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Research Article

Effect of twine thickness on selectivity of gillnets for bogue, *Boops boops*, in Turkish waters

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Abstract

To investigate the effect of twine thickness on the selectivity of multifilament gillnet targeting bogue, *Boops boops* L., four different stations were sampled between March and November 2008 in the North Aegean Sea. Gillnets with 22, 23, and 25 mm nominal mesh size (bar length) each having two different twine thicknesses (approximately 0.45 mm and 0.54 mm ∅) were applied for this purpose. The deviances from the SELECT method revealed that lognormal models provided the best fits for both of the twine thicknesses. Results from the two-way ANOVA analyses revealed that the mean total lengths increased with the mesh size ($F = 87.36$; $df = 2$; $P < 0.0001$) and decreased with the twine thickness ($F = 46.12$; $df = 1$; $P < 0.0001$). The 22 mm mesh size net (0.45 mm ∅) captured significantly larger fish than the 23 mm mesh size net (0.54 mm ∅), probably due to the higher elasticity and flexibility of the thinner twine. Thus, fisheries' managers should take into consideration twine thickness while advising mesh size regulations in gillnet fisheries.

Keywords: Bogue; Twine thickness; Gillnet selectivity; Drive-in fishing method; SELECT method; North Aegean Sea.

Introduction

Knowledge of the size selectivity of commercial fishing gears is one of the most critical factors for successful fisheries management (MILLAR, 1992). Fisheries managers need to know the size distribution of the commercial catch as well as of the population itself to apply proper measurements that will protect the fish populations and sustain the fishery. The size distribution of a fish population can be estimated by adjusting the length frequency distribution of commercial fish landings with the selectivity curve (MILLAR, 1992). Without adjusting the landings length frequency for gear selectivity, estimation of the population parameters (i.e. age, growth, and mortality) might be biased, which may result in mismanagement.

The size selectivity of gillnets depends on various factors such as the mesh size, elasticity of the net, the hanging ratio, twine thickness, twine colour, fish behaviour and fishing method (HAMLEY, 1975; CLARK, 1960). Previous studies on gillnet selectivity focused mainly on the mesh size (SANTOS *et al.*, 1995; FONSECA *et al.*, 2005; PETRAKIS & STERGIOU, 1995; STERGIOU & ERZINI, 2002; DINCER & BAHAR, 2008; SBRANA *et al.*, 2007; FABI & GRATI, 2008; AYAZ *et al.*, 2009; KARAKULAK & ERK, 2008). Little information exists in the literature on the selectivity effects other than the mesh size. Although twine thickness was reported as an important factor on selectivity by affecting visibility and elasticity of the net meshes (HAMLEY, 1975), only a few studies have analyzed the twine thickness effect on gillnet selectivity (HOVGARD, 1996; HOLST *et al.*, 2002; YOKOTA *et al.*, 2001; HANSEN, 1974). These studies employed monofilament gillnets and were carried out outside the Mediterranean Sea.

Bogue, *Boops boops* (L.), is a commercial species inhabiting coastal waters in different habitats and is intensively fished throughout the Mediterranean (MONTEIRO *et al.*, 2006; KATSANEVAKIS *et al.*, 2010). Bogue is captured on line gear, with bottom trawls, purse seines, beach seines, trammel nets, and gillnets. In the North Aegean Sea, bogue is targeted using multifilament gillnets without any mesh size regulation. The most common mesh sizes used are 22, 23, and 25 mm with different twine thicknesses.

It is known that gillnet mesh sizes effect the size selectivity of the captured fish. Although it has been stated that twine thickness can affect the size selectivity of the catch, very few studies have been carried out on this topic. The main goal of this study was to investigate the effect of the twine thickness on the size selectivity of multifilament gillnet targeting bogue in the North Aegean Sea, Turkey.

Materials and Methods

This study was carried out monthly, with different frequencies, between March and November 2008 in a coastal region with 5-30 m depth in the North Aegean Sea (Fig. 1). Four different stations with similar habitats consisting of rocks and Neptune grass, *Posidonia oceanica* (L.) Delile, were selected.

A total of six nets with three different mesh sizes, 22, 23, and 25 mm nominal bar length, and two different twine thicknesses 210d/3 (approximately 0.45 mm ∅) and 210d/4 (approximately 0.54 mm in ∅) were rigged for the study. Other than the twine thicknesses and mesh sizes, all other features and specifications of the gillnets were identical. Each of the gillnets had a hanging ratio of E = 0.5 and was 100 m long. The nets had 100 mesh depth, resulting in depths of 3.78 m for the 22 mm, 3.96 m for the 23 mm, and 4.30 m for the 25 mm mesh sizes. For each twine thickness, one fleet of gillnet was composed by combining the three different mesh sizes, resulting in a 300 m long gill net fleet. To avoid bias, after five consecutive fishing operations, the order of the nets was alternated within a fleet. During the study period, 30 gillnet samplings were conducted for each gillnet fleet. Each type of fleet was employed on the same night but at a different sampling site, located 3 km apart at most (Fig. 1).

Drive-in fishing with gillnet technique was used in this study. This technique is widespread and is especially known off the Mediterranean coasts and also off those of West Africa and south Asia (GABRIEL *et al.*, 2005). During the night, the nets were set in a kind of a spiral form. Fish were then frightened by striking the water with pulse sticks or by flash-

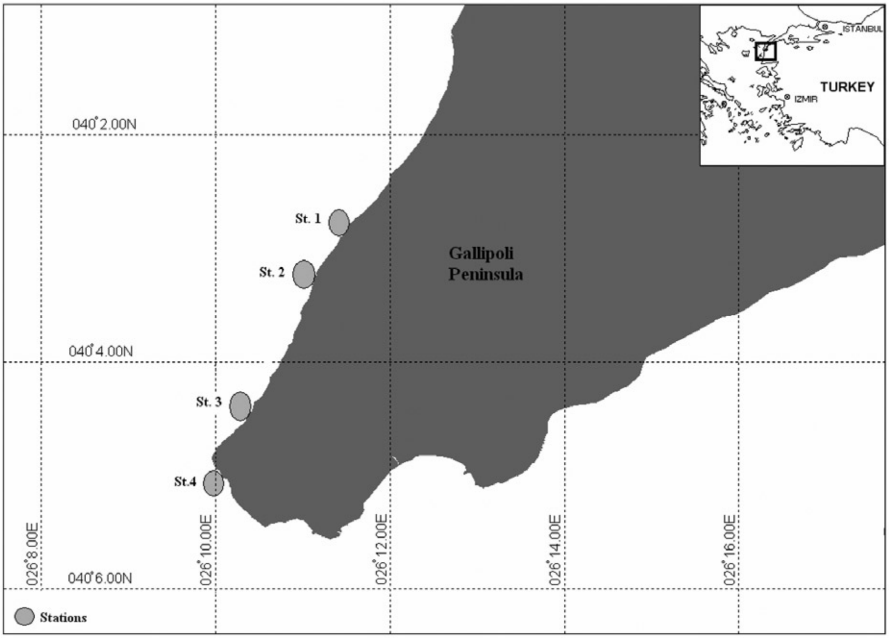

Fig. 1: Sampling stations (St.) in the study area.

ing light into the water. Nets were immediately hauled out of the water and the captured fish were measured to the nearest mm.

Selectivity analysis for the gillnet fleets with 210d/3 and 210d/4 twine thicknesses were analyzed separately. SELECT (Share Each Length's Catch Total) method was used in the estimations of the parameters for the selectivity curves (MILLAR, 1992; MILLAR & HOLST, 1997; MILLAR & FRYER, 1999). The SELECT model is described by the following expression:

$$n_{lj} \approx \text{Pois}\,(p_j\,\lambda_l\,r_j(l)),$$

where n_{lj} is the number of fish of length l caught in mesh size j, p_j is the fishing intensity, λ_l is reflecting the abundance of the length class l, $r_j(l)$ denotes the retention probability of length l fish in the j'th mesh size.

The log likelihood of the model is:

$$\sum_l \sum_j \{n_l \log[p_j\,\lambda_l\,r_j\,(l)] - p_j\,\lambda_l\,r_j\,(l)\}$$

Five different models, normal location shift, normal scale shift, log-normal, gamma, and bi-normal scale shift were calculated using the GILLNET (ConStat, Hjørring, Denmark) computer program. The equations for each of the models are:

$$\exp\left(-\frac{(L-k.m_j)^2}{2\sigma^2}\right)$$

for normal location shift in which means is proportional to mesh size,

$$\exp\left(-\frac{(L-k_1.m_j)^2}{2k_2^2.m_j^2}\right)$$ for normal scale shift,

$$\frac{1}{L}\exp\left(-\mu+\log\left(\frac{m_j}{m_1}\right)-\frac{\sigma^2}{2}-\right.$$

$$\left.-\frac{\left(\log(L)-\mu-\log\left(\frac{m_j}{m_1}\right)\right)^2}{\sigma^2}\right)$$

for log-normal,

$$\left(\frac{L}{(\alpha-1).k.m_j}\right)^{\alpha-1}\exp\left(\alpha-1-\frac{L}{k.m_j}\right)$$

for gamma, and

$$\exp\left(\frac{(L-k_1.m_j)^2}{2k_2^2.m_j^2}\right)+c.\exp\left(-\frac{(L-k_3.m_j)^2}{2k_4^2.m_j^2}\right)$$

for bi-normal scale shift,

where L is the total length in cm, m_1 is the smallest mesh size, m_j is the mesh size j, μ is the mean size (length) of fish caught, σ is the standard deviation of the size of fish, and k is a constant. Decision on the most appropriate model fitting the data was evaluated by comparing the deviances of each model and by examining the residual plots.

To determine if the mean total lengths of the retained fish increases with mesh size or with twine thickness, a two-way ANOVA analysis was performed using the Generalized Linear Models procedure in SPSS (Version 18). The two-sampled Kolmogorov-Smirnov test with Bonferroni correction was used to test for significant differences in univariate distribution. Statistical analyses were deemed as significant for P values less than 0.05.

Results

A total of 1682 bogue ranging between 16.2 and 29.5 mm TL was captured (Fig. 2). The total catches were 981 for 22 mm mesh size net, 490 for the 23 mm mesh size net, and 211 for the 25 mm mesh size net (Table 1). The mean total lengths and their standard errors of bogue captured by the nets with twine thickness 210d/3 and 22, 23, and 25 mm mesh sizes were 20.70 ± 0.08, 21.30 ± 0.12, and 21.82 ± 0.16, respectively. The values for the nets with the twine thickness 210d/4 and 22, 23, and 25 mm mesh sizes were 19.99 ± 0.05, 20.46 ± 0.08, and 21.64 ± 0.10, respectively.

The results from the two-way ANOVA revealed that the mean total lengths increased with the mesh size (F = 87.36; df = 2; P < 0.0001) and decreased with the twine thickness (F = 46.12; df = 1; P < 0.0001) (Fig. 3). However, the effect of twine thickness on the mean total length depended on the mesh size (F = 3.88; df = 2; P = 0.0209). The mean total length of bogue captured with the 22 mm 210d/3 net was significantly greater than that of 23 mm 210d/4 (P = 0.028). Except for the 210d/3 and 210d/4 in the 25 mm mesh size, all other pairwise comparisons for the mean total lengths were significantly different (P < 0.05) (Table 1).

The size-frequency distributions were significantly different (P > 0.05) between 210d/3 and 210d/4 twine thicknesses in the 25 mm mesh size gillnet (Table 1). The two-sample Kolmogorov-Smirnov test revealed that the pairwise comparisons between different net types were significantly different except for four pairwise comparisons (Bonferroni's adjusted P > 0.0033) (Table 1).

By comparing the deviances from the models, the lognormal models gave the best fit for both gillnet fleets. The lognormal model deviance was 77.31 for the gillnet fleet

Table 1
Mean total lengths and their standard errors (SE) of bogue and the results of two-way ANOVA pairwise comparisons. Kolmogorov–Smirnov test results for comparing length frequency distributions between different net types. Net 1 and Net 2 represent the different gillnet configuration of mesh size and twine thickness. N is the number of bogue captured by the corresponding gillnet type.

Net 1				Net 2				Test	
Mesh Size	Twine	N	Mean±SE	Mesh Size	Twine	N	Mean±SE	Twoway-ANOVA	Kolmogorov-Smirnov*
22	210d/3	390	20.70±0.08	22	210d/4	591	19.99±0.05	P < 0.001	P < 0.001
23	210d/3	204	21.30±0.12	23	210d/4	286	20.46±0.08	P < 0.001	P < 0.001
25	210d/3	110	21.82±0.16	25	210d/4	101	21.64±0.10	P = 0.351	P = 0.869
22	210d/3	390	20.70±0.08	23	210d/3	204	21.30±0.12	P < 0.001	P < 0.001
22	210d/3	390	20.70±0.08	25	210d/3	110	21.82±0.16	P < 0.001	P < 0.001
23	210d/3	204	21.30±0.12	25	210d/3	110	21.82±0.16	P = 0.001	P = 0.009
22	210d/4	591	19.99±0.05	23	210d/4	286	20.46±0.08	P < 0.001	P < 0.001
22	210d/4	591	19.99±0.05	25	210d/4	101	21.64±0.10	P < 0.001	P < 0.001
23	210d/4	286	20.46±0.08	25	210d/4	101	21.64±0.10	P < 0.001	P < 0.001
22	210d/3	390	20.70±0.08	23	210d/4	286	20.46±0.08	P = 0.028	P = 0.054
22	210d/3	390	20.70±0.08	25	210d/4	101	21.64±0.10	P < 0.001	P < 0.001
23	210d/3	204	21.30±0.12	22	210d/4	591	19.99±0.05	P < 0.001	P < 0.001
23	210d/3	204	21.30±0.12	25	210d/4	101	21.64±0.10	P = 0.040	P = 0.043
25	210d/3	110	21.82±0.16	22	210d/4	591	19.99±0.05	P < 0.001	P < 0.001
25	210d/3	110	21.82±0.16	23	210d/4	286	20.46±0.08	P < 0.001	P < 0.001

*For the pairwise comparisons the Bonferroni's adjusted α was lowered to 0.0033.

with twine thicknesses 210d/3 and was 36.57 for the gillnet fleet with 210d/4 twine thicknesses (Table 2). The modal lengths and the spread values were greater for the gillnet fleets with 210d/3 twine thickness compared to the gillnet fleets with 210d/4 twine thickness (Fig. 4).

Discussion

Gillnets with thinner twine captured significantly larger fish within the 22 mm and 23 mm mesh sizes.. These results imply that thinner twine is more flexible and elastic than the thicker one. Gillnets with the same nominal mesh sizes but different twine thicknesses will possibly result in different mesh openings during the fishing operation. In fact, the mean total length for the 22 mm mesh size with the thinner twine was significantly greater than the 23 mm mesh size with the thicker twine, implying that the 22 mm nominal mesh size had a greater mesh opening than that of the 23 mm mesh size. On the other hand, the non-significant difference of the mean total length between the different twine thicknesses for the 25 mm mesh size gillnets was attributed to the relatively small size frequency distribution of the bogue population. A significant difference between the 25 mm mesh sizes with the different twine thicknesses could be expected if there were larger individuals out in the population.

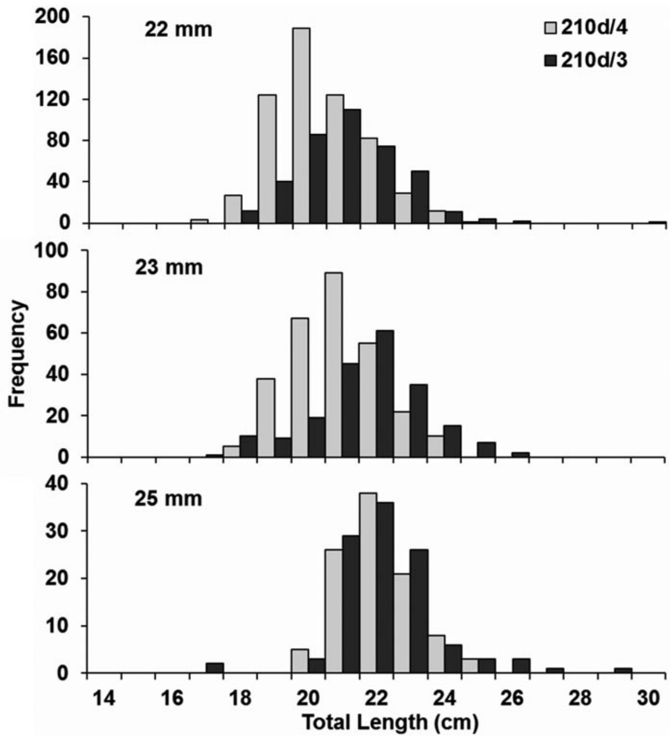

Fig. 2: Length frequency distribution of bogue captured with 22, 23, and 25 mm mesh sizes for twine thicknesses 210d/3 (black bars) and 210d/4 (grey bars).

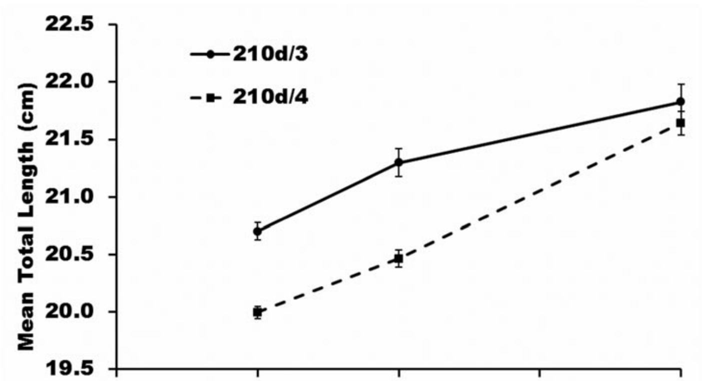

Fig. 3: Mean total lengths with standard error bars for bogue captured with gillnets of 22, 23, and 25 mm mesh size and 210d/3 and 210d/4 twine thickness.

Table 2
Result of the gillnet selectivity analysis for bogue using the SELECT method for the estimation of 210d/3 and 210d/4 twine thickness gillnets.

Twine No:	Model	Equal fishing powers			Fishing power mesh size			
		Parameters	**Model deviance**	**P**	**Parameters**	**Model deviance**	**P**	**d.f.**
3	Normal scale	(k_1, k_2) = (0.52700, 0.05209)	79.89	<0.001	(k_1, k_2) = (0.53206, 0.05178)	79.93	<0.001	24
	Normal location	(k, σ) = (0.52746, 2.70462)	81.85	<0.001	(k, σ) = (0.53383, 2.72168)	82.20	<0.001	24
	Log normal	(μ, σ) = (3.16196, 0.11449)	77.31	<0.001	(μ, σ) = (3.17506, 0.11449)	77.31	<0.001	24
	Gamma	(k, α) = (0.00621, 86.00058)	77.63	<0.001	(k, α) = (0.00621, 87.00058)	77.63	<0.001	24
	Bi-modal	No fit			No fit			
4	Normal scale	(k_1, k_2) = (0.49753, 0,03663)	47.11	<0.001	(k_1, k_2) = (0.50021, 0.03652)	47.16	<0.001	16
	Normal location	(k, σ) = (0.49574, 1.80866)	43.73	<0.001	(k, σ) = (0.49877, 1.81394)	44.11	<0.001	16
	Log normal	(μ, σ) = (3.09157, 0.08096)	36.57	<0.005	(μ, σ) = (3.09812, 0.08096)	36.57	<0.005	16
	Gamma	(k, α) = (0.00306, 163.71128)	39.59	<0.001	(k, α) = (0.00306, 164.71128)	39.59	<0.001	16
	Bi-modal	No fit			No Fit			

HANSEN (1974) found that 19 mm mesh sized monofilament gillnets with thinner filament (0.133 mm vs. 0.267 mm) captured larger peamouth, *Mylocheilus caurinus*, and also larger yellow perch, *Perca flavescens*. In a Baltic cod, *Gadus morhua*, gillnet trial, HOLST *et al.* (2002) reported that the modal length of the selection curve for a thinner twine (0.8 mm vs. 1.2 mm) was significantly higher. However, in a second trial period, the difference of the modal lengths between the twine thicknesses was marginal. Controversial results regarding the twine thickness effect on the fish size selectivity exists in the literature. For example, HOVGARD (1996) found no direct effect of twine thickness on selection for gillnets used in Greenland that had mesh sizes of 16.5, 18.5, 24, 28, and 34 mm with twine diameters of 0.24, 0.20, 0.38, 0.28, and 0.33 mm, respectively. It should be noted that the twine thicknesses he compared had different mesh sizes and therefore a comparison within a mesh size was not possible. GRAY *et al.* (2005) found no evidence to support the size composition of fish caught being correlated with the twine thickness of 0.41, 0.56, 0.62 mm with 81 mm mesh size gillnet. TURUNEN (1996) reported no differences in the size composition of pike-perch, *Stizostedion lucioperca*, captured with gillnets having different twine thicknesses (0.15 vs 0.20 mm). On the other hand, YOKOTA *et al.* (2001), in an experiment conducted in 4 m concrete tanks, found that rainbow

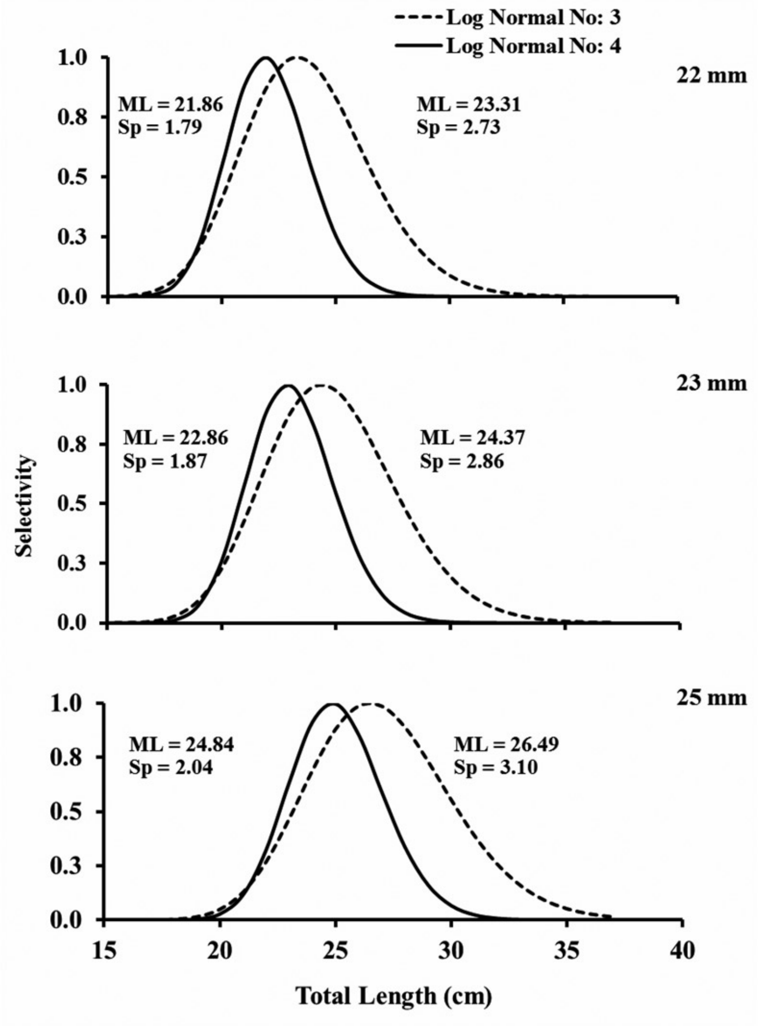

Fig. 4: Selectivity curves of bogue captured with gillnets of 22, 23 and 25 mm mesh sizes (nominal bar length) and twine thicknesses of 210d/3 and 210d/4. The selectivity curves were obtained from the SELECT method with log normal model. Modal length (ML) and spread value (Sp) for the 210d/4 twine thickness (straight line) on the left and for the 210d/3 twine thickness (dashed line) on the right.

trout girth-mesh ratio mode was greater for gillnets with thicker twine (0.16 vs. 0.28 mm). The reported controversial results in the studies for the size selectivity of fish caught by gillnets with different twine thicknesses may result from different gear material used as well as the species-specific differences. Intuitively, thinner twines are less visible, easier to stretch, and more flexible, which should result in a greater number of fish becoming entangled and in larger size composition, as long as the twines are not so thin as to be broken by larger fish (HAMLEY, 1975).

Modal lengths for bogue from gillnet selectivity studies with 22 mm mesh size, were reported as 21.55 cm by AYAZ *et al.* (2009), as 21.01 cm by KARAKULAK & ERK (2008), as 22.94 cm by STERGIOU & ERZINI (2002), and as 23.31 cm (210d/3 twine thickness) and 21.86 cm (210d/4 twine thickness) by the present study. The differences of the modal lengths between the studies may arise from the differences in the fishing method, season, and net material. AYAZ *et al.* (2009) and this study used an active fishing method, whereas KARAKULAK & ERK (2008) and STERGIOU & ERZINI (2002) used passive methods. In active methods, the velocity a fish encountering the net is much higher compared to passive methods that can affect the retention probability. Another factor affecting the selectivity for a given species is the season. In the reproductive season, fish, especially females, have a lower length/girth ratio (i.e. the fish become fatter) which decreases the modal lengths. Net material (mono vs. multifilament) as well as the diameter of the twine may affect both the visibility and the elasticity of the net that would result in different modal lengths for the same mesh size.

Differences in the selectivity existed between gillnets having different twine thicknesses. The difference between the modal lengths was 1.45 cm for the 22 mm mesh size. PARK *et al.* (2011) found that the size selectivity of the trammel net and gillnet was significantly different with only 0.2 cm difference in the modal length. In terms of fisheries management, 1.2 years are required for a bogue to grow from 21.86 to 23.31 cm, recalculated from the von Bertalanffy growth parameters provided by MONTEIRO *et al.* (2006). Although, this difference may not be very important for the bogue population management in the NorthAegean Sea at the present time, this difference can be important in overfished bogue stocks or in other slow growing fish populations.

The main findings of the present study were that differences in the size selectivity existed between gillnets with different twine thicknesses and that smaller twine thickness captured larger bogue. Further research is required to elucidate the effects of twine thickness on the size selectivity of gillnets for different species especially when the size limit is crucial for the sustainability of the fishery. Regulation of mesh size only may not always be a solution for size limit regulation. Thus, fisheries' managers should take into consideration the twine thickness when advising mesh size regulations in gillnet fisheries.

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