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RESEARCH PAPER

Mesh Size Recommendation for Turkey Pike (*Esox lucius* L., 1758) Gillnet Fishery

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Abstract

The pike is one of the most valuable freshwater fish species in Turkey. This study was carried out in order to estimate the selectivity properties of gillnet used in pike (*Esox lucius* L., 1758) fishing in Çivril Lake, Turkey. The study was performed between January 2005 and December 2005 and selectivity estimates were based on six different monofilament gillnet mesh sizes (i.e. 4, 5, 6, 7, 8 and 9 cm). The SELECT method was used to estimated the selectivity parameters. According to the bi-normal model, optimum model lengths for 4, 5, 6, 7, 8 and 9 cm mesh sizes were determined as 20.99, 26.24, 31.49, 36.73, 41.98 and 47.23 cm respectively. When considering minimum landing size, the findings of the study showed that the use of gillnets of mesh size less than 8 cm should be prohibited for the fishing of *E. lucius* in Çivril Lake.

Keywords: Gillnet selectivity, *Esox lucius*, SELECT method, Çivril Lake, Pike.

Introduction

The Pike (*Esox lucius* Linnaeus, 1758) is widely distributed in Europe, Asia and North America. It is an important species for commercial and recreational fisheries throughout its natural range (Moslemi-Aqdam, Imanpour Namin, Sattari, Abdolmalaki, & Bani, 2014; Paukert, Stancill, DeBates, & Willis, 2003).

E. lucius is also a main target species for inland fisheries in Turkey due to the high commercial value. There has been an increase in fishing pressure on *E. lucius* and a significant reduction in its landings in Turkish water. For instance, landing amount reached 350 t in 1997 but decreased to 203 t in 2015 (Anonymus 2016). Aside from fishing pressure, other reasons for that reduction in landing might pollution, diseases, habitat degradation and invasive species.

Apaydın Yağcı, Alp, Uysal, Yeğen, and Yağcı (2009) reported the first maturity length as 24.9 cm for female and 22.9 cm for male *E. lucius* caught from the Lake Işıklı. In another study carried out by Balık , Çubuk, Özkök, and Uysal (2004) in the Lake Karamık, the first maturity length was reported as 18 cm (fork length) for female *E. lucius*.

One of the main principles for sustainable fisheries management is to let fish to reproduce at least once in natural habitat. In the other words, catch size should be larger than the length at first maturity (L_m). Thus, it is necessary to know the selectivity properties of fishing gear used in commercial fisheries. Fisheries management decision makers can make legal regulation for mesh size to catch fish above first breeding by using the size selectivity data. That is to say it is very easy to implement the results of studies on selectivity of gill nets within the scope of minimum mesh size.

Gear selectivity is an important tool for fisheries managers who, by regulating the minimum mesh sizes of a fishing fleet, can more or less determine the minimum sizes of the target species of certain fisheries (Sparre & Venema, 1998). An ideal selection of a fishing gear for optimum fish length should aim to catch larger fish than the first maturity (Yuksel, Gündüz, & Demirol, 2014). Therefore, result of this study are very valuable for improving the management of commercial pike fishery in Çivril Lake and other inland waters of Turkey.

One of the most selective fishing gears is gillnet and it allow fisherman to catch certain sized species at an optimum level (Hamley, 1975; Hoşsucu, 2011; Kiyağa, 2008; Özekinci, 1995). Generally, fishermen use gillnet for fishing *E. lucius* in the Lake Çivril because of easy use, affordability, durability and productivity.

Legislative regulations for both minimum landing size and minimum mesh size are the case in commercial pike fisheries. However, gillnet

selectivity properties for current minimum landing size (40 cm total length) is unclear. This present results would be very valuable for fisheries management authorities who are responsible for the determination of minimum mesh size for commercial pike fisheries.

There are very limited studies selectivity characteristics of gillnets in *E. lucius* fishing. Pierce, Tomcko, and Kolander (1994) compared size selectivity of gill net by indirect and direct methods. Authors reported that indirect estimates show that gill nets were most effective for retaining northern pike when fish length/mesh perimeter ratio was between 3.5 and 3.7 besides increasing selectivity with increasing fish length by the direct estimates. In the another study which was conducted by Balık (2008), investigated selectivity properties of gillnets by SELECT method for 3.6, 4, 4.4, 5 and 6 cm mesh sizes. In this study, we improved former research in respect to used model type and large mesh size range in accordance with commercial fishery. The purpose of this study was to estimate the selectivity properties of gillnets for commercial fishery of *E. lucius* in the Lake Çivril.

Materials and Methods

The Lake Çivril is located within the boundaries of Denizli province (west Anatolia) (Figure 1). Surface of the lake is 64.53 km^2, maximum depth is 7 m and altitude is 821 m (İlhan & Balık, 2003). Fish samplings were carried out monthly in two different stations with a total of 24 trials between from January and December 2005. Gillnets were made of monofilament material with 4, 5, 6, 7, 8 and 9 cm stretched mesh sizes, 0.20 mm twine thickness and 0.50 of hanging ratio. Depths of all nets were 50 meshes and panel length of them 100 m. All nets were set in the afternoon and retrieved in the next morning. Fish were classified according to mesh sizes of the nets and total fish length was measured using a measurement board with 1 mm precision.

The SELECT (Share Each Length's class Catch Total) method was used to determine selectivity as an indirect estimation method (Millar, 1992; Millar & Fryer, 1999; Millar & Holst, 1997). Data obtained from field studies were analyzed with RStudio (version 0.99.903) (RStudio, 2016). R codes are developed by Millar (2010, 2011). 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 & Fryer, 1999; Park *et al*., 2011). The Kolmogorov-Smirnov (*K-S*) test was used to determine differences between pairs of size frequency distributions per mesh size of the net (Karakulak & Erk, 2008; Siegel & Castellan, 1989).

Results

A total of 317 specimens of *E. Lucius* was caught over the study period. Fish lengths ranged between 22.9 and 52.9 cm. Catch composition and length frequency distributions of specimens are shown in Table 1 and Figure 2 for each mesh size of the nets, respectively.

A comparison of the deviances of five models of SELECT method revealed that bi-normal model yielded the best fit with the lowest deviance of 139.41 (Table 2). The selectivity curves and deviance residual plots are shown in Figure 3 were drafted by bi-normal parameters via RStudio software (RStudio, 2016). The optimum length and spread values estimated by the bi-normal model per different mesh sizes of the net are shown in Table 3. Estimated model length for 4 cm mesh size was adapted as scale proportionally for all other mesh sizes (i.e. 5, 6, 7, 8 and 9 cm) (Park *et al*., 2011). The K-S test showed differences between all paired comparisons of length frequency distributions per mesh sizes of gillnets (Table 4).

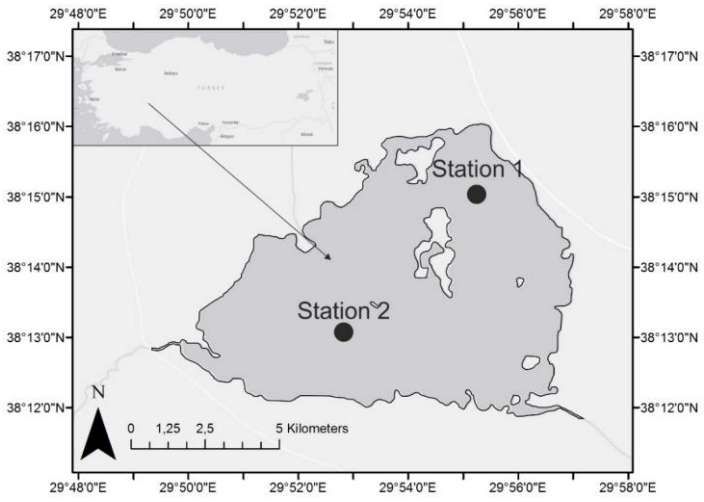

Figure 1. Study area and sampling locations.

Table 1. Descriptive statistics of the sampled individuals caught with the different mesh sizes of the nets

Length of mesh size (cm)	Number of fish caught (N)	Number of fish caught (%)	Average length (SD) (cm)	Minimum Length (cm)	Maximum Length (cm)
4	30	9.4	26.2(2.3)	23.9	34.2
5	76	23.8	29.1(4.1)	22.9	46.6
6	131	40.9	33.3(4.0)	23.8	52.9
7	47	14.7	37.7(3.6)	30.1	46.7
8	24	7.5	41.6(2.5)	34.7	46.1
9	9	2.8	43.9(4.4)	35.8	50.8

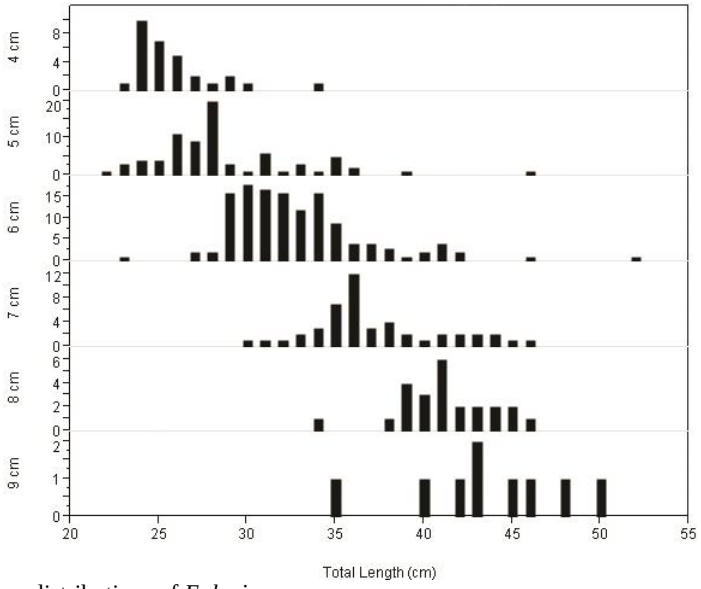

Figure 2. Length frequency distributions of *E. lucius.*

Table 2. Selectivity model parameters of *E. lucius* and estimated selection curves for the 4 cm mesh size

Model	Parameters	Equal fishing power						
		Estimates	Mode 1	Spread 1	Mode 2	Spread 2	Deviance	df
Normal location	k	5.53(0.04)	22.15(0.16)	4.35(0.19)	-	-	199.21	153
	σ	4.35(0.19)						
Normal scale	k_1	5.73(0.04)	22.94(0.18)	2.98(0.12)	-	-	221.52	153
	k_2	0.55(0.04)						
Lognormal	μ_1	3.12(0.00)	22.36(0.16)	2.94(0.13)	-	-	183.86	153
	σ	0.12(0.00)						
Gamma	k	0.09(0.00)	22.54(0.17)	2.93(0.13)	-	-	194.37	153
	α	60.83(5.02)						
Bi-normal	k_1	3.04	20.99(0.15)	1.11(0.17)	23.65(0.44)	3.77(0.31)	139.41	135
	k_2	0.05						
	k_3	3.18						
	k_4	0.15						
	c	0.81						
Model	Parameters	Fishing power α mesh size						
		Estimates	Mode 1	Spread 1	Mode 2	Spread 2	Deviance	df
Normal location	k	5.63(0.04)	22.53(0.18)	4.42(0.20)	-	-	195.31	153
	σ	4.42(0.20)						
Normal scale	k_1	5.83(0.04)	23.33(0.18)	2.95(0.12)	-	-	222.06	153
	k_2	0.54(0.04)						
Lognormal	μ_1	3.14(0.00)	22.73(0.17)	2.99(0.14)	-	-	183.86	153
	σ	0.12(0.00)						
Gamma	k	0.09(0.00)	22.92(0.18)	2.96(0.13)	-	-	194.37	153
	α	61.83(5.02)						
Bi-normal	k_1	3.04	21.05(0.15)	1.11(0.17)	24.21(0.49)	3.88(0.34)	139.41	135
	k_2	0.05						
	k_3	3.21						
	k_4	0.15						
	c	0.68						

(Standard errors are in parentheses; bold value is lowest deviance).

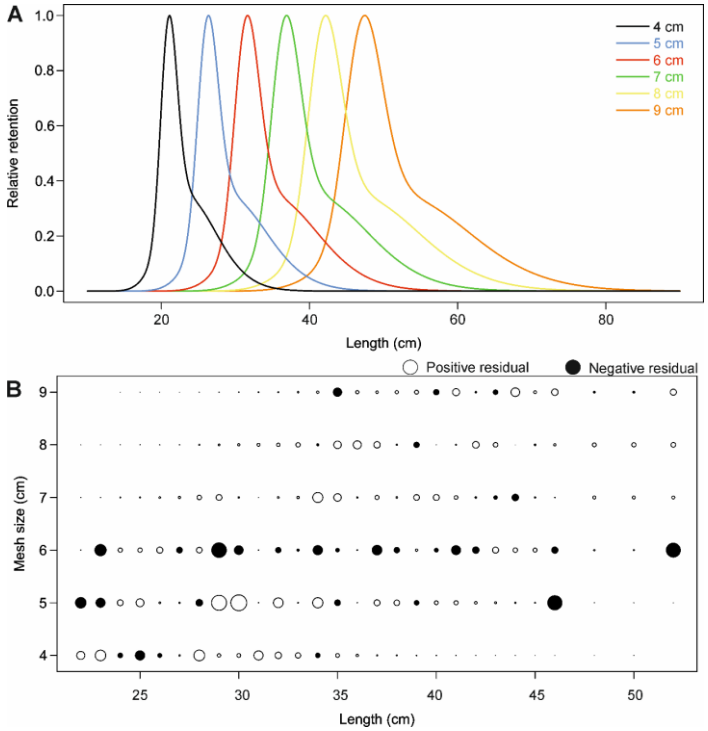

Figure 3. Selectivity curves (A) and deviance residual plots (B) of gillnets for the *E. Lucius.*

Table 3. Optimum length and spread values of *E. lucius* according to the Bi-normal model

Mesh size (cm)	Model Length (cm)	Spread Value (cm)
4	20.99	1.11
5	26.24	1.39
6	31.49	1.67
7	36.73	1.94
8	41.98	2.22
9	47.23	2.50

Table 4. Results of the K-S test used to compare length frequency distributions between pairs of different mesh sizes of gillnets of *E. Lucius*

Net 1	Net 2	K-S Test	Decision	Net 1	Net 2	K-S Test	Decision
4	5	0.4792>0.2912	H_0 Reject	5	9	0.9099>0.4082	H_0 Reject
4	6	0.8296>0.2745	H_0 Reject	6	7	0.6065>0.2245	H_0 Reject
4	7	0.9471>0.3129	H_0 Reject	6	8	0.8574>0.2832	H_0 Reject
4	8	0.9667>0.3574	H_0 Reject	6	9	0.8467>0.3955	H_0 Reject
4	9	1.0000>0.4516	H_0 Reject	7	8	0.6520>0.3247	H_0 Reject
5	6	0.6472>0.1950	H_0 Reject	7	9	0.6890>0.4262	H_0 Reject
5	7	0.7766>0.2462	H_0 Reject	8	9	0.4968>0.4683	H_0 Reject
5	8	0.9380>0.3007	H_0 Reject				

H_o: There are no significant differences in the length frequency distributions (α=0.05; k=1.36).

Discussion

There is a circular regulating the commercial fishery in Turkey. According to this, legal minimum landing size of *E. lucius* is 40 cm total length for all inland waters of Turkey. Besides the sustainability of *E. lucius* commercial stocks, catch quotas and closed season regulations are issued by certain governmental organizations in Turkey. All of these regulations are not only for *E. lucius* but also perform on other commercial inland species (*Cyprinus carpio*, *Astacus leptodactylus*, *Sunder lucioperca*, *Siluris glanis*, *Perca fluviatilis, Leucisus cephalus etc…)*. The regulations of minimum mesh size limitations are monitored by provincial directorates on behalf of Ministry of Food, Agriculture and Livestock Directorate.

Expectedly, the mean total lengths increased

with increasing mesh size. The most productive net was that of 6 cm mesh size, whereas the worst was that of 9 cm. The best suitable model was the bi-normal model in terms of the modal deviances (Table 2), which is considered as the most suitable in cases of capturing fish in mesh by jamming, wrapping and trammeling and large length frequency ranges in captured fish (Akamca, Kiyağa, & Özyurt, 2010; Holt, 1963; Hovgård, 1996). In this study, we observed many cases of tangled fish captured from sharp teeth of the pike. This result blend in Pierce *et al*. (1994), who reported that *E. lucius* captured by gill nets wedging or tangling.

There are very limited studies on *E. lucius* gillnet selectivity. One of them was conducted by Balık (2008) in Karamık Lake with the SELECT method and the authors reported as model lengths as 20.420, 22.689, 24.958, 28.362 and 34.034 cm (as fork length) for 3.6, 4, 4.4, 5 and 6 cm mesh size.

Reported optimum fork lengths by Balık (2008) for *E. lucius* in Lake Karamık are higher than those of the present study for the similar mesh sizes. One reason for this difference can be habitat and seasonal differences. Accordingly, selectivity of gillnets can vary for each fish species so selectivity should be determined separately for each species (Balık and Çubuk 2001). Another reason can be the model selected for the calculation. While the calculation was made according to the lognormal model in the former study (Balık, 2008), the bi-normal model was used in present study.

The estimation of selectivity parameters is needed to ensure a proper management of commercial gillnet fishery; protection of small fish thereby escape from fishing gear. Therefore, it is necessary to determine the optimum mesh size for sustainable production (Hamley, 1975; Sümer *et al*., 2010).

Taking into account the first maturity estimates reported by Apaydın Yağcı *et al*. (2009) and Balık *et al*. (2004) as well as the legal size limitation (40 cm), gillnet mesh sizes for catching *E. lucius* in Çivril Lake should not be less than 8 cm. Given also that, *E. lucius* is a very popular fish for anglers in Turkey, studies are required to determine the effects of hook selectivity and amateur fishing activities on the stocks.

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