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Short Communication

Common sole, *Solea solea* (Linnaeus 1758) in Izmir Bay, Aegean Sea: A special morphometric approach to dimorphic structures

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Introduction

The Mediterranean is a significant region for marine (Yildiz *et al.*, 2020) fish particularly flatfish species with high commercial value. The common sole, *Solea* sp. (Linnaeus 1758) is a flat fish species that has high commercial importance in Turkey as well as in the whole world. Turkey's most important sole fishing areas are Güllük Bay, Karina and Izmir Bay in Aegean Sea (Ulutürk *et al.*, 2012). As known, morphological characteristics are crucial in defining species or subspecies and serve as the primary basis of systematic science (Chan, 2001). However, biometric characters' similarities or differences vary due to geographical variations (Ezzat *et al.*, 1975). Therefore, understanding population characteristics and growth dimorphisms between sexes across various geographical areas is vital for these economically important flatfish species. Although studies on biological characteristics of *Solea solea* exist (Amara *et al.*, 2007; Parma *et al.*, 2019; Cerim and Ateş, 2020), research on whether growth causes any morphometric differentiation in both sexes is insufficient, considering the length groups. This study aims to determine the dimorphism in growth and geographic characters in the *S. solea*, caught from the Aegean Sea off the coast of Türkiye, depending on sexes and length groups, using morphometric combinations, which are an integral part of biological studies.

Material and methods

The specimens used in this study were collected on a monthly basis from 2019-2020 in areas where commercial fishing is allowed in Izmir Bay, Türkiye. The specimens were mainly adult common sole, likely due to commercial trawling. Only adult specimens were taken into consideration, with very few exceptions among fish that met legal size requirements. Specimens were collected in all months except January-February, when seasonal trawling was prohibited in Izmir Bay (Anonymous, 2020). The total length (TL mm), morphometric measurements (mm) and total weight (W gr) were determined for the specimens. The specimens were evaluated into three size groups determined by the TL data (190-229 mm; small, 230-269 mm; medium; >270 mm; large). Morphometric measurements were described according to Afonso-Dias *et al.* (2002) (Fig. 1). The study used Ricker's (1975) method to evaluate the length-weight relationship (*LWR*) of the specimens and Wootton's (1998) equation for determinations in allometric relationships. Pairwise analysis was used to determine the source of any significant differences between sexes and length groups, and Student's t-test was used to reveal morphometric differences and similarities (Miller and Siegmund, 1982).

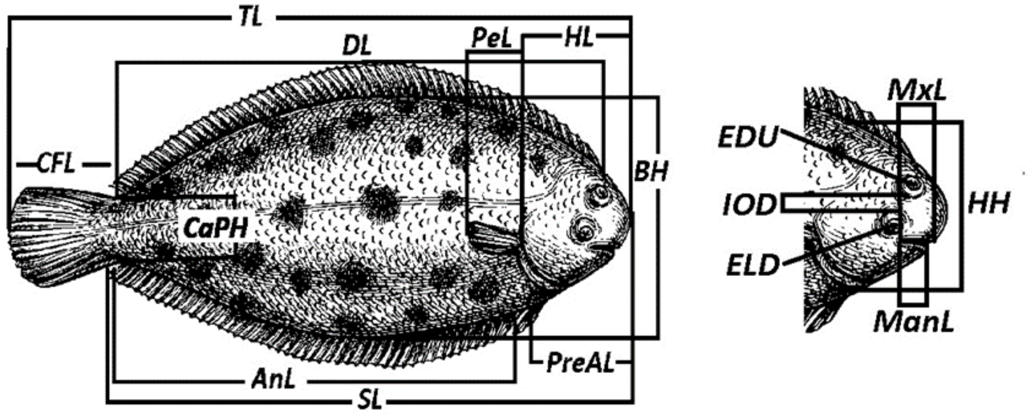

Figure 1: Morphometric protocol Illustrated by *E. Taskavak* (modified from Afonso-Dias *et al.*, 2002).

Results and discussion

A total of 240 specimens (♀=166; ♂=66; unidentified=8) were evaluated in this study. According to the length groups examined the medium size is the most common length group among specimens. The *LWR* were calculated for sexes (W=0.0099TL$^{2.97}$ R^2=0.86 2.97-0.050 95% CI (♀); W=0.0033TL$^{3.27}$ R^2=0.91 3.27-0.059 95% CI (♂). The statistical difference between W values of males and females is significant (t:3.040, p:0.002, $p<0.05$). While females are heavier than males in terms of W values, there is no difference between the sexes in terms of TL. According to the *b* values, the growth patterns for females and males are isometric and + allometric, respectively, with *b*=2.97-0.050 95% CI (♀) and *b*=3.27-0.059 95% CI (♂). The combined values of females and males

(3.07-0.045 95% CI) also demonstrate + allometric growth. Although there was no difference between the sexes in terms of TL values, there was a difference in W values. However, Başusta *et al.* (2020) found no difference between the sexes of *S. solea* in terms of both TL and W values on the NE Mediterranean coasts. It is important to note that the observed differences in growth values are influenced by various biotic factors (Tesch, 1971). On the other hand, in terms of *LWR* values, our results are similar to the southern Aegean population (Cerim and Ates, 2020), our specimens show a better growth than the Mediterranean population (Mehanna *et al*., 2015). It is possible to accept these differences seen in growth value as an indicator of general factors affecting growth suggested by Tesch (1971). There are differences between the sexes of samples in terms of the morphometric measurements in Table 1.

Table 1: The results of the body parts with sexual dimorphism in sexes according to body lengths.

Dimorphic Features	Small size (199–229 mm)	Medium size (230–269 mm)	Large size (>270 mm)
Head Length	(♀): 38.06±3.53 (♂): 36.56±3.40 $p>0.05$	44.11±3.79 41.47±3.39 $p<0.05$*	50.38±3.98 46.56±2.73 $p<0.05$*
Head Height	(♀): 42.64±3.69 (♂): 41.12±4.30 $p>0.05$	49.42±4.83 46.17±3.42 $p<0.05$*	57.07±3.62 52.22±2.43 $p<0.05$*
Interorbital Distance	(♀): 6.67±1.48 (♂): 6.38±1.05 $p>0.05$	8.82±1.80 7.19±1.79 $p<0.05$*	13.36±1.12 10.12±1.31 $p<0.05$*
Eye Diameter Length	(♀): 5.70±0.92 (♂): 5.64±0.80 $p>0.05$	6.69±0.94 6.03±1.02 $p<0.05$*	7.88±1.11 6.72±0.77 $p<0.05$*
Mandibula Length	(♀): 9.37±1.42 (♂): 9.39±1.41 $p>0.05$	11.35±2.02 10.21±1.18 $p<0.05$*	13.36±1.12 11.64±1.48 $p<0.05$*
Body Height	(♀): 63.88±4.66 (♂): 58.28 ±6.64 $p<0.05$*	71.25±7.45 66.69±6.21 $p<0.05$*	88.16±3.12 74.24±2.98 $p<0.05$*
Caudal peduncle Height	(♀):18.22±1.64 (♂):17.54±2.06 $p>0.05$	22.00±2.60 19.72±1.87 $p<0.05$*	24.51±2.50 21.87±1.63 $p<0.05$*

$p<0.05$*: Statically difference.

Regarding head measurements, females have larger head than those of males ($t_{(HL)}$:2.251, p=0.025 ($t_{(HH)}$:2.375, p=0.018, $p<0.05$). Growth of females is isometric in the *LWR*, and allometric in the *LLR* (length-length relationship), in terms of HL values that developed due to TL ($t_{(HL)}$:2.699, p=0.007, $p<0.05$). In males, this *LLR* remains isometric in terms of HL and TL ($t_{(HL)}$:0.443, p:0.65, $p>0.05$). Accordingly, the IOD and EDL values in the head also differ statistically between the sexes. Since females by length isometric growth has started to differ from males with + allometric growth, it is apparent that both features are important for females ($t_{(EDL)}$:2.965, p:0.03; $t_{(IOD)}$:2.805 p=0.05, $p<0.05$). Another distinctive morphological character of the head is ManL and it is larger in females than males ($t_{(ManL)}$:2.339, p=0.020; $t_{(BH)}$:3.534, p=0.0004, $p<0.05$). This means that females have a higher body than males (Fig. 2A-B-C-D-E).

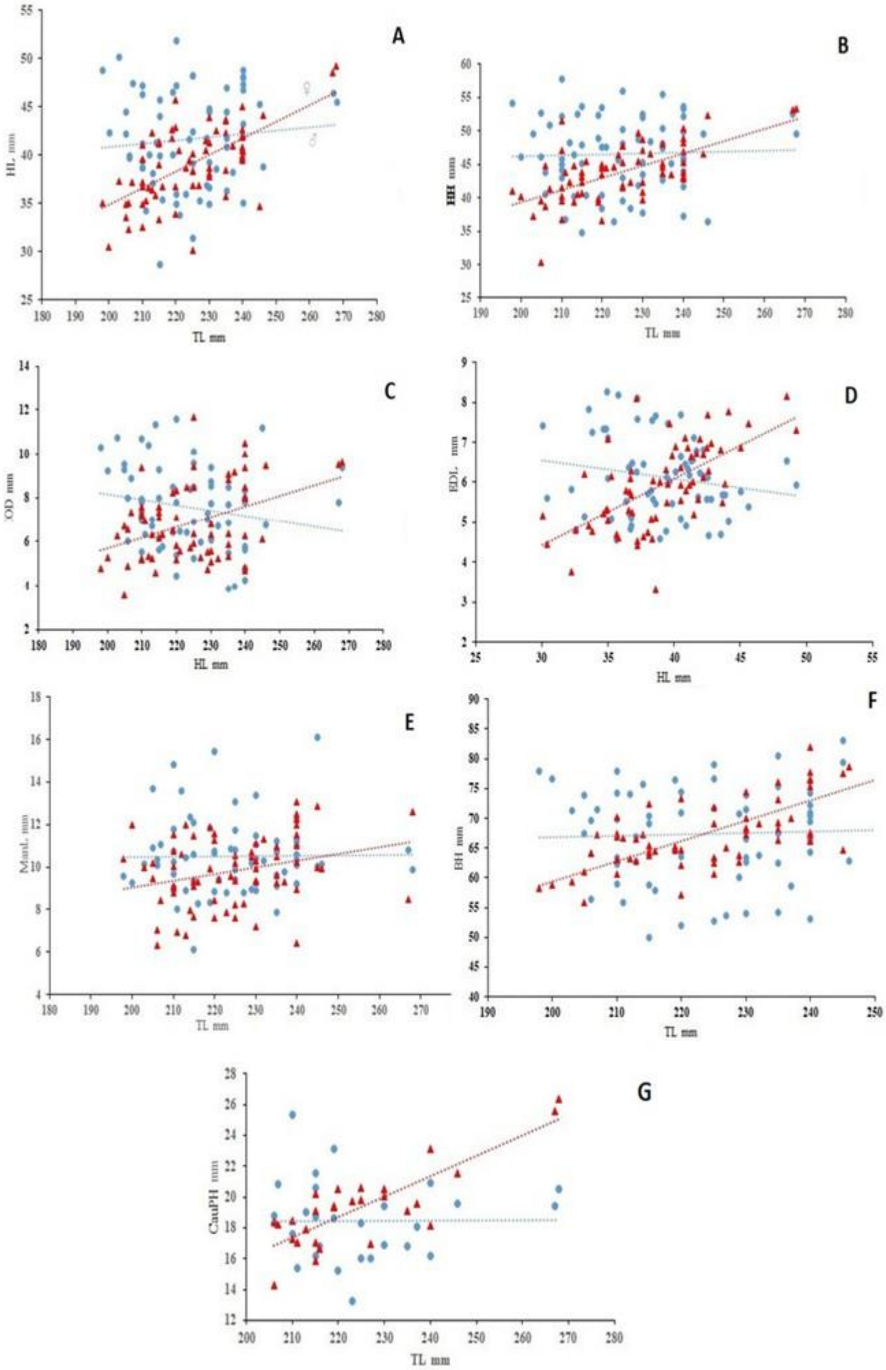

Figure 2: (A) allometric growth relationship between head length and total length (• ♂male ▲♀female); (B) Allometric growth relationship between head height and total length (• ♂male ▲♀female); (C) Allometric growth relationship between interorbital distance and head length (• ♂male ▲♀female); (D) Allometric growth relationship between head length and lower eye diameter (• ♂male ▲♀female); (E) Allometric growth relationship between mandibula length and total length (• ♂male ▲♀female); (F) Allometric growth relationship between body height and total length (• ♂male ▲♀female);(G) Allometric growth relationship between total length and minimum height of the caudal peduncle (• ♂male ▲♀female)

Maji *et al.* (2015) found that fish, being highly sensitive to changes in their environment, can adapt quickly by modifying their relevant morphometric characteristics. Marques *et al.* (2006) suggest that morphological descriptions are a key factor in the ecological differentiation of flatfish populations. However, both studies agree that differences or similarities in morphological structures determine the visual differentiation of sympatric Soleidae species. Reports on sole fish distributed along the coasts of Portugal and Egypt indicate that there are differences in body measurements (Ezzat *et al*., 1975; Marques *et al*., 2006). Similarly, significant differences in morphometric features were found between sexes when evaluating the Aegean Sea's common sole in terms of size groups.

Sánchez *et al.* (2010) and Fernández (2012) emphasized that female *S. senegalensis* show sexual differences in appearance once they reach a certain size, compared to males. Our study also found that females differ from males in terms of body height and show sexual differences, which supports the findings of Sánchez *et al*. (2010) and Fernández (2012). The morphological characteristics of a fish species are known to be influenced by temperature factors during the early stages of its life (Barlow, 1961). This means that changes in water temperature and density values may result in changes in the caudal vertebrae region of the relevant fish (Maji *et al*., 2015). Females have a greater CauPH than males ($t_{(CauPH)}$:3.949, p=0.001, p<0.05). There is sexual dimorphism in BH in the length group 190-229 mm. Females in this group have higher bodies than males ($t_{(BH)}$:3.872, p=0.0002, p<0.05) (Fig. 2F-G), and this differentiation favors females. The significant difference in BH and CauPH in our study indicates a phenotypic response of *S. solea* to water temperature factors in the Aegean Sea. Our study found that different body parts reveal differences in growth between the sexes, depending on their size groups. Thus, the findings we have obtained regarding the physical characteristics and potential growth variations among common sole specimens from Izmir Bay can be used to develop strategies for spatial management and/or modelling approaches based on fish morphology.

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