Condition of common sole (Solea solea L.) in the fishing season in Istrian waters of the Adriatic sea

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ORIGINAL SCIENTIFIC PAPER

Condition of common sole (*Solea solea* L.) in the fishing season in Istrian waters of the Adriatic sea

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Abstract
To determine the condition of the common sole (*Solea solea*, Linnaeus, 1758) in Istrian waters during the fishing season research was conducted from November 2020 to January 2021. In 20 fish sexed monthly sex ratios were 1.22:1 in November, 1.86:1 in December, and 1.50:1 in January, in favour of males. Average values of length-weight ratio were the highest in November, and the lowest in January. Positive allometric growth was recorded with coefficient b values of approximately 3.6. Both sexes exhibited the lowest values of gonadosomatic index in November, and the highest in December. Hepatosomatic index in males was declining from November to January. In females, the highest values of HSI were observed in January, and the lowest in December. High values of GSI indicate that sampled months fall into the spawning season.

Key words: common sole, Adriatic sea, Fulton`s condition factor, allometric growth, hepatosomatic index, gonadosomatic index

Introduction

The common sole (*Solea solea* Linnaeus, 1758) is one of the most commercially important species of the Mediterranean and Black Sea which provides about 15% of the overall worldwide landings (FAO, 2021). In the Adriatic Sea in 2019 total landing of common sole were 1993 metric tons which corresponds to 40% of total landings (FAO, 2021). According to Rogers (1992) the species was reported to be the most abundant in the central and northern parts of the Adriatic due to low depths and wide occurrence of soft bottoms. High-density aggregations are recorded in certain regions such as the western coast of Istria in autumn and winter (Piccinetti and Giovanardi, 1984) when it represents a target species for beam trawlers and small-scale fisheries (Matić-Skoko and Stagličić, 2020). In the small-scale fisheries, which rank second in landings in Croatia, sole gillnets and trammel nets are mostly used when targeting common sole (Matić-Skoko and Stagličić, 2020). The goal of this paper is to determine the condition state of the common sole and to comprehend the physiological changes in form of reserve expenditures and gonadal growth during the fishing season in Istrian waters and to compare them to other investigated populations.

Material and methods

Samples were collected in Istrian waters (Croatia) using trammel nets with a mesh size of 42 mm from November 2020 to January 2021. Samples of *S. solea* were identified in total catch, 40 individuals per each month were picked randomly and measured in total length and

weight, out of which 20 were collected for dissection and further analyses. Liver and gonads were separated and weighed. The sex of the fish was determined macroscopically by examining the shape and colour of the gonads.

Weight–length relations were computed using power regression and the derived formula had the shape: $W=a \cdot Lb$, where W = mass, L = length and a, b = regression coefficients (Le Cren, 1951). Coefficient a determines the shape of the fish, and coefficient b, the type of growth. If $b<3$ fish progress faster in length (negative allometric growth), $b=3$ growth is equal in weight and length (isometric growth), and if $b>3$ fish progress faster in weight (positive allometric growth). Fulton's condition factor (CF) was calculated using the formula: CF = W/L3 x 100, where W = mass, L = total length (Ricker, 1975). Gonadosomatic index (GSI) was calculated using the formula: GSI = (Mass of the gonads/Mass of the fish) x 100 (de Vlaming et al., 1982). Hepatosomatic index (HSI) was calculated using the formula: HSI = (Mass of the liver/Mass of the fish) x 100 (Wootton et al., 1978).

All the data were analysed using Microsoft Excel 2016. Differences in observed characteristics between sexes were determined using t-test, and differences in monthly proportions of males and females in the sample were determined using chi-squared test.

Results and discussion

Monthly sex ratios were as follows: 1.22:1 in November 2020, 1.86:1 in December 2020 and 1.5:1 in January 2021, always in favour of males. Statistically significant differences were not found using chi-squared test ($p<0.05$). Although not statistically significant, this result differs from the findings of Piccinetti and Giovanardi (1984) who indicated that sex ratio is always roughly 1:1.

The average recorded length and mass values were at their highest in November 2020 for all groups following a slightly decreasing trend throughout the sampling period with the lowest values recorded in January 2021. Average weight and length values were always higher in females (Table 1).

Table 1. Average monthly values of total length and mass of *Solea solea* for all individuals and both sexes separately in November and December 2020 and January 2021 (n = number of individuals, mean = average value, SD = standard deviation)

Species	Month	Sex	n	Total length TL (cm)	Body weight W (g)
				Mean ± SD	Mean ± SD
Solea solea	November	All	40	29.86 ± 1.03	246.4 ± 30.66
		M	11	28.35 ± 2.17	197.0 ± 50.57
		F	9	29.96 ± 1.37	265.0 ± 47.94
	December	All	40	28.93 ± 2.61	217.55 ± 88.78
		M	13	27.25 ± 1.99	173.63 ± 46.10
		F	7	29.57 ± 2.03	248.33 ± 55.57
	January	All	40	28.43 ± 1.09	180.85 ± 32.20
		M	12	26.84 ± 1.35	175.57 ± 39.76
		F	8	27.97 ± 0.71	185.67 ± 18.15

Positive allometric growth was recorded throughout the sampling period with coefficient b values of approximately 3.6 (Fig. 1). High recorded values of coefficient b are due to correspondence of sampling and spawning period. Prior to spawning fish increase food consumption and allocate available energy to gonadal growth (Wooton, 2011). This results in an increase in body weight relative to length which causes an increase in the b value of the weight-length ratio (Ricker, 1975). Contrary to the findings in this paper, Bolognini et

al. (2013) determined b coefficient to be 3.057 for 5401 individuals of *S. solea* sampled between January 1999 and December 2009 in the Italian waters of central and northern Adriatic. Differences in coefficient b in western and eastern coasts of the Adriatic may be due to difference in sampling period, but can also be attributed to the spatial distribution of adults and juveniles. Landings of *S. solea* in Italian waters consist of 80% juvenile specimens (Grati et al., 2013) which do not undergo physiological changes during the spawning period and therefore show lower b coefficient values. Seasonal data on b coefficient values are non-existing for the Adriatic.

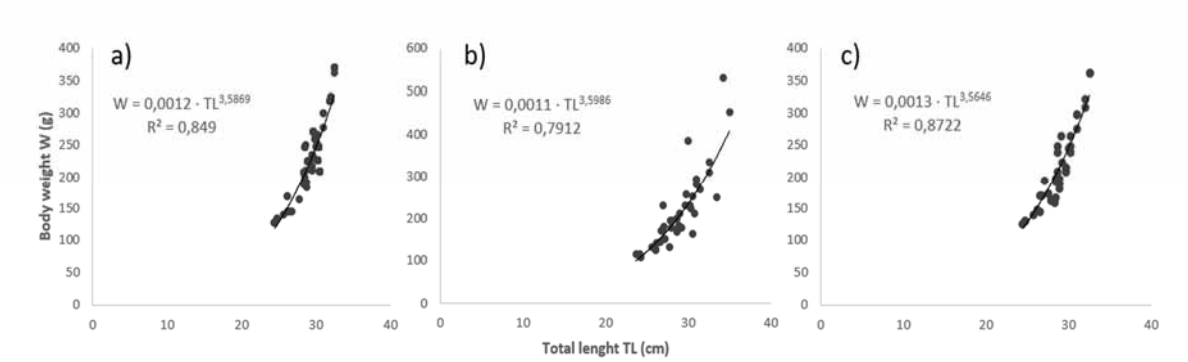

Figure 1. Weight-length relations of *Solea solea* in a) November 2020, b) December 2020 and c) January 2021

Mean values of Fulton's condition factor for 40 monthly measured individuals ranged from 0.86 ± 0.16 g/cm^3 in December 2020 to 0.9 ± 0.09 g/cm^3 in November 2020. In females CF decreased from 0,98 ± 0.07 g/cm^3 in November 2020 to 0.88 ± 0.08 g/cm^3 in January 2021. In males it ranged from 0.84 ± 0.12 in December 2020 to 0.9 ± 0.07 in January 2021 (Fig. 2). Statistically significant differences between males and females were found using t-test in November ($t=3.93$, $p<0.05$) and December ($t=2.14$, $p<0.05$). Data regarding Fulton`s condition factor of spawning individuals in Adriatic are scarce and previous research focused mainly on juveniles (Bolognini et al., 2013).

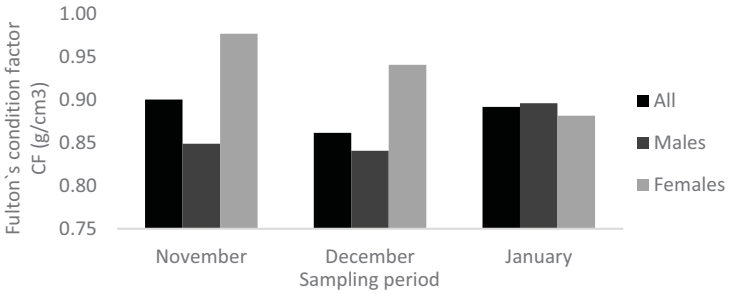

Figure 2. Average monthly values of Fulton`s condition factor of *Solea solea* during the sampling period

According to Pauly (1994) geographical differences in growth are caused by differences in temperature that affect distinct metabolism and oxygen consumption of the two sexes. This can cause variations in food intake (Lozán, 1992) and allocation of surplus energy towards somatic growth or reproduction (Rijnsdorp, 1993) which contributes to the life cycle variability of the same species in different areas. *S. solea* are batch spawners (Murua and Saborido-Rey, 2003) and there are noticeable differences in spawning periods observed by different authors. In the northern Atlantic spawning occurs in spring and in the Mediterranean during the winter (Quéro et al., 1986). High values of GSI recorded in females in this paper indicate that sampled months fall into the spawning season in the northern

Adriatic, which agrees with Bolognini et al. (2013). All examined fish ranging from 24.2 cm to 35 cm had developed gonads. Both sexes exhibited lowest values of gonadosomatic index in November 2020 (0.10 ± 0.04 for males, and 9.25 ± 2.42 for females) and highest in December 2020 (0.23 ± 0.07 for males, and 13.02 ± 1.27 for females) (Fig. 3.a). It is noticeable that GSI values of females were extremely high compared to GSI values of males, all statistically significant and determined using t-test ($p<0.05$), which agrees with Teixeira and Cabral (2010). In order to determine the exact extent of spawning season further research with a longer sampling period is needed.

Values of hepatosomatic index (HSI) in males were declining from November 2020 (1.05 ± 0.36) to January 2021 (0.85 ± 0.16). In females, the highest values of HSI were observed in January 2021 (1.69 ± 0.43) and the lowest in December 2020 (1.35 ± 0.17) (Fig. 3.b). Monthly differences in HSI between sexes were determined using t-test and are all statistically significant ($p<0.05$). Monthly HSI values in males exhibited reverse trends compared to GSI. This suggests that energy stored in the liver is being mobilized due to lower food intake during the spawning season (Wooton, 2011).

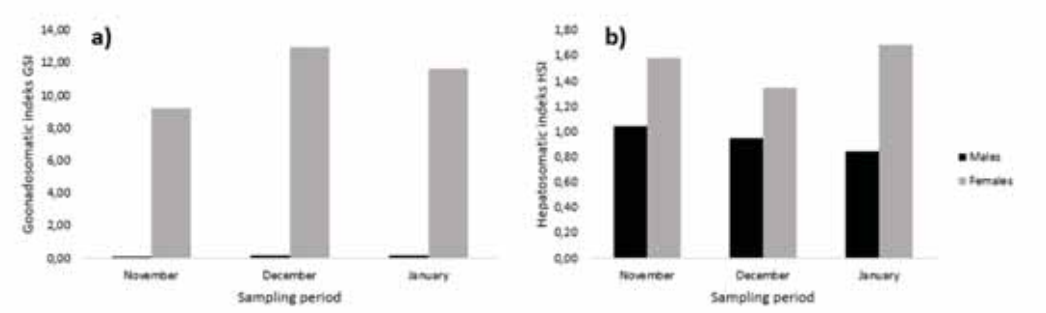

Figure 3. a) GSI and b) HSI of male and female *Solea solea* during the sampling period

Conclusions

Positive allometric growth of common sole was recorded in the coastal waters of Istria throughout November, December and January with coefficient b values of approximately 3.6. Sex ratio ranged from 1.22 to 1.86, in favour of males. High recorded values of GSI in females indicate that sampled months fall into the spawning season. Reverse trends of monthly HSI values in males compared to GSI suggest that energy stored in the liver is being mobilized due to lower food intake during the spawning season.

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Kondicijsko stanje lista (*Solea solea* L.) tijekom ribolovne sezone u istarskom akvatoriju Jadranskog mora

Sažetak

Cilj rada bio je utvrditi kondicijsko stanje lista (*Solea solea* Linnaeus, 1758) u istarskom akvaktoriju istraživanjem provedenim od studenog 2020. do siječnja 2021. godine. Zabilježeni omjer spolova bio je 1,22:1 u studenom, 1,86:1 u prosincu i 1,50:1 u siječnju, u korist mužjaka. Prosječne vrijednosti odnosa mase i duljine bile su najveće u studenom, a najniže u siječnju. Zabilježen je pozitivan alometrijski rast s vrijednostima koeficijenta b od približno 3,6. Oba spola su imala najniže vrijednosti gonadosomatskog indeksa u studenom, a najviše u prosincu. Hepatosomatski indeks kod mužjaka opadao je od studenog do siječnja. U ženki su najveće vrijednosti HSI zabilježene u siječnju, a najniže u prosincu. Visoke vrijednosti GSI ukazuju na to da uzorkovani mjeseci spadaju u sezonu mrijesta.

Ključne riječi: list, Jadransko more, Fultonov factor kondicije, alometrijski rast, hepatosomatski indeks, gonadosometski indeks