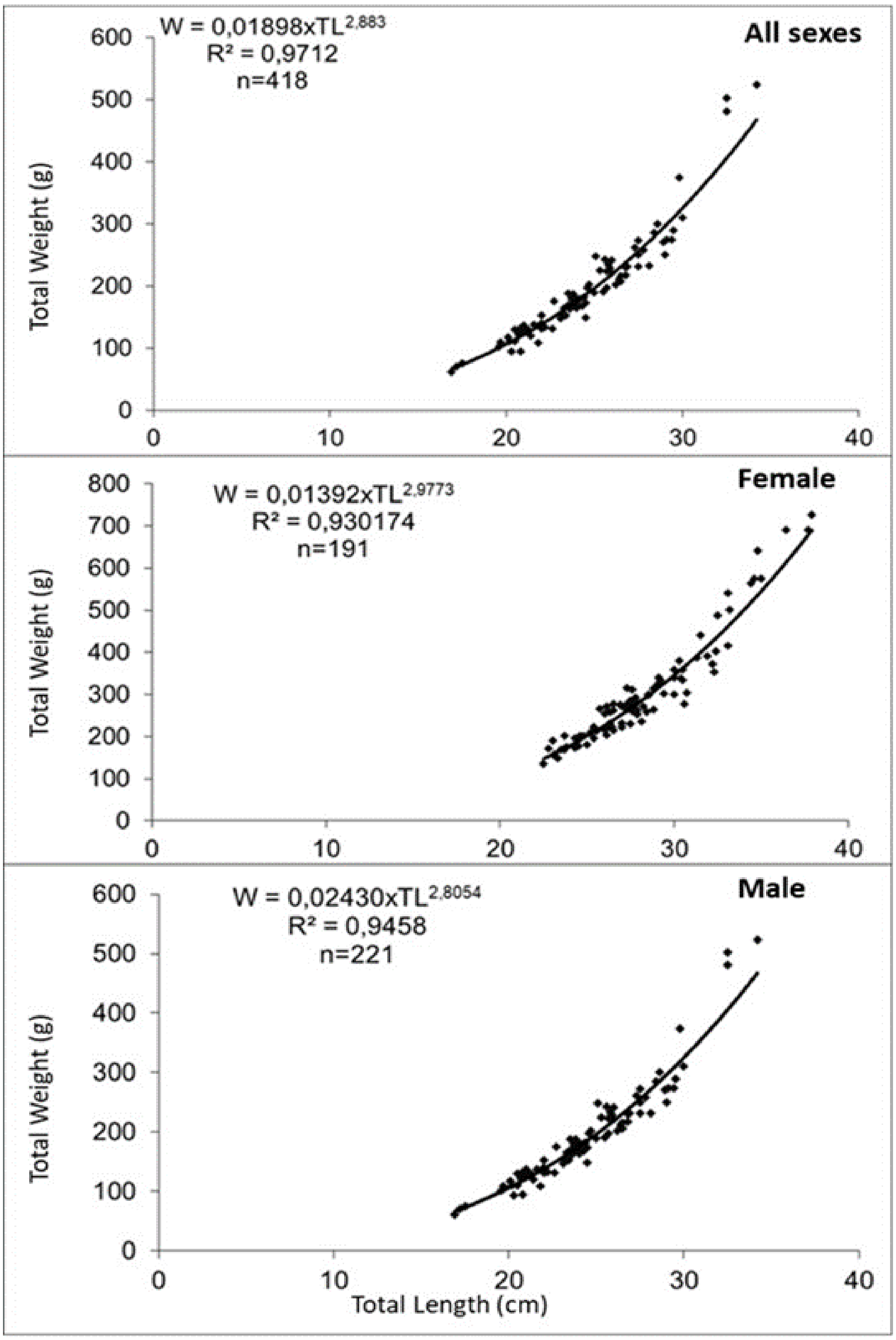

Figure 3. Length-weight relationship of male, female, and all sexes of salema

The age distribution of all sexes varied between 0 and 7 according to the reading of sagittal otoliths of the 412 salema individuals. The 4 and 3 age groups were the most abundant, with 30.1% and 26.5% of the total individuals, respectively. It was determined that the daily ages of the six individuals belonging to the 0-age group ranged from 221 to 230. The low individual number from 0 and 1 age group stemmed from the selectivity of commercial gillnets (Table 1).

Table 1. Age-length key of the salema distributed around North Aegean Sea

Length (TL;cm)	Age (t)							
	0	1	2	3	4	5	6	7
10	6							
11								
12								
13								
14								
15								
16		1						
17		3	1					
18		1						
19			4					
20			15	1				
21			11	1				
22			8	7				
23			20	13	1			
24			16	22	5			
25			5	20	9			
26				21	26	3		
27				14	31	11		
28				10	22	10		
29					23	6		
30					6	11	3	
31					1	13	3	
32						10	4	
33						4	3	
34						2	6	
35						2	2	1
36							1	
37								3
38								1
Total	6	5	80	109	124	61	22	5
Lmean (TL;cm)	10.48	17.58	22.59	25.4	27.6	29.8	33.07	37.32

According to non-linear regression analyses, the von Bertalanffy growth parameters were calculated as L_∞=41.6 cm, K=0.21 y^{-1}, and t_0=-1.50 y for all data set, L_∞=39.1 cm, K=0.24 y^{-1}, and t_0=-1.50 y for females, and L_∞=35.2 cm, K=0.24 y^{-1}, and t_0=-2.13 y for males. The von Bertalanffy growth curves are shown in Figure 4.

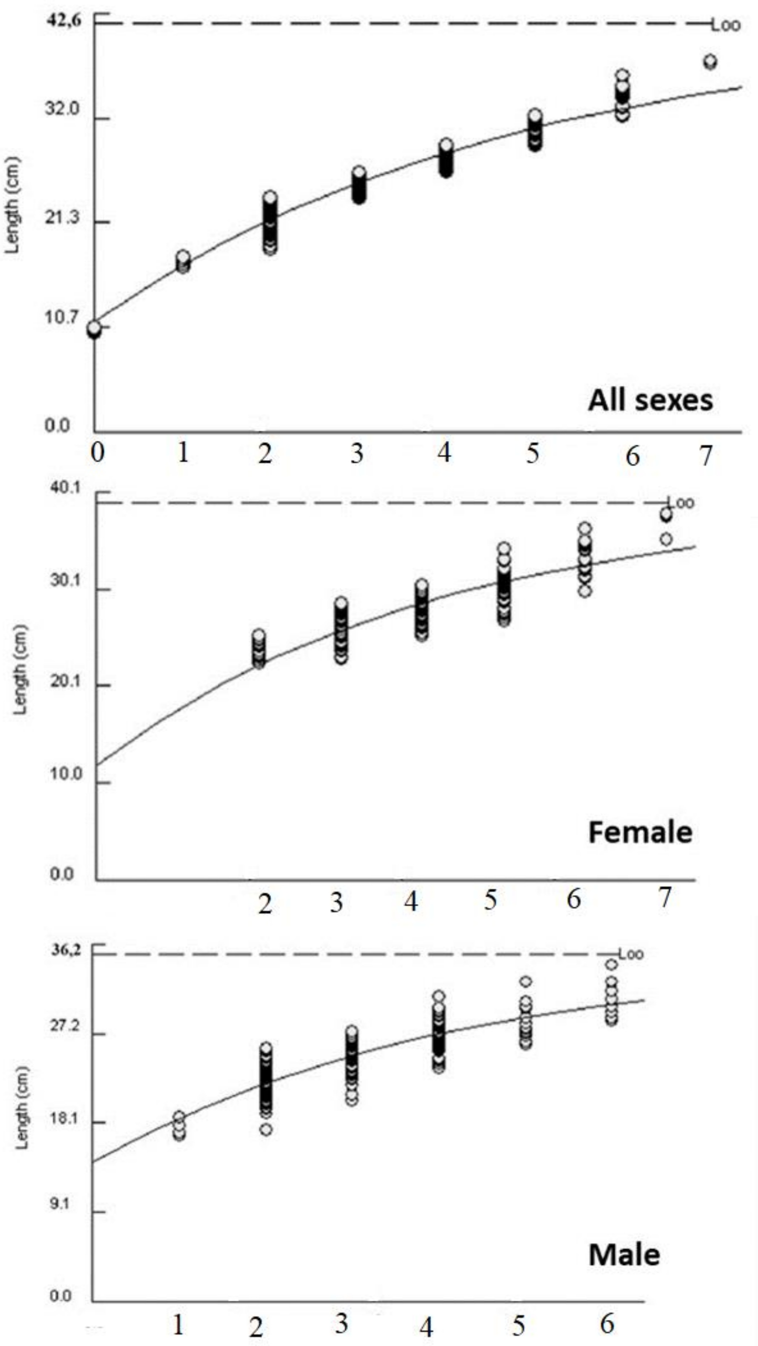

Figure 4. The von Bertalanffy growth curve of male, female and both sex of salema, *Sarpa salpa*.

When analyses were applied for all data set, the total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) were calculated as 2.04, 0.44, 0.81, and 0.65, respectively. There were no statistically important differences ($p>0,05$) between the mortality rates of females and males. Reference points such as fishing mortality optimum reference point (Fopt), fishing mortality limit reference point (Flim), optimum exploitation rate (Eopt) and the length where the maximum yield can be obtained (Lopt) were calculated as Fopt=1.02, Flim=1.36, Eopt=0.44 and Lopt=28.6, respectively.

4. Discussion

Body shape is one of the most important parameters to effect growth type of fish [41]. The *b* value of fusiform-shaped fish usually has isometric growth, limiting or extreme values are seen mostly in flattened or elongated fish. The mean *b* value of salema was given as 3.04, and the body shape was defined as fusiform by [42]. The negative allometry given in this study for males and both sexes of salema may result from unfavorable habitats due to the shortage of vegetative areas around the North Aegean Sea. Our results on LWRs were more coincide with [29], [28], and [43]. Whereas the findings of [31] differed from ours due to positive allometry even though nearby areas between all previous studies. The differences in LWR parameters can be the result of geographical differences, food availability, age distribution, maturation stage, and environmental situations [44]. The age, length and sex distribution of these two studies were similar. Thus, the differences in *b* values may arise from the decrease in food in the area from 2017 to 2022.

The scientific trial with nylon gillnets enabled us to sample the individuals which 0 year old (221-230 day^{-1}) in July. Thus, the hatch date of these individuals was determined as 1st week of November and reached the 10 cm TL at 7.5 months after hatching. The smallest individual at 1 age-year-old was found in a 16 cm length group. Thus, it was observed that the individuals that varied between 10 cm and 16 cm in length could not be sample by commercial gill nets due to their selectivity. [27] were stated that the specimens of salema hatched in autumn reached 1st age of 14 months after hatching. Thus, the findings of [27] and our's were consistent. Also, the spawning season of the salema was determined between October and November from the reproductive characteristics of adult individuals from the same area [50]. This results were overlap with hatch date of this study.

As in this study, the length-age distribution was similar in all studies where the largest individual in the length data set was less than 38 cm TL [26], [27], and [31]. [28] were determined the age maximum age as 11 years old from the individuals distributed between 11.9 cm to 45.2 cm TL, whereas they determined that the smallest size of 8 year-old individual was 38 cm TL. Conversely, the results on age distribution of [30] and [29] were differ from others due to they found bigger ages for smaller length groups. This may be a result of the over-estimation of annual rings in bigger-sized individuals.

The ϕ growth performance index was calculated between 2.44 and 2.69 in this study and previous ones. The highest values were found by [28] around Canarian Archipelago, whereas the lowest values were determined by [26] and [29]. The ϕ index of this study was determined as a 2.56, which is acceptable within limits. The estimated asymptotic length is slightly above the biggest individual. It may be a result of high accuracy of sampling due to detailed effort to find individuals with any sizes.

Table 2. Comparison of length-weight relationship parameters and von Bertalanffy growth parameters of salema, *Sarpa salpa*.

Author	Area	Sex	*a*	*b*	r^2	*Growth*	*Length Interval*	L_∞	K	t_0	Age	ϕ
van der Walt &Berkley, 1997 [26]	South Africa	Both Sex	*	*	*	*	4 - 26 cm FL	22.4	0.55	-0.51	1 - 6	2.44
Criscoli et al., 2006 [27]	Italy coasts, Mediterranean	Both Sex	0.0128	3.04	0.84	Isometric	9 - 33 cm TL	37.27	0.27	-0.53	0 -7	2.57
Paiva et al., 2018 [29]	Portugal Coasts, Atlantic	Both Sex	0.02	2.98	0.85	Isometric	5.2 - 41.4 cm TL	45.07	0.14	-1.43	0 - 14	2.45
		Females	0.02	2.91	0.81	Isometric						
		Males	0.06	2.64	0.85	A (-)						
Mendes-Villamil et al., 2002 [28]	Canarian Archipelago, Atlantic	Both Sex	0.0000134	3.01	0.99	Isometric	11.9 - 45.2 cm TL	48	0.21	-0.97	0 - 11	2.69
		Females	0.0000183	2.96	0.94	A (-)		49.7	0.20	-1.26		2.69
		Males	0.0000164	2.98	0.97	Isometric		44.5	0.23	-1.02		2.66
Pallaoro et al., 2008 [30]	Adriatic, Mediterranean	Both Sex	0.00893	3.11	0.99	A (+)	10.3 - 43.9 cm TL	36.62	0.22	-0.92	1 - 15	2.47
		Females	0.0071	3.17	0.95	A (+)		40.85	0.18	-2.61		2.48
		Males	0.0123	3.01	0.99	Isometric		33.11	0.51	-0.91		2.75
Bektaş, A.,2017 [31]	Gökçeada Island, Türkiye	Both Sex	0.0085	3.17	0.95	A (+)	12.5 - 33.1 cm TL	35.55	0.31	-9.2	1 - 6	2.59
		Females	0.0073	3.23	0.90	A (+)						
		Males	0.0138	3.01	0.96	A (+)						
Bayhan and Kara, 2015 [43]	Izmir Bay, Türkiye	Both Sex	0.0189	2.89	0.96	A (-)	15.6 - 42.6 cm TL	*	*	*	*	*
		Females	0.0216	2.84	0.98	A (-)						
		Males	0.0294	2.75	0.96	A (-)						
This study*	North Aegean Sea, Türkiye	Both Sex	0.01898	2.88	0.97	A (-)	10.2 - 38 cm TL	41.6	0.21	-1.50	0 - 7	2.56
		Females	0.01392	2.98	0.93	Isometric		39.1	0.24	-1.50		2.57
		Males	0.02430	2.81	0.95	A (-)		35.2	0.24	-2.13		2.47

The mortality rates were calculated by two previous studies, whereas reference points were presented first in our study. Although nearby areas, [31] was found relatively low fishing mortality rates around Gökçeada islands. Barely natural mortality (M) was to be higher than total mortality (Z). Hence, fishing mortality may have beenmiscalculated. The mortality rates were similar to the findings of van der Walt and Govender [45].

Table 3.Comparison of mortality and exploitation rates of salema, *Sarpa salpa*.

Author	Area	Z	M	F	E	Fopt	Flim	Eopt	Lopt
Van der Walt & Govender, 2007 [45]	South Africa	1.41	0.60	0.81	*	*	*	*	*
Bektaş, A.,2017 [31]	Gökçeada Island, Türkiye	0.98	0.71	0.27	0.61	*	*	*	*
This study*	North Aegean Sea, Türkiye	1.25	0.44	0.81	0.65	1.02	1.36	0.44	28.6

The calculating fishing mortality rate (F=0.81) in this study was lower than the estimated optimum (Fopt=1.02) and limit (Flim=1.36) fishing pressure. There was no potential risk for fisheries mortality of salema. Also, the length where the maximum yield can be obtained (Lopt) was calculated as 28.6 cm TL. Conversely, the minimum landing size has not been stated by the Turkish Fisheries Management Authority, yet.

Salema is known as an important predator of vegetative areas. Also, another herbivorous fish species, *Siganus luridus* expanding its distribution from South to North day by day in the Aegean Sea. The extinction of benthic algae (especially *Dictyota* sp., *Caulerpa* sp., *Pocidonia* sp., *Cystoseira* sp.) may become more important issue in the near future. Salema increased the consuption of seagrass with an increase of the age and the older individuals consumed more *P. oceanica* in Revellata Bay (Gulf of Calvi, Corsica, France) [15]. Fishermen can be encouraged to catch large salema individuals if *P. oceanica* stocks are faced with a reduction due to a *P. oceanica*-dominated diet of the salema.

However, the economic return of the species should increase to encourage fishermen to catch this species. It was stated that salema is rich in n − 3 PUFAs, with a favorable n3 – n6 ratio [51]. Salema stated as one of 13 species between 58 different species of wild fish that did not exceed 0.5 μg g−1 ww total mercury levels in the Western Mediterranean [52]. Contrary to these, the price category showed as a medium [53] and consumption as fresh is not in high demand. The meat of salema can be processed into a meatball-like product and made more acceptable. Meat should be checked for toxicity before processing, as toxicity cases have been reported in previous studies

It was reported that the interaction between salema and *P. oceanica* may increase with the warming of the sea surface temperatures [55]. Whereas it was identified that attention should be paid to conserve the marine ecosystem in the Mediterranean due to climate warms [56]. Thus, the stock size information and exploitation of salema will become more essential in the coming years from an ecological point of view. In terms of management, if the sustainability of the species is desired, the minimum landing size should arrange above 28.6 cm TL, if it is desired to decrease the stock, it should be determined below this value.

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