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Fish Morphology and Barrier Trap Bar Spacing in Lagoon Fisheries along the Aegean Coast of Turkey

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ABSTRACT

The most important fishing rule implemented in Turkish lagoon fishery is 3 cm minimum distance between the reeds (stick) of the barrier traps. Based on this arrangement, usually 3 cm bar spacing reeds and sometimes 3 cm square mesh wires are used in lagoon barrier traps. The body shape of fish may be the most important factor, necessary to understand the consequences of changes in barrier trap selectivity. For this reason, data were collected to determine the relevant dimensions of fish body in relation to openness of a barrier trap of coastal lagoons along the Aegean coast of Turkey in 2013. As Minimum Landing Size (MLS) was built on Total Length (TL) basis, regression analyses were carried out to find out the relationships between the TL and the other measured dimensions (width and height) of the fish using least-square regression. Morphometric measurements of fish species caught in barrier traps show a great variation. While all Common sole individuals pass from the 3 cm distance with its width, all Flathead grey mullet and European sea bass individuals retained. All Gilthead sea bream individuals under 25 cm TL pass the distance. However, many Golden grey mullet and European eel individuals retain. The implemented 3 cm bar spacing in Turkish lagoon barrier traps is thought to be suitable only for sea bass with a 1% reduction. However, the bar spacing is not suitable for Sea bream, Common sole, European eel, due to commercial loss, nor for Flat head grey mullet and Golden grey mullet due to capture of small individuals below their MLS. For this reason, a graded barrier system with different bar spaces or regulation according to the biology of the fish species and migration seasons can be suggested for sustainable lagoon fishery. In this respect, the continuously changing distance paradox in barrier traps will be overtaken in Turkey.

KEYWORDS: Aegean Sea, coastal lagoon, barrier trap, openness, fish morphology

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1. Introduction

Coastal lagoons are bodies of salt water (from brackish to hypersaline) partially separated from an adjacent sea by barriers of sand or sediment, with openings through which sea water can flow (Ardizzone et al., 1988). The brackish ecosystems are transitional waters (wetland) between inland and sea and receivers of nutrients of continental origin, are among the most productive water environments at least in the Mediterranean region (Kapetsky, 1984). Coastal lagoons characterized by the presence of hydraulic control systems (both freshwater and seawater) and fixed traps at lagoons mouths for the capture of migrating fish or by exclusive production ownership can all be considered as *Extensive Aquaculture Systems* (Cataudella et al., 2015). This system is not supplied with nutritional inputs but depend solely on natural food in the culture facility, including that brought in by water flow e.g., currents and tidal exchange (Edwards, 1997). The basic principle of fishery exploitation of the all Aegean lagoons is extensive aquaculture based on seasonal ongoing migrations of fish species from lagoon to the sea- offshore fish migration (Tosunoğlu et al., 2017a, b). In fact, although demanding different types of management and representing different forms of exploitation, extensive aquaculture and artisanal capture fisheries are strongly linked due to the common use of living resources within the lagoon ecosystems (Cataudella et al., 2015).

In Turkey, the lagoons are primarily exploited by barrier traps followed by trammel nets, fyke nets and longline. In the Aegean coastal lagoons, fish can enter the lagoons by the way of opened barrier traps (weir) and inlets (canals) from February to June for food and shelter. Barrier traps, constructed on the inlets of the lagoon, make it possible to catch and harvest the migrant fish assemblages during their movement from lagoon to the sea at the rest of the year. While reed sticks are generally preferred for the construction of a barrier trap in Turkey, iron (Akyatan and Ağyatan Lagoons, Adana) and plastic (Akköy) sticks are preferred by a few lagoon exploiter. However, Köyceğiz barrier traps are made of 30-35 mm square mesh wire manufactured at the cooperative workshop. A standard distance is obtained between the iron bars and the square netting wires, while there is no standard distance between the reed sticks. The most important fishing rule implemented for the Turkish lagoons is *distance between the sticks of the barrier traps cannot be less than 3 cm* according to Turkish Fishery Regulations (Anonymous, 2016). However, the European Union (EU) countries such as Italy, Greece and Spain, which have a large number of coastal lagoons, do not have a regulation regarding distance between the sticks of barrier traps. Instead of this, Minimum Landing Size (MLS) regulation is implemented on fish caught in coastal lagoons in EU countries. Only in Albania, there is a strict rule for the distance between the two bars of the barrier trap. According to this rule, it is forbidden to put fishing poles (or plastic, metallic tubes, etc.) in the barrier traps with a distance less than 12 mm from each other (Anonymous, 1997).

The most abundant species caught in Turkish lagoons are grey mullets (Gökçe and Tosunoğlu, 2016). These grey mullet species are Flathead *Mugil cephalus*, Thinlip *Chelon ramada*, Thicklip *Chelon labrosus*, Leaping *Chelon saliens*, Golden *Chelon auratus*, Boxlip *Oedalechilus labeo* and Keeled *Liza carinata*. Other main fish species are Gilthead sea bream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*) Common sole (*Solea solea*) and European eel (*Anguilla anguilla*). All fish species caught in the lagoons were identified according to Froese and Pauly (2017). The body shape of these fish and their MLS are quite different. According to the Turkish Fisheries Regulation, the MLS is 30 cm for *M. cephalus* and *C. auratus*, 25 cm for *D. labrax* and 20 cm for *S. aurata, O. labeo, C. labrosus, C. ramada, C. saliens* and *S. solea* (Anonymous, 2016). In addition to fish species, Blue crab (*Callinectes sapidus*), Caramote prawn (*Melicertus kerathurus*) and Green tiger prawn (*Penaeus semisulcatus*) are the most important commercial crustacean species of the lagoons.

The relationship between the openness of sticks of a barrier trap and the morphology of fish species was firstly investigated by Önem (2014) in the

Aegean Lagoons and Gökçe et al. (2018) in the Mediterranean Lagoons. Selectivity of different distances between the sticks for various fish species was also measured via an experimental method by Gökçe et al. (2018). The relations between total length and opercular and maximum girths, for the eight most representative lagoon fish species in Greek lagoons were estimated by Moutopoulos et al. (2017). Two significant length-girth relations were identified corresponding to different body shapes in this study and the implications for lagoon gear selectivity estimates are also discussed.

Unlike the bar spacing of barrier trap, there are only a few studies that investigate the relationship between fish body shape and trawl cod-end mesh shape in Turkey (Tosunoğlu et al., 2003a, b; Tokaç et al., 2016). In these studies, it has been attempted to determine the most appropriate mesh shape and hanging ratio for the major commercial fish species in accordance with their body shape. Studies regarding fish morphology and mesh shape are also available (Efanov et al., 1987; Matsushita and Ali, 1997; Mendes et al., 2006; Stergiou and Erzini, 2002; Herrmann et al., 2013a, b).

In this study, the relationship between fish body morphology and openness between two sticks or square wire mesh of barrier traps (which is traditional passive catching method of Aegean lagoons) was investigated**.** However, this test was done only empirically for obtaining optimum width and height measurement of the commercial species based on the minimum bar spacing measurement. Passing between the two bars or square mesh is not directly related to the total length of the fish species, but to the width of the fish, and sometimes to the height. For this reason, firstly the relationship between body width/height and total length of some fish species caught in Aegean lagoons has been revealed. Then, the total length of the six fish species from 3 cm bar spacing and square mesh, and the bar spacing corresponding to the MLS of these species were estimated from these results.

2. Material and Methods

The study material was obtained from Karina, Akköy and Homa coastal lagoons along the Aegean coast of Turkey between September and December 2013 (Figure 1). A total of 184 Flathead grey mullet, 80 Golden grey mullet, 173 Gilthead sea bream, 143 European seabass, 59 European eel and 191 Common sole were randomly taken from the barrier traps of the lagoons. All fishes sampled here represent lagoon fish populations in relation to size, age, sex etc. in sampling period.

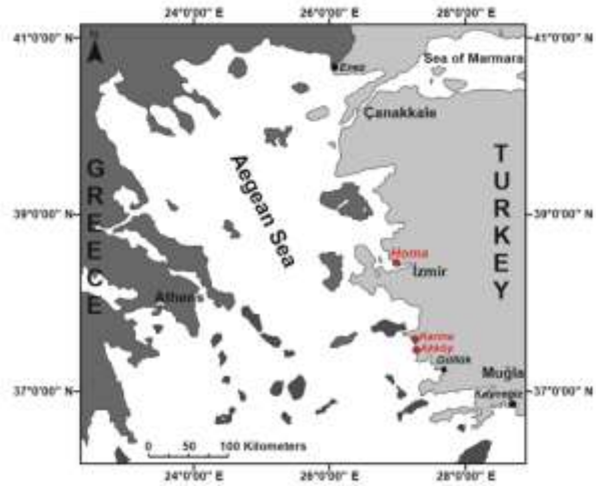

Figure 1. Sampling lagoons (red indicated) along the Aegean coast of Turkey.

Data were collected to determine the relevant dimensions of fish body in relation to distance between sticks of the barrier trap. Width (W), height (H) and total length (TL) of the species were measured to the nearest mm. W and H values were taken from the maximum cross-sectional area of the each fish species (Figure 2).

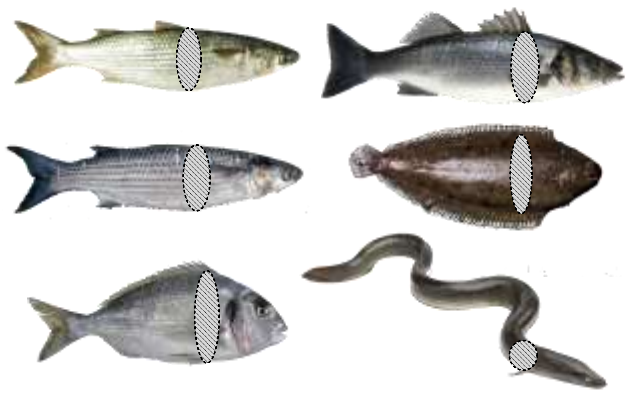

Figure 2. Maximum cross-sectional area of the each fish species.

As MLS was built on TL basis, regression analyses were carried out to find out the relationships between the TL and the other measured dimensions of the fish using least-square regression (Zar, 1999). TL-W relationship is seasonally influenced by factors such as gonad development and spawning frequency, food availability, feeding rate of the species in lagoon (Moutopoulos et al., 2017). Thus, the estimated relations should not be considered as mean annual values, as the samples were collected during the only seaward migration (September to December). From W values, total lengths of the species that pass from the 3 cm bar spacing and square mesh wire and also the bar spacing corresponding to MLS of these species were calculated separately for each species. In these calculations, H value for square mesh diagonally and W values for bar spacing are taken into account. However, if it is thought that the fish is passing through the square mesh, the maximum crossing height should be calculated as 4.24 cm from the 3 cm square mesh. When these values were calculated, behaviour of the fishes passing through the barrier traps was not considered.

3. Results

Morphometric measurements of fish species caught in barrier traps show a great variation (Table 1). The mean, minimum and maximum W, H and TL values for six lagoon fishes are given in the table. The H values of the fishes are higher than their W values. In addition to these values, regression parameters, intercept, slope and coefficient of determination (R^2) values carried out between the TL and W and H values are given in the table. All R^2 values estimated from regression analysis are highly positive except Common sole TL-W relation.

Table 1. Descriptive statistics of width (W), height (H) and total length (TL) of the six species in cm. Intercept, slope and coefficient of determination (R^2) values were also given in the table.

	M. cephalus (n 136)		*C. auratus* (n 80)		*S. aurata* (n 156)	
	Width	Height	Width	Height	Width	Height
Mean	4.5	5.4	2.9	4.2	2.6	6.5
Min.	3.2	4.0	2.2	2.6	1.4	4.7
Max.	6.7	7.7	4.2	5.7	4.6	10.4
Conf. Interval (95%)	4.40 4.64	5.29 5.56	2.80 2.98	4.10 4.35	2.47 2.63	6.32 6.66
Intercept	-1.315	-0.524	0.009	0.656	-0.071	-0.269
Slope	0.175	0.179	0.116	0.143	0.127	0.329
r-square	0.86	0.72	0.61	0.52	0.70	0.95
Mean TL (Min-Max)	33.3 (26.3-42.5)		24.9 (19.2-34.1)		20.5 (15.4-31.2)	
	D. labrax (n 143)		*S. solea* (n 191)		*A. anguilla* (n 59)	
	Width	Height	Width	Height	Width	Height
Mean	4.0	6.5	1.2	6.3	3.1	3.8
Min.	2.9	4.8	0.8	5.0	2.1	2.5
Max.	5.8	8.6	1.6	7.9	4.4	4.8
Conf. Interval	3.95	6.39	1.23	6.18	2.93	3.68

(95%)	4.12	6.61	1.28	6.33	3.20	3.95
Intercept	-0.487	0.159	0.024	-0.827	-0.235	0.737
Slope	0.132	0.186	0.061	0.349	0.059	0.054
R-square	0.64	0.70	0.22	0.62	0.64	0.61
Mean TL (Min-Max)	34.2 (25.6-43.8)		20.3 (17.6-23.8)		56.6 (44.6-73.4)	

Regression analysis carried out between the TL and W and H show positive linear relationships for all the species (Figure 3). W and H data points, linear regression lines and theirs confidence intervals (grey shaded area around the lines) are illustrated in the figure. Straight flat blue lines which indicate 3 cm width of the fish species according to 3 cm distance rule between the two sticks and vertical dashed lines belong to the MLS for the fish species are also given in the figure. In addition to 4.24 cm (flat purple line) indicating the diagonal distance of the square mesh, H corresponds to fish body height. While all the Common sole individuals pass through the 3 cm distance with its width, all Flathead grey mullet and European sea bass individuals retained behind the sticks of the barrier trap. All Gilthead sea bream individuals under 25 cm TL pass through the distance. However, many Golden grey mullet and European eel individuals retain at the barrier traps with their width. The H values of all measured fish species are more than 3 cm when the square mesh wire height is taken into consideration. In the figure, red rectangular areas indicate percentage of the fish which escape with its narrow width (under 3 cm), while green areas show commercial loss of the escaped percentages over MLS. The percentages of commercial loss are 100 for Common sole, 36 Gilthead sea bream, 32 for European eel and 1 for European sea bass.

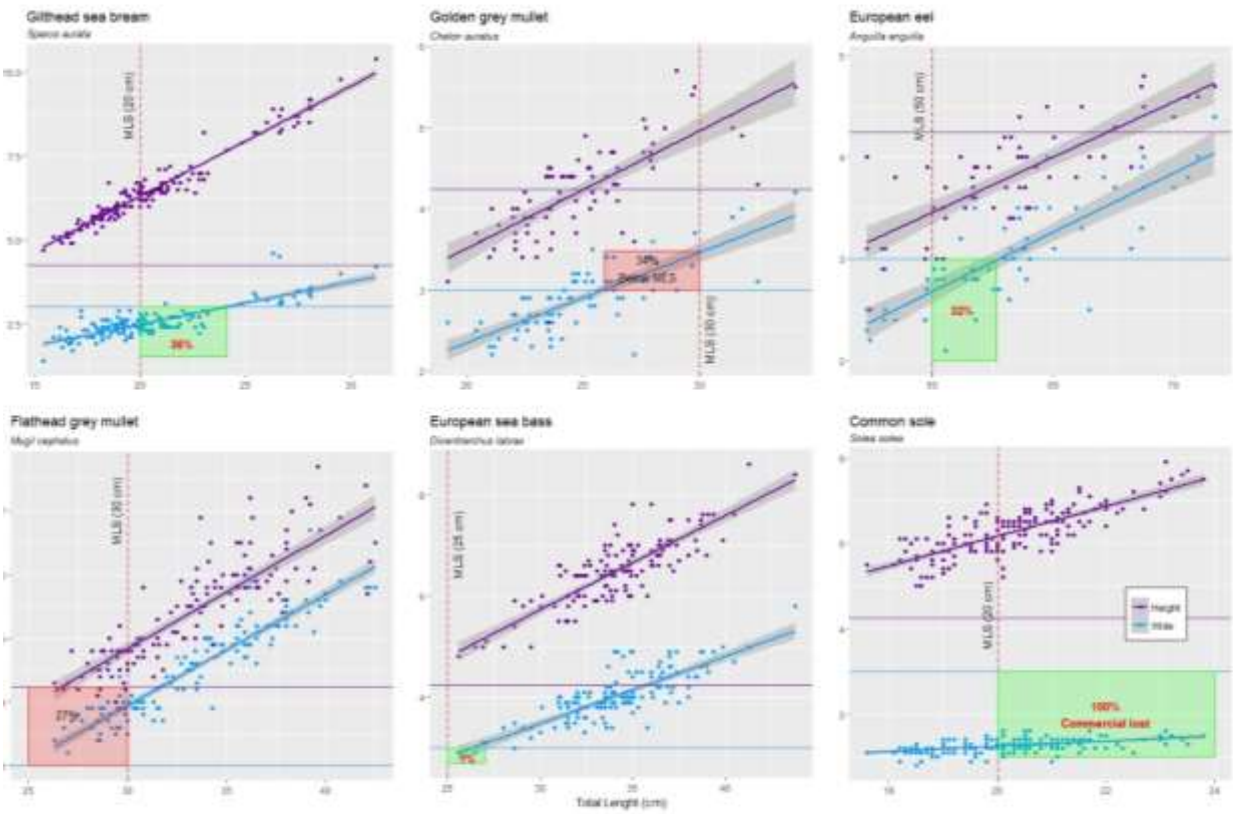

Figure 3. TL-W and TL-H data points and their linear regression lines (blue-width and purple-height, respectively) for the six species. X axis is total length in cm and y axis is morphological measurements of fish in cm. Flat lateral blue and purple lines indicate 3 cm width and 4.24 cm diagonal height of the square mesh barrier trap and vertical dashed lines show the Minimum Landing Sizes (MLS) for each species. Red

rectangular areas indicate percentage of the fish which escape with its narrow width (below 3 cm), while green areas show commercial loss of the escaped percentages over MLS.

4. Discussion

Diversity of fish caught in the barrier traps is just like the demersal trawl cod-end, which hinders the implementation of multi-species management with only 3 cm bar spacing of the barrier trap. The reason is that there are many fish species that have different body shapes in lagoon catch composition. For instance, flathead grey mullet and gilthead sea bream have fusiform and laterally compressed body shapes, respectively. Width of flathead grey mullet that correspond to its enforced MLS is wider than 3 cm. However, width of gilthead sea bream that correspond to its enforced MLS is lower than 3 cm. In this case, the fish that escaped on their MLS will result in significant loss of commercial sizes of the species (Figure 3).

Square mesh is suitable only for European eel when it is thought to try to escape with diagonally according to its MLS. The mesh shape negatively affects escaping individuals of the other five fish species under MLS. W and H values of MLS of the fish species do not allow escape from square mesh. If the square mesh is designed as a 4 cm W, 6 cm H rectangle shape, it may be more effective in escaping fish under MLS.

The multispecies nature of the lagoon fisheries, which in turn implied the exploitation of numerous species with different growth, maturity, behaviour, and body shape are increasing the uncertainty on the determination of gear-specific efficiency (Moutopoulos et al., 2017). The body shape of fish may be the most important factor necessary to understand the consequences of changes in barrier trap selectivity. The maximum width of a fish is expected to be equal to the distance between the two sticks of the barrier trap than the total length in order to escape from the trap. Size selectivity of a barrier trap is strongly related to their technical characteristics, dimension of fish species and their behaviours. However, there is a great variability between the barriers traps used in Turkey. Fish that have different body shapes and similar body shapes with different MLS are the multi-species nature of the lagoon fishery in the Mediterranean (Moutopoulos et al., 2017). For this reason, reduction of undersized fish can be very difficult in mixed fisheries, as there are many varieties of fish shapes in the landings.

5. Conclusion

Sustainable fishery of a lagoon depends on the stability of the ecological conditions and state of target fish populations. For this reason, bar space of the barrier trap is the most important regulation for the exploitation of the target fish populations in the lagoon fishery. The implemented 3 cm bar spacing in Turkish lagoon barrier traps is thought to be suitable only for sea bass with a 1% reduction in catch. However, the bar spacing is not suitable for Sea bream (36% loss over MLS), Common sole (100% loss over MLS), Flat head grey mullet (27% below MLS), European eel (32% loss over MLS) and Golden grey mullet (34% below MLS) in relation to their MLS. In this situation, capture of the grey mullets below MLS is inevitable. Although the use of the square mesh in the barrier is not clearly framed in the regulation, iron square meshed fence is used in the barrier which causes to capture the fish under MLS for all commercial fish species except European eel.

Some management tools can be suggested for exploitation of the commercial species in the lagoon such as graded barrier system with different bar spaces or regulation according to the biology of the fish species and migration seasons. However, lagoon fish species which have different morphology, shape, and maturity size require optimum conditions. Therefore, urgent sustainable management is essential but not a simple issue. In contrast to Turkish minimum bar spacing distance regulation, some EU countries use only MLS regulation for lagoon catches. Instead of the uncontrolled application of minimum bar spacing regulation, the MLS regulation may apply in lagoon catches. In this respect, the continuously changing minimum bar spacing paradox in barrier traps will be overtaken in Turkish lagoon fisheries.

This unique wet land area has a very important ecological importance beside the economical income. The area offers valuable benefits or "ecosystem services" including economic advantages: ranging from freshwater supply, food, building materials and commercial fishery as well as ecologic advantages such as biodiversity, flood control, groundwater recharge, and climate change mitigation**.** These should be taken in to account when management strategies are developed.

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