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Spawning Season, First Maturity Length and Age of 21 Fish Species from the Central Aegean Sea, Turkey

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Abstract

The aim of this study was to determine the spawning season and length and ages at first maturity lengths of demersal fish species in the central Aegean Sea. Fish samples were collected by bottom trawling in İzmir Bay. Sampling was carried out at monthly intervals over a three-year period. The sample size of 21 species was sufficient to estimate their spawning period and length at first maturity. These species were *Arnoglossus laterna*, *A. thori*, *Blennius ocellaris*, *Boops boops*, *Buglossidium luteum*, *Cepola macrophthalma*, *Citharus linguatula*, *Deltentosteus quadrimaculatus*, *Dentex macrophthalmus*, *Diplodus annularis*, *D. vulgaris*, *Gobius niger*, *Lepidotrigla cavillone*, *Merluccius merluccius*, *Mullus barbatus barbatus*, *Pagellus acarne*, *P. erythrinus*, *Serranus cabrilla*, *S. hepatus*, *Spicara maena* and *Trisopterus minutus*. It was determined that the current prohibited season protects only 47.1% of these during peak spawning periods and that some commercial species' spawning periods are not covered by recent closed seasons. Although it was determined that a total of 13 species were fish targeted by artisanal fisheries, there are only four minimum landing size regulations in place for them. Therefore, for the study area we recommend a new prohibited season for fisheries carrying out bottom trawling as well as minimum landing sizes.

Keywords: Spawning period, minimum landing size, reproduction, fisheries management.

Introduction

The spawning season and length at first maturity of a species are essential parameters to know for the sustainable management of fish stocks within an ecosystem. When the spawning period of a species is known, refraining from fishing this species during this period is a reasonable measure that has been practiced for a long time. Moreover, only fishing those individuals which have reached maturity is one of the basic rules that should be followed to ensure sustainability. Although the common belief is that a fishery can be easily managed by following these two rules, the reality is not so simple. Adhering to minimum fishing size rules for species with different body forms which are targeted by the same fishing vessels requires significant effort. However, it is also quite difficult to impose a seasonal fishing ban which applies to all species in areas where many different species with different spawning periods live (Samy-Kamal, Forcada, & Lizaso, 2015). To manage such a fishery, it is necessary to determine the spawning periods of species living in the area being fished, to identify the ideal time and duration for a ban and also to take socio-economic factors into account.

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In this study, the parameters of spawning season, and length and age at first maturity were determined for 21 fish species and the findings obtained were compared to the current fishing regulations in order to make recommendations. These recommendations have been derived from findings related to reproductive biology obtained in a completed research project. Although this study uses previously published findings produced within the scope of the same project, it uses them in a different way. This is because, in order to ensure that robust and reliable recommendations could be presented, it was necessary to analyse the findings of other studies conducted in the study area at the same time using the same method. To this end, the findings obtained both in this study and other studies are given together in tables and figures and the parameters which were not included in this study are presented clearly within these tables and figures. We feel obliged to offer this explanation to prevent our practice in this regard from being perceived as not complying with scientific ethics due to the manner in which the findings are dealt with.

The main objectives of this study were to provide the specific information required by those who manage and regulate fisheries and to contribute to the regulation of fisheries by designing approaches based on this information.

Materials and Methods

Fish samples were collected from İzmir Bay (corner coordinates: 38º40'N 26º31'E and 38º02'N 26º08'E) by the research vessel EGESÜF. The sampling gear was a demersal trawl and the sampling period was at monthly intervals from July 2004 to June 2007. The trawl cod-end was knotless diamond shaped meshes made of polyamide material (PA) with 22 mm stretched mesh size netting in order to capture smaller individuals. The samplings were conducted in sandy and muddy bottoms between 30 and 70 m depth contours.

The samples collected were transported to the laboratory in cold storage for further analyses. The total length (*TL*) of each individual was measured in the natural body position and recorded with 1 mm precision. Total weight (*W*) and gonad weight (W_g) were measured to the nearest 0.01 g, and the sexes were recorded.

Determination of sexes and maturity stages were carried out by macroscopic inspection of the gonads to assess whether individuals were female, male, hermaphroditic or immature. Maturity stages were classified into five categories: I: immature; II: resting; III: developing; IV: ripe; and V: spent (Gunderson, 1993). Sagittal otolith pairs were removed, cleaned and stored in dry containers inside microplates or Eppendorf tubes. Age determination was performed using a stereoscopic zoom microscope under reflected light against a black background. Depending on their physical and chemical condition, some otoliths were prepared for age readings by profiling, rubbing and polishing (Metin & Kınacıgil, 2001) and estimations of age were made by at least two experienced independent researchers.

The species' spawning periods were determined based on monthly variations of the gonadosomatic index (GSI);

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$$GSI = \frac{W_g}{W - W_g} \times 100$$

where W_g is the gonad weight (g), W is the total weight (g) of the fish (Ricker, 1975). Spawning intensity was separated into three categories, "absent", "low" and "peak", from the GSI graphics.

Coverage rate values, which show the appropriateness of specific closed seasons for a given species, were found by calculating to what degree these seasons covered the species period of peak spawning. Additionally, the coverage rate of these seasons was calculated for all species and the relevant findings are presented in diagrammatic form.

Four different curve models were used for estimating the species' length at first maturity (L_m), that of half of the samples was determined as mature (İlkyaz, Metin, & Kınacıgil, 1998). The LogLog equations;

$$r(l) = \exp\left(-\exp-\left(a + b \times l\right)\right)$$

$$L_m = \frac{-\ln(-\ln(0.5)) - a}{b}$$

the CLogLog equations;

$$r(l) = 1 - \exp\left(-\exp\left(a + b \times l\right)\right)$$

$$L_m = \frac{\ln\left(-\ln\left(0.5\right)\right) - a}{b}$$

the Logit and the Probit equations;

$$r(l) = \left(\frac{\exp\left(a + b \times l\right)}{1 + \exp\left(a + b \times l\right)}\right) \text{ and } r(l) = \Phi\left(a + b \times l\right)$$

$$L_m = \frac{-a}{b}$$

where $r(l)$ is the proportion of mature individuals in each length class (%), a is intercept, b is slope, l is the fish total length (cm) and L_m is the mean total length at sexual maturity (50%, cm), were used. The degree of association between total length and percentage of variables in mature individual was calculated by the determination coefficient (R^2), and this value was used to select the best model for the species.

The economic values of the species were determined from fishery statistics (TUIK, 2014) and their presence in the fish market.

Results and Discussion

Although a total of 90 fish species were sampled in the study period, only the sample sizes of 21 species were suitable for estimating the spawning period and length at first maturity. From these 21 species, a total of 33153 individuals were used for further analyses. The sampling length range is important for

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determining the accuracy of the parameters. It is required that the samples cover all the different lengths found in the groups, from the smallest to the largest (Trippel & Harvey, 1991).

In the current study, the length at first maturity and age were estimated for both sexes. It is usual to find a size difference between the sexes, which changes from species to species, and is related to the species' life, history and reproductive biology (Darwin, 1871; Ghiselin, 1974; Shine, 1989). In addition, hermaphroditism is well known in the marine fish, especially in the Sparidae family, and also in the Serranidae family (Mitcheson & Liu, 2008) that together made up nearly half of the species in the present study. It was determined that common pandora (*P. erythrinus*) (Metin, İlkyaz, Soykan, & Kınacıgil, 2011b), European hake (*M. merluccius*) (Soykan, İlkyaz, Metin, & Kınacıgil, 2015a) and blotched picarel (*S. maena*) (Soykan, İlkyaz, Metin, & Kınacıgil, 2010) males reached first maturity at a greater length than females. Therefore, the suggested minimum landing sizes considered which sex had the greater length, because of the need to allow reproductive activity.

On the other hand, for comber's (*Serranus cabrilla*) and brown comber's (*Serranus hepatus*) (Soykan, İlkyaz, Metin, & Kınacıgil, 2013) the lengths and ages at first maturity of the male could not be determined because of an insufficient sample of males in these protogynous hermaphroditic fish species. Furthermore, for bogue's (*Boops boops*) (Soykan, İlkyaz, Metin, & Kınacıgil, 2015b), the length and age at first maturity of the males could also not be determined because of an insufficient sample size and range of sampling length. Accordingly, minimum landing sizes were not suggested for these three species.

The age at first maturity of 18 species varied between I and IV. The most common age was II with 11 species (61.1%); three species were at ages I and III (16.7%) and only one species was at age IV (5.6%). This age distribution shows that the situation is relatively good for Turkish deep trawl fisheries, because when the ages at first maturity are much higher the effective management of fisheries is, in theory, much more difficult (King, 2007). In other words, the minimum time required to observe the positive or negative effects of any new regulation regarding stocks is one or two generations and the shorter this time is, the less time it will take to determine which regulations are useful and will best contribute to the formation of a good model for fisheries.

It was determined that four species were of low commercial value (19.0%), three species were of mid-commercial value (14.3%), six species were of high-commercial value (28.6%) and eight species were discards (38.1%). Recommendations for the minimum landing size for 18 species were given whether these were of commercial value or not. Although it was determined that a total of 13 species were commercial, only four minimum landing size regulations were found for them (MFALT, 2016). While one regulation conformed to our findings, that for red mullet (*Mullus barbatus barbatus*), the others did not; these were the regulations for European hake (*Merluccius merluccius*) (Soykan et al., 2015a) and common pandora (*Pagellus erythrinus*) (Metin et al., 2011b). For these two species, we recommend a total length of 26 cm and 17 cm respectively as the minimum landing sizes. On the other hand, the minimum landing size in the regulation for the common two-banded seabream (*Diplodus vulgaris*) (Soykan et al., 2015b) was greater than in our recommendation. Although some of the species were

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commercial and target species for artisanal fisheries, there were no minimum landing size regulations. In view of this, we recommend a size of 13 cm for blotched picarel (*Spicara maena*) (Soykan et al., 2010), 12 cm for large-eye dentex (*Dentex macrophthalmus*) (Soykan et al., 2015b), 15 cm for axillary seabream (*Pagellus acarne*) (Soykan et al., 2015b), and 14 cm total length for poor cod (*Trisopterus minutus*). Our findings were acceptable for the study area due to its abiotic environmental features, and the regulations are valid for all sea areas around Turkey, which do themselves differ slightly (Table 1).

Figure 1 shows the monthly variation of gonad sizes (gonadosomatic index (GSI, %)) for the females and males of 21 fish species. On the other hand, comber (*Serranus cabrilla*) and brown comber's (*Serranus hepatus*) (Soykan et al., 2013) GSI resulted in female members only because of the insufficient sample size of males (Figure 1, r and s). All fish species' GSI pattern was specific and most of them were different from the others. Because of this, it is difficult to find a prohibited season that would be suitable for all fish species. Figure 2 demonstrates the monthly peak (dark grey boxes) and low (light grey boxes) spawning periods of the species, and the current prohibited season (black box and straight line) in brief. Considering the peak spawning periods (dark grey boxes only), the current prohibited period (15 April to 31 August) fully covers the spawning periods of three species (*A. laterna*, *P. erythrinus* and *S. hepatus*); however, it does not cover those of five species (*B. boops*, *C. linguatula*, *D. quadrimaculatus*, *D. vulgaris* and *T. minutus*) at all, and, finally, it only partially covers those of the other 13 species. In economic terms, among the commercial species only *P. erythrinus* is fully covered, while *B. boops*, *D. vulgaris* and *T. minutus* are not covered at all by the prohibited period. Additionally, the second y axis of Figure 2 shows the coverage rate of the current and suggested prohibited season, according to periods of peak spawning observed. Consequently, the current four and a half month prohibited season protects only 47.1% of the peak spawning periods.

We recommend that bottom trawl gears be prohibited from 1 March to 15 July. This period of four and a half months will completely cover eight species (*B. luteum*, *D. annularis*, *G. niger*, *M. merluccius*, *M. barbatus barbatus*, *P. erythrinus*, *S. cabrilla* and *S. maena*), five of which are economically important. However, the suggested time period will not protect three species (*C. linguatula*, *D. quadrimaculatus* and *D. vulgaris*) and will only partially cover the other 10 species. Nevertheless, the suggested prohibited season will protect 60.0% of the peak spawning periods which will be 27.4% more than the current arrangement. The percentage of protection given could be increased by extending the prohibited length of time. However, doing this might cause socio-economic problems. Moreover, the recommended prohibited season only takes into account the spawning periods of the 21 fish species in the study area. Recruitment is a complex process and is affected by many factors, however our recommendation considers only one part of this. As a result, other parameters that have an effect on reproduction, such as spawning migrations or environmental factors, have not been considered.

The current study reports on the spawning season, lengths and ages at first maturity of various species, factors that are absolutely essential for fisheries' management. Consequently, this study serves as baseline data on 21 fish species in the central Aegean Sea and should be helpful for the successful management of fisheries in the future.

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Table 1. First maturity length and age of 21 fish species from the central Aegean Sea.

Name of Species	*n*	SLR	*L*±SE	F(A)	M(A)	SL	MLS	EI	Referance
Arnoglossus laterna Mediterranean scaldfish	2,469	4.4-19.8	9.41±0.05	11.88(2)	11.41(2)	12		N	İlkyaz et al., 2017
Arnoglossus thori Thor's scaldfish	422	4.4-12.5	8.67±0.06	8.81(2)	8.64(2)	9		N	Current study
Blennius ocellaris Butterfly blenny	279	5.5-16.5	9.73±0.13	10.02(3)	9.25(2)	10		N	Current study
Boops boops Bogue	421	11.0-23.8	15.46±0.10	12.96(1)	-	-		M	Soykan et al., 2015b
Buglossidium luteum Solenette	1,211	5.8-11.6	8.54±0.02	8.12(2)	7.89(2)	8		N	İlkyaz et al., 2010a
Cepola macrophthalma Red bandfish	1,889	6.3-51.6	28.78±0.19	31.07(3)	34.69(3)	35		N	Current study
Citharus linguatula Spotted flounder	2,345	4.9-26.5	13.43±0.08	11.98(2)	12.89(2)	13		L	Current study
Deltentosteus quadrimaculatus Four-spotted goby	1,696	3.1-9.2	7.08±0.02	6.15(2)	6.38(2)	6		N	Metin et al., 2011a
Dentex macrophthalmus Large-eye dentex	716	3.9-21.3	9.63±0.12	10.83(1)	11.77(1)	12		H	Soykan et al., 2015b
Diplodus annularis Annular seabream	2,393	7.7-18.3	11.48±0.03	10.02(2)	10.53(2)	11		L	Current study
Diplodus vulgaris Common two-banded seabream	709	7.5-19.0	12.40±0.07	12.87(1)	13.37(1)	14	18	M	Soykan et al., 2015b
Gobius niger Black goby	1,065	3.8-16.3	11.50±0.06	11.42(3)	11.09(3)	11		N	Current study
Lepidotrigla cavillone Large-scaled gurnard	2,342	3.4-15.2	9.71±0.05	10.55(2)	10.55(2)	11		L	İlkyaz et al., 2010b
Merluccius merluccius European hake	2,108	5.2-45.5	23.77±0.17	21.49(1)	25.65(2)	26	20	H	Soykan et al., 2015a
Mullus barbatus barbatus Red mullet	2,691	5.1-28.2	12.83±0.05	12.33(2)	11.56(2)	13	13	H	Current study
Pagellus acarne Axillary seabream	842	8.5-20.2	13.52±0.05	14.45(2)	13.91(2)	15		H	Soykan et al., 2015b
Pagellus erythrinus Common pandora	1,428	4.1-26.9	13.59±0.10	11.45(2)	16.49(4)	17	15	H	Metin et al., 2011b
Serranus cabrilla Comber	1,780	6.9-24.5	15.05±0.07	9.86(1)	-	-		L	Current study
Serranus hepatus Brown comber	2,410	3.9-12.3	8.68±0.02	7.76(3)	-	-		N	Soykan et al., 2013
Spicara maena Blotched picarel	2,457	7.5-20.0	13.02±0.04	11.51(2)	13.12(2)	13		M	Soykan et al., 2010
Trisopterus minutus Poor cod	1,480	5.7-20.5	13.04±0.06	13.28(1)	12.60(1)	14		H	Current study

Species listed in alphabetical order. Scientific and common names are based on FishBase (Froese and Pauly, 2017) and FAO (Fischer et al., 1987). *n*: Total sample size (all sexes combined). SLR: Sampling length range (cm). *L*±SE: Arithmetical mean of length and its standard error (TL, cm). F(A) and M(A): First maturity length (TL, cm) and age of female and male. SL: Suggested minimum landing size (TL, cm). MLS: Current legal minimum landing size (MFALT, 2016). EI: Economic importance of the species [N: Non-commercial (discard), L: Low commercial, M: Mid-commercial, H: High commercial].

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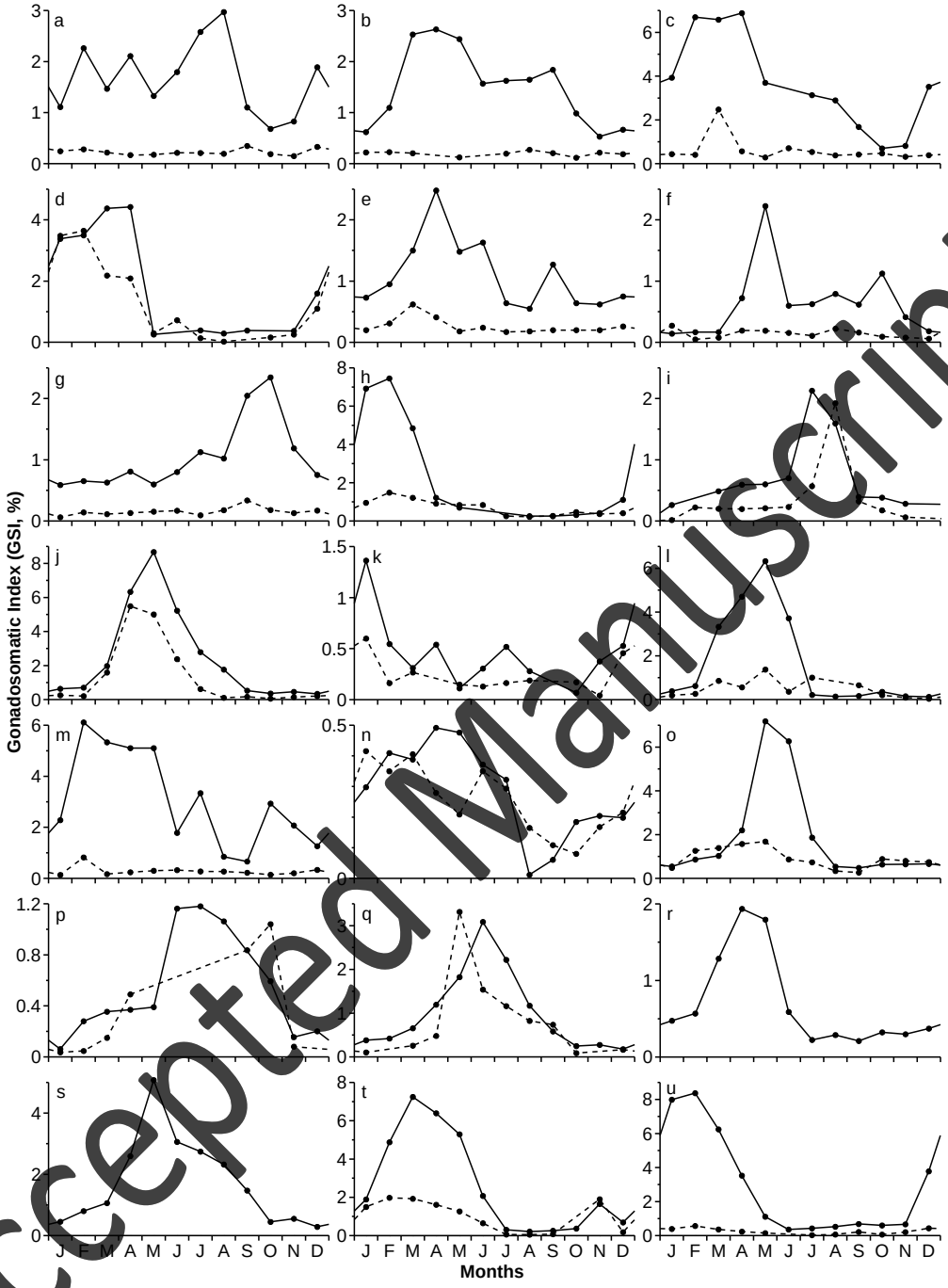

Figure 1. Gonadosomatic index (GSI, %) of 21 fish species from the central Aegean Sea. (a: *Arnoglossus laterna* (İlkyaz et al., 2017), b: *Arnoglossus thori*, c: *Blennius ocellaris*, d: *Boops boops* (Soykan et al., 2015b), e: *Buglossidium luteum* (İlkyaz et al., 2010a), f: *Cepola macrophthalma*, g: *Citharus linguatula*, h: *Deltentosteus quadrimaculatus* (Metin et al., 2011a), i: *Dentex macrophthalmus* (Soykan et al., 2015b), j: *Diplodus annularis*, k: *Diplodus vulgaris* (Soykan et al., 2015b), l: *Gobius niger*, m: *Lepidotrigla cavillone* (İlkyaz et al., 2010b), n: *Merluccius merluccius* (Soykan et al., 2015a), o: *Mullus barbatus barbatus*, p: *Pagellus acarne* (Soykan et al., 2015b), q: *Pagellus erythrinus* (Metin et al., 2011b), r: *Serranus cabrilla*, s: *Serranus hepatus* (Soykan et al., 2013), t: *Spicara maena* (Soykan et al., 2010) and u: *Trisopterus minutus*. |: Female. ¦: Male.)

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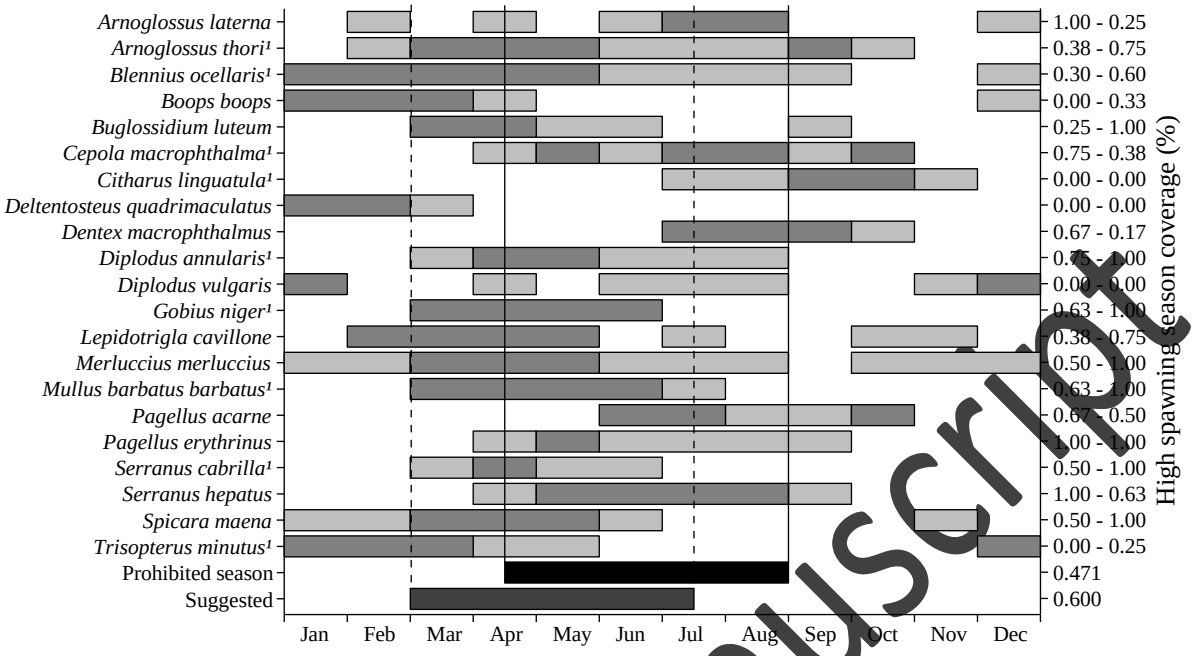

Figure 2. Diagram of spawning, prohibited and suggested prohibited season for 21 fish species from the central Aegean Sea. (Second y axis is observed peak spawning season coverage of current and suggested prohibited season (%). ¹: This study's' findings. ■: Low spawning observed. ■: High spawning observed. ■ and |: Prohibited season for bottom trawl fisheries. ■ and ¦: Suggested prohibit season for bottom trawl fisheries.)