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Research Article

Seasonal Variation in Trawl Codend Selectivity for Annular Sea Bream (*Diplodus annularis* L., 1758)

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Abstract: This study investigated the selectivity of a 40 mm mesh size polyethylene codend commonly used by Turkish demersal trawlers. Seasonal selectivity data were collected for annular sea bream (*Diplodus annularis*), which is the most abundant discard species in the catch composition in Gülbahçe Bay. Four sets of data were collected in spring (4-18 April 2002), summer (10-25 July 2002), autumn (26 September-2 October 2002) and winter (22-23 January 2003). The selectivity of the same codend was tested under very similar conditions except for the seasonal variables. The data were obtained using the covered codend technique, and analysed by logistic equation with the maximum likelihood method. Parameters of mean curves for each trip were estimated using Fryer's between haul variation model.

The results show that although there is a pattern of decrease in selectivity from summer (L_{50} = 9.3 cm, SR = 0.9 cm) to autumn (L_{50} = 9.2 cm, SR = 0.9 cm), winter (L_{50} = 8.9 cm, SR = 1.1 cm) and spring (L_{50} = 8.7 cm, SR = 1.1 cm), seasonal differences in selectivity for annular sea bream are not very high.

Key Words: Seasonal variation, trawl selectivity, the Aegean Sea, Annular sea bream (*Diplodus annularis*)

Isparozun (*Diplodus annularis* L., 1758) Trol Torba Seçiciliğinde Mevsimsel Değişimi

Özet: Bu çalışma Türk dip trollerinde yaygın olarak kullanılan 40 mm göz açıklığındaki polietilen torbanın seçiciliğini incelemektedir. Mevsimsel seçicilik verileri Gülbahçe Körfezi av kompozisyonunda en bol ıskarta türü olan ısparoz (*Diplodus annularis*) için toplanmıştır. Veriler ilkbahar (4-18 Nisan 2002), yaz (10-25 Temmuz 2002), sonbahar (26 Eylül-2 Ekim 2002) ve kışın (22-23 Ocak 2003) toplanmıştır. Aynı torbanın seçiciliği mevsimsel değişkenler haricinde birbirine çok benzer şartlar altında denenmiştir. Veriler örtü torba tekniği kullanılarak elde edilmiş ve 'En Yüksek Olabilirlik Yöntemi' ile Lojistik denklem kullanılarak analiz edilmiştir. Her sefer için ortalama eğrinin parametreleri Fryer'in çekimler arası değişkenlik modeli kullanılarak hesaplanmıştır.

Sonuçlar, ısparozun seçiciliğinde yaz mevsiminden (L_{50} = 9,3 cm, SA = 0,9 cm) sonbahara (L_{50} = 9,2 cm, SA = 0,9 cm), kışa (L_{50} = 8,9 cm, SA = 1,1 cm) ve ilkbahara (L_{50} = 8,7 cm, SA = 1,1 cm) doğru bir azalma eğilimi olmasına rağmen, mevsimler arası farklılıkların çok yüksek olmadığını göstermektedir.

Anahtar Sözcükler: Mevsimsel değişim, trol seçiciliği, Ege Denizi, Isparoz (*Diplodus annularis*)

Introduction

Demersal trawling in Turkish waters is carried out in grounds where more than 50 species encounter the gear (1). Annular sea bream (*Diplodus annularis*) is one of the most abundant demersal species in İzmir Bay (2) and can be considered the most commonly discarded species in trawl catch composition. Due to its low market value only large fish are landed and a great proportion of the catch is discarded. Even so, its reported annual catch in 2001 was 280 t in Turkey, of which 70% was harvested in the Aegean Sea (3). Minimum landing size (MLS) for this species is not specified in Turkish Fisheries Regulations (4). However, Metin and Akyol (5) report that females of annular sea bream reach sexual maturity at 10.4 cm total length in İzmir Bay.

Demersal trawl codends used in Turkish waters are rather unselective (6). There have been intensive studies conducted in the Aegean Sea to find solutions to the poor selectivity of commercially used trawl codends, particularly since the mid 1990s. However, although a

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significant number of these experiments were conducted using similar codends in fishing grounds very close to one another (mostly in İzmir Bay), their results for the same species are rather variable. One of the likely reasons for that is the effect of the time of the experiments on the results. In most of the publications, dates of the individual hauls are not provided and the data were pooled over variable periods of time.

The effect of seasonal variation on codend selectivity is considered very important, but it is not well understood. However, Özbilgin et al. (7) reported that the selectivity of the same codend for haddock (*Melanogrammus aeglefinus*) in the North Sea showed an increase at the end of the summer feeding period that coincided with the highest point of the annual cycle of water temperature. On the other hand, selectivity decreased during the post-spawning stage of the fish, which takes place in the low temperature range in April.

An investigation of the seasonal variation in selectivity may answer the main questions: a) Are the variations in past selectivity studies where the dates of the individual hauls are not provided likely to have been caused by seasonal changes? and b) Is there a major change in the selectivity of the same gear between the seasons? In other words, does the escape probability of the same size of fish change throughout the year? In this study, seasonal changes in selectivity of a 40 mm nominal mesh size polyethylene (PE) codend commonly used by Turkish demersal trawlers were investigated in Gülbahçe Bay. Selectivity of the same codend attached to the same gear was tested for annular sea bream using the same vessel in the same fishing ground for the same towing speed and duration.

Materials and Methods

Four sets of codend selectivity data were collected in spring (4-18 April 2002), summer (10-25 July 2002), autumn (26 September-2 October 2002) and winter (22-23 January 2003). The raw data collected during the April trip were previously used by Özbilgin and Tosunoğlu (8) to compare the selectivities of double and single codends in the form of combined hauls. Fishing was carried out in Gülbahçe Bay, in the Eastern Aegean Sea, during all the trips. A traditional, 600 meshes round the mouth, commercially used bottom trawl (9), with a 40 mm mesh size PE netting codend was used for fishing. The codend had 200 meshes around the circumference and a 5 m stretched length. Its mesh size was measured as 42.4 mm (se. 0.26) using an ICES mesh gauge with 4 kg weight (10). The same gear was used in all the operations and all the hauls were carried out aboard the R/V Egesüf (27 m, 500 HP). Towing duration was standardised as 45 min. All the tows were carried out during daylight, mostly between 10 am and 3 pm. Towing speed varied between 2.2 and 2.6 knots. Water depth of the fishing area varied between 25 and 30 m. Warp length used in this depth was 150 m.

The covered codend method with hoops was used to collect the data (11,12). The cover was 8 m in length and was made of 24 mm mesh size knotless PA netting. It was supported by two 1.8 m diameter hoops to stop the masking effect of the cover netting on codend mesh openings, and to provide a better flow in and around the codend.

After each haul, first the cover and then the codend catches were removed and sorted by species. Annular sea bream and the rest of the codend and cover catch were separately weighed. Total lengths of the target species were measured to the nearest half a centimetre. Selectivity parameters for individual hauls were estimated by means of an MS-Excel file (13), which is run by the 'solver' tool. Codend selectivity curves were obtained in the program file by fitting a logistic equation by means of the maximum likelihood method (11). The selectivity of codends was determined by the relationship between the probability *p* of a fish entering the codend and fish length *l*. This relationship is described by the logistic function

$$p\ (l) = \frac{\exp\ (a + bl)}{1 + (\exp\ (a + bl))}$$

where the parameters *a* and *b* are the intercept and slope of the linear logistic function

$$\mathrm{Ln} = \left(\frac{p}{1 - p}\right) = a + bl$$

Consequently, the values of L_{50}, L_{25} and L_{75} can be estimated from the expressions

$$L_{50} = -\frac{a}{b}$$

$$L_{25} = \frac{(-\mathrm{Ln}(3) - a)}{b}$$

$$L_{75} = \frac{(-\mathrm{Ln}(3)-a)}{b}$$

and

$$SR = L_{75} - L_{25}$$

Parameters of the mean curves and between haul variations (14) for each season were calculated by ECModel (Con-Stat).

Results

A total of 37 hauls (9 in spring, 12 in summer, 9 in autumn and 7 in winter) were carried out during the trials. Total numbers of annular sea bream caught in these hauls were 10,979 in the codend and 1308 in the cover. Weight of annular sea bream and its percentage in total catch were 86.3 kg and 23% in spring, 68.7 kg and 9% in summer, 136.3 kg and 12% in autumn, 47.3 kg and 8% in winter and 338.6 kg and 12% overall, respectively. Other species usually present in the catch were red mullet (*Mullus barbatus*), picarel (*Spicara smaris*), common pandora (*Pagellus erythrinus*), hake (*Merluccius merluccius*), striped mullet (*Mullus surmuletus*), gilthead sea bream (*Sparus aurata*), poor cod (*Trisopterus minutus capelanus*), common sole (*Solea solea*), tub gurnard (*Trigla lucerna*), John Dory (*Zeus faber*), comber (*Serranus cabrilla*), brown comber (*Serranus hepatus*), bogue (*Boops boops*), two-banded sea bream (*Diplodus vulgaris*), axillary sea bream (*Pagellus acarne*), common eagle ray (*Myliobatis aquila*), black goby (*Gobius niger*), and scald fish (*Arnoglossus laterna*).

Selectivity and regression parameters with their standard errors, variance matrix values and number of the fish caught in the codend and cover in every single haul as well as mean curves for each season are given in the Table. Individual and mean selectivity ogives are shown separately in the Figure for each season. The results show that the best selectivity was in summer while the poorest was in spring. Fifty percent retention lengths (L_{50}) of the mean curves were 8.7 cm (se. 0.37) in spring, 9.5 cm (se. 0.35) in summer, 9.2 cm (se. 0.39) in autumn and 8.9 cm (se. 0.53) in winter. These results show that although there is a pattern of decrease in selectivity from summer to autumn, winter, and spring, seasonal differences in the L_{50}s of the mean curves are not considerably high. Moreover, the sizes of the standard errors indicate that the individual curves are likely to overlap between the seasons. This means that the variation in the L_{50}s of the past selectivity studies for annular sea bream in Turkish waters is unlikely to have been considerably influenced by seasonal changes.

Selection ranges (SR) were 1.1 cm (se. 0.05) in spring, 0.9 cm (se. 0.04) in summer, 0.9 cm (se. 0.05) in autumn and 1.1 cm (se. 0.06) in winter.

The Figure also shows the length-frequency distribution of the fish that entered the codend (thick broken line) and of fish that escaped from the codend (thin broken line) in each season. Size ranges of the fish in the population entering the codend in summer, autumn and winter are similar to each other. However, in spring proportions of both smaller fish (for example, smaller than 8 cm) and larger fish (for example, larger than 13 cm) in the population are higher.

Discussion

Several factors, such as spawning period, condition of fish, water temperature, and size structure of the population, change seasonally and are expected to play a role in selectivity. The results of this study show that there is a small but steady seasonal change in the mean selectivity of the 40 mm mesh size PE codend for annular sea bream. The selectivity in general was better in summer and autumn than it was in winter and spring.

Annular sea bream start to spawn in April in the study area (15). This was confirmed during the selectivity trials carried out in spring, when most of the larger females were observed with fully developed gonads. In other words, annular sea bream were either ready to start spawning or had just started to spawn during the spring trials of this study. Spawning might be the reason leading to the reduction in L_{50} (8.7 cm) in spring. However, it has to be kept in mind that annular sea bream reach maturity at the length of 10.4 cm (15), and almost all the fish larger than that size are retained in the codend in all the seasons (Figure) using a 40 mm PE codend. Therefore, stage of gonad development is unlikely to have a major effect on the reduction of selectivity in spring.

Özbilgin (16) reported that the best selectivity for haddock was obtained in September, when the fish were in their best condition after summer feeding, and the worst selectivity was seen in April, when the fish were in

Table. Annular sea bream. Fifty percent retention lengths (L_{50}), selection ranges (SR), regression parameters (*a* and *b*), their standard errors (in brackets), variance matrix values (R_{11} R_{12} and R_{22}) and numbers of fish in codend (CD) and cover (CV) for individual hauls and mean curves.

		L_{50}	SR	*a*	*b*	R_{11}	R_{12}	R_{22}	CD	CV
	04 April 1	8.7 (0.18)	1.3 (0.21)	-14.378 (2.64)	1.648 (0.28)	6.944	-0.7279	0.07682	296	33
	04 April 2	8.5 (0.21)	1.1 (0.22)	-16.755 (3.56)	1.964 (0.38)	12.670	-1.3471	0.14400	352	24
S	05 April 1	8.7 (0.16)	1.3 (0.22)	-14.988 (2.84)	1.719 (0.30)	8.054	-0.8571	0.09167	277	39
P	05 April 2	8.3 (0.22)	1.2 (0.25)	-15.534 (3.61)	1.881 (0.40)	13.015	-1.4238	0.15649	293	22
R	10 April 1	9.1 (0.08)	0.8 (0.10)	-26.443 (3.63)	2.917 (0.39)	13.179	-1.4075	0.15074	416	55
I	12 April 1	9.2 (0.08)	0.7 (0.10)	-29.557 (4.47)	3.208 (0.48)	20.002	-2.1265	0.22668	421	51
N	12 April 2	9.0 (0.11)	0.7 (0.13)	-29.509 (5.95)	3.276 (0.64)	35.401	-3.8168	0.41273	340	28
G	18 April 1	8.3 (0.21)	1.3 (0.23)	-13.846 (2.69)	1.671 (0.29)	7.227	-0.7772	0.08418	421	28
	18 April 2	8.4 (0.19)	1.2 (0.22)	-16.125 (3.34)	1.909 (0.36)	11.185	-1.2120	0.13211	354	24
	Mean Curve (Fryer)	8.7 (0.37)	1.1 (0.05)	-18.362 (0.68)	2.102 (0.07)	4.189	-0.4267	0.04368	3170	304
	10 July 1	9.4 (0.10)	0.8 (0.14)	-26.997 (4.89)	2.866 (0.50)	23.881	-2.4619	0.25452	191	31
	10 July 2	9.1 (0.10)	0.9 (0.14)	-22.449 (3.78)	2.468 (0.40)	14.316	-1.5077	0.15930	234	40
	10 July 3	9.2 (0.11)	1.0 (0.14)	-20.085 (2.91)	2.195 (0.30)	8.456	-0.8688	0.08963	364	48
	10 July 4	9.2 (0.09)	0.8 (0.12)	-26.053 (4.18)	2.842 (0.44)	17.476	-1.8348	0.19318	318	37
S	11 July 1	9.1 (0.14)	0.7 (0.16)	-26.743 (6.10)	2.943 (0.64)	37.186	-3.9092	0.41218	196	16
U	11 July 2	9.5 (0.18)	1.1 (0.29)	-18.345 (4.90)	1.940 (0.49)	23.977	-2.4277	0.24667	79	21
M	11 July 3	9.5 (0.11)	0.6 (0.12)	-34.436 (7.26)	3.637 (0.75)	52.670	-5.4108	0.55683	214	18
M	11 July 4	9.1 (0.11)	0.7 (0.12)	-28.397 (5.12)	3.118 (0.54)	26.249	-2.7597	0.29089	332	25
E	24 July 1	9.4 (0.13)	1.2 (0.18)	-17.500 (2.78)	1.859 (0.28)	7.737	-0.7699	0.07696	250	48
R	24 July 2	9.6 (0.09)	0.6 (0.11)	-33.521 (5.87)	3.477 (0.59)	34.512	-3.4855	0.35276	210	31
	25 July 1	9.7 (0.10)	0.8 (0.14)	-25.637 (4.37)	2.653 (0.44)	19.085	-1.9109	0.19180	188	40
	25 July 2	9.5 (0.13)	0.9 (0.15)	-22.682 (3.94)	2.396 (0.40)	15.535	-1.5615	0.15759	212	30
	Mean Curve (Fryer)	9.3 (0.35)	0.9 (0.04)	-22.725 (0.38)	2.441 (0.04)	1.725	-0.1827	0.01963	2788	385
	26 September 1	8.9 (0.13)	0.9 (0.15)	-20.860 (3.55)	2.347 (0.37)	12.565	-1.3226	0.13965	359	37
	26 September 2	8.6 (0.19)	0.9 (0.18)	-21.751 (4.95)	2.516 (0.53)	24.531	-2.6044	0.27746	362	16
	26 September 3	8.9 (0.12)	0.9 (0.13)	-20.822 (3.13)	2.352 (0.33)	9.804	-1.0296	0.10859	470	37
A	26 September 4	9.1 (0.08)	0.6 (0.09)	-33.079 (5.09)	3.636 (0.54)	25.873	-2.7257	0.28782	477	31
U	27 September 1	9.8 (0.09)	0.9 (0.15)	-23.106 (3.60)	2.368 (0.37)	12.985	-1.3376	0.13823	117	82
T	27 September 2	9.6 (0.06)	0.5 (0.09)	-39.027 (6.36)	4.055 (0.65)	40.478	-4.1611	0.42843	167	59
U	27 September 3	9.6 (0.10)	1.1 (0.16)	-19.162 (2.92)	1.998 (0.29)	8.519	-0.8655	0.08827	156	65
M	02 October 2	8.8 (0.16)	1.2 (0.15)	-15.596 (2.18)	1.777 (0.22)	4.737	0.4814	0.04923	644	44
N	02 October 3	9.4 (0.07)	0.7 (0.09)	-31.506 (4.47)	3.341 (0.46)	20.016	-2.0634	0.21320	411	48
	Mean Curve (Fryer)	9.2 (0.39)	0.9 (0.05)	-23.487 (0.76)	2.553 (0.08)	5.209	-0.5241	0.05385	3163	419
	22 January 2	8.7 (0.16)	1.1 (0.15)	-18.223 (2.94)	2.089 (0.31)	8.668	-0.8975	0.09337	522	35
W	22 January 3	8.9 (0.29)	1.2 (0.34)	-16.706 (5.18)	1.869 (0.53)	26.815	-2.7562	0.28474	101	11
I	22 January 4	8.9 (0.15)	1.0 (0.18)	-19.183 (3.57)	2.149 (0.37)	12.757	-1.3274	0.13858	276	38
N	23 January 1	8.9 (0.18)	1.0 (0.22)	-19.545 (4.55)	2.202 (0.48)	20.688	-2.1829	0.23131	149	20
T	23 January 2	8.7 (0.53)	1.3 (0.52)	-14.693 (6.63)	1.688 (0.67)	43.959	-4.4448	0.45153	91	6
E	23 January 3	8.9 (0.14)	1.1 (0.16)	-17.204 (2.69)	1.937 (0.28)	7.257	-0.7473	0.07722	506	55
R	23 January 4	9.2 (0.14)	1.0 (0.20)	-19.755 (4.01)	2.144 (0.41)	16.096	-1.6457	0.16871	213	35
	Mean Curve (Fryer)	8.9 (0.53)	1.1 (0.06)	-17.950 (0.53)	2.015 (0.06)	1.967	-0.2030	0.02113	1858	200

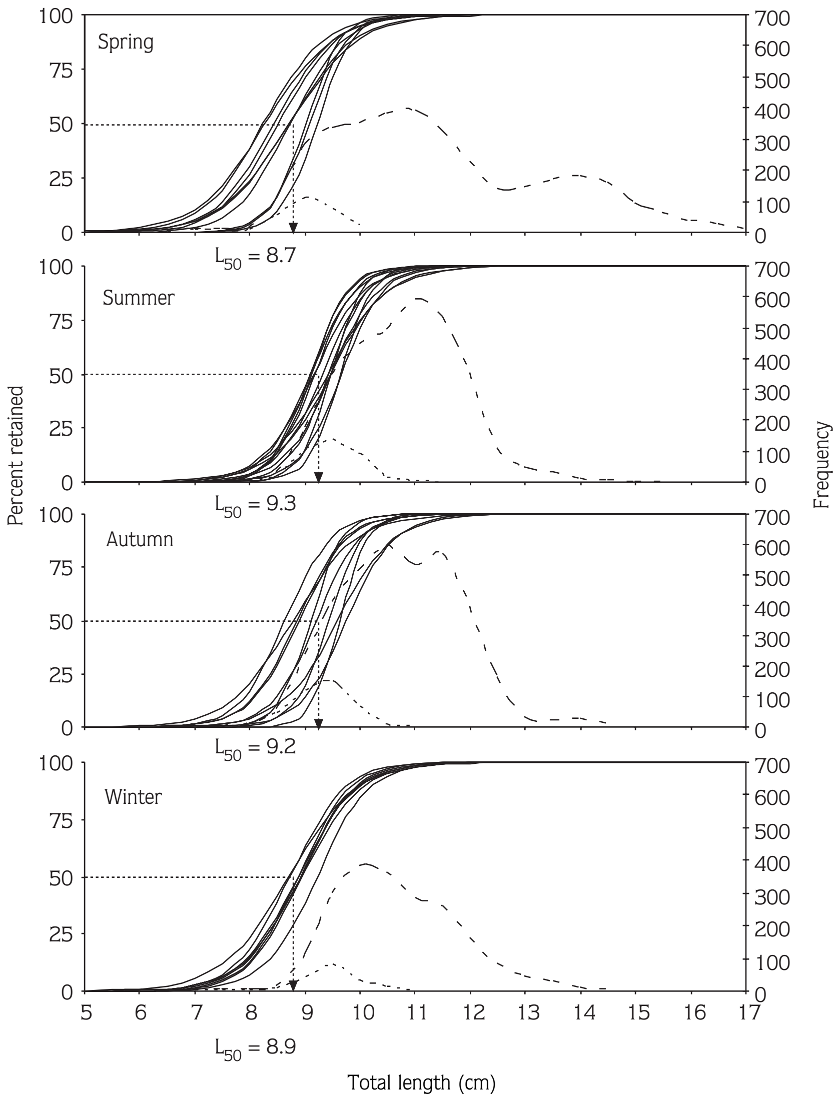

Figure. Individual (thin straight line) and mean (thick straight line) selection curves and length frequency distribution of the annular sea bream population entering the codend (thick broken line) and escaping from the codend (thin broken line) in each season. Mean L_{50} values are also shown in the figure.

their poorest condition at the post-spawning stage. Although no data are available to evaluate the seasonal changes in the condition of fish in the present study, it can be assumed that fish are likely to be in better condition in summer and autumn than in winter and spring, which might be a reason for better selectivity in summer and autumn in comparison to winter and spring.

Changes in water temperature are another possible reason for the seasonal variation in selectivity. It is well established that an increase in water temperature is likely to enhance swimming speed and hence escape performance of fish. He (17) theoretically calculated escape probabilities of fish from a moving net at various water temperatures. Özbilgin and Wardle (18) demonstrated that a temperature rise from 7 to 12 °C significantly increased the escape speed of haddock. The same effect was also observed for whiting (*Merlangius merlangus*) (19). A similar effect of water temperature is also expected in this study. Monitoring data collected by the R/V K. Piri Reis in the study area between 1994 and 2002 show that temperature recorded the depths of 25 and 26 m varied between 13.4 and 24 °C. From these data, it can be estimated that approximate water temperature during the present study was 15 ºC in winter and spring, 19 ºC in summer and 21 ºC in autumn. Therefore, the lower selectivities observed in winter and spring can be partially related to lower water temperature in these seasons.

Variation in population size structure might be another factor influencing selectivity. In the spring trial of these experiments the proportion of the younger size classes in the population was higher than those in any other season. Although a great majority of these fish escape, some are also observed to be retained, which naturally reduces the L_{50}.

Several studies have been carried out on the trawl codend selectivity of annular sea bream in the Aegean Sea (1,8-10,12,15,20-23). The results obtained in these studies are variable. However, relatively recent studies using the covered codend method with hoops and tested commercially used gear and codends produced L_{50} values around 9 cm and selection ranges of about 1 cm. For example, Tosunoğlu et al. (1) carried out a trial in a fishing ground near our study area between 9 August and 4 September 2002 using the same material and methodology described in this study and found an L_{50} of 9.4 cm (se. 14) and an SR of 0.8 cm (0.12). Tosunoğlu et al. (10) also carried out a trial between 16 January and 14 February 2002 in the same fishing ground using the same material and methodology described in this paper and found an L_{50} of 8.6 cm (se. 0.10) and an SR of 0.9 cm (0.11). Both these studies, which were carried out using the same codend described in the present study, produced L_{50}s which fit the pattern of seasonal changes in L_{50}s found in this study fairly well.

Seasonal variation in the selectivity of a commercially used trawl codend (measured as 44 mm by wedge gauge with 4 kgf) was also reported by Kınacıgil and Akyol (15) in a study carried out in İzmir Bay between October 1997 and September 1999. Although the codends used in both studies have similar mesh sizes, and both were made of PE material, there are significant differences between their results. L_{50}s and SRs, respectively, reported by Kınacıgil and Akyol (15) are as follows 12.7 and 3.5 cm in spring, 13.2 and 5.0 cm in summer, 10.7 and 2.2 in autumn, and 10.6 and 3.1 in winter. In comparison to the present study, all the selection parameters as well as their seasonal variations are much higher in Kınacıgil and Akyol (15), in which the precise times of the hauls were not provided, and the data from a smaller number of hauls were pooled over each season, and analysed using different software (L50 Ver (1.0.0) (24).

According to the L_{50}s observed in all the seasons in this study, the commercially used 40 mm nominal mesh size PE codend (although the legal mesh size is 44 mm) is rather unselective for annular sea bream in the Aegean Sea. During all the trials in this study the L_{50} values were significantly lower than the length at first maturity reported by Metin and Akyol (5). Although there is a general tendency for selectivity to increase in summer and autumn, the difference between them and winter and spring is not large: probably because the 40 mm PE codend retains more than 89% of the fish on average, which does not leave many to escape to allow seasonal variation to be investigated. This study reveals once again that there is an urgent need to improve the selectivity of commercial trawl codends presently used in Turkish waters.

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