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Research Article

Determination of the Appropriate Hanging Ratios to Ease the Escape of Juvenile Red Mullet (*Mullus barbatus* L., 1758) and Annular Sea Bream (*Diplodus annularis* L., 1758) from a Trawl Codend

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Abstract: This study investigates the relationship between total length (TL) and fork length (FL), girth (G), height (H) and width (W) of red mullet (*Mullus barbatus*) (n = 953) and annular sea bream (*Diplodus annularis*) (n = 944) collected during trawl selectivity trials carried out in İzmir Bay between July 1996 and February 1997. The FL, G, H and W of red mullet were 89, 53, 20 and 11% of the TL, respectively. For annular sea bream these values were 91, 80, 34 and 11%, respectively. The ratios for average body thickness (W/H) were 0.573 for red mullet and 0.319 for annular sea bream. The hanging ratios (E_{RM} and E_{ASB}) of codends designed to ease the escape of juveniles of these species were 0.497 for red mullet and 0.304 for annular sea bream.

Key Words: Body shape, mesh hanging ratio (E), red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*)

Küçük Boy Barbunya (*Mullus barbatus* L., 1758) ve Isparozun (*Diplodus annularis* L., 1758) Trol Torbasından Kaçışını Kolaylaştırmak İçin Uygun Donam Faktörünün Belirlenmesi

Özet: Bu çalışmada Temmuz 1996 ve Şubat 1997 arasında İzmir Körfezinde yürütülen trol seçiciliği çalışmaları sırasında toplanan barbunya (*Mullus barbatus*) (n = 953) ve ısparozların (*Diplodus annularis*) (n = 944) total boyları (TL) ile çatal boy (FL), çevre (G), sırt yüksekliği (H) ve genişlikleri (W) arasındaki ilişki araştırılmıştır. Barbunyaya ait FL, G, H ve W değerlerinin sırasıyla TL'nin yüzde 89, 53, 20, ve 11'ine eşit olduğu bulunmuştur. Bu değerler ısparoz için sırasıyla 91, 80, 34 ve 11'dir. Ortalama vücut kalınlığı oranı (W/H) barbunyada 0,573, ısparozda 0,319 olarak bulunmuştur. Bu türlerin küçük bireylerinin kaçışını kolaylaştırmak için tasarlanılan torbaların donam faktörleri barbunya için (E_{RM}) 0,497, ısparoz için (E_{ASB}) 0,304 olarak hesaplanmıştır.

Anahtar Sözcükler: Vücut şekli, Donam faktörü (E), Barbunya (*Mullus barbatus*), Isparoz (*Diplodus annularis*)

Introduction

Good fisheries management requires that fishing gears retain large fish in the catch, while small juveniles are allowed to escape (1). If that is provided, at least for one species, it can be said that the gear is highly selective. Recently, there have been many studies aiming to improve selectivity by modifying gear design such as square mesh codends, escape panels and windows (2-6), sorting grids (7-9) and separator trawls (10-13). Conventionally, selectivity has been regulated by means of a legally defined minimum mesh size for the codend (14). Nevertheless, it has become apparent that many other aspects of gear design can also influence gear selectivity. Amongst these, the effect of the number of meshes around the codend on selectivity is well documented by Reeves et al., (14), Robertson and Ferro (15), Broadhurst and Kennelly (16) and Lök et al., (17).

The number of the meshes around the codend directly affects the shape of the meshes in the codend when the gear is towed. In general, the higher this number is the closer the meshes. The closer the meshes, the more muscle power is needed by round fish to penetrate through the netting. If the shape of the maximum cross-section area of the fish is known and the codend is rigged in a way to provide suitable mesh form, escaping fish would need less power to penetrate. Thus, a higher proportion of immature fish can be expected to escape (17), and relatively less injury to escaping individuals, will occur.

In this study, the most suitable codend hanging ratios (E) are calculated for red mullet (*Mullus barbatus* L., 1758) and annular sea bream (*Diplodus annularis* L., 1758) by using the maximum body height and width of the fish. Differences in the body shapes of the fish are demonstrated. Regressions of the total length (TL) and fork length (FL), girth (G), height (H) and width (W) of red mullet and annular sea bream are also presented.

Materials and Methods

The study material was obtained during trawl codend selectivity trials carried out onboard RV Egesüf (27 m, 500 HP) in July, August and October 1996 and January and February 1997. All the samples were collected from the same fishing ground: İzmir Bay in the central eastern Aegean Sea (Figure 1). A total of 953 red mullet and 944 annular sea bream were randomly taken from both the codend and cover catch. The TL, FL, G, H and W of fish were measured to the nearest millimeter. G measurements were taken by means of a tape measure at the area of the maximum cross-section of the body without applying any extra force.

Regression analyses were carried out to find out the relationships between TL and the other measured dimensions of the fish by using data analysis tools in MS Excel 2000.

Mean W/H values, for red mullet and annular sea bream separately, were used to find the most suitable mesh shape and for calculations of E, which is the ratio of the length of rope on which a net panel is mounted to a length of stretched netting hung on the rope (18). If we assume that the fish has a symmetrical maximum cross-sectional area, which is very often possible for red mullet and annular sea bream, E can be calculated from the average W and H values as

$$E = \frac{W}{\sqrt{W^2 + H^2}}$$

Results

Regressin analysis carried out between the TL and FL, G, H and W shows highly positive linear relationships for both red mullet and annular sea bream.

TL and FL data points and linear regression lines are illustrated in Figures 2 and 3 for red mullet and annular sea bream, respectively. Linear regression equations, r^2 values and sample sizes are also given in the figures.

TL-G data points and linear regression lines are shown in Figures 4 and 5 for red mullet and annular sea bream, respectively. Regression equations, r^2 values and sample sizes are also given in the figures.

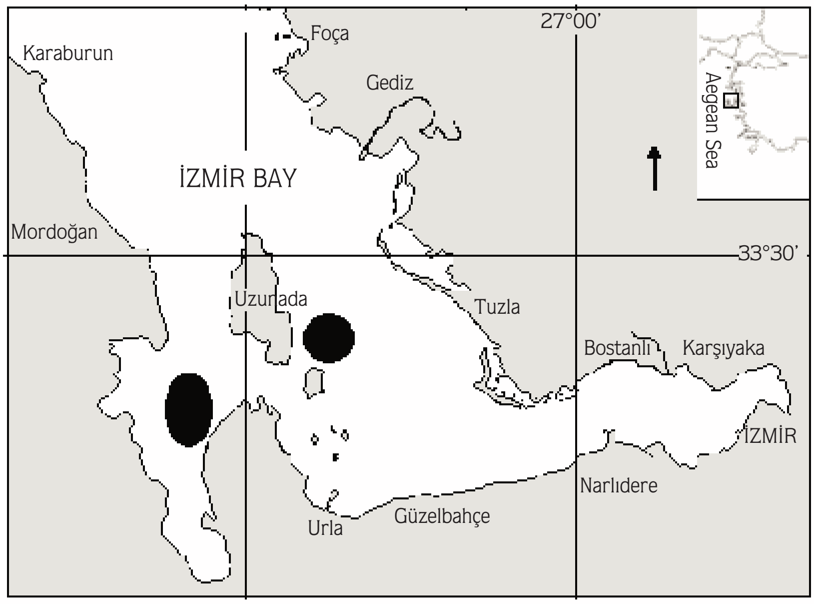

Figure 1. Map of the fishing area.

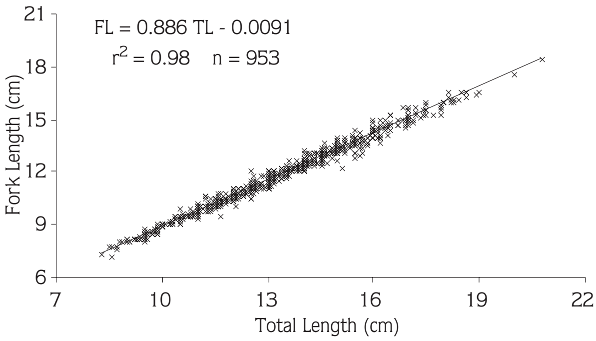

Figure 2. TL-FL data points and linear regression line for red mullet.

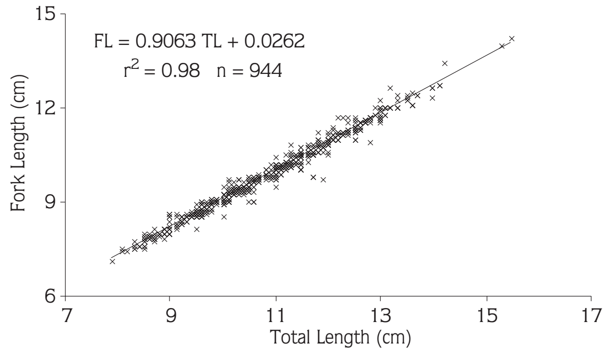

Figure 3. TL-FL data points and linear regression line for annular sea bream.

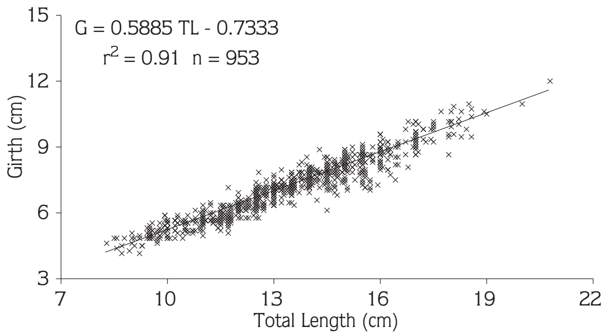

Figure 4. TL-G data points and linear regression line for red mullet.

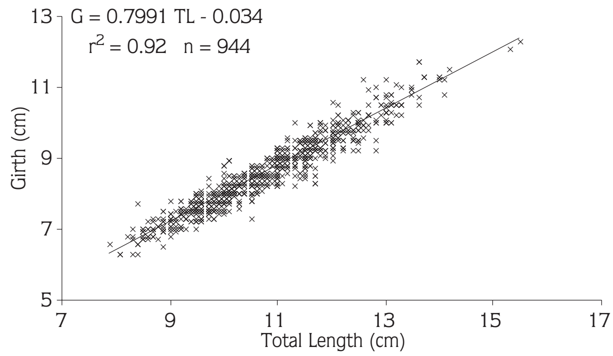

Figure 5. TL-G data points and linear regression line for annular sea bream.

TL-H data points and linear regression lines are demonstrated in Figures 6 and 7 for red mullet and annular sea bream, respectively. Regression equation, r^2 values and sample sizes are also given in the figures.

TL-W data points and linear regression lines are illustrated in Figures 8 and 9 for red mullet and annular sea bream, respectively. Regression equations, r^2 values and sample sizes are also given in the figures.

Figure 10 shows the W/H ratio of red mullet and annular sea bream versus TL. Table 1 gives the mean W/H values, their standard errors, sample sizes, and 95% confidence levels. It was found that annular sea bream has a significantly lower W/H ratio (0.319) than red mullet (0.573) (t test, $P < 0.001$). Figure 11 shows the lateral and cross-sectional shapes of both species. This figure also demonstrates the difference in the shapes of the mesh openings, which suit the best to the body cross-sectional shapes of both species.

The mean value of FL in terms of TL percentage was calculated for practical use for both species. These values were 89% for red mullet and 91% for annular sea bream. Similarly, the other measured dimensions were calculated (Table 2).

Rigging ratio (E) calculated from the W/H ratios were

$$E_{RM} = \frac{W_{RM}}{\sqrt{W_{RM}^2 + H_{RM}^2}} = \frac{0.573}{\sqrt{0.573^2 + 1^2}} = 0.497 \cong 0.5$$

and

$$E_{ASB} = \frac{W_{ASB}}{\sqrt{W_{ASB}^2 + H_{ASB}^2}} = \frac{0.319}{\sqrt{0.319^2 + 1^2}} = 0.304 \cong 0.3$$

for red mullet and annular sea bream, respectively.

Discussion

The data presented in this study were collected in July, August and October of 1996, and January and February of 1997. In other words, body measurements were taken in mid-summer, mid-autumn and mid-winter. The expected seasonal variation in the condition factors of

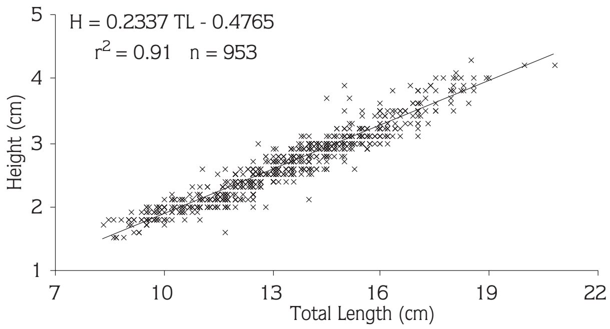

Figure 6. TL-H data points and linear regression line for red mullet.

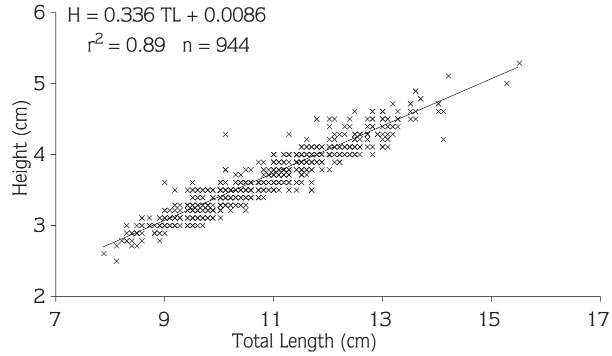

Figure 7. TL-H data points and linear regression line for annular sea bream.

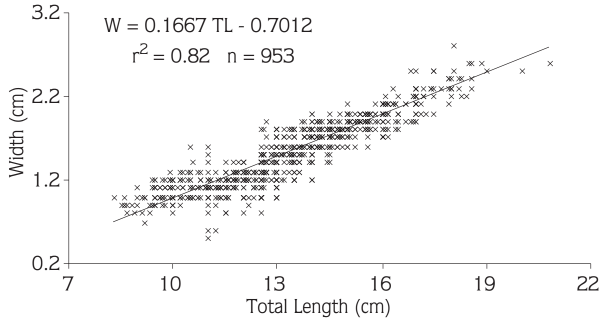

Figure 8. TL-W data points and linear regression line for red mullet.

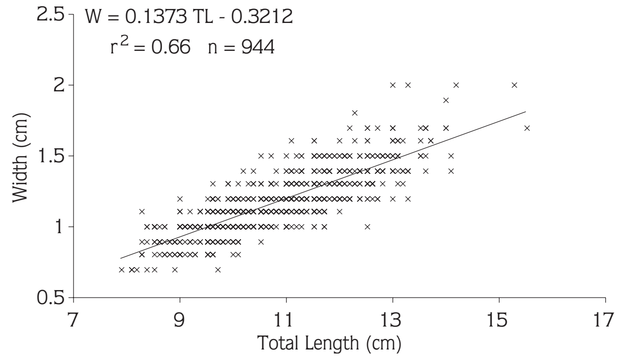

Figure 9. TL-W data points and linear regression line for annular sea bream.

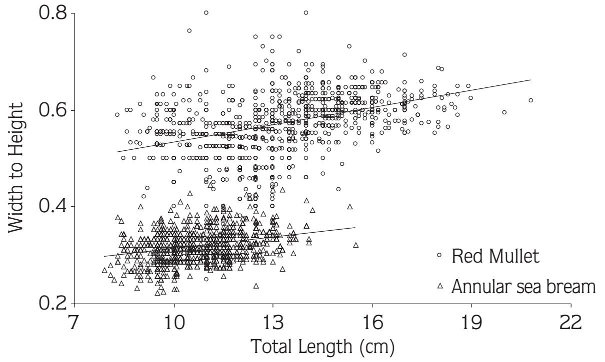

Figure 10. W/H-TL data points for red mullet and annular sea bream.

the fish due to spawning and feeding (19,20) could not be investigated in this study. To determine the significance of seasonal difference on fish body dimensions, sampling needs to be carried out just prior to and just after the spawning period, which usually takes place in spring, and just after the feeding period, which usually takes place in summer.

Figures 2 and 3 show a strong positive linear relationship between the TL and FL of red mullet and annular sea bream, respectively, with r^2 values of 0.98 for both species. This strong relationship is very much expected, as the shape of the tail is very likely to be free from changes in fish body dimensions due to spawning and feeding. However, very often there is confusion between the results of fish biology and gear selectivity studies when a value is presented in terms of length. Usually the scientist working on fish biology uses FL (21-23), while in gear selectivity studies 50% retention length (L_{50}) is presented in terms of both FL (6,17, 24,25) and TL (5,26-28). Furthermore, minimum landing sizes are given usually in terms of TL (29). Table 2 gives the expression of the FL, G, H and W of red mullet and annular sea bream in terms of TL percentage for practical uses.

Lök et al., (17) reported that for the same codend the 50% retention length of annular sea bream was smaller than that for red mullet. Though this may have several

Table 1. Descriptive statistics of W/H ratios for red mullet and annular sea bream.

Descriptive statistics	W/H ratios	
	Red mullet	Annular sea bream
Mean	0.573	0.319
Standard error	0.002	0.001
Number of specimens	953	944
Confidence level (95%)	0.004	0.002

Table 2. Expression of the FL, G, H and W of red mullet and annular sea bream in terms of TL percentage.

Species	Fork Length	Girth	Height	Width
Red mullet	89	53	20	11
Annular sea bream	91	80	34	11

explanations related to differences in the behaviour of these 2 species, differences in the girth percentage in terms of TL given in Table 2 indicate that such results are very much expected. This is because when the mesh penetration is considered, maximum girth of fish in relation to the maximum mesh perimeter is important. The results of this study clearly show that for a given length, the maximum girth of annular sea bream (80% of its TL) is 51% higher than that of red mullet (53% of its TL).

Determining optimum mesh size in the catching part of the trawl is an efficient method of fishery regulation ensuring the maximum yield and survival of junior age groups while fish of commercial sizes are retained (30). However, the codends of the trawls, where the majority of escapes take place (31), sometimes could be rigged to the aft of the tunnel in a way ensuring most of its meshes remain closed or too narrow for many juveniles to escape through. If this is the case, mesh size regulations become ineffective. The closeness of codend meshes when being towed is rather hard to understand when the gear is on deck. Nevertheless, underwater observations (32,33) clearly show that when a square mesh panel is inserted, a large majority of round fish escape through there rather than through diamond meshes. Moreover, for the species studied here most of the fishes which have a smaller girth than the mesh perimeters are retained in the codend (34,35). One of the major issues regarding gear design is

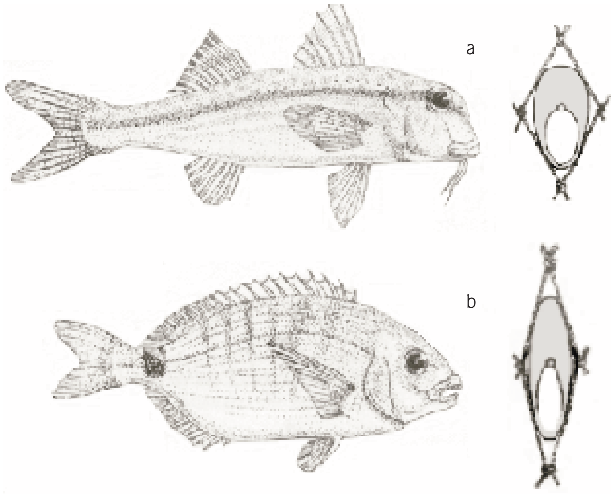

Figure 11. Lateral and crossectional views of red mullet (a) and annular sea bream (b).

considered to be closeness of diamond shape codend meshes. Therefore, there is a need to determine the most suitable working mesh form in trawl codends to help juveniles escape. The results of the study clearly show that there is a significant difference in the body forms of red mullet and annular sea bream. According to the classifications of fish body forms made by Efanov et al. (30), red mullet, for which an average W/H ratio of 0.573 was found here, has a torpedo form body, while annular sea bream, whose W/H ratio was 0.319, has a compressed or high body form. The forms of the maximum cross-sectional areas of the 2 species are shown in Figure 11. This figure also illustrates the difference in the mesh form required to provide the best mesh shape to assist juveniles in escaping.

To provide such a mesh form, the codend meshes need to be rigged to the aft of the tunnel with an E value of 0.497 for red mullet and 0.304 for annular sea bream. This is usually easy enough to do if the circumference of the aft end of the tunnel is known. However, it is still rather difficult to decide the E value to be used in mixed species fisheries. To solve this problem, more complicated codend designs with more than one E value, in the upper and lower panels of the codends or the forward and aft parts of the codend, could be suggested but at this stage it remains to be investigated. At present commercial trawlers off the eastern coast of the Aegean Sea generally use a very high number of meshes around the codend, which leads to the total closure of the meshes when the gear is towed. The success of narrow codends, or in other words codends with a decreased number of meshes, in increasing the L_{50} values for round fish (14,15,17,36) can be partially related to a more suitable working mesh form. It can be concluded that the specification of only the mesh size in fishery regulations can easily be ineffective. To provide a suitable working mesh form to ease the escape of juveniles, the necessary E values should be calculated from the W and H measurements of fish.

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