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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Selectivity of multifilament trammel and gillnets for common carp (*Cyprinus carpio* L., 1758) in Lake Marmara

Marmara Gölü'nde sazan balığı (*Cyprinus carpio* L., 1758) için multifilament fanyalı ve galsama uzatma ağlarının seçiciliği

Celalettin Aydın[1]* • Mehmet Cilbiz[2] • Ali İlhan[1] • Hasan Musa Sarı[1]

[1] *Ege University, Faculty of Fisheries, 35100 Bornova-İzmir, Turkey*
[2] *Fisheries Research Institute, Eğirdir- Isparta, Turkey*
* *Corresponding author:* caydina@gmail.com

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Abstract: This study was aimed to estimate the selectivity properties of multifilament trammel and gillnets for common carp (*Cyprinus carpio* L., 1758) in Marmara Lake in Manisa, Turkey. Trammel and gillnets of 4, 6, 8, and 10 cm stretched mesh size and 210 d/2 no twine thickness were tested in the Marmara Lake. In addition, selectivity parameter of 11, 12, 13 and 14 cm mesh size of trammel and gillnets were modelled. SELECT method was used to estimate the selectivity parameters. Experiments were carried out monthly in the three different stations identified eastern, middle and western areas which represent longitudinal length of the lake. A total of 36 trials were conducted both nets. A total of 119 common carps were caught ranges between 11.3 - 49.0 cm total lengths. According to the Bi- normal model, which gave the lowest deviance for both trammel and gillnets, selectivity curves were estimated for 4, 6, 8, 10, 11, 12, 13 and 14 cm stretched mesh size modelled lengths as 12.98, 19.47, 25.96, 32.45, 35.70, 38.94, 42.19 and 45.43 cm for trammel nets, 12.40, 18.60, 24.80, 31.00, 34.10, 37.20, 40.30 and 43.40 cm for gillnets, respectively. When considering minimum landing size (40 cm total length), it is recommended that both nets under 13 cm mesh size should be prohibited for common carp fishery in the Lake Marmara.

Keywords: *Trammel net, gillnets, common carp Cyprinus carpio, size selectivity, Lake Marmara*

Öz: : Bu çalışmada, Marmara Gölü'ndeki sazan balığı (*Cyprinus carpio* L., 1758) için multifilament fanyalı ve galsama uzatma ağlarının seçicilik özelliklerinin tahmin edilmesi amaçlanmıştır. 210d/2 ip kalınlığına ve 4, 6, 8, 10 cm ağ gözü açıklığına sahip fanyalı ve galsama ağlar Marmara Gölü'nde test edilmiştir. Ayrıca elde edilen verilerle 11, 12, 13 ve 14 cm göz açıklığındaki fanyalı ve galsama uzatma ağlarının optimum yakalama boyları için modelleme yapılmıştır. Seçicilik parametrelerinin tahmininde SELECT metot kullanılmıştır. Avcılık denemeleri gölü yatay olarak temsil edecek şekilde; batı, orta ve doğu kısmından belirlenen üç farklı istasyonda aylık olarak yürütülmüştür. Hem fanyalı hem de galsama ağları ile 36 adet avcılık denemesi yapılmıştır. 11,3 - 49,0 cm boy aralığında toplam 119 adet sazan yakalanmıştır. Hem fanyalı hem de galsama ağları için en düşük sapmayı veren Bi-normal modele göre; 4, 6, 8, 10, 11, 12, 13 ve 14 cm göz açıklığındaki fanyalı ağların model boyları; 12,98, 19,47, 25,96, 32,45, 35,70, 38,94 ve 42,19 cm, aynı göz açıklığındaki galsama ağları için model boyları 12,40, 18,60, 24,80, 31,00, 34,10, 37,20, 40,30 ve 43,40 cm, olarak tahmin edilmiştir. Sazan balığının 40 cm minimum avlama boyu göz önüne alındığında, 13 cm göz açıklığının altındaki hem galsama hem de fanyalı uzatma ağlarının yasaklanması tavsiye edilmektedir.

Anahtar kelimeler: *Fanyalı uzatma ağı, galsama uzatma ağı, sazan balığı, Cyprinus carpio, boy seçiciliği, Marmara Gölü*

INTRODUCTION

Common carp (*Cyprinus carpio* L., 1758) is one of the main target species in Turkey Inland fisheries. This species distributes through Turkey (Cilbiz et al., 2015) and landings reached 13718 t in 2005 and then decreased to 8036 t in 2014 (TUIK, 2015). This might be due to; overfishing, pollution, diseases and parasites habitat degradation and invasive species (such as *Carassius gibelio* reported by Emiroğlu (2011)).

Due to the prohibited to using monofilament nets in Turkey since 1 September 2010 (Anonymous, 2008), fishers have been handled multifilament net. However, selectivity properties of multifilament nets is unknown for carp fishery. There is a minimum mesh size regulation in Turkey inland fisheries. Notwithstanding, different provincial directorate announcement employed different minimum mesh size utilization. Such as, Provincial Directorate of Food, Agriculture and Live Stock in Konya is announcement 13 cm, while Isparta is declarate 11 cm.

Lake Marmara is located within the boundaries of Manisa province in the Aegean region of Turkey. Although an alluvial bank lake, it is gain of the dam lake function by means of artisanal raceway and bank (Arı and Derinöz, 2011). İlhan and Sarı (2013) reported that there are 15 fish species (*Atherina boyeri, Alburnus battalgilae, Cyprinus carpio, Carassius gibelio, Chondrostoma holmwoodii, Capoeta bergamae, Ladigesocypris mermere, Pseudorasbora parva, Petroleuciscus symrnaeus, Rhodeus amarus, Vimba vimba, Cobitis fahirae, Sander lucioperca, Gambusia affinis* and *Knipowitschia mermere*) in the Lake Marmara. It is also reported that one of the most commercial fish species in the lake is the *C. carpio* and then *Sander lucioperca, Siluris glanis* and *Alburnus battalgilae* (İlhan and Sarı, 2013).

There is some selectivity studies conducted on the species. Balık (1999), Özyurt and Avşar (2005) and Yalçın (2006) estimated monofilament gillnet selectivity by Holt (1963); Carol and García-Berthou (2007) determined monofilament gillnet selectivity by SELECT method. Cilbiz et al. (2015) analysed monofilament trammel net selectivity by SELECT method in Turkey. However, there is no study conducted on estimating selectivity properties of both multifilament trammel and gillnet in same time and area for freshwater fish.

This study was aimed to estimate the selectivity properties of multifilament trammel and gillnets with 4, 6, 8, and 10 cm mesh size for common carp in Marmara Lake in Manisa. In addition, selectivity parameter of 11, 12, 13 and 14 cm mesh size of trammel and gillnets were modelled. It is the first time presented both multifilament trammel and gillnets selectivty proporties in same fishing area and experiment period.

MATERIALS AND METHODS

Study area

The study was conducted on Lake Marmara which altitude is 79 m and surface between 3200-6800 ha based on depth differences. Average depths are about 3-4 m but lake depth is changes coupled with year by year (Arı and Derinöz, 2011). Experiments were carried out in three different stations identified eastern, middle and western areas which represent the longitudinal length of the lake. In order to ensure homogeneity between stations, twelve nets were used on each station (totally 36 nets) on a monthly basis in 2012 (Figure 1).

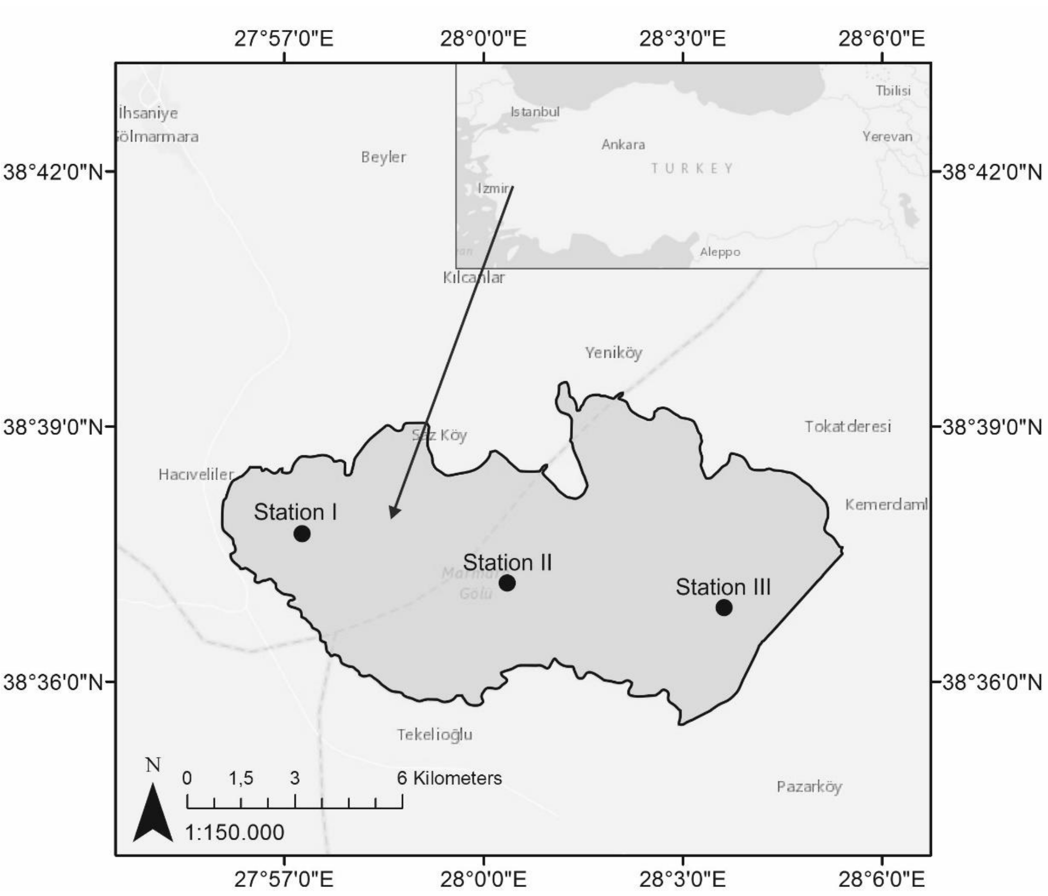

Figure 1. Lake Marmara and sampling stations

Sampling and data collection

Multifilament 4, 6, 8 and 10 cm stretched mesh size of both trammel and gillnets were used in the experiments. Each gillnet has 35 m in length and 210 denier/2 twine thickness. All nets vertical mesh numbers were 50 meshes in depths and each hanging ratio (E) was 0.50. Trammel nets inner panels have same character with gillnets. Experimental nets information is given in Figure 2. All nets were connected each other with float line and lead line randomly and set at the bottom of sampling station in the afternoon and was hauled the following day. Average fishing time for per catching operation was 16 hours. Fish were classified depending on the nets. Total lengths were measure as 1 mm precision with measurement board.

Figure 2. Technical plan of trial nets (not in scale)

Selectivity analysis

As indirect estimation method, SELECT (Share Each Length's Class Catch Total) method was used to determine selectivity (Millar, 1992; Millar and Holst, 1997; Millar and Fryer, 1999). Data were analysed by R-codes which developed by Millar (2009) and Millar (2010) in R version 3.1.2. Length selectivity of each mesh size was described by five different models (normal location, normal scale, gamma, lognormal and bi-normal) of the SELECT method (Millar and Fryer, 1999; Park et al., 2011). The equations for each model are given in below.

Normal Location :

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

Normal Scale :

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

Log-Normal :

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

Gamma :

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

Bi-modal :

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

Park et al. (2011) reported that determinated selectivity curve for the smallest mesh scale proportionally to mesh size for all other mesh sizes in their study that was carried out with Millar's (2010) R-codes. Due to the trial nets estimated value gave below the minimum landing size (40 cm), we also modelled for 11, 12, 13 and 14 cm mesh size using same constant.

The most suitable model was chosen taking into account the lowest deviation value. The Kolmogorov-Smirnov (K-S) test was used to compare the catch size frequency distributions of the common carp caught for gillnet and trammel nets separately (Siegel and Castellan, 1989; Karakulak and Erk, 2008). The t-test was utilized total length difference between same mesh size.

RESULTS

A total of 119 common carp were caught. Those which 79 of them trammel and 40 of them with gillnet. Trammel nets caught more 97% individuals than gillnet. The most effective net was found as 8 cm mesh size for both trammel net (58.2%) and gillnet (65.0%) (Table 1). Minimum lengths class were very close for both trammel nets and gillnet, while there are gap between maximum lengths class (Table 1, Figure 3). In addition, carp length ranges very narrow gillnet then trammel nets for same mesh size.

Depends on increasing mesh size, average total lengths of the specimens in gillnet was linearly increase, however, slight fluctuations were observed in trammel nets. On the basis of same mesh size, trammel nets specimens average length generally higher then gillnet (Figure 3).

Table 1. Common carp catch composition obtained from experiments (N: number of fish, TL: total lengths, Se: Standard error, Min: Minimum, Max: Maximum)

	Trammel Nets				Gillnets			
Mesh size (cm)	N	N (%)	TL ± Se (cm)	Min. – Max. (cm)	N	N (%)	TL ± Se (cm)	Min. – Max. (cm)
4	11	13.9	20.30 ± 2.84	11.3-34.3	4	10	11.60 ± 0.12	11.3-11.8
6	17	21.5	29.08 ± 2.08	17.8 -43.5	5	12.5	18.08 ± 0.59	16.8-20.3
8	46	58.2	27.17 ± 0.58	21.5-37.70	26	65	25.42 ± 0.45	21.1-30.7
10	5	6.3	30.80 ± 4.85	21.5-49.0	5	12.5	28.88 ± 1.06	25.4-31.9

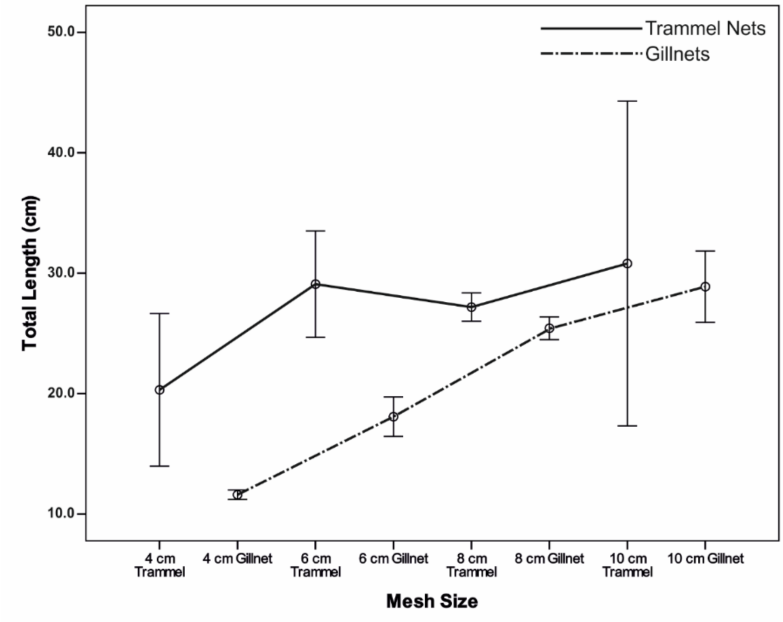

Figure 3. Error bar plot of total length by different mesh size

When comparing model deviance, bi-normal model was best suitable model (lowest deviance) for trammel nets (Table 2). Selectivity curves drafted by that model (Figure 4), k1 determined as 2.57 for 1 cm precision mesh size. Deviance of other model were founded 103.80, 111.81, 97.95 and 102.71 for normal location, normal scale, gamma and lognormal, respectively. Similarly to trammel nets, best suitable model determined as bi-normal for gillnets by lowest deviance (7.60) and selectivity curves drafted by bi-normal model (Table 3, Figure 5). k1 determined as 2.52 for trammel nets.

Deviance of other model were founded 13.78, 10.86, 10.35 and 10.18 for normal location, normal scale, gamma and lognormal, respectively.

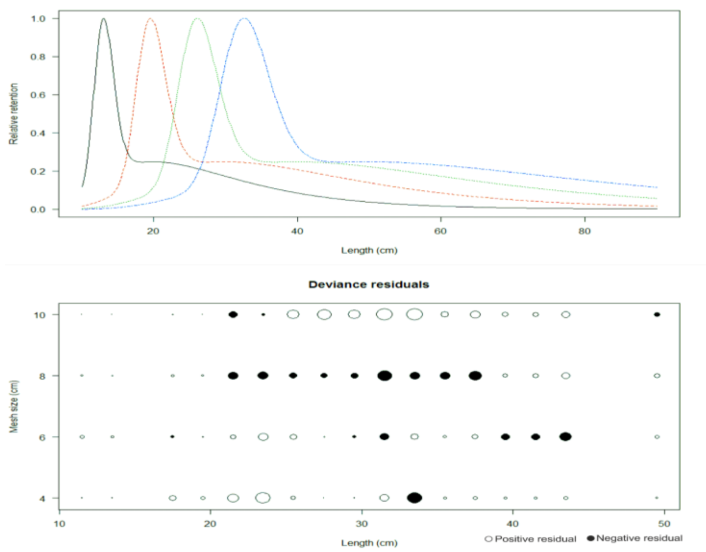

Figure 4. Selectivity curves and deviance residual plots of trammel nets for the *C. carpio*

Table 2. Selectivity model parameters of common carp and estimated selection curves for the 4 cm mesh size for the trammel nets

Model	Parameters	Equal fishing power						
		Estimates	**Mode 1**	**Spread 1**	**Mode 2**	**Spread 2**	**Deviance**	**df**
Normal location	*k*	3.82 (0.21)	15.29 (0.8)	9.87(1.37)	-	-	103.80	49
	σ	9.87 (1.37)						
Normal scale	k_1	4.07 (0.48)	16.30 (1.92)	3.46 (1.83)	-	-	111.81	49
	k_2	4.48 (1.94)						
Lognormal	μ_1	2.84 (0.06)	15.04(0.89)	7.09(1.33)	-	-	97.95	49
	σ	0.37 (0.04)						
Gamma	*k*	0.62 (0.17)	15.66 (1.03)	6.75(1.04)	-	-	102.71	49
	α	7.24 (1.79)						
Bi-normal	k_1	2.57	12.98 (0.32)	1.37(0.33)	20.07(3.37)	13.93(7.41)	***76.70***	***46***
	k_2	0.10						
	k_3	3.22						
	k_4	0.47						
	c	1.21						
Model	**Parameters**	**Fishing power α mesh size**						
		Estimates	**Mode 1**	**Spread 1**	**Mode 2**	**Spread 2**	**Deviance**	**df**
Normal location	*k*	4.38 (0.29)	17.52(1.16)	10.87(1.78)	-	-	99.02	49
	σ	10.87 (1.78)						
Normal scale	k_1	5.02 (0.36)	20.11(1.45)	7.53(1.31)	-	-	113.97	49
	k_2	3.54 (1.24)						
Lognormal	μ_1	2.98 (0.08)	17.26(1.08)	8.14(1.80)	-	-	97.95	49
	σ	0.37 (0.04)						
Gamma	k	0.62 (0.17)	18.17(1.17)	7.20(1.21)	-	-	102.71	49
	α	8.24 (1.79)						
Bi-normal	k_1	2.58	13.12(0.34)	1.38(0.34)	25.06(5.92)	17.40(11.11)	76.70	46
	k_2	0.13						
	k_3	3.44						
	k_4	0.47						
	c	0.67						

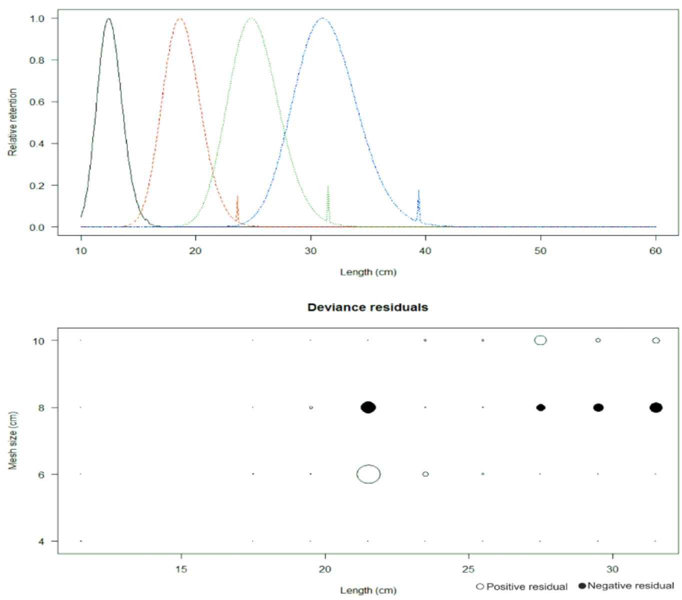

Figure 5. Selectivity curves and deviance residual plots of gillnets for the common carp

Table 3. Selectivity model parameters of common carp and estimated selection curves for the 4 cm mesh size for the gillnets

Model	Parameters	Equal fishing power						
		Estimates	Mode 1	Spread 1	Mode 2	Spread 2	Deviance	df
Normal location	*k* σ	3.12(0.05) 2.48(0.29)	12.48(0.22)	2.48(0.29)	-	-	13.78	25
Normal scale	k_1 k_2	3.18(0.06) 0.09(0.02)	12.74(0.26)	1.25(0.17)	-	-	10.86	25
Lognormal	μ_1 σ	2.53(0.02) 0.09(0.01)	12.53(0.24)	1.25(0.18)	-	-	10.18	25
Gamma	*k* α	0.03(0.00) 102.(27.81)	12.60(0.24)	1.25(0.17)	-	-	10.35	25
Bi-normal	k_1 k_2 k_3 k_4 c	2.52 0.08 2.75 0.001 1.76	12.40(0.23)	1.10(0.22)	15.75(0.02)	0.02(0.08)	***7.60***	***22***
Model	**Parameters**	**Fishing power α mesh size**						
		Estimates	**Mode 1**	**Spread 1**	**Mode 2**	**Spread 2**	**Deviance**	**df**
Normal location	*k* σ	3.15(0.05) 2.52(0.30)	12.61(0.23)	2.52(0.30)	-	-	13.00	25
Normal scale	k_1 k_2	3.21(0.06) 0.09(0.02)	12.87(0.27)	1.25(0.17)	-	-	10.87	25
Lognormal	μ_1 σ	2.54(0.02) 0.09(0.01)	12.66(0.25)	1.26(0.18)	-	-	10.18	25
Gamma	*k* α	0.03(0.008) 103.97(27.8)	12.73(0.26)	1.26(0.18)	-	-	10.35	25
Bi-normal	k_1 k_2 k_3 k_4 c	2.53 0.08 2.75 0.001 2.11	12.51(0.19)	1.12(0.12)	15.75(0.03)	0.02(0.09)	8.32	22

Modal lengths which determinate as for 4 cm mesh size used estimating all other mesh sizes (constant x mesh size) model length with constant shown in Table 4. For 40 cm MLS regulation as using constant, calculated minimum mesh size as 12.33 cm for trammel and 12.90 cm for gillnet (Table 4). It is seeing that the model lengths are very close each other for small mesh size, while increasing mesh size enhanced the differences between model lengths (Figure 6).

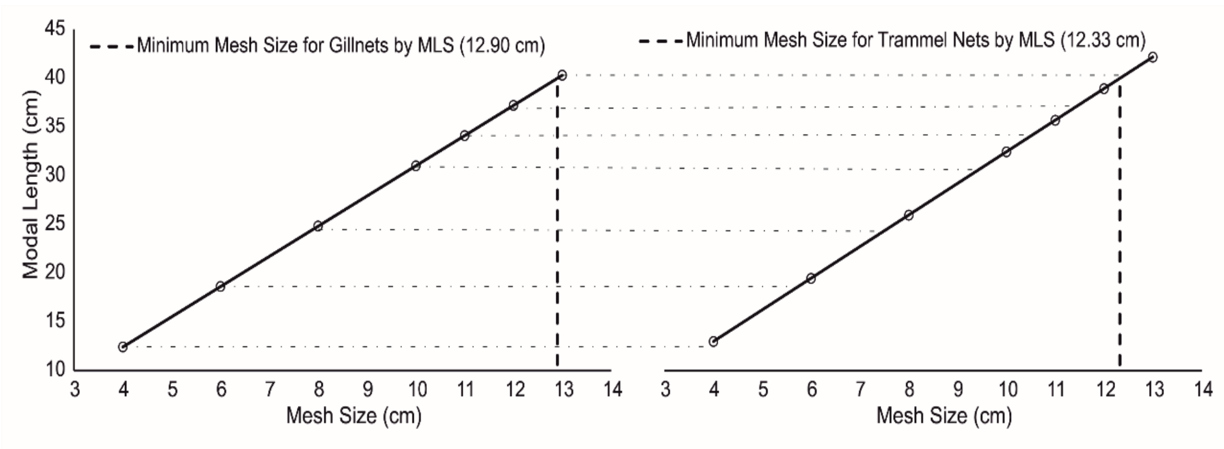

Figure 6. Model length comparison of gillnets and trammel nets

Table 4. Model length and spread values of common carp according to the bi-normal model both trammel nets and gillnets

	Mesh size (cm)	Trammel Nets		Gillnets	
		Model Length (cm)	Spread Value (cm)	Model Length (cm)	Spread Value (cm)
Used	4	12.98	1.37	12.40	1.10
	6	19.47	2.06	18.60	1.65
	8	25.96	2.74	24.80	2.20
	10	32.45	3.43	31.00	2.75
Modelled	11	35.70	3.77	34.10	3.03
	12	38.94	4.11	37.20	3.30
	13	42.19	4.45	40.30	3.58
	14	45.43	4.80	43.40	3.85
Constant		3.245[a]	0.3425[b]	3.100[c]	0.275[d]

According to the K-S test, there are significantly differences for 4, 6 and 10 cm trammel and gillnet specimens. Significant differences (t-test, $P< 0.05$) were determined on average total length of catch between trammel and gillnets for 4, 6, 8 cm mesh size, but no statistical differences ($P> 0.05$) were found for 10 cm mesh size (Table 5). This might be due to the limited specimens in 10 cm mesh size experiments.

Table 5. Kolmogorov-Smirnov (K-S) and t-test result

Trammel Nets Mesh Size (cm)	Gillnet Mesh Size (cm)	Kolmogorov-Smirnov Test			*t-test*	
		D max	Critical Values	Decision	F	p
4	4	0.5000	0.6319	H_0 Not Reject	39.55	0.000
6	6	0.5556	0.5606	H_0 Not Reject	6.69	0.018
8	8	0.7797	0.3192	H_0 Reject	9.64	0.003
10	10	0.5556	0.7586	H_0 Not Reject	2.92	0.125

DISCUSSION

Trammel nets have found more productive than gillnets. This result supported with Balık (1996) who reported multifilament trammel nets 3.08 times efficient then multifilament gillnets in common carp fishing in Beyşehir Lake. Moreover, Karakulak and Erk (2008) found a clear difference between catching efficiency trammel and gillnets. In addition, Thomas et al. (2003) presented that trammel nets caught on average two times more prawns than monofilament gill net on penaeid prawns.

There are gap between maximum lengths class of trammel and gillnets specimens. The reason might be due to the gillnetting. Fabi et al. (2002) reported that most of fishes were obtained by gilling and/or wedging. Therefore, the proportion of fish caught in this way was smallest and generally negligible in gillnets, larger in monofilament nets and largest in the standard trammel nets. In the same way, Karakulak and Erk (2008) given that model lengths of 16 mm trammel nets with 16 mm model lengths reported as 16.20, 8.82, 14.70, 14.16 and 13.22 for bogue (*Boops boops*), annular sea bream (*Diplodus annularis*), striped red mullet (*Mullus surmuletus*), axillary sea bream (*Pagellus acarne*) and blotched picarel (*Spicara maena*), respectively and gillnet as 15.28, 8.86, 13.68, 12.19 and 13.42 cm *B. boops*, *D. annularis*, *M. surmuletus*, *P. acarne* and *S. maena*, respectively.

There are some studies conducted on determination of selectivity properties both gill and trammel nets. Fabi et al. (2002) used the Sechin method to estimate the gear selectivity of *Lithognathus mormyrus*, *D. annularis* and *Mullus barbatus* caught by gill and trammel nets. Karakulak and Erk (2008) utilized the SELECT method to compare the gillnet vs trammel nets selectivity of *B. boops, D. annularis, M. surmuletus, P. acarne* and *S. maena*. Park et al. (2011) used the SELECT method to estimate the gill and trammel selectivity of Korean flounder (*Glyptocephalus stelleri*). Due to the no study conducted on trammel and gillnet selectivity for *C. carpio* from same region and same fishing time, we could not directly compare with other studies.

When comparison with previously studies conducted on gillnet for common carp (Table 6), similar optimum length were found by Balık (1999) with 13 cm mesh size (39.33 cm) and Yalçın (2006) with 10 (30.4 cm) and 12 cm (36.5 cm) mesh sizes. However, Cilbiz et al. (2015) presented model lengths of 10, 12 and 14 cm mesh size of trammel nets as 39.05 cm, 46.85 cm and 54.66 cm from Lake Manyas, respectively. In addition, model lengths reported by Carol and García-Berthou (2007) for 10.15 cm mesh size of gillnets (38.12 cm) very higher then ours 10 cm mesh size result (31.00 cm). It is thought that the differences might be due to the habitat variation and net material.

One of the basic principles of responsible fishery, fish has reproduced at least once before captured. The optimum selection length of the fishing gear should ideally be same as size of the fish at first maturity. In this context MLS reported as 40 cm in the notification below 13 cm mesh size should not be used for common carp fishery. Besides, in order to get definite conclusion more study need to be investigated with 11, 12, 13 and 14 cm mesh size of both trammel and gillnets.

Table 6. Some selectivity studies conducted on common carp

Author	Location	Method	N	Mesh Size (mm)	Material	Model Length (cm)
(Özyurt and Avşar, 2005)	Seyhan Dam Lake	Holt	294	28[c]	Monofilament	17.55
				32[c]	Gillnets	20.06
				40[c]		24.44
				45[c]		27.50
(Balık, 1999)	Beyşehir Lake	Holt	352	70[a]	Monofilament	18.07
				80[a]	Gillnets	20.66
				130[a]		39.33
				140[a]		42.35
(Yalçın, 2006)	Different Anatolian Reservoirs	Holt	1139	45[b]	-	27.4
				50[b]	Gillnets	30.4
				55[b]		33.4
				60[b]		36.5
(Carol and García-Berthou, 2007)	Different Reservoirs in Catalonia (NE Spain)	SELECT	116	29[a]	Monofilament	10.89
				38[a]	Gillnets	14.27
				51[a]		19.15
				64[a]		24.03
				84.5[a]		31.73
				101.5[a]		38.12
				135.5[a]		50.89
				177.5[a]		66.66
				201.5[a]		75.67
				253[a]		95.01
(Cilbiz et al., 2015)	Manyas Lake	SELECT	208	100[a]	Monofilament	39.05
				110[a]	Trammel nets	42.95
				120[a]		46.85
				130[a]		50.76
				140[a]		54.66
Present study	Lake Marmara	SELECT	40	4[a]	Multifilament	12.98
				6[a]	Gillnets	19.47
				8[a]		25.96
				10[a]		32.45
				11[a]		35.70
				12[a]		38.94
				13[a]		42.19
				14[a]		45.43
			79	4[a]	Multifilament	12.40
				6[a]	Trammel Nets	18.60
				8[a]		24.80
				10[a]		31.00
				11[a]		34.10
				12[a]		37.20
				13[a]		40.30
				14[a]		43.40

[a] mesh size (stretched); [b] mesh size (bar length); [c] not defined

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