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Original Article

The relationship among spawning period, length at first maturity and depth distribution of *Mullus barbatus* and *Upeneus moluccensis* inhabiting the Northeastern Mediterranean coast of Turkey

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Abstract: This study examined some spawning characteristics and distribution of *Mullus barbatus* and *Upeneus moluccensis* in Babadillimani Bight, in the northeastern Mediterranean (near Mersin, Turkey) between of May 1999 and April 2000. Sampling was carried out monthly at depths of 0-50 m, 50-100 m and >100 m using commercial trawl net mesh size 22 mm knot to knot. The results showed no difference between the length at first maturity of males and females (P>0.001) in either *M. barbatus* or *U. moluccensis*. This length for the combined sexes was calculated to be 11.7 cm and 10.9 cm in *M. barbatus* and *U. moluccensis*, respectively. When monthly changes in the Gonadosomatic Index (GSI) values were evaluated, the spawning period was determined as July-November for *M. barbatus* and May-August for *U. moluccensis*. The mean total lengths from the individuals belonging to *M. barbatus* from depth layers of 0-50 m, 50-100 m and >100 m were calculated as 8.65 cm, 8.70 cm and 12.70 cm, respectively. Total lengths for *U. moluccensis* were calculated as 8.40 cm, 11.66 cm and 13.32 cm, respectively. The mean total length of *M. barbatus* and *U. moluccensis* increased from coastal areas to deeper waters. Therefore bottom trawl fishing must be conducted in waters deeper than 100 m for both *M. barbatus* and *U. moluccensis*.

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Introduction

For fisheries management, each individual fish should be given the chance to reproduce at least once (Beverton and Holt, 1957). Therefore, it is necessary that catching of target fish species occur only after reaching to its length at first maturity. It is known that the size of fish changes as their distributed area varies (Sparre and Venema, 1992). In particular, smaller sized groups prefer to stay in coastal area (Bone et al., 1995; Pitcher and Hart, 1982; Bingel, 2002). Thus, in fisheries management, prohibition is the preferred means through which commercial fisheries protect the immature individuals inhabiting in coastal area. In Turkey, deep trawl fisheries are prohibited in the waters within three miles of the coastal strip (Anonymous, 2006). These issues become more important because Mediterranean-type deep trawl nets have low selectivity and are commonly used along the Mediterranean coasts of Turkey (Tokaç et al., 1998; Özbilgin and Tosunoğlu, 2003).

Between 1990 and 2001, Mullid species comprised 16% of the demersal fish catches from the Mediterranean coasts of Turkey (Anonymous, 1990-2005). Both the native species *Mullus barbatus* and the Lessepsian immigrant *Upeneus moluccensis* constitute the majority of this production. Hence, this study was aimed to determine the length at first maturity and the spawning season of *M. barbatus* and *U. moluccensis*. In addition, this study aimed to determine the size groups of these species, the differences between their size distributions in

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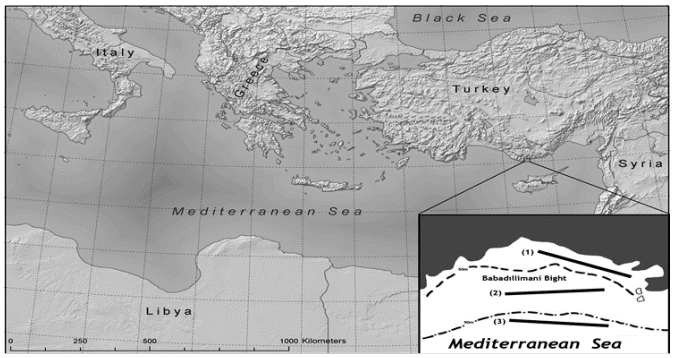

Figure 1. Sampling stations in Babadıllimanı Bight ((1): 0-50 m, (2): 50-100 m and (3): >100 m depth ranges).

relation to depth and the depth ranges in which the mature individuals are distributed. In light of these data, our aim in this study was to determine the most appropriate depth layers for sustainable fisheries.

Materials and methods

This study was carried out at three depth layers including 0-50 m, 50-100 m and >100 m in Babadillimani Bight of the northeastern Mediterranean, near Silifke-Mersin, between May 1999 and April 2000 (Fig. 1). Sampling was performed monthly during daytime in three above mentioned depth layers, using a traditional Mediterranean-type deep trawl net with one-hour haul duration. After identifying of fish species in each catch, the quantity of the catch was assessed. If the quantity of fish in the catch was low, the whole catch was used for analysis. Alternatively, if the quantity was high, then the catch was sub-sampled based on Holden and Raitt (1974). The samples were transported to the laboratory after fixation into 4% formaldehyde solution buffered with borax. The total length of specimens was measured to the nearest 0.1 cm. The gonads were removed and measured to the nearest 0.01 g to determine spawning season and length at first maturity.

The age of specimens was determined using sagittal otoliths and the criteria recommended by Chilton and Beamish (1982). The monthly change of GSI values were used to determine the spawning season (Gibso and Ezzi, 1978).

The gonadal development of both sexes was analyzed using the five-stage sexual maturity scale recommended by Holden and Raitt (1974). In order to determine the length at first maturity, which is the size where 50% of the individuals have reached sexual maturity, the individuals in the 1st stage were considered immature and specimens in the 4th and 5th stages were considered mature. Specimens in 2nd and 3rd stages were thought to have reached this stage for the first time, therefore they were considered immature, and alternatively, if they laid eggs and returned to the 2nd and 3rd stages, they were denoted as mature. Thus, for both sexes, a two-stage scale of maturity and immaturity was created. Using this scale, the size group in which 50% of the individuals reached sexual maturity was determined. In fishes, the sexual maturity follows a normal distribution, which can be modeled with a logistic function (King, 1995; Welcomme, 2001). The length at first maturity of male and female individuals of *M. barbatus* and *U. moluccensis* was modeled with the equation given by Sparre and Venema (1992):

$$M(L) = \frac{1}{1 + e^{(a-b)*L}}$$

In this equation, M(L): percentage of matured individuals, which is in "L" length group, L: length group (cm), a and b: regression constants. The size group in which 50% of the individuals in the stocks has reached sexual maturity was determined using the equation below:

$$M(L_{50}) = \frac{a}{b}$$

One-way analysis of variance (ANOVA) was applied to determine the differences between depth layers with regard to size groups and Duncan Test was performed to determine if there were differences between the depth layers.

Results

The monthly changes in the GSI values of *M. barbatus* and *U. moluccensis* are given in Figures 2 and 3. Figure 2 indicates that the GSI value of *M. barbatus* increases from November, reaching the highest level between May and August and then decreased. The alterations in the GSI value shows that the gonad of *M. barbatus* matures between

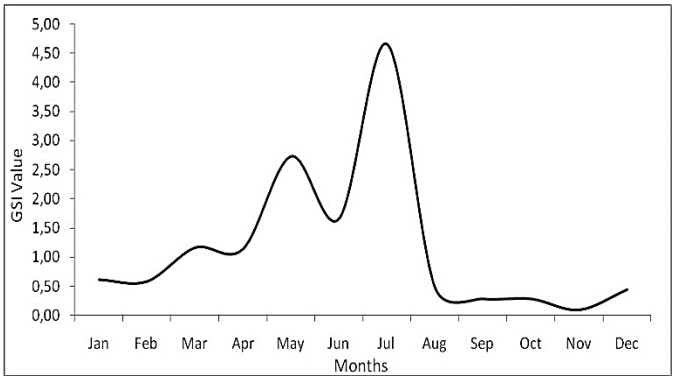

Figure 2. Monthly changes in GSI values for *Mullus barbatus*.

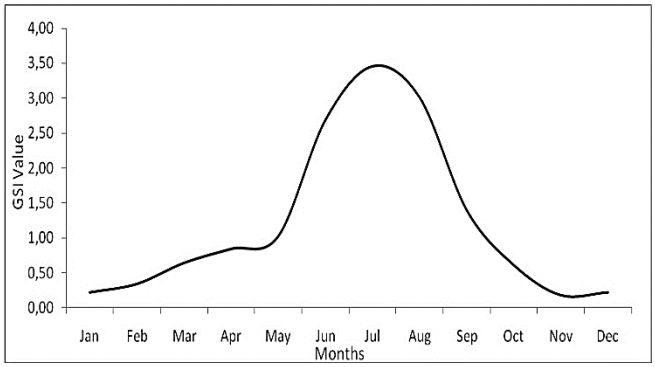

Figure 3. Monthly changes in GSI values for *Upeneus moluccensis*.

Table 1. Monthly changes of maturity stage for *Mullus barbatus*.

Months	**N**	**Sexual Maturity Stages**				
		1st	**2nd**	**3rd**	**4th**	**5th**
May	41	1	2	2	18	18
June	42	-	-	-	18	24
July	26	-	-	-	2	24
August	43	12	-	-	2	29
September	68	45	23	-	-	-
October	40	34	6	-	-	-
November	67	36	31	-	-	-
December	41	14	27	-	-	-
January	122	14	105	3	-	-
February	55	1	37	16	1	-
March	60	-	51	9	-	-
April	81	-	20	16	45	-

November and May and spawning is occurred between May and August. Figure 3 shows the monthly changes in GSI of *U. moluccensis* that is started to increase in January and after reaching to the highest value in July, decreases again. These changes in the GSI values suggest that the gonads started maturing in January and began to empty from July through November. Therefore, we conclude that *U. moluccensis* spawned between July and November.

The monthly changes in the sexual maturity stages of *M. barbatus* are shown in Table 1. The months in which the most of individuals in the 4th maturity stage were April and June and the period in which the individuals had just laid eggs was from May through August. Therefore, the result supports the findings obtained from the monthly changes of the GSI values.

Monthly changes in the sexual maturity stages of *U. moluccensis* are shown in Table 2. Although the individuals in 4th maturity stage were commonly observed between May and October, we did not encounter specimen at 5th maturity stage in May or June, therefore we concluded that this species starts laying eggs in July. The 5th maturity stage individuals are those that have just laid eggs and these began to appear in July till October. Thus, the results obtained both from Table 2 and Figure 3 confirm the conclusion that *U. moluccensis* reproduces between July and October.

The length at first maturity for males and females of *M. barbatus* and *U. moluccensis* were determined as 11.9 cm and 11.1 cm and 11.0 cm and 11.4 cm, respectively. No significant difference was observed for the length at first maturity between male and female of *M. barbatus* and *U. moluccensis* (t-test, $P<0.01$). Therefore, we combined both sexes to calculate the length at first maturity. The lengths at first maturity for combined sexes of *M. barbatus* and *U. moluccensis* were calculated as 11.7 cm and 10.9 cm, respectively (Fig. 4).

The distribution of age groups for *M. barbatus* and

Table 2. Monthly changes of maturity stage for *Upeneus moluccensis*.

Months	n	Sexual Maturity Stages				
		1st	2nd	3rd	4th	5th
May	34	1	21	9	3	-
June	32	1	2	10	19	-
July	26	-	1	7	14	4
August	64	-	5	15	25	19
September	65	4	16	29	10	6
October	59	16	22	-	1	20
November	1	1	-	-	-	-
December	44	16	28	-	-	-
January	67	37	30	-	-	-
February	53	14	39	-	-	-
March	50	-	50	-	-	-
April	8	-	-	8	-	-

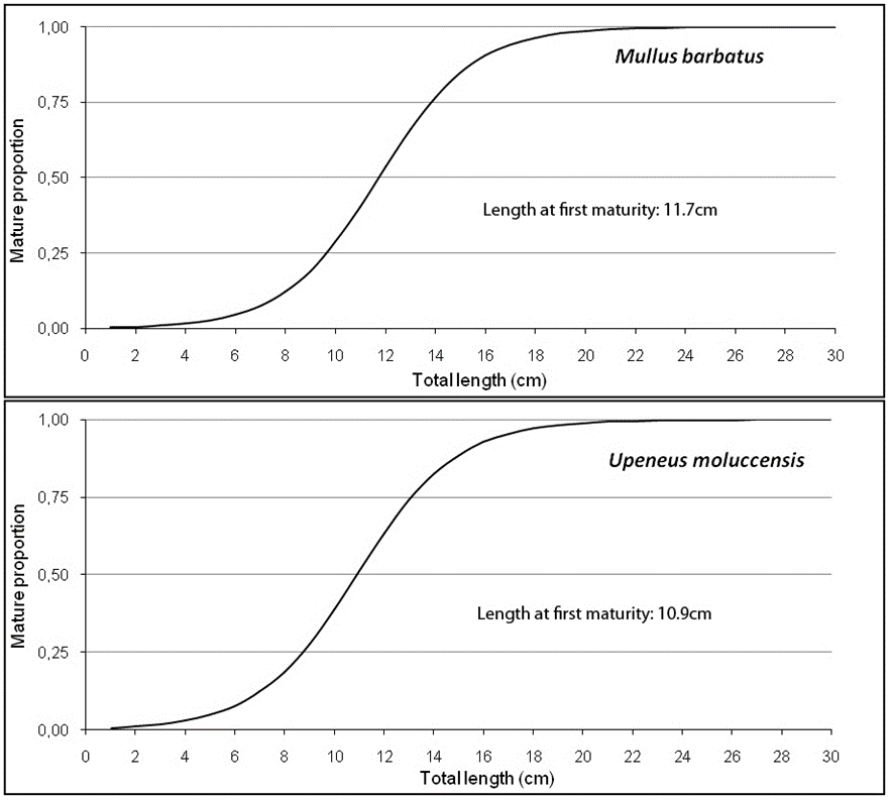

Figure 4. Length at first maturity of *Mullus barbatus* and *Upeneus moluccensis* for combined sexes.

U. moluccensis in different depth layers is shown in Table 3. The percentages of the individuals of *M. barbatus* in the first age group and below in the 0-50 m, 50-100 m and >100 m depth layers were calculated as 90.24%, 85.87% and 44.35%, respectively. Therefore, in the 0-50 m and 50-100 m depth layers, the 0 and first age groups were dominant, while the first and second age groups were dominant in waters deeper than 100 m. At depths greater than 100 m, 56.65% of individuals were more than 2 years old.

The proportion of *U. moluccensis* individuals belonging to 0 and the first age group in 0-50 m depth layer was determined as 92.31 %, this value decreased with increasing water depth and was calculated as 44.91% at 50-100 m and 21.92% at depths greater than 100 m. The proportions of individuals that were in the second age group and had reached sexual maturity in the three depth ranges were 6.95%, 42.68% and 63.01%, respectively.

Therefore, the age of individuals of *M. barbatus* and *U. moluccensis* increase with increasing depths i.e.

Table 3. Age groups of *Mullus barbatus* and *Upeneus moluccensis* for each depth range.

Species	Age Groups	Depth Ranges					
		0-50m		50-100m		100m>	
		N	%	n	%	n	%
M. barbatus	0	248	25.46	225	35.32	15	4.13
	I	631	64.78	322	50.55	146	40.22
	II	94	9.65	78	12.24	166	45.73
	III	1	0.10	8	1.26	25	6.89
	IV	-	-	2	0.31	9	2.48
	V	-	-	2	0.31	2	0.55
U. moluccensis	0	120	32.97	8	2.55	-	-
	I	216	59.34	133	42.36	32	21.92
	II	24	6.59	134	42.68	92	63.01
	III	3	0.82	13	4.14	16	10.96
	IV	1	0.27	13	4.14	6	4.11

Table 4. Mean total length of *Mullus barbatus* and *Upeneus moluccensis* for each depth range.

Species	Depth Ranges (m)	n	Mean Length (cm)	Standard Deviation
M. barbatus	0-50	974	8.65	2.5456
	50-100	637	8.70	3.1686
	>100	390	12.70	2.5626
U. moluccensis	0-50	486	8.40	2.4398
	50-100	325	11.66	2.7892
	>100	146	13.32	2.2093

the younger individuals are found in the coastal area, while the older ones distributed in the deeper waters. There was no significant difference between the mean total length of *M. barbatus* for 0-50 m and 50-100 m depth layers. However, the mean total length at >100 m depth was significantly different than those of other depth layers (ANOVA, $P<0.01$). In *U. moluccensis*, significant differences were found between the mean total lengths in the different depth layers (ANOVA, $P<0.01$).

The changes in the mean total length for *M. barbatus* and *U. moluccensis* by depth layer are given in Table 4. The mean total lengths from the individuals belonging *M. barbatus* for these three depth layers were calculated as 8.65 cm, 8.70 cm and 12.70 cm and for *U. moluccensis*, they were calculated as 8.40 cm, 11.66 cm and 13.32 cm, respectively. Similar to the age distribution, the mean total length of *M. barbatus* and *U. moluccensis* increased from the coastal area to the deeper waters (Table 4).

There were no significant differences between the mean total length of *M. barbatus* for 0-50 m and 50-100 m depth layers. However, the mean total length at >100 m depth was quite different than that of other depth layers (ANOVA, $P<0.01$). In *U. moluccensis*, significant differences were found between the mean total lengths in the different depth layers (ANOVA, $P<0.01$).

Discussion

The results indicate that *M. barbatus* spawns between May and August. In previous studies, the spawning period of *M. barbatus* in Iskenderun Bay was reported to occur between April and August (Mümann and Denizci, 1955), May and August (Akyüz, 1957) and May and August in Antalya Bay (Mert et al., 1983). Therefore, the data on reproductive period determined in this study is in agreement with previous studies.

The length at first maturity for *U. moluccensis* was calculated as 10.9 cm and spawning is occurred between July and October. Moreover, the average size group of *M. barbatus* in depths greater than 100 m depth was higher than that of other two depth ranges and the mean length of *U. moluccensis* increased in the deeper areas.

The spawning period of *U. moluccensis* was reported occurring between June and September in the eastern Mediterranean (Golani, 1990), in Antalya Bay (Mert et al., 1983) and in the Aegean and Mediterranean coasts of Turkey (Kaya et al., 1999). In this study, we determined the spawning period to occur from July till October. Whereas, we observed that in Babadillimani Bight the spawning starts and finishes one month later than in previously described areas. However, spawning may show delays of several months with changing environmental factors (Woynarovich and Horváth, 1980).

The reproductive periods of *M. barbatus* and *U. moluccensis* suggest that deep trawl fisheries should be banned from May till October to create a sustainable stock. Our data indicate that delaying the start of fishing season one month and expanding the restrictions (Anonymous, 2006) on deep trawl fishing along the Mediterranean coasts of Turkey to occur between 1st April and 15th September would be beneficial for fisheries management.

Mert et al. (1983) and Çelik and Torcu (2000) reported that *M. barbatus* reached its size at first sexual maturity in their first age group. The length at first maturity is not reported in these studies, however, the size distribution of the individuals belonging to the first age group was reported as 10.2-13.5 cm by Mert et al. (1983) and 10-13 cm by Çelik and Torcu (2000). In addition, İşmen and İşmen (2001) and Özyurt (2003) reported that the length at first maturity for *M. barbatus* is 11 cm. The previous findings are supported by our results, which indicate the length at first maturity is 11.7 cm.

The age at first maturity for *U. moluccensis* was reported to fall within the first age group by Mert et al. (1983) and Kaya et al. (1999). The length range for individuals from the first age group was reported as 10-13 cm by Mert et al. (1983) and the mean length for individuals from the first age group was reported 11.3 cm for females and 10.0 cm for males (Kaya et al., 1999). These results are in agreement with finding of this study, which determined the length at first maturity to be 10.9 cm for *U. moluccensis*.

The mean lengths of *M. barbatus* in 0-50 m and 50-100 m depth layers were 8.65 cm and 8.7 cm, respectively, which are significantly smaller than the 11.7 cm length at first maturity we recorded for this species. However, the mean total length for water layers deeper than 100 m (12.7 cm) was greater than the length at first maturity.

Although the 8.39 cm mean length for *U. moluccensis* in the 0-50 m depth layer was smaller than the length at first maturity (10.9 cm), it should be noted that in the 50-100 m and <100 m depth layers, the mean lengths (11.66 and 13.32 cm, respectively) were higher than the length at first maturity.

In addition, the percentage of individuals belonging the 0 age group for *M. barbatus* was 25.46%, 35.32% and 4.3% in the 0-50 m, 50-100 m and >100 m depth layers, respectively. Because the 1st age group in this species was thought to have reached sexual maturity (Mert et al., 1983; Çelik and Torcu, 2000). It is obvious that 60.78% of the individuals in 0-100 m depth layer have not reached sexual maturity. When the 1st age group of *M. barbatus* is taken to be representative of 64.78%, 50.55% and 40.22% of individuals in the 0-50 m, 50-100 m and >100 m depth layers, respectively, it is apparent that 59.16% of the individuals in the 0-100 m depth layer have just reached sexual maturity. Yet, in the waters deeper than 100 m, the 0 age group of *M. barbatus* is represented by 4.13 % of total individuals and the 1st age group represents 40.22 % of the total sample.

While the individuals belonging to the 0 age group for *U. moluccensis* represented 32.97% and 2.55% of the total sample in the 0-50 m and 50-100 m depth layers, respectively, this age group was not found at depths greater than 100 m. The 1st age group of this species was found to represent 59.35 %, 42.36 % and 21.92% of the total individuals in the 0-50 m, 50-100 m and >100 m depth layers, respectively. These data shows that the 0 age group of *U. moluccensis* at 0-100 m was represented by 19.25% of the individuals at this depth and that the first age group represented 52.48% of the total. Therefore, while the 0th and first age groups of *U. moluccensis* represented 71.73% of

the individuals in the 0-100 m depth layer, this proportion decreased to 21.92% at depths below 100 m.

It is known that the distribution of fish stocks in a fishing area is more concentrated along the coast, especially for small-sized groups (Bone et al., 1995; Pitcher and Hart, 1982; Bingel, 2002). The results of this research clearly showed that smaller individuals are common in the coastal areas. Indeed, Valioni et al. (1998) reported that the *M. barbatus* individuals dispersed within areas shallower than 100 m in depth were smaller than 14 cm and that individuals distributed between 100 and 200 m in depth were generally 19-21 cm in length. Similarly, Somarakis and Machias (2002) reported that mature individuals of this species were common in 60-80 m depth layers, while their juveniles were generally found in the shallower waters. In light of these data, it is obvious that fishing should be conducted in deeper waters. This is because the fish in deeper waters are more likely to have reproduced.

Therefore, the length and age at first maturity determined for *M. barbatus* and *U. moluccensis* indicate that the fishing conducted in the 0-100 m depth layer using a traditional Mediterranean-type deep trawl net with poor selectivity excessively exploits newly matured individuals on the Mediterranean coast of Turkey. This type of fishing causes extensive over-fishing of these fish stocks. In this study, the average distances of 50 m and 100 m depth waters from the coastal strip were 0.8 miles and 2.5 miles, respectively. The average distances of the deep trawl stations from the coastal strip (0-50 m, 50-100 m, >100 m depth layers) were determined as 0.5, 1.6 and 2.9 miles, respectively. Therefore, as individuals longer than the length at first maturity are common the waters deeper than 100 m, deep trawl fishing in the waters shallower than 2.9 miles can impose over-fishing pressure on *M. barbatus* and *U. moluccensis* stocks. In this area, deep trawl fishing within the two-mile distance from the coast is forbidden (Anonymous, 2006). Therefore, expanding deep trawling prohibition to three miles offshore in Babadıllimanı Bight (as in some other parts of Mediterranean coast) is an appropriate and necessary action for the protection and sustainability of *M. barbatus* and *U. moluccensis* stocks.

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