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RESEARCH PAPER

Gillnet Selectivity Estimating for Sustainable Stock Management of Endemik Tarek (*Alburnus tarichi* Güldenstädt, 1814) Population in Lake Van (Eastern, Turkey)

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Abstract

This study was carried out to estimate the selectivity properties of gillnets for Tarek (*Alburnus tarichi* Güldenstädt, 1814) in Lake Van, Turkey. The Tarek is the most fished freshwater fish species in Turkey. The study was carried in 2021 fishing season at seven different sampling locations in the lake. Gillnet selectivity estimated was based on eight different gillnet mesh sizes (i.e. 1.25, 1.6, 2.0, 2.5, 3.1, 3.9, 4.4, 4.8 cm). The *SELECT* method was used to determine the selectivity parameters. According to the gamma model, optimum modal lengths for 1.25, 1.6, 2.0, 2.5, 3.1, 3.9, 4.4 and 4.8 cm mesh sizes were estimated as 6.61, 8.46, 10.58, 13.22, 16.39, 20.62, 23.27 and 25.38 cm respectively. When considering the minimum landing size, the findings of the study showed that use of gillnets which have less than 3.9 cm mesh size should be prohibited for the fishing of *A. tarichi* in Lake Van.

Introduction

Global capture production in 2018 was 96.4 million tons in total and 12 million tons (12.5%) of this production was obtained from inland fisheries. The significantly increased production between 1896 and 2015 has been in the range of 10.6 – 12.0 million tons in recent years (FAO, 2020). Although their share of the total production is low, inland water-based fisheries provide an important food source for many local communities, such as in many areas of Asia (FAO, 2020). Inland water-based fisheries production in Turkey in 2018 was 33,119 tons and corresponds to only 0.25% of global production, and Tarek (*Alburnus tarichi*, Güldenstädt, 1814) accounts for 9,945 tons (33.0%) of the total national catch (TurkStat, 2022). The contribution of *A. tarichi,* which constitutes the largest fish stock in Turkey's inland waters in terms of production in 2021 to the country's economy, was approximately USD$ 6.7 million. *A. tarichi* is an important source of protein in eastern Turkey and is directly or indirectly the source of livelihood for 20,000 people living in the region (Akkuş, 2021; Oğuz, 2013).

A. tarichi, a member of the cyprinidae family, is an endemic fish species that lives only in the Lake Van Basin. Although the amount of production is higher than other inland fish species, *A. tarichi* was declared by the *IUCN* (International Union for Conservation of Nature) red list as "Near Threatened" in 2013 (Freyhof, 2014). In this process, an approximately 60% decrease has been observed in the annual production amount in the following years, which reached the maximum level of 21,000 tons in 1997 (FAO, 2022).

The fact that *A. tarichi* continues to survive in a closed and restricted basin and is frequently exposed to human-induced interventions, (overfishing, catching during the reproductive period, pollution, habitat destruction) seriously jeopardizes the sustainability of its population. Fish stocks in inland waters are more sensitive to overfishing because they are in a smaller habitat than marine ecosystems (Akkuş, 2021). In this context, in addition to planning balanced fishing in terms of the sustainability of the species, it is extremely important to use fishing gear with appropriate size selectivity. In this way, it is ensured that small fish that have not reached the minimum length at first maturity are excluded from the catch composition and each fish is allowed to reproduce at least once. However, the most important criterion in achieving this goal is that the size selectivity of the fishing equipment should be investigated properly, and the results should be put into practice. Juvenile fish under the minimum landing size *(MLS)* are defined as bycatch by FAO (2011). Both FAO and the European Commission encourage the practice of more selective fishing practices to reduce or eliminate bycatch (Pérez Roda et al., 2019; Suárez et al., 2021).

In Lake Van, legal *A. tarichi* fishing is performed with gillnets year-round, except during the reproductive period (April 15-July 15). To date, only one study has been conducted on the selectivity of gillnets in *A. tarichi* fisheries. The selectivity of trammel nets with 17 and 22 mesh sizes was investigated by (Çetinkaya et al., 1995) according to the Holt (1963) method. The first study carried out under the technological conditions of that period should be revised with today's modern equipment and methods to better understand the gillnet selectivity in *A. tarichi* fishing. The Holt (1963) method was evaluated as restrictive by Balık (2008). Recently, the *SELECT* method has been widely used in gillnet selectivity studies (Aydın et al., 2018; Cilbiz et al., 2017; Dereli et al., 2022; Shoup & Ryswyk, 2016; Tesfaye, 2019). The European Union has published a standard in this regard to prevent the use of different methods in fish sampling from lakes (EN 14757), thus enabling all member countries to adhere to the same methodology and to compare the results of the study homogeneously. Unlike the previous study, our study was conducted within the framework of "EN 14757" standards. This study aimed to determine the minimum mesh size to be used in fishing to ensure the sustainability of the endemic *A. tarichi* population in Lake Van.

Material & Methods

Study Area

The study was conducted in Lake Van, Turkey's largest lake with a surface area of 3,712 km² (38.32-39.00ºN and 42.29-43.65ºE). The water of the lake is highly alkaline and salty with a pH between 9.7-9.9 (‰ 22) (Akkuş, 2021). In this context, the lake is not biologically suitable for living beings. However, *A. tarichi* has been able to adapt to the lake and form the most productive inland fish population in the country. The biodiversity of the lake is significantly different from both freshwater and marine environments.

Sampling and Data Collection

Sampling methods and equipment in line with the European Standard methodology EN 14757:2015 (Water quality - Sampling of fish with multi-mesh gillnets) which was determined by the European Union for pelagic sampling were used during fishing. These nets are designed to catch freshwater fish of all sizes and types. According to the standard, each gillnet consists of 12 panels with a mesh size (knot to knot) ranging from 0.5 cm to 5.5 cm. However, the smallest mesh (0.5 m) has been excluded, because it has not been possible to manufacture 0.5 cm panels mesh as deep as 6 m. The mesh widths increase by a rate of some 1.25 by EN 14757 standards. A panel with 2.2 cm mesh size, which is not normally within the standard, was added to the group as an extra due to commonly used by local fishermen. These nets are made of homogeneous monofilament nylon single twine. Technical specifications of the pelagic experimental nets are given in Table 1. The hanging ratio was 0.5 for all mesh sizes.

A combined gillnet with a length of 30 m float line was obtained by connecting 12 different panels, each with 2.5 m lead line length, as given in Table 1. A total of 4 combined gillnets were used for the study. With

Table 1. Technical specification of pelagic experimental gillnets

Number of panels in net	Mesh size (cm)		Thread diameter (mm)	Length of buoyancy line (m)	Length of lead line (m)	Depth o panel (m)
	Knot to knot	Stretched mesh				
1	4.3	8.6	0.20	2.5	3	6
2	1.95	3.9	0.15	2.5	3	6
3	0.625	1.25	0.10	2.5	3	6
4	1.0	2.0	0.12	2.5	3	6
5	5.5	11.0	0.25	2.5	3	6
6	0.8	1.6	0.10	2.5	3	6
7	1.25	2.5	0.12	2.5	3	6
8	2.4	4.8	0.17	2.5	3	6
9	1.55	3.1	0.15	2.5	3	6
10	3.5	7.0	0.20	2.5	3	6
11	2.9	5.8	0.17	2.5	3	6
12	2.2	4.4	0.17	2.5	3	6

experimental gillnets with a total length of 120 m, fishing operations was performed at 7 different locations (mean depth was 13.5 m) of the lake in the 2020 fishing season. The soak time was an average of 12 h. The total length (*TL*) of all caught fish was measured at a precision of 0.5 cm.

Selectivity and Data Analysis

As indirect estimation method, *SELECT* (Share Each Length's Class Catch Total) method was used to determine selectivity (Millar, 1992; Millar & Fryer, 1999; Millar & Holst, 1997). Data were analysed in RStudio software by using R codes developed by Millar (2015, 2017). 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 model parameters were primarily estimated for gillnet with lowest mesh size (1.25 cm) and the selection curves for all other mesh sizes scale proportionally to mesh size with 1.25 cm (Park *et al.,* 2011). The most suitable model was chosen taking into account the lowest deviation value.

ANOVA with the *Tukey*^{HSD} test was used to compare fish lengths according to mesh sizes. In the evaluation and visualization of the data, *ggstatsplot v 0.9.1* (Patil, 2021*), agricolae v* 1.3-5 (Mendiburu, 2021), *ggplot2 v 3.3.*5 (Wickham, 2016*)* R packages were used. RStudio (v 2021.09.0) program was used for statistical computations. In previous studies, length data values given as fork length were converted to total length by using the total length - fork length relationship (*TL*=1.058FL+0.5025) equation reported by Bostanci and Polat (2011) for *A. tarichi*, in order to be comparable with our study. 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

Catch Composition

As a result of fishing trials, a total of 1737 *A. tarichi* were caught, ranging between 5.5 and 25.5 cm in total length. Fish were mainly caught by gilling. The nets with 5.8, 7.0, 8.6 and 11.0 cm mesh size had no catches. The proportional distribution of the catch according to the net panels was found to be 0.3%, 0.5%, 0.5%, 24.8%, 23.3%, 20.4%, 23.6% and 6.6% for the nets with mesh size of 1.25, 1.6, 2.0, 2.5, 3.1, 3.9, 4.4 and 4.8 cm, respectively. In this context, gillnets of 1.25 cm mesh size were determined to be the most inefficient while the 4.4 cm mesh size was determined to be the most efficient panel. An increase was observed in the average total length of the catch, as a result of the increase in the mesh size (Figure 1). The differences between the average lengths of the catch according to the mesh size was found to be statistically significant ($p<0.05$, Figure 1). While the mean and median values were found to be quite close to each other in all other nets except the 2.0 cm mesh size, the median value was 8.0 cm, the mean value was 10.1 cm, and the standard deviation of the mean was 3.27 with this net.

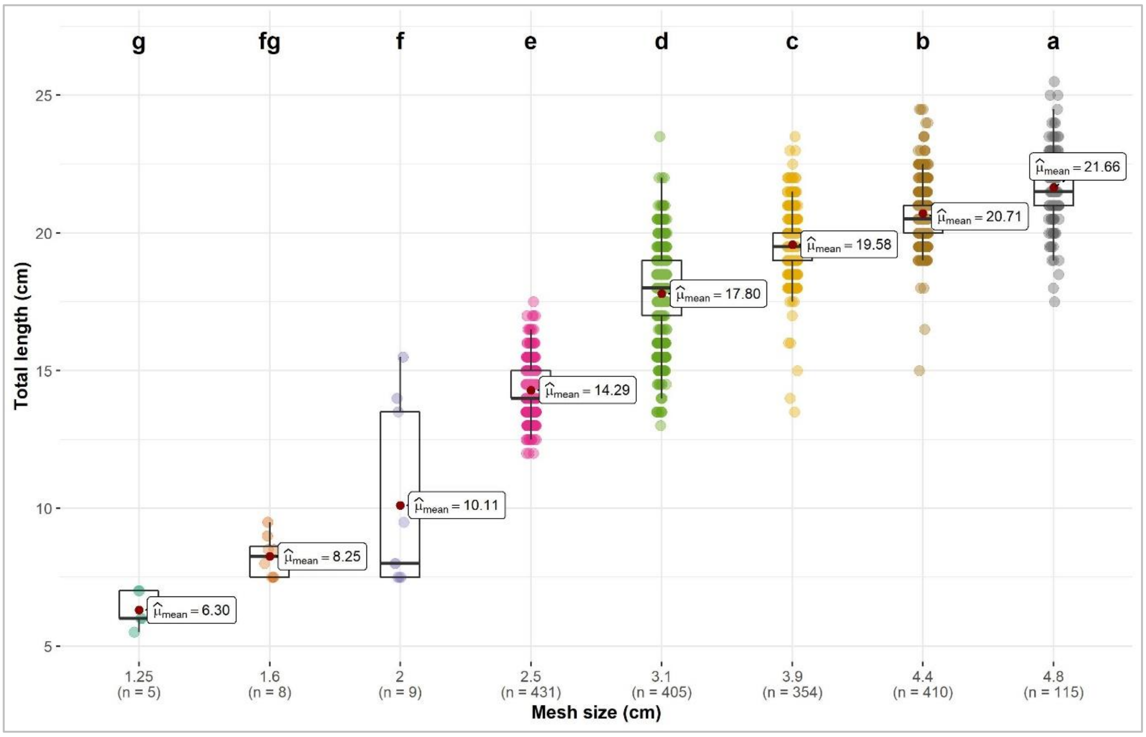

Figure 1. Mean total length of *A. tarichi* by trial net mesh size (different letters represent statistically significant differences between mesh sizes).

The length distribution of the catches according to the mesh size and the *MLS* (18 cm *TL*) are given in Figure 2. It can be seen that the effectiveness of EU standard nets in *A. tarichi* increased significantly for 2.5 cm mesh and greater mesh sizes. All of the nets with a mesh size of 1.25 – 2.5 cm caught fish below *MLS*. Fish over *MLS* (>18 cm) started to be caught with the 3.1 cm mesh size, and the rate of undersized fish in the catch started to decrease significantly with the 3.9 cm mesh size.

Selectivity Properties

Normal location, normal scale, lognormal, gamma and *bi-normal* model parameters are given in Table 2 according to Equal fishing power and Fishing power α mesh size. According to Equal fishing power, the modal lengths predicted for the 1.25 cm mesh size varied between 6.39 and 6.70 cm, and the spread values varied between 0.75 and 2.05 cm. The *gamma* model with the lowest deviation was determined to be the most suitable model for the current data set. On the other hand, the dispersion parameter (deviance/d.f.) was found to be above 1 for all models.

In the deviance residual plots given in Figure 3-A, it is seen that negative (open circles) and positive residuals (filled circles) are more or less equal for all mesh sizes. In the selectivity curves drawn according to the *gamma* model with Millar's R functions, it is predicted that the trial nets of 1.25 – 3.1 cm mesh size, caught *A. tarichi* under *MLS* and the other nets caught marketable sized *A. tarichi* (Figure 3-B).

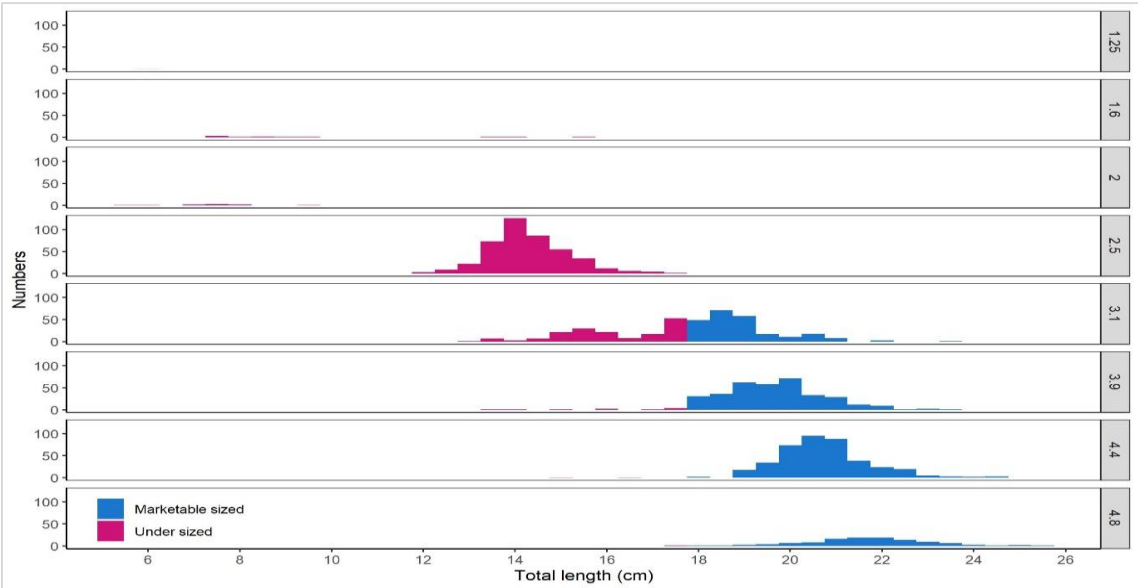

Figure 2. Length frequency distribution of *A. tarichi* by trial net mesh size and MLS.

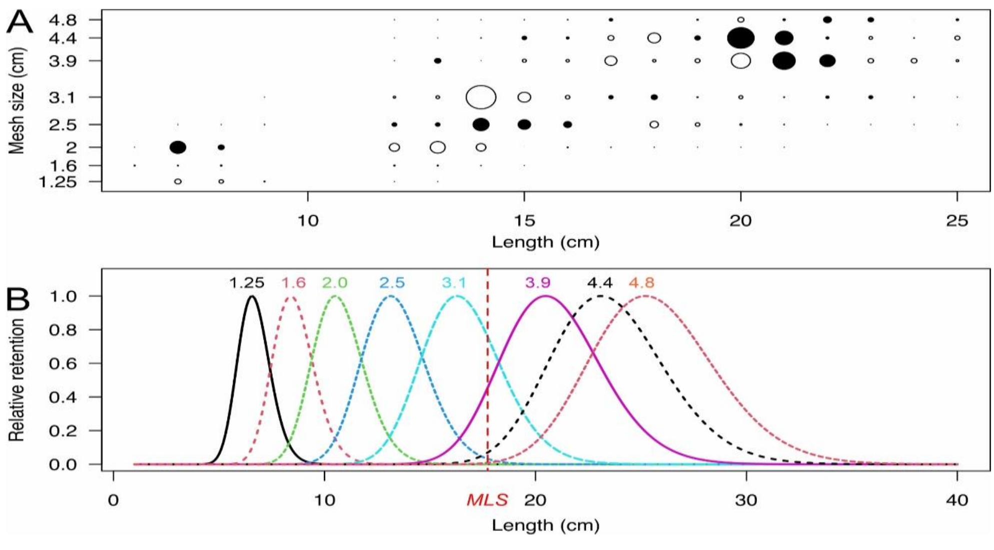

Figure 3. A: Deviance residual plots (open and filled circles correspond to negative and positive residuals, respectively, with the size of the circle proportional to the square of the residual) and B: Selection curves of gillnets for *A. tarichi* (vertical dashed red line represented as *MLS*).

Table 2. Selectivity model parameters of *A. tarichi* and estimated selection curves for the 1.25 cm mesh size

Model	Parameters	Equal fishing power						
		Estimates	Mode 1	Spread 1	Mode 2	Spread 2	Deviance	df
Normal location	k	5.11(0.01)	6.39(0.02)	2.05(0.03)	-	-	723.16	124
	σ	2.05(0.03)						
Normal scale	k_1	5.35(0.01)	6.70(0.02)	0.75(0.01)	-	-	543.96	124
	k_2	0.35(0.01)						
Lognormal	μ_1	1.90(0.00)	6.57(0.01)	0.77(0.01)	-	-	550.12	124
	σ	0.11(0.00)						
Gamma	k	0.07(0.00)	6.61(0.02)	0.76(0.011)	-	-	541.73	124
	α	77.78(2.71)						
Bi-normal	k_1	1.47	No fit	No fit	No fit	No fit	No fit	No fit
	k_2	0.02						
	k_3	1.90						
	k_4	0.11						
	c	-2.76						
Model	**Parameters**	**Fishing power α mesh size**						
		Estimates	Mode 1	Spread 1	Mode 2	Spread 2	Deviance	df
Normal location	k	5.18(0.05)	6.48(0.02)	2.09(0.03)	-	-	743.80	124
	σ	2.09(0.04)						
Normal scale	k_1	5.41(0.02)	6.77(0.02)	0.74(0.01)	-	-	544.17	124
	k_2	0.35(0.01)						
Lognormal	μ_1	1.91(0.00)	6.65(0.02)	0.78(0.02)	-	-	550.12	124
	σ	0.11(0.00)						
Gamma	k	0.07(0.00)	6.69(0.02)	0.76(0.01)	-	-	541.73	124
	α	78.88(2.71)						
Bi-normal	k_1	1.47	No fit	No fit	No fit	No fit	No fit	No fit
	k_2	0.02						
	k_3	1.90						
	k_4	-0.11						
	c	-2.76						

Table 3. Modal length and spread values of *A. tarichi* according to the *gamma* model for fitted to the experimental gillnet data

Mesh size (cm)	Modal Length (cm)	Spread Value (cm)
1.25	6.61	0.76
1.6	8.46	0.97
2.0	10.58	1.22
2.5	13.22	1.52
3.1	16.39	1.88
3.9	20.62	2.37
4.4	23.27	2.68
4.8	25.38	2.92

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

Net 1	Net 2	K-S Test	Decision	Net 1	Net 2	K-S Test	Decision
1.25	1.6	0.6000<0.7753	H_0 not reject	2.0	3.1	0.3333<0.4583	H_0 not reject
1.25	2.0	0.6000<0.7586	H_0 not reject	2.0	3.9	0.3390<0.4591	H_0 not reject
1.25	2.5	0.6000<0.6117	H_0 not reject	2.0	4.4	0.4122<0.4583	H_0 not reject
1.25	3.1	0.6000<0.6120	H_0 not reject	2.0	4.8	0.3333>0.4707	H_0 not reject
1.25	3.9	0.6000<0.6125	H_0 not reject	2.5	3.1	0.4672>0.0941	H_0 reject
1.25	4.4	0.6000<0.6119	H_0 not reject	2.5	3.9	0.4891>0.0976	H_0 reject
1.25	4.8	0.6000<0.6213	H_0 not reject	2.5	4.4	0.4919>0.0938	H_0 reject
1.6	2.0	0.1528<0.6608	H_0 not reject	2.5	4.8	0.4919>0.1427	H_0 reject
1.6	2.5	0.4919>0.4853	H_0 not reject	3.1	3.9	0.2222>0.0990	H_0 reject
1.6	3.1	0.3750<0.4856	H_0 not reject	3.1	4.4	0.3406>0.0953	H_0 reject
1.6	3.9	0.3750<0.4862	H_0 not reject	3.1	4.8	0.2846>0.1437	H_0 reject
1.6	4.4	0.4122<0.4855	H_0 not reject	3.9	4.4	0.2097>0.0987	H_0 reject
1.6	4.8	0.3750<0.4973	H_0 not reject	3.9	4.8	0.2781>0.1460	H_0 reject
2.0	2.5	0.3808<0.4580	H_0 not reject	4.4	4.8	0.2818>0.1435	H_0 reject

The estimated modal lengths and spread values for the 1.25 cm mesh size panel were adjusted to the other panels used in the sampling and the results are given in Table 3. All panels (1.25, 1.6, 2.0, 2.5, 3.1 cm) with a mesh size less than 3.9 cm, caught fish below *MLS* in the application, according to all the estimated modal lengths. The *K-S* test showed differences between some paired comparisons of length frequency distributions of different mesh sizes of gillnets (Table 4).

Discussion

A total of 1737 *A. tarichi* were caught in the study period, which is quite a large sample size compared to other inland water selectivity studies (Cilbiz et al., 2017, Dereli et al., 2022, Yüksel et al., 2020). The total length range of the population, which was 5.5 - 25.5 cm in the study, while ranges of 15.3 – 25.9 cm (Çetinkaya et al., 1995), 15.6 – 20.8 cm (Bostanci & Polat, 2011), 14.3 – 25.4 cm (Sarı, 2001) were reported in other studies (converted from fork length). When the results of other studies are compared with the current study, it is seen that there is a significant difference in minimum lengths, although the maximum lengths are similar. This is thought to be due to the sampling methodology. In this context, it can be said that the sampling made according to EN 14757:2015 standard, strongly represents the fish population size structure in inland water environments.

It has been observed that there is a steady increase in the average length of the catch with the increase in the mesh sizes (Figure 1), and this is considered an indicator of the success of the length selectivity of the trial nets in the fishing of this fish species. This result is consistent with other similar studies (Aydın et al., 2018; Cilbiz et al., 2017; Hanol et al., 2015).

In the length distribution of the fish taken from different panels (Figure 1), the mean and median values were found to be quite close to each other in all nets except the 2.0 cm mesh size, while the median value was 8.0 cm, the mean value was 10.1 cm, and the standard deviation of the mean was 3.27 in this net. This may be due to operational errors (the entanglement of the net, insufficient tension, etc.) or sample insufficiency due to the size distribution of the population.

Since the length-frequency distribution of the fish is evaluated according to the mesh sizes (Figure 2), it is observed that there is a steady increase in the size distributions in line with the increase in the mesh sizes; in case the catch is evaluated according to *MLS*, it exceeds the marketable length in all (mesh sizes greater than 3.1 cm). In our study, compared to other studies (Cilbiz et al., 2014; Cilbiz et al., 2017; Hanol et al., 2015), it is seen that the length-frequency distributions of the catches taken from panels with different mesh sizes, are significantly different from each other. It is thought that the main reason for this may be due to the sampling methodology applied and the body structure of the species studied. It is seen that the population representation ability of EN 14757:2015 standard, which is based on a constant rate of increase between panels, is quite successful. In other studies, the same unit increase was applied to all trial panels without applying a standard rate. For example, Cilbiz et al. (2017) increased the mesh opening by 1 cm for all panels (4, 5, 6, 7, 8, 9 cm); Aydın et al. (2018) increased the mesh opening by 2 cm for all panels (4, 6, 8, 10 cm); and Dereli et al. (2022) increased the mesh opening by 0.5 cm for all panels (6.5, 7.0, 7.5, 8.0 cm). This is because there is no constant increase between the mesh openings. This resulted in a high increase in small-meshed nets (e.g. an increased rate of 1.50 from 2 cm to 3 cm mesh sizes) and a low increase in large-meshed nets (an increased rate of 1.125 from 8 cm to 9 cm mesh sizes).

In line with the selectivity parameters given in Table 1, it is seen that the dispersion parameter is above 1 for all models. This indicates an over-dispersion. Over-dispersion indicates either lack of fit or violation of the assumption of an underlying Poisson distribution (Holst et al., 1998; Tesfaye, 2019). In the majority of other studies conducted on gillnet selectivity, it is seen that the dispersion parameter is above 1 (Cilbiz et al., 2017; Dereli et al., 2022; Xu et al., 2021; Yüksel et al., 2020).

In the previous study, Çetinkaya et al. (1995) reported the modal lengths as 17.1 and 22.0 cm (converted from fork length) for 1.7- and 2.2-cm mesh sized (knot to knot) trammel nets. The small difference in modal lengths, which is quite similar to our study results, is thought to be due to the selectivity model applied (Holt (1963) - *SELECT*) and the structural differences of the nets (gillnet-trammel net).

Conclusion

In commercial *A. tarichi* fishing in Turkey, the *MLS* is 18 cm total length (Anonymous. 2020). On the other hand, in studies conducted on the reproduction biology of different *A. tarichi* populations in the Lake Van Basin, the *length* at first maturity (L_{50}) of the species was reported as 13.68, 11.61 and 13.5 cm *TL* (converted from fork length) for Lake Van, Koçköprü Dam Lake and Lake Nazik, respectively (Elp, 1996; Elp, 2002; Kocabaş and Çetinkaya, 2011). In this context, it can be said that the 18 cm *TL MLS* length applied is well above the *length* at first maturity (L_{50}) of *A. tarichi*. Consequently, considering both *MLS* length and length at first maturity of the species, gillnets below 3.9 cm mesh size should not be used in *A. tarichi* fishing.

Ethical Statement

Not applicable

Funding Information

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Author Contribution

Ferhat Demirol collected the data. Mehmet CİLBİZ analysed the data. Mehmet CİLBİZ wrote the first draft of the manuscript. Mehmet CİLBİZ and Ferhat Demirol contributed to manuscript revision, and read and approved the submitted version.

Conflict of Interest

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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