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Review Article

An Overview of Gillnet and Trammel Net Size Selectivity in the Turkish Inland Fisheries

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ABSTRACT

This study compiled and remodelled length selectivity studies carried out on fish caught with gill nets and trammel nets in the inland fishery in Türkiye and evaluated them based on both the initial reproduction length and minimum landing size of species. The required data for the study were obtained through a literature review. 34 selectivity studies in total were identified, and 26 (76.5%) of them were carried out with gill net while the remaining 8 (23.5%) were conducted with trammel net. 24 of the studies were carried out according to *SELECT* (Share Each Length-class's Catch Total) and 10 of them according to Holt (1963). In conclusion, it was found that minimum conservation reference size (*MCRS*) values determined by the Ministry in the inland fishery in Türkiye were substantially greater than lengths at first maturity (*LFMs*) of species and that fishing gears used for fishing typically tended to fish mature individuals above *MCRS*. The major problem in terms of management is that different ideal mesh sizes are applied to different fish species that are in the same fishing place. Set nets with an ideal-mesh size for a species has a potential of catching individuals below *LFM* of other species in the same fishing grounds. It is thought that this problem can only be resolved with the Ecosystem Approach to Fisheries Management (*EAFm*).

Keywords: Inland fisheries, Length at first maturity, Minimum conservation reference size, Small scale fisheries, Sustainable fishery

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INTRODUCTION

Inland fisheries are defined as "any activity conducted to extract fish and other aquatic organisms from inland waters" by *FAO* (1997), which has vital importance for especially low-income developing countries in the world, as it supports the livelihood of 60 million people and is a source of food for hundreds of millions more (Moutopoulos et al., 2022; Smith et al., 2005; World-Bank, 2012). In addition to nutritional value, inland fisheries are important for poverty alleviation, gender empowerment, cultural services, ecosystem function and biodiversity (Funge-Smith and Bennett, 2019). Inland fisheries provide employment to millions of people in the world (Rabuffetti et al., 2022). The global capture fisheries production was 90.3 million tonnes in 2020, 12.7% of which was obtained from inland fisheries (FAO, 2022). The ratio of inland based capture fisheries production of Türkiye is almost 9.1% of the total production (Anonymous, 2021).

In general, inland fisheries are undervalued and ignored as a national or regional priority, despite their importance, however most sustainably generated source of animal protein of the world may be well-managed inland fisheries (Cooke et al., 2016; Moutopoulos et al., 2022). Marine-based fisheries are always very popular among managers and scientists due to their economic importance; however, inland fisheries are also quite important as marine fisheries in terms of considerable livelihood impacts in some countries (such as Bangladesh, Myanmar, Uganda, Nigeria, Cambodia, etc.)

Lakes, rivers, streams, canals, reservoirs, and other land-locked waters are defined as inland waters (FAO, 2014; Lynch et al., 2016). Commercial inland fishing occurs on mainly lakes and dam lakes. Fisheries cooperatives or private entrepreneur have to take a licence from Ministry of Forestry and Agriculture and should be pay a hire charge to the government. A total of 87 dam lakes, 16 natural lakes and three rivers were licenced by the ministry for fish production to inland fishermen in 2022 (fisheries cooperatives hired 82 fishing areas, while private entrepreneurs hired 24) (Anonymous, 2022a). Although Türkiye has 320 natural lakes (Anonymous, 2022b), the majority of them dry up in the summer, making them unsuitable for fisheries. The most important inland fishing areas of Türkiye are Van Lake (eastern Anatolia, 3, 713 km^2), Beyşehir Lake (southwestern Anatolia 656 km^2), Eğirdir Lake (south-western Anatolia 482 km^2), Atatürk Dam Lake (south-eastern Anatolia, 817 km^2), Keban Dam Lake (eastern Anatolia, 675 km^2) and Ilısu Dam Lake (south-eastern Anatolia, 313 km^2).

Inland fisheries are carried out in a small-scale (*SSFs*) concept in Türkiye. Using the efficient fishing gears, such as purse seine and trawl are banned in inland fisheries by legislation. The Turkish inland fisheries fleet consists of 3181 vessels, 97.36% of them are less than 10 m (Anonymous, 2021). Gillnets (tarek, common carp, gibel carp, pikeperch), trammel nets (common carp, gibel carp, European catfish), fyke nets (crayfish, European ell, northern pike), long lines (northern pike, pikeperch) and beach seines (sand smelt) are used by fishermen for catching the aquatic species. Most (94.0%) of the species caught from Türkiye's inland waters are fish, while others are crayfish, crabs, frogs, and snails (Turkstat, 2022).

Capture based inland fisheries production has decreased in Türkiye year by year; the total production declined 22.75% from 2000 (42,824 tonnes) to 2020 (33,119 tonnes). Increased fishing pressure, damming of rivers, deforestation, water pollution, and inadequate practices for managing fisheries are serious challenges to the sustainability of the inland waters (Barletta et al., 2010; Rabuffetti et al., 2022); however, managing the harvest of freshwater species is important for both food security and reducing biodiversity loss (Shephard et al., 2022; Tickner et al., 2020)

It is very important to use selective fishing gears for the sustainability of the natural fish stock in addition to determining the maximum sustainable yield (*MSY*) or the total allowable catch (TAC). Removing non-target species and under-sized fish that have not yet reproduced from the catch composition can only be achieved using the high size and species-selective fishing gear.

Gill nets (*GNs*) and trammel nets (*TNs*) which are widely used especially in developing countries in small-scale fishery because they are productive and relatively cheap (Acosta and Appeldoorn, 1995) are widely used by fishermen in the inland fishery in Türkiye. Set nets (*GNs* and *TNs*) rigged with monofilament material are typically preferred by fishermen instead of those rigged with multifilament material because they are (i) relatively cheap, (ii) long-lasting, (iii) resistant to contamination, (iv) easy to carry due to their lightness, (v) not gaining weight by taking in water when they are in the water.

In gilling type fishing, small fish may escape from the gill nets as they pass through the mesh and big fish may do the same as their heads do not fit into the mesh (Pope et al., 1975), in this case, gill nests can only catch a range of length where mesh size is larger than the fish head but smaller than fish body (Yüksel and Aydın, 2012). If a suitable mesh size is determined, both fish which are below the initial reproduction length and which have high reproduction potential (super-spawners) will be concurrently protected (Cilbiz et al., 2022). For this reason, set net selectivity parameters are extremely important scientific data for sustainable management of the natural fish stock. Both the FAO and the European Commission encourage the use of more selective fishing practices to reduce or eliminate bycatch and improve sustainability (Pérez Roda et al., 2019; Suárez et al., 2021).

Despite being highly selective, set nets to be used for species having different minimum landing sizes (MLS) (or in other words length at first maturity) are likely to capture bycatch. Therefore, knowing about the interaction between the species fished, minimum landing sizes and mesh sizes will significantly contribute to the maintenance of stocks. In this context, this study compiled and remodelled size selectivity studies conducted on the commercial fish species in the inland fishery in Türkiye and evaluated based on both the initial reproduction size and minimum landing size of species.

MATERIAL AND METHODS

Review of set net fishing technology and selectivity properties

Certain technical characteristics of *GNs* and *TNs*, and data needed for setting forth the model used for determining selectivity and the results achieved were obtained through literature review. To this end, peer-reviewed scientific journals and grey literature (e.g. conference proceedings, scientific research project final reports) that published the results of studies performed in the inland fishery in Türkiye were searched. In this section, (i) manufacturing technique for set net (gill net or trammel net), (ii) mesh size of nets tested (*MS*: stretched mesh size in mm), (iii) estimated model length for respective *MS* (*ML*: in cm) and (iv) methods used for modelling selectivity were investigated.

Review of biological - administrative reference points and commercial fish species

Conformity of estimated model lengths with the biological characteristics of species needs to be set forth in order to reveal the contribution of the results of selectivity studies to the sustainability of stocks. In this context, a literature review was made to (i) determine the commercial species in Türkiye, (ii) for which of the commercial species *GNs* and *TNs* selectivity studies are carried out, (iii) present lengths at first maturity (*LFM*) and (iv) minimum conservation reference sizes (*MCRS*) for those species. In case of presence of multiple studies on the same species, the most recent study was taken into account. Data needed were taken from peer-reviewed scientific journals, governmental institutions' data and legislation review.

Statistical approach

The relationship between MS and ML values obtained in selectivity studies was explained using simple linear regression model in the study. The model is described as follows;

$y = b.x + \mathcal{E}$

where:

y: denotes the response variable (MS)

x: denotes the predictor variable (ML)

b: the regression coefficient

$\mathcal{E}$: is the measurement error and any variation unexplained by linear model

For species with only one study, linear regression parameters were taken as basis, however, data were bootstrapped in case of presence of two or more studies. A simple linear regression based bootstrapping resampling method was used for estimating the uncertainties for reported selectivity data. 1000 times bootstraps were applied on *MS~ML* data by using tidymodels (v1.0.0) (Kuhn and Wickham, 2020) in RStudio software.

The ideal MS were computed by using regression model parameters for reference point *LFM* and *MCRS* separately. In case of existence of a legal length limit, *LFM* was primarily taken into account; if there was no available *LFM* value determined for a species, then *MCRS* was taken as the valid biological reference point.

RESULTS

There are almost 20 different fish species caught in Türkiye's inland fisheries (excepting the lagoon areas and other aquatic products such as crustaceans) by the 2021 data, and total production was 30,309 tonnes (Turkstat, 2022). It is determined that selectivity studies were conducted for 14 different fish species *Arabibarbus grypus, Alburnus tarichi, Blicca bjoerkna, Capoeta antalyensis, Cyprinus carpio, Carassius gibelio, Capoeta umbla, Esox lucius, Luciobarbus esocinus, Rutilus rutilus, Oncorhynchus mykiss, Scardinius erythrophtalmus, Sander lucioperca,* and *Vimba vimba*). In this context, it can be said that the set net selectivity is known for 70.0 % of caught fish species.

As a result of the literature review, 34 set net selectivity studies were identified in total. 26 (76.5%) of these studies were carried out with *GNs* and the remaining 8 (23.5%) were carried out with *TNs* (Table 1). 24 of the studies were conducted according to *SELECT* (Share Each Length-class's Catch Total) and 10 of them were conducted according to Holt (1963). As for the number of studies per species; 10 studies were carried out for *C. carpio*, seven for *C. gibelio*, four for *S. lucioperca*, two for *E. lucius*, two for *A. tarichi* and one study for each of all other species. When looked at the methods used for estimating selectivity, it was seen that *SELECT* (Share Each Length-class's Catch Total) method was widely preferred (70.6%) and Holt (1963) method was partly (29.4%) preferred (Table 1). Minimum conservation reference sizes (*MCRS*) determined for species by the Ministry of Agriculture and Forestry were found to vary between a total length range of 18 to 50 cm and no *MCRS* was determined for six species (*B. bjoerkna*, *C. gibelio*, *R. rutilus*, *O. mykiss*, *S. erythrophtalmus* and *V. vimba*) (Anonymous, 2020). Length at first maturity values were known for a major portion (76.9%) of species for which a set net length selectivity study was performed whereas only for three species (*A. grypus*, *B. bjoerkna* and *C. antalyensis*) *LFM* values were not known. *MS* of *GNs* used in selectivity study varied between 16-200 mm while *MS* of *TNs* varied between 34-160 mm (Table 1). Despite being the second mostly fished species in inland fishery in Türkiye, no *MCRS* was determined for *C. gibelio*. In this study, 25 cm of minimum economic length arising under market conditions was considered *MCRS*. For species for which more than one *LFM* reporting was provided for the same species and for species for which separate *LFMs* were reported for female-male individuals in the same study, the lower value was preferred as the reference *LFM* value with a protectionist approach. For example, out of *LFM* values reported by Yüce et al. (2016) as 30.85 for male individuals and as 32.01 for female individuals of *C. carpio*, the lower value proposed for male individuals was taken as reference.

The ideal mesh size for fishing the relevant species was determined in line with the results of the selectivity study (Table 2). In calculations carried out based on *MS~ML* relationship, *MCRS* value was primarily taken as basis as the point of intersection, and *LFM* value was used in the absence of *MCRS*.

As there were adequate number of studies for the species of *C. carpio* (*GNs-TNs*), *C. gibelio* (*GNs-TNs*), *E. lucius* (*GNs*), and *S. lucioperca* (*GNs*), ideal mesh sizes were determined according to bootstrap analysis (Figure 1). Ideal mesh sizes of other species given in Table two were determined according to simple linear regression model. Although there were 2 studies for *A. tarichi*, the fact that only two panels were used in the study carried out by Çetinkaya et al. (1995) made bootstrapping of data impossible. For this reason, the ideal mesh size for the species *A. tarichi* was given according to simple linear regression model. The ideal mesh size could not be modelled for *B. bjoerkna* which has neither an *MCRS* value nor an *LFM* value although a selectivity study was conducted on it. It was seen that *MCRS* values declared for all other species except for *C. umbla* were higher than (*C. carpio, C. gibelio, E. lucius, S. lucioperca*, *A. tarichi*) or equal to (*A. grypus, L. esocinus*) *LFM* values.

When *MS~ML* relationship graphs given in Figure 1 are reviewed, it is seen that confidence interval for *TNs* is wider compared to that of *GNs* considering the studies carried out on the same species. Mesh sizes of the nets used for *E. lucius* ve *S. lucioperca* selectivity are smaller than those of the nets used for *C. carpio* ve *C. gibelio* (Figure 1).

In order to observe which net mesh size corresponds to which reference point of which species; model lengths of set nets according to species and reference points (*MCRS - LFM*) are given as a whole in Figure 2. A green shaded area remaining on the right of the orange region for the same species means a greater *MCRS* than *LFM* for the species in question (i.e. *MCRS/LFM* is greater than 1). Disappearance of green shaded area may result either from the fact that *LFM* of the species is not known or *MCRS* limit is not available in commercial fishing (e.g. *R. rutilus*, *S. erythrophtalmus*, *V. vimba*). The most notable point in Figure 2 is that modelled mesh size which is in the confident area for a species corresponds to the unconfident area for another. For example, mesh size of 52.9 mm which is considered ideal for *S. lu-*

Table 1. Summary of the selectivity studies and the parameters considered for the analysis.

Gear	Species	*MCRS* (cm)	*LFM* (cm)	*MS* (mm)	*ML* (cm)	*Sel EM*	Reference
GNs	*Arabibarbus grypus*	45	-	40-80	40.12-80.24	Sel	(Anonymous, 2020a; Yuksel et al., 2020)
TNs	*Alburnus tarichi*	18	13.68	34-44	15.7-20.3	Holt	(Anonymous, 2020a; Çetinkaya et al., 1995; Elp, 1996)
GNS	*Alburnus tarichi*	18	13.68	16-48	8.5-25.4	Sel	(Anonymous, 2020a; Demirol and Cilbiz, 2023; Elp, 1996)
GNs	*Blicca bjoerkna*	-	-	40-52	9.8-13.8	Holt	(Balık and Çubuk, 2001)
GNs	*Capoeta antalyensis*	20	-	32-90	14.8-41.7	Sel	(Cilbiz and Yalım, 2017)
GNs	*Cyprinus carpio*	40	30.85	40-140	12.4-43.4	Sel	(Anonymous, 2020a; Aydın et al., 2016; Yüce et al., 2016)
GNs	*Cyprinus carpio*	40	30.85	130-160	53.3-65.6	Sel	(Anonymous, 2020a; Şen, 2016; Yüce et al., 2016)
GNs	*Cyprinus carpio*	40	30.85	140-200	56.9-84.2	Sel	(Anonymous, 2020a; Dereli et al., 2022; Yüce et al., 2016)
GNs	*Cyprinus carpio*	40	30.85	70-140	18.1-42-4	Holt	(Anonymous, 2020a; Balık, 1999a; Yüce et al., 2016)
GNs	*Cyprinus carpio*	40	30.85	56-90	17.6-27.5	Holt	(Anonymous, 2020a; Özyurt and Avşar, 2005; Yüce et al., 2016)
GNs	*Cyprinus carpio*	40	30.85	90-120	30.0-43.4	Holt	(Anonymous, 2020a; Yalçın, 2006; Yüce et al., 2016)
GNs	*Cyprinus carpio*	40	30.85	90-120	30.0-37.1	Holt	(Anonymous, 2020a; Dartay and Atessahin, 2017; Yüce et al., 2016)
TNs	*Cyprinus carpio*	40	30.85	100-140	39.1-54.7	Sel	(Anonymous, 2020a; Cilbiz, Küçükkara, et al., 2015; Yüce et al., 2016)
TNs	*Cyprinus carpio*	40	30.85	40-140	13.0-45.4	Sel	(Anonymous, 2020a; Aydın et al., 2016; Yüce et al., 2016)
TNs	*Cyprinus carpio*	40	30.85	130-160	50.8-62.6	Sel	(Anonymous, 2020a; Dereli et al., 2022; Yüce et al., 2016)
GNs	*Carassius gibelio*	25	9.7	32-90	8.8-24.7	Sel	(Balik et al., 2004; Cilbiz et al., 2014)
GNs	*Carassius gibelio*	25	9.7	32-90	8.7-24.6	Sel	(Balik et al., 2004; Cilbiz et al., 2014)
GNs	*Carassius gibelio*	25	9.7	40-100	12.3-30.7	Sel	(Aydın et al., 2018; Balik et al., 2004)
TNs	*Carassius gibelio*	25	9.7	100-140	24.9-34.9	Sel	(Balik et al., 2004; Cilbiz et al., 2014)
TNs	*Carassius gibelio*	25	9.7	100-140	27.2-38.1	Sel	(Balik et al., 2004; Cilbiz et al., 2014)
TNs	*Carassius gibelio*	25	9.7	100-120	23.8-28.5	Sel	(Balik et al., 2004; Korkmaz and Kuşat, 2014)
TNs	*Carassius gibelio*	25	9.7	40-100	12.0-30.1	Sel	(Aydın et al., 2018; Balik et al., 2004)
GNs	*Capoeta umbla*	20	23.3	56-76	26.0-35.3	Sel	(Anonymous, 2020a; Çoban et al., 2013; Gündüz et al., 2019)
TNs	*Capoeta baliki*	20	-	64-96	26.52-39.78	Sel	(Aydin et al., 2015)
GNs	*Esox lucius*	40	19.7	36-60	20.4-34.3	Sel	(Anonymous, 2020a; Balık, 2008; Balık et al., 2004)
GNs	*Esox lucius*	40	19.7	40-90	21.0-47.2	Sel	(Anonymous, 2020a; Balık et al., 2004; Cilbiz et al., 2017)
GNs	*Luciobarbus esocinus*	50	50	50-70	36.6-51.3	Holt	(Anonymous, 2020a; Eskandary et al., 2001; Yuksel et al., 2014)

Table 1. Continue.

Gear	Species	*MCRS* (cm)	*LFM* (cm)	*MS* (mm)	*ML* (cm)	*Sel EM*	Reference
GNs	*Oncorhynchus mykiss*	-	28.7	32-80	16.06-40.16	Sel	(Cilbiz, Yalım, et al., 2015; Wali et al., 2022)
GNs	*Rutilıs rutilus*	-	16.8	32-80	12.5-30.4	Sel	(Hanol et al., 2015; Tarkan, 2002)
GNs	*Scardinius erythrophtalmus*	-	19.2	40-52	12.6-16.5	Holt	(Balık and Çubuk, 2001; Tarkan, 2002)
GNs	*Sander lucioperca*	26	25.6	40-52	21.2-27.5	Sel	(Anonymous, 2020a; Ozyurt et al., 2011)
GNs	*Sander lucioperca*	26	25.6	32-90	16.3-45.8	Sel	(Anonymous, 2020a; Cilbiz et al., 2022)
GNs	*Sander lucioperca*	26	25.6	34-70	15.9-32.9	Holt	(Anonymous, 2020a; Balık, 1999b; Ozyurt et al., 2011)
GNs	*Sander lucioperca*	26	25.6	40-52	20.6-26.8	Holt	(Anonymous, 2020a; Kiyağa, 2008; Ozyurt et al., 2011)
GNs	*Vimba vimba*	-	12.23	32-90	12.9-36.4	Sel	(Cilbiz, Apaydın Yağcı, et al., 2015; Erol, 2019)

Gear: *GNs* (Gill nets) and *TNs* (Trammel nets; *MCRS*: Minimum Conservation Reference Size as total length; *LFM*: Length at First Maturity; MS: Mesh Size (intended as stretched mesh length, range min-max); *ML*: Modal Length (range min-max); *Sel EM* (Estimation Method): *SEL* (SELECT), Holt (Holt, 1963); Reference for *MCRS*, *LFM*, gear selectivity

Table 2. Some biological reference points and linear regression parameters modelling the relationship between mesh length and modal length for the species targeted by gears.

Species	Net type	*MCRS* (cm)	*LFM* (cm)	*MCRS / LFM* ratio	Ideal mesh size (mm) Mean *(CI 95%)*	Linear regression parameters			
						Intercept (*SE*)	Mesh (*SE*)	*p*	R^2
*C. carpio**	*GNs*	40	30.84	1.29	114.4 (111.0 – 117.8)	35.62 (3.12)	1.95 (0.07)	<0.001	0.94
*C. carpio**	*TNs*	40	30.84	1.29	112.2 (105.7 – 118.7)	20.58 (7.00)	2.25 (0.16)	<0.001	0.93
*C. gibelio**	*GNs*	25	10.67	2.34	86.7 (83.8 – 89.7)	3.52 (2.47)	3.34 (0.13)	<0.001	0.97
*C. gibelio**	*TNs*	25	10.67	2.34	93.5 (88.7 – 99.8)	-4.34 (9.35)	3.96 (0.32)	<0.001	0.90
*E. lucius**	*GNs*	40	24.54	1.62	75.0 (72.8 – 77.1)	-4.26 (2.22)	1.99 (0.07)	<0.001	0.98
*S. lucioperca**	*GNs*	26	22.00	1.18	52.9 (52.0 – 53.8)	1.42 (1.37)	1.95 (0.05)	<0.001	0.98
A. grypus	*GNs*	45	45	1.00	46.00	1.00 (5.00)	1.00 (9.00)	<0.001	1.00
A. tarichi	*GNs*	18	13.68	1.32	34.04	-0.002 (0.005)	1.89 (0.00)	<0.001	1.00
C. antalyensis	*GNs*	20	-	-	43.12	-0.001 (0.007)	2.16 (0.00)	<0.001	1.00
C. umbla	*GNs*	20	23.31	0.86	43.05	-0.006 (0.03)	2.15 (0.00)	<0.001	1.00
L. esocinus	*GNs*	50	50	1.00	68.28	0.018 (0.02)	1.37 (0.00)	<0.001	1.00
O. mykiss	*GNs*	-	28.7	-	57.17	0.006 (0.003)	1.99 (0.00)	<0.001	1.00
R. rutilus	*GNS*	-	16.8	-	42.48	-1.20 (9.10)	2.60 (4.10)	<0.001	1.00
S. erythrophtalmus	*GNs*	-	19.2	-	79.46	0.92 (1.28)	3.09 (0.9)	<0.001	1.00
V. vimba	*GNs*	-	12.23	-	26.66	-3.90 (2.01)	2.53 (7.93)	<0.001	1.00

* Ideal mesh size computed by using bootstrapped model for *MCRS* point; *GNs*: gillnets; *TNs*: trammel nets; *LFM*: length at first maturity: *MCRS*: Minimum conservation reference size.

cioperca is quite below the ideal mesh size for *C. carpio* with which it probably shares the same fishing grounds.

The selectivity indicator diagrams (Figure 3) used in this study which was developed by Lucchetti et al. (2020) for provide an immediate visual representation of whether a net can catch immature individuals. Figure 3 represents four catching scenarios. (*i*) The best scenario -catches mature individuals above the *MCRS*- (Figure 3- green area); (*ii*) discard scenario -catches mature individuals under the *MCRS*- (Figure 3- yellow area); (*iii*) worst case scenario -catches immature individuals under the *MCRS*- (Figure 3- red area); bad case scenario catches immature individuals above the *MCRS*- (Figure 3- pink area).

The selectivity indicator diagrams were applied for only *C. carpio* (*GNs-TNs*), *C. gibelio* (*GNs-TNs*), *E. lucius* (*GNs*) and *S. lucioperca* (*GNs*) for which we have enough studies (Figure 4). A shift towards the upper right quadrant was observed in density graphs for all net types, so it indicates that the nets catch mature individuals above the *MCRS* (Figure 3, Figure 4).

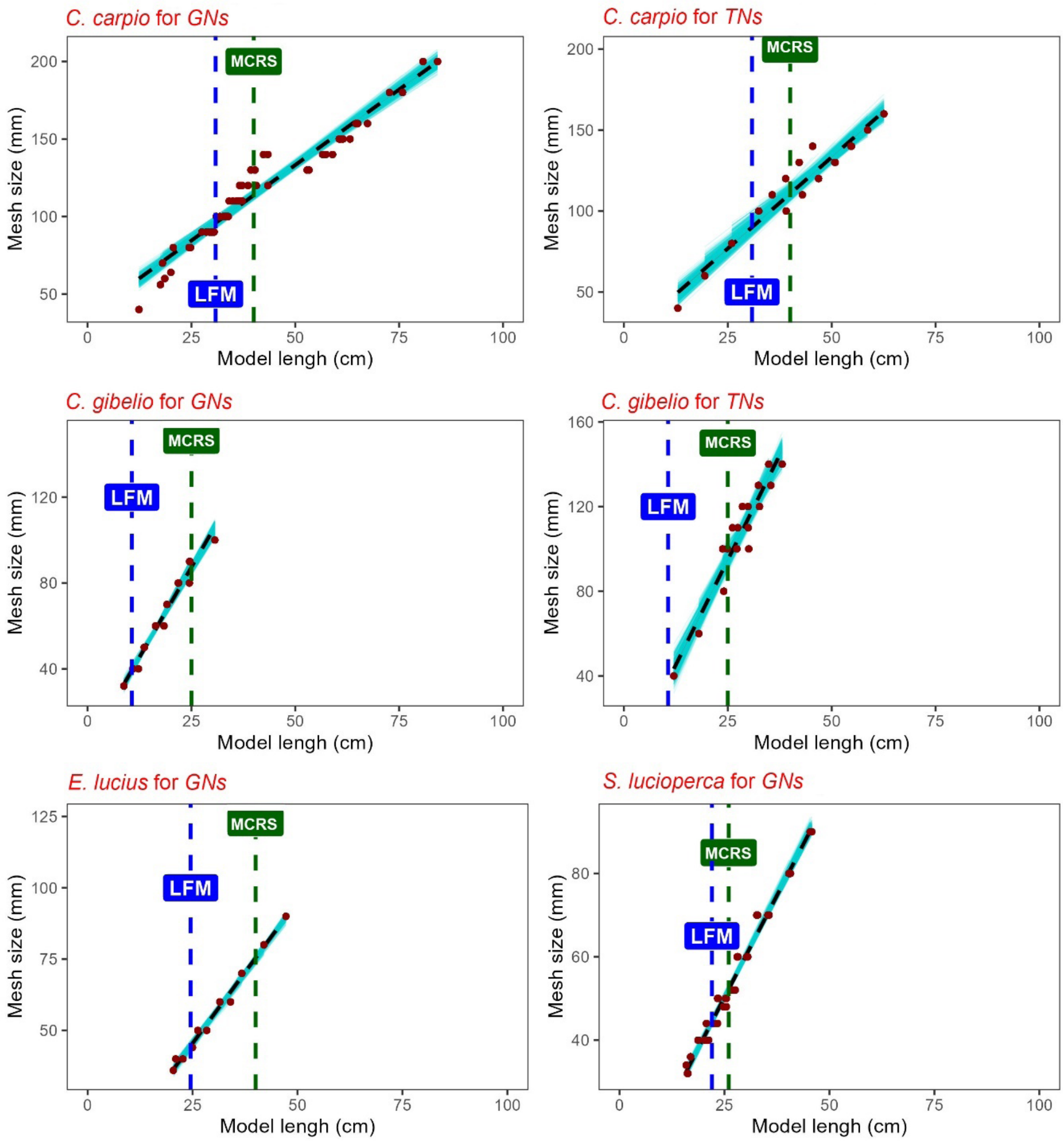

Figure 1. Relationship between mesh size and modal length in gillnets and trammel nets for the species that can be studied. (Shadowed area: 95% confidence interval; solid cyan; black dotted line: linear regression; blue dotted line: *LFM*; green dotted line: *MCRS* obtained from the review).

DISCUSSION

In the present study, in which selectivity features of *GNs* and *TNs* used in fishing 14 fish species in the inland fishery in Türkiye were evaluated, 34 set net selectivity studies were evaluated. The majority of the studies (75.7%) were carried out with *GNs*. Likewise, in a similar study conducted by Lucchetti et al. (2020), selectivity studies were found to be more common on *GNs* (65.0%) compared to *TNs* (35.0%). Specific to Türkiye, this is supposed to be related to cost. The cost to the fishermen of *TNs* made up by combining three different panels instead of *GNs* consisting of a single panel is higher; they prefer this cost only for fishing relatively bigger fish (e.g. *C. carpio*) which they have difficulty in fishing with *GNs*. The big *C. carpio* cause breakage of the net rope because of fluttering while they are caught in the form of gilling on the side of *GNs* and in this way they can break away from the net, however, this is not the case when they are caught with *TNs*. In support of this argument, Balık (1996) reports that *TNs* are more efficient than *GNs* in fishing *C. carpio*.

As for the number of studies per species, 10 studies were carried out for *C. carpio*, seven for *C. gibelio*, four for *S. lucioperca*, two for *E. lucius*, two for *A. tarichi* and one study for each of the other species. This distribution is supposed to be due to the generality across the country of the species in general and their share in total production. According to Turkstat (2022) data, the first four species that are mostly fished in the inland fishery in Türkiye in 2001 and their production amounts are *A. tarichi* (9925), *C.*

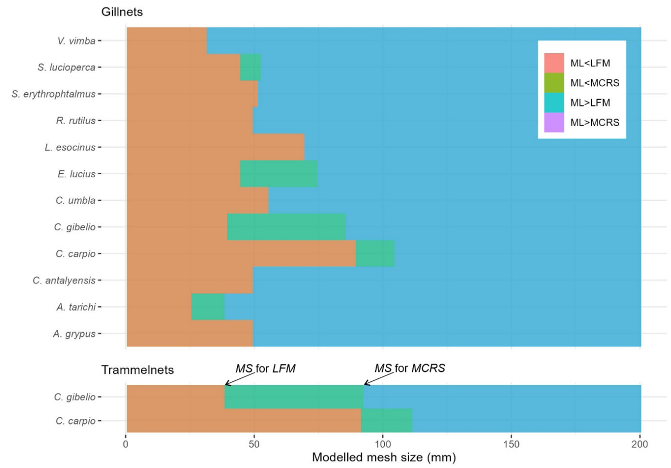

Figure 2. Ideal MS versus reference point comparison for different species (gillnets: upper; trammel nets: lower; MS: mesh size; LFM: length at first maturity; MCRS: Minimum conservation reference size).

Figure 3. Definition of theoretical selectivity indicator diagrams (Lucchetti et al., 2020) (*ML*: Modal length; *LFM*: Length at first maturity; *MCRS*: Minimum conservation reference size).

gibelio (8039 tonnes), *A. boyeri* (6404 tonnes) ve *C. carpio* (3212 tonnes). In fishing *A. boyeri* in Türkiye, the coastal beach seine is used rather than *GNs* and *TNs* (Cilbiz et al., 2020).

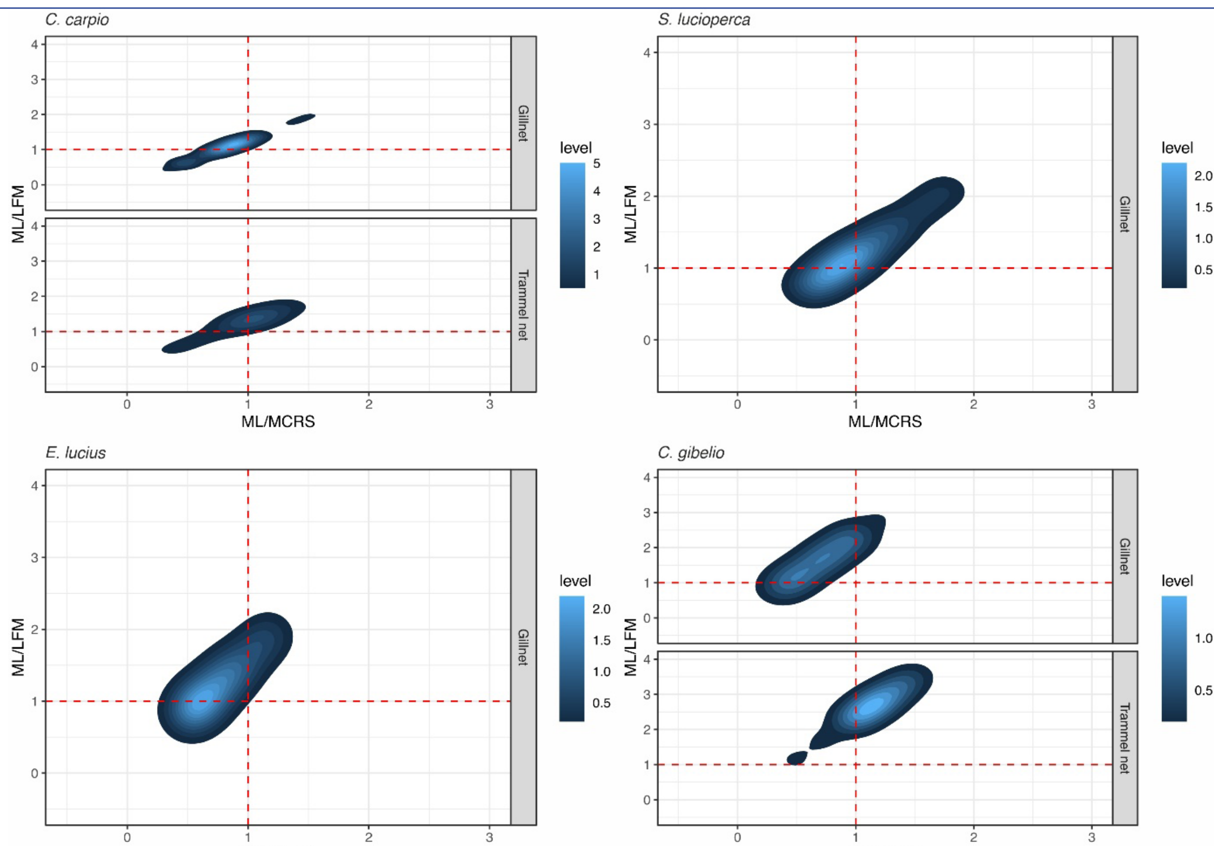

Figure 4. Selectivity indicator diagrams for the different species (*ML*: modal length; *LFM*: length at first maturity; *MCRS*: minimum conservation reference size).

Researchers mostly preferred *SELECT* method (69.7%) and partly Holt (1963) method (30.3%) in their studies for investigating *GNs* and *TNs* size selectivity. In general, it can be said that *SELECT* method was preferred in the more recent studies. This results from the fact that researchers prefer methods with relatively higher reliability within the framework of developing data evaluation technologies. According to Balık (2008), despite being one of the most widely used methods in set net selectivity, Holt (1963) is limiting; instead of it, the use of the *SELECT* method which is a statistical model estimating selectivity curve comparatively among different mesh size fishing and which provides an approach compatible with selectivity analysis has become widespread recently.

In this study, it was found that *LFM* for *A. grypus, B. bjoerkna* and *C. antalyensis* species is still not known and there is need for scientific studies for determining this value which is very important for sustainability of the species. On the other hand, there are species for which *MCRS* is not applied in commercial fishing although their *LFMs* are known (*C. gibelio, O. mykiss, R. rutilus, S. erythrophtalmus, V. vimba, A. boyeri*). There is no length limit in both amateur and commercial fishing for *C. gibelio, O. mykiss, A. boyeri* which are listed among the ecologically harmful (and potentially harmful species) for inland waters in Anonymous (2020b). In particular, although *C. gibelio* and *A. boyeri* that are among the first four species fished mostly in inland waters make significant contributions to the economy of both fishermen and the country, the fact that *MCRS* has not been declared for commercial fishing them may indicate that the ministry is not planning for the sustainability of natural stocks of these species.

The *MCRS* values declared for all species except *C. umbla* was found to be higher (*C. carpio, C. gibelio, E. lucius, S. lucioperca, A. tarichi*) than or equal (*A. grypus, L. esocinus*) to *LFM* value. In this context, the requirement that "the stock should find the chance of reproduction at least once before being caught for ensuring maintainability of the biomass" suggested by Beverton and Holt (1957) for a significant part of species is met in theory. However, whether determined legal regulations have been put into practice, in other words, whether fishermen comply with *MCRS* limits should be strictly inspected. Otherwise, no contribution should be expected from the criteria determined to the sustainability of natural fish stocks.

There is a selectivity study carried out by Balık and Çubuk, in 2001 for *B. bjoerkna*, however, it is a species with a very low economic value in the inland fishery in Türkiye and there is no legal length limit (*MCRS*) in fishing this species as it is often caught as a bycatch of other more important species; in addition, it was not subjected to further evaluation since no studies were found on the reproduction biology of the species.

When the relationship graphs given in Figure 1 are reviewed, it is seen that in general, the confidence interval for *TNs* is wider compared to that of *GNs* considering the studies carried out on the same species. This may be resulting from the higher spread value (*SR*) of *TNs* compared to that of *GNs* (from the fact that they capture a wider length range). In a study by Aydın et al. (2016), selectivity features of *GNs* and *TNs* with the same mesh size in fishing *C. carpio* were investigated and for nets with the mesh sizes of 40, 60, 80 and 100 mm, *SR* values for *GNs* were reported to be 1.10, 1.65, 2.20, 2.75 cm in the same order while *SR* values for *TNs* were reported to be higher being 1.37, 2.06, 2.74 ve 3.43 cm respectively. Similarly, Lucchetti et al. (2020) also state that out of the set nets, especially *GNs* have high selectivity.

Under the legislation regulating commercial fisheries in Türkiye (Anonymous, 2020a), minimum mesh size application in inland waters is in place for removing certain lengths of certain species from the catch composition. Minimum mesh size that can be used by fishers in fishing is determined by local administrative units. At this point, because the legal practice does not follow a strategy that is based on a scientific foundation, different mesh sizes are declared in different fishing places for the same species and this leads to discomfort among the fishers. This study has a lot of promise for overcoming this handicap. When looked at other countries where composition of species is wide, it is observed that a standard ideal mesh size cannot be determined as is the case in Türkiye. For example, in Greece, the mesh size of nets used by professional fishermen in inland fishing is required to be longer than 20 mm (bar length), however, this rule does not apply to *C. carpio* (55 mm), *Alburnus sp.* and *Atherina boyeri* (15 mm) (Petriki et al., 2014).

Consequently, it was found that *MCRS* values determined by the Ministry in the inland fishery in Türkiye are substantially greater than *LFMs* of species. In this context, it can be asserted that the criterion that species should find the opportunity of reproducing at least once before being fished is met, and that sustainability of fishery is significantly guaranteed. On the other hand, fishing gears used for fishing were found to be typically tending to fish mature individuals on *MCRS*. The major problem in the use of set net in the inland fishery in Türkiye is that different ideal mesh sizes are determined for different fish species that are in the same fishing place. A mesh size that is ideal for a species may have the potential of fishing individuals below *LFM* for another species in the same fishing grounds. For resolution of this problem, fishery management authorities are advised to determine vulnerable species (that are exposed to overfishing, economically much more valuable, among endangered species, of high importance in ecological terms) within the frame of fishing place-based on-site management and to determine mesh width based on the objective of protecting them to a minimum extent. This problem which is not very likely to be resolved with conventional fishery management focusing on single or targeted species is likely to be resolved with the Ecosystem Approach to Fisheries Management (*EAFm*) specifically recommended for inland fisheries by FAO (2021).

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