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Selectivity and Catch Efficiency of Three Spinner Hook Sizes in Angling for Rainbow Trout (*Oncorhynchus mykiss* Walbaum, 1792) in Karakaya Dam Lake (Eastern Turkey)

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Abstract

The aim of this study was to determine the relationship between spinner hook sizes (2, 3 and 4) and hook selectivity for *Oncorhynchus mykiss* (rainbow trout), a species important to recreational fisheries in Karakaya Dam Lake in Eastern Turkey. A total of 24 sampling trips were carried out twice per month by the same three anglers from May 2013 to April 2014. The SELECT method was used to determine the selectivity parameters. An analysis to determine the differences in the catch per unit effort (CPUE), yield per unit effort (YPUE) and condition factor values based on different hook sizes was conducted using one-way ANOVA. During the spinner hook-size experiments, we captured 202 *Oncorhynchus mykiss*, which ranged from 14.5 cm to 46.0 cm TL in length and weight 30.2 g to 1320.2 g. The mean lengths (±SE) of *Oncorhynchus mykiss* captured on the three spinner hook sizes were determined. The optimum lengths calculated by log-normal model were found to be 18.28, 27.41 and 36.55 cm for No 2, No 3 and No 4 hook sizes, respectively.

Keywords: Hook selectivity, rainbow trout, *Oncorhynchus mykiss*, catch efficiency, Karakaya Dam Lake.

Karakaya Baraj Gölü Gökkuşağı Alabalığı'nın (*Oncorhynchus mykiss* Walbaum, 1792) Üç Farklı Spinner İğne Seçiciliği ve Avcılık Etkinliği

Özet

Bu çalışmada, Karakaya Baraj Gölünde amatör balıkçılıkta önemli bir tür olan *Oncorhynchus mykiss*'in avcılığında kullanılan farklı boyuttaki spinner kancaların (2, 3 ve 4) seçiciliği ve avcılık verimlikleri araştırılmıştır. Mayıs 2013 - Nisan 2014 tarihleri arasında aynı oltacılarla ayda iki kez ve toplamda 24 avcılık operasyonu gerçekleştirilmiştir. Seçicilik parametrelerinin belirlenmesinde SELECT metot kullanılmıştır. Ayrıca kanca numaralarına göre CPUE, YPUE ve K değerleri istatistiksel olarak değerlendirilmiştir. Yakalanan 202 *Oncorhynchus mykiss* 14,5-46,0 cm toplam uzunluğunda, ağırlıkları 30,2-1320,2 g arasında değişkenlik göstermiştir. 2, 3 ve 4 numaralı iğnelerin optimum yakalanma boyları sırası ile 18,28, 27,41, 36,55 cm olarak bulunmuştur.

Anahtar Kelimeler: İğne seçiciliği, gökkuşağı alabalığı, *Oncorhynchus mykiss*, avcılık verimi, Karakaya Baraj Gölü.

Introduction

Recreational fishing, a leisure activity enjoyed by many people throughout the world (Hickley and Tompkins, 1998; Ditton, 2008; Arlinghaus and Cooke, 2009), has an economic value estimated in the hundreds of millions, or perhaps billions of dollars annually in the United States and in the European Union, among other regions (Ditton, 2008).

Fisheries managers are frequently tasked with developing and maintaining quality recreational fishing opportunities while protecting a population's aquatic resources. The use of recreational fishing regulations as a management tool can have a substantial effect on fisheries and, if used appropriately, can enhance angling opportunities (Bloom, 2013). Recreational fishing is a small-scale fishing activity which is performed in inland or marine waters (Hickley and Tompkins, 1998). Fishing gear and duration of the operations significantly affect the catch composition (Kaykaç *et al.*, 2003), the catch per unit effort (CPUE) and the yield per unit effort (YPUE) efficiency. In addition to these parameters, other important issues (e.g. hook size, environmental changes) must be considered in recreational fishery.

The fundamental property of the indirect method is that a functional relationship is being fitted to catch data with no information about the sampled population. Therefore, a method that tests various functions against catch data, such as the Share Each Length's class Catch Total (SELECT) method (Millar 1992), could prove useful. There are numerous ways of measuring hook dimensions, including total length, gape, throat, wire diameter, bite, barb, shank, front length, offset and bend (Campbell *et al.*, 2014). In this study, we chose to measure total hook size, since, in Turkey, spinner-hook models are sold according to their total length.

Substantial interest and research have focused on hooking mortality based on gear, hook type and fish species; however, less effort has been put into evaluating the probability of capture associated with these variables (DuBois and Dubielzig, 2004; Meka, 2004; Bloom, 2013). It is critical that fishery managers evaluate, adopt and monitor special regulations with specific strategies and objectives. This approach will allow for the assessment of regulations and associated responses within a fishery activity (Bloom, 2013). Minimum legal sizes are the most common tools used worldwide to manage recreational fisheries (Alós *et al.*, 2009). While the size-selective nature of gear, such as trawls (Wileman *et al.*, 1996; Tokaç *et al.*, 2004) and gill nets (Kalaycı and Yeşilçiçek, 2012), are well known, there is still no clear consensus on the form of the size-selection curve for hooks on longlines (Czerwinski *et al.*, 2010; Campbell *et al.*, 2014). Especially in Turkey, there are few studies on hook selectivity and efficiency with respect to recreational fisheries. The aim of this study, therefore, was to determine the hook selectivity and catch efficiency associated with fishing for *Oncorhynchus mykiss* in Karakaya Dam Lake in Eastern Turkey.

Materials and Methods

Karakaya Dam Lake, located in Eastern Anatolia (Turkey), is one of the region's largest and most important water sources, both for irrigation and for fisheries. The lake's surface area is 268 km^2, and its reservoir volume, at normal water-surface elevation, is 9,580,000 hm^3 (Ozmen *et al.*, 2006) (Figure 1).

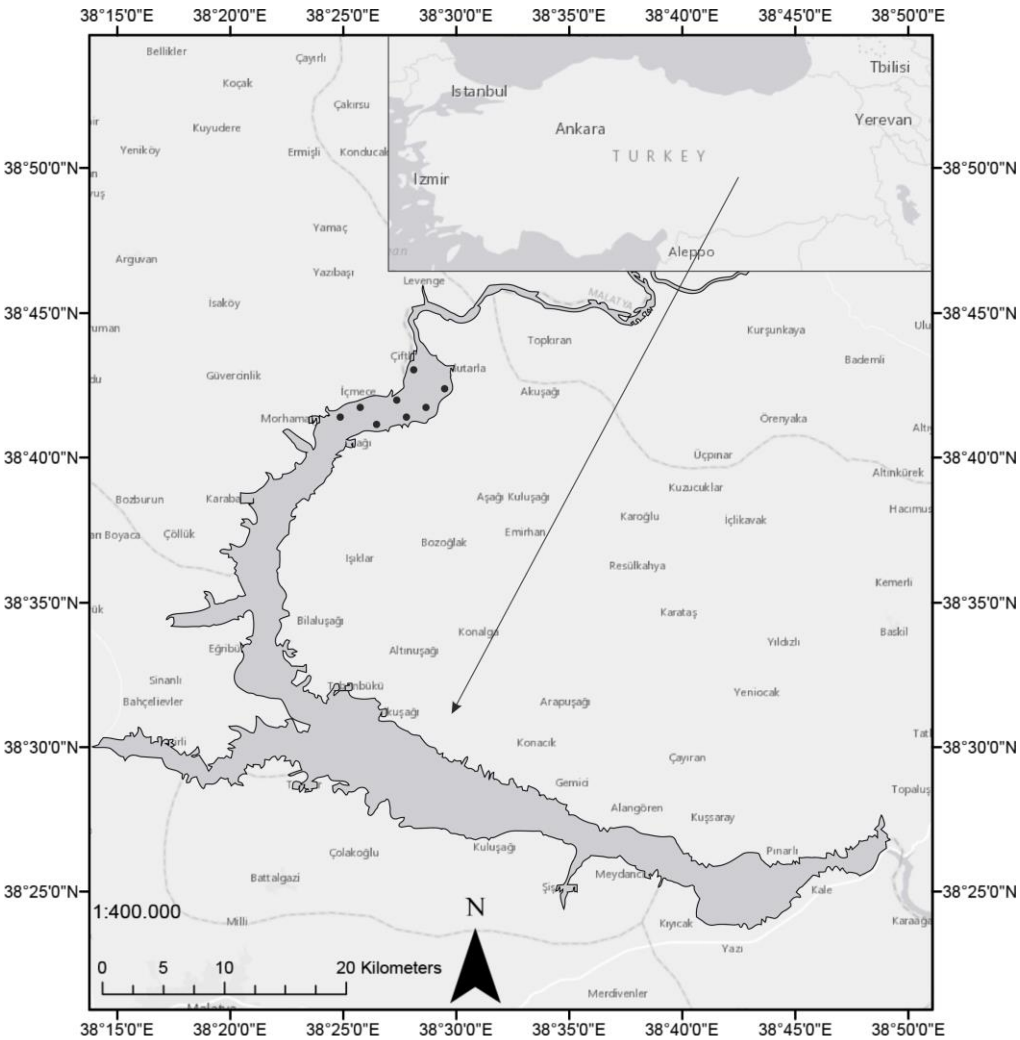

Figure 1. Study area and fishing station in Karakaya Dam Lake, Region 10.

From May 2013 to April 2014, a total of 24 fishing trips were carried out twice per month by the same three anglers at Karakaya Dam Lake, Region 10 (Figure 1). The depth of the fishing areas varied between 2–15 m, based on samplings conducted by three anglers using identical hook sizes (i.e. 2, 3 and 4). For the experimental angling sessions, three anglers with similar levels of experience were selected. The duration of each sampling was fixed and limited to 4 hours. Experimental trials were carried out at 08:00 and 12:00 a.m. A technical plan of the fishing line of the spinner used is shown in Figure 2. The spinner hook sizes were approximately No2 = 2 cm, No3 = 3 cm and No4 = 4 cm (Figure 1). The total length (TL) of all individual samples was measured to the nearest 0.1 cm using a 100 cm ruler, and weight (W) was measured using a digital scale with a precision of 0.1 g.

The CPUE and YPUE values, calculated with the formula recommended by Godøy *et al.* (2003) and customized by Aydın (2011), are presented below.

$$CPUE=\frac{\sum n}{\sum number\ of\ hooks\ x \sum (fishing\ trials\ x\ angling\ time)}$$

$$YPUE=\frac{\sum weight}{\sum number\ of\ hooks\ x \sum (fishing\ trials\ x\ angling\ time)}$$

Condition factor (K) was calculated according to Fulton (1911); the relevant equation is shown below.

$$K=\frac{W}{L^3}x100$$

W= Weight (g) L= Total length (mm)

To determine the differences in CPUE, YPUE and K value by different hook sizes, a one-way ANOVA test was used. To perform a statistical analysis, R version 3.1.2 (R Development Core Team, 2013) software was used.

The SELECT method was used to determine the selectivity of each hook type (Millar, 1992; Millar and Holst, 1997; Millar and Fryer, 1999). This method assumes that the number of fish of a particular length lj (j = 1, 2, 3, ... n) caught with a hook size m_i (i = 1, 2, 3, … k) has a Y_{lj} Poisson distribution, defined by the following equation:

$$[Y_{lj} \sim P_0(p_j.\ \lambda_l)]$$

where λl is the abundance of fish size l caught on the hook; pj (l) is the relative fishing intensity (the relative abundance of fish size l that j hook size can catch). The Poisson distribution of the number of fish size l caught by fishing gear with J hook size is defined as $[N_{lj} \sim P_0\ (P_j.\lambda_l.r_l(J))]$and is the selectivity curve for j hook size (Acarlı *et al.*, 2013; Öztekin *et al.*, 2014).

The log-likelihood of n_{lj} is as follows:

$$L=\sum_{l,j}(n_{lj}.\log(v_{lj})-v_{lj}=\sum n_{lj}\left[\log(p_j)+\log(\lambda l)+\log(rj(l))\right]-p_j.\lambda_l.r_j(l)$$

The most suitable model was chosen as the one with the lowest deviation. Model equations of the SELECT method are as follows:

Normal Location:

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

Normal Scale:

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

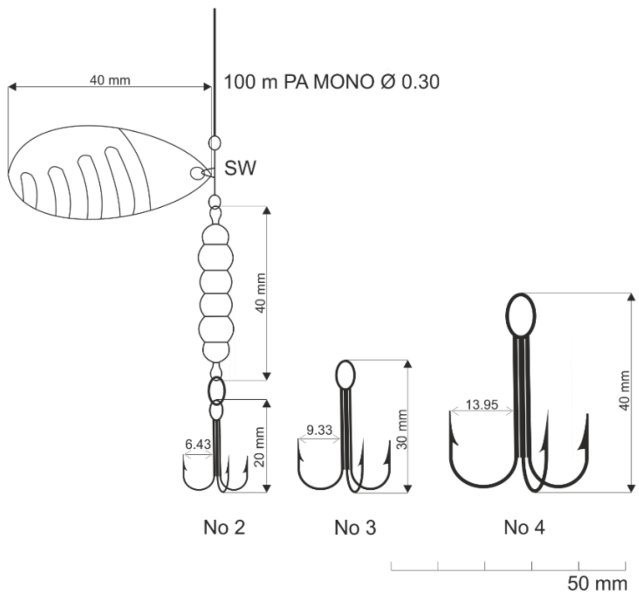

Figure 2. Technical plan of spinner used in experiment.

Gamma:

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

Log-Normal:

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

Bi-modal:

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

The Kolmogorov-Smirnov (K-S) test was used to determine differences between size frequency distributions of fish caught by hooks of varying sizes (Siegel and Castellan, 1989; Karakulak and Erk, 2008; Aydın, 2011).

Results

A total of 202 *O. mykiss* were caught via a spinner fishing technique during the study. These fish ranged in size from 145 to 460 mm TL and number (50, 88 and 64), mean lengths 24.8 ± 0.6 cm, 27.7 ± 0.5 cm and 29.3 ± 0.6 cm for hook sizes 2, 3 and 4, respectively. Numbers, sizes and weights of catches for each hook size are presented in Table 1.

There were significant differences in the average total length of retained fish according to different hook sizes, especially hook No2, which caught fish that were smaller than those caught by No3 and No4 (Figure 3).

The CPUE value increased in proportion to increases in hook size. There were statistically significant differences between different hook sizes and the CPUE values ($P<0.05$). It is thought that, in this case, the samples would yield more large fish than small fish in this location. Similarly, the YPUE value also increased in proportion to increases in the hook length. We detected significant differences on the hook sizes with the No2 hook versus the No3 and No4 hooks by an ANOVA test ($P<0.05$). However, there were no statistical differences in the fish-condition factor based on different hook sizes (Table 2) ($P>0.05$).

Although the number of fish caught did not change based on the hook size ($P>0.05$), the No3

Table 1. Descriptive statistics of catch by different hook sizes

Hook	Total length (cm)				Total Weight (g)		
Number	N	Mean	Min.	Max.	Mean	Min.	Max.
2	50	24.8 (0.6)	14.5	32.4	196.4 (13.5)	30.2	411.3
3	88	27.7 (0.5)	17.4	46.0	278.5 (20.6)	63.4	1320.2
4	64	29.3 (0.6)	19.5	40.9	328.1 (24.7)	60.4	1020.4

Standard errors are in parentheses.

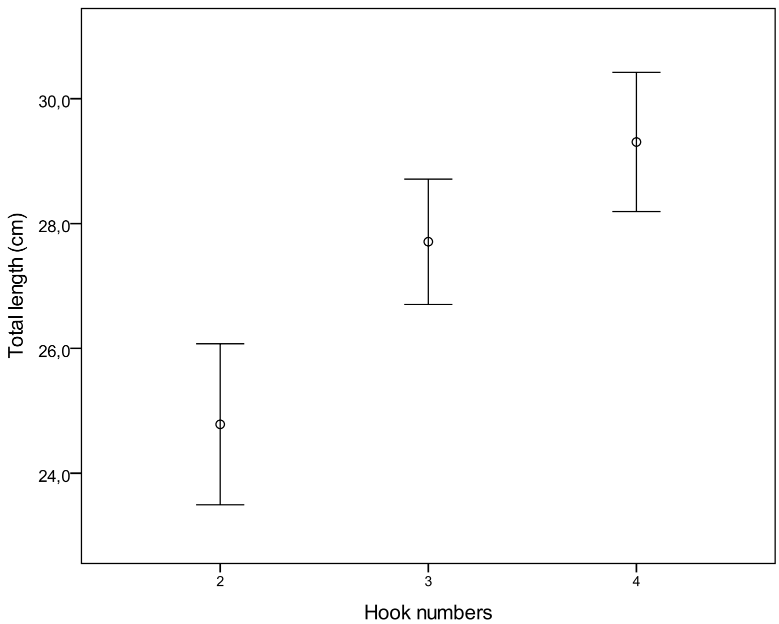

Figure 3. Average total length and the error bars plot by different hook sizes.

hook was found to be more effective in terms of catching efficiency (Table 1). On the other hand, hook size had a significant effect on the length of the fish caught ($P<0.05$), according to variance analyses results that examined different hook sizes in relation to the CPUE value. The length of fish caught increased along with an increase in hook size (Table 2).

The selectivity parameters for equal catch efforts were estimated with five models (Table 3). A log-normal model was accepted as a compatible model because its deviance is the lowest. Selectivity curves and deviance residuals of the model are shown in Figure 5 and in Figure 6, respectively.

The optimum length and spread values calculated by the log-normal model (shown in Table 4) were found to be 18.28, 27.41 and 36.55 cm for No2, No3 and No4 hook sizes, respectively.

According to the K-S test result (Table 5), there were significant differences in the length frequency distributions of fish captured with hook size No2 when compared with those of No3 and No4, but significant differences were not observed in the length frequency distributions of fish captured with hook sizes No3 and No4 (Figure 4). This finding is consistent with the ANOVA test results.

Table 2. Comparison of CPUE, YPUE and K value by different hook sizes via one-way ANOVA test

Parameter	Hook No	Mean+SE	df	MS	F	p
	2	$0.174 (0.03)^{a}$	2	0.054	3.292	0.05
CPUE	3	$0.224 (0.03)^{b}$				
	4	$0.307 (0.05)^{ab}$				
	2	$34.08 (6.80)^{a}$	2	8516.07	5.435	0.009
YPUE	3	$85.09 (14.18)^{b}$				
	4	$72.91 (12.02)^{b}$				
	2	1.167 (0.03)	2	0.002	0.059	0.943
K	3	1.169 (0.02)				
	4	1.178(0.02)				

Standard errors are in parentheses

Table 3. Results of the models fit using the SELECT method for hook sizes selectivity estimation

		Equal fishing power						
Model	Parameters	Estimates	Mode 1	Spread 1	Mode 2	Spread 2	Deviance	df
Normal location	k	8.80(0.28)	17.60(0.56)	8.66(0.82)	-	-	17.78377	28
	σ	8.64(0.82)						
Normal scale	k1	9.88(0.33)	19.768(0.67)	6.58(0.69)	-	-	18.33871	28
	k2	0.56(0.04)						
Lognormal	μ_1	3.01(0.03)	18.28(0.60)	7.35(0.94)	-	-	***15.03620***	28
	σ	0.33(0.03)						
Gamma	k	1.04(0.19)	18.79(0.62)	6.61(0.68)	-	-	15.60996	28
	α	9.96(1.77)						
Bi-normal	k1	3.016	18.29(0.16)	7.36(0.19)	159.06(-)	80.82(-)	15.03970	25
	k2	0.332						
	k3	5.154						
	k4	0.292						
	c	1.551						
		Fishing power α hook size						
Model	Parameters	Estimates	Mode 1	Spread 1	Mode 2	Spread 2	Deviance	df
Normal location	k	9.79(0.34)	19.59(0.69)	9.44(1.04)	-	-	17.66359	28
	σ	9.44(1.04)						
Normal scale	k1	10.91(0.31)	21.83(0.62)	6.22(0.58)	-	-	18.86084	28
	k2	9.69(1.83)						
Lognormal	μ_1	3.12(0.03)	20.41(0.71)	8.21(1.21)	-	-	15.03597	28
	σ	0.33(0.00)						
Gamma	k	1.04(0.19)	20.89(0.67)	6.94(0.76)	-	-	15.60996	28
	α	10.96(1.77)						
Bi-normal	k1	3.12	20.41(0.71)	8.21(1.22)	71.94(-)	7.20(-)	15.03599	25
	k2	0.33						
	k3	4.28						
	k4	0.09						
	c	2.40						

Standard errors are in parentheses.

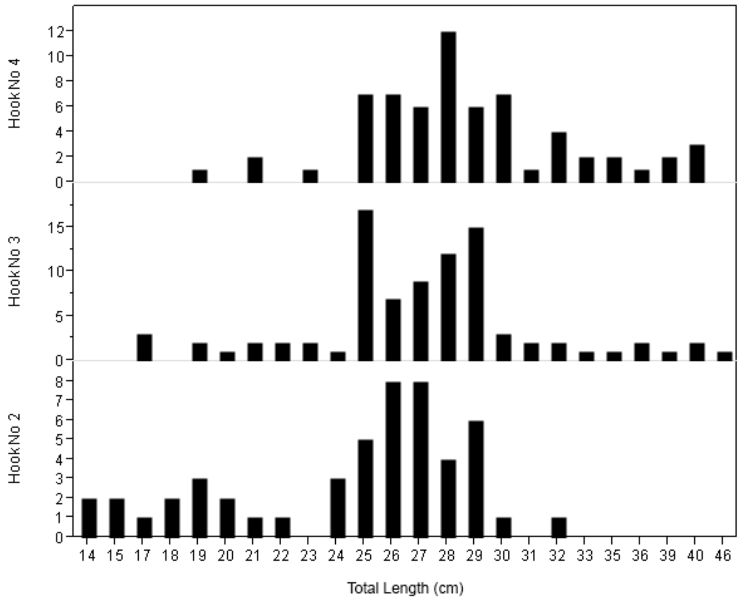

Figure 4. Length- Frequency of *O. mykiss* by different hook sizes.

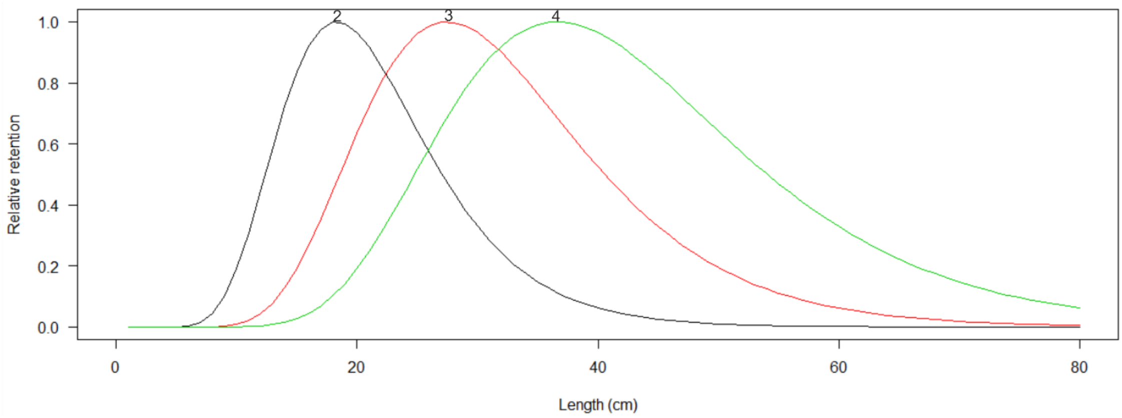

Figure 5. Selectivity curves of hook sizes for the *O. mykiss*.

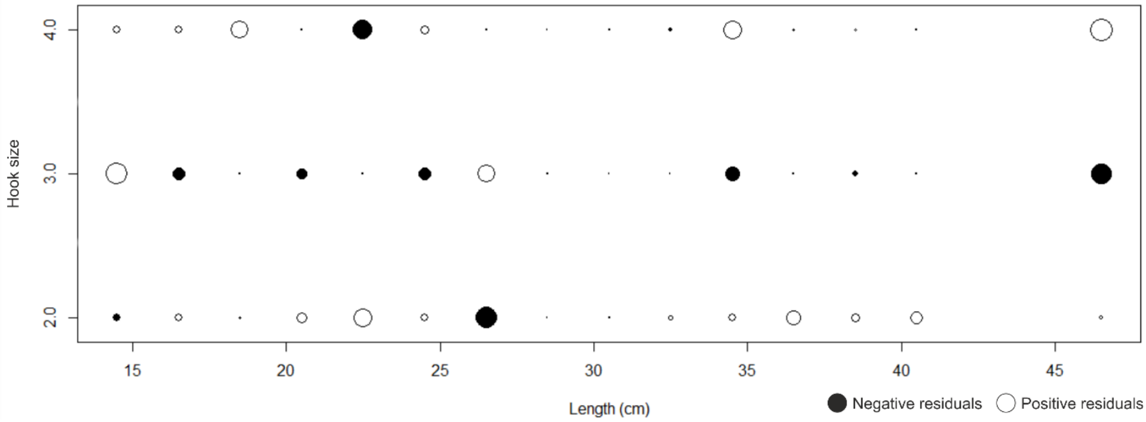

Figure 6. Deviance residuals of hook sizes for the *O. mykiss.*

Discussion

The selectivity of fishing gear is an important fishery management tool in terms of giving at least once changes of reproduction to fish. In many parts of the world many studies have been done on the selectivity of various fishing gear, but there has been no research on the selectivity of spinner hook size,

Table 4. The optimum lengths and spread values of *O. mykiss* according to the lognormal (it has lowest deviance value)

Hook Number	Model Length (cm)	Spread Value (cm)
2	18.28	7.30
3	27.41	10.95
4	36.55	14.60

Table 5. Result of the K-S test used to compare length frequency distributions of catch

		Kolmogorov-Smirnov Test		
Hook 1	Hook 2	D max	Critical Values (α=0.05)	Decision
2	3	0,2600	0.2389	H_0Reject
2	4	0.4071	0.2534	H_0Reject
3	4	0.2119	0.2196	H_0Not Reject

H_o: There are no significant difference between length frequency distributions (α=0.05, K=1.36).

although spinner hooks are the most important fishing gear used in recreational fishing. When amateur fishermen, who's number more than commercial fishermen, are taken into account, the importance of this study is evident.

Estimates of size selectivity of fishing gear provide important information regarding the conservation of fishery resources (Czerwinski *et al.*, 2010). Moreover, fishing-gear selectivity is one of the most important pieces of information needed to manage a fishery and is used to detect the minimum catchable length for the purpose of determining the target species and, subsequently, the gill-net mesh size (Sparre *et al.*, 1989) and in determining the hook size (Czerwinski *et al.*, 2010; Öztekin *et al.*, 2014).

Researchers have conducted much research on the topic of amateur fishing, especially with respect to the *O. mykiss* species. These researches generally focused on the effects of fishing hooks on fishing efficiency, catch and release (Meka, 2004), hook injury and hook damage (DuBois and Dubielzig 2004); however, studies on the selectivity of hook size are limited. In this study, the selections of the spinner hook sizes used were made according to the SELECT method. It is necessary to take into account selectivity studies in terms of fishery management. The size of the spinner hook is recommended to be smaller than No3.

The results obtained in this study revealed that hook size affected the size of the captured fish, consistent with other selectivity studies. This study also showed that hook size compliancy was different for each population: the number of captured fish in this study was 50 with an No2 hook, 64 with an No4 hook and 88 with an No3 hook. This result shows us that the size distribution in a population has an important effect on the catchability of fish based on different hook sizes. Consequently, more studies should be done on the selectivity of different fishing gear in the context of fishery management in Turkey.

Öztekin *et al.* (2014), in a study of *Phycis blennoides* in Saros Bay, conducted research on the selectivity of bottom longlines using the SELECT method and found that 6, 7, 8 and 9 hook sizes were optimal for capturing fish with lengths of 48.45, 41.49, 37.44 and 32.35 cm, respectively. Amarasinghe *et al.* (2011) studied *Caranx ignobilis* and *Carangoides gymnostethus*in terms of hook selectivity [a modification of Baranov-Holt's method for gill-net selection (Baranov, 1914; Holt, 1963) was employed, as explained by Pauly (1984)]; L_{op} size for *C. ignobilis* 8, 9, 10 and 11 mm hook sizes, respectively, for capturing fish with lengths of 16.7, 22.4, 27.1 and 33.9 cm; *C. gymnostethus* for 10, 11, 12 and 13 mm hook sizes, respectively, for capturing fish with lengths of 29.9, 39.1, 45.9 and 56.9 cm. The authors found a relationship between optimum size of capture and hook size. In this study, we found that the optimal hook sizes for capturing fish with lengths of 18.28, 27.41 and 36.55 cm, are No2, No3 and No4, respectively. These results are consistent with those of Oztekin *et al.* (2014) and Amarasinghe *et al.* (2011). Our study showed that the selectivity curve has quite a wide size range (Figure 5), a finding that is similar to that reported by Campbell *et al.* (2014) regarding *Rhomboplites aurorubens*, *Lutjanus campechanus* and hook types and which conforms to the selectivity curves.

The *O. mykiss* is not a species native to Karakaya Dam Lake and was introduced after the activities of the trout aquaculture in a net cage. The fish have an important place in the day-to-day fish populations of dam lakes; thus, it is very important, in terms of economic value, for fish to be brought into recreational fisheries (Ateşşahin *et al.*, 2011). Cilbiz *et al.* (2015) reported that gill-nets are not efficient for *O. mykiss* fishing and recommended that angling should be encouraged for this species in dam lakes. There are no legal-length regulations (minimum landing size) on *O. mykiss* fishing in Turkey, because, according to the circular (Turkish Amateur Fishery Regulations No: 2012/66), which regulates recreational fisheries, fish classified in unfavourable species categories have ecological aspects that must be considered. However, fishing for *O. mykiss* that are of less than a portion-size weight (180–200 g) may be a troublesome situation in terms of a bioeconomic approach. The portion length of *O. mykiss* has been reported as 27.04 cm (total length) in Karacaören I Dam Lake by Cilbiz *et al.* (2015). In this context, hooks less than No3 (3 cm) should not be used in *O. mykiss* fishing in Karakaya Dam Lake.

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