

STATUS OF THE TURBOT (*Scophthalmus Maeoticus*, Pallas, 1814) AGGLOMERATIONS ALONG THE ROMANIAN BLACK SEA COAST

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Abstract. *The main commercially valuable species in the Black Sea is turbot (Scophthalmus maeoticus, Pallas, 1814). Thus, turbot stock assessment is vital to ensure its sustainable use, to support economic and ecological stability, to inform science-based management decisions, and to promote the conservation of marine biodiversity. To determine turbot aggregations, the BioIndex routine, developed in R language, was used to estimate different biological indicators related to this target species. In particular, the routine allows the estimation of time series of mean abundance and biomass indices, the inverse CV of abundance indices, mean individual weight and sex ratio at the GSA level. Taking into account the biomass values resulted for the study period (2019-2020) a significant increase was observed in the values from the period 2012-2018 and the maximum yield (RMM) obtained of 329,048 tons for the Romanian area of the Black Sea.*

Keywords: *turbot, growth parameters, assessment, biomass index*

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INTRODUCTION

Fish stock assessment is a critical process in fisheries science and management, offering numerous benefits. The primary goal of fish stock assessment is to ensure the sustainable management of fishery resources. By evaluating the abundance and dynamics of fish populations, help set appropriate catch limits and management measures that prevent overfishing and promote long-term sustainability.

The main commercial valuable species from the Black Sea is turbot (*Scophthalmus maeoticus*, Pallas, 1814). In spring, from March to April, the sexually mature specimens leave the overwintering grounds from the deep sea and

undertake short trips to the coast, where, at a depth of 20-30 m, they lay their eggs [1].

Research surveys are organized every year since 2008 by NIMRD (National Institute for Marine Research and Development “Grigore Antipa”) in the framework of the National Data Collection Fisheries Program. The number of hauls established for our continental shelf is minimum 40 in spring and respectively minimum 40 in autumn. The study presents the results obtained during 2019-2020 period.

MATERIALS AND METHODS

To determine turbot agglomerations BioIndex routine has been used, developed in R language, with the purpose of estimating different biological indicators related to a given target species. In particular it allows to estimate the time series of the mean abundance and biomass indices, the inverse of the CV of the abundance indices, the mean individual weight, and the sex ratio at GSA level. Using the time series of the indices previously estimated, the routine performs the analysis of trends using two different tests: Spearman's rho test and the Interception Union Test. The estimation of the indices is also performed with the resolution of the 30 second GFCM statistical grid. Bubble plots of the abundance of recruits and spawners by hauls were also generated [2].

Data compilation has been realized in 3 csv files (TA, TB, TC) based on Medits Manual in which are included information regarding: trawling (number of hauls, date, time, depth, warp length, trawl characteristics, etc.), catch (species, total catch in grams, number of individuals, maturity, sex, etc.) and also salinity and temperature parameters.

Data quality checks of the csv files have been performed by RoME routine; a script that detects errors based on a sequence of functions.

To estimate spawners and recruits a threshold, 45 cm has been used and for depth stratification of the Romanian shelf were used 3 strata: 10-30 m; 30-50 m, 50-70 m.

BioIndex and RoME for Black Sea, were presented for the first time in Burgas (May 27-30, 2019) during the "*Data preparation meeting of benchmark session for Black Sea turbot*" organized by GFCM through BlackSea4Fish project. Estimation of Maximum Sustainable Yield (MSY) was made by using the Gulland's formula proposed by Cadima (2003) [3] and for growth parameters the von Bertalanffy function was applied according to Sparre and Venema (1998) [4].

RESULTS AND DISCUSSION

Spring season 2019

The length of turbot individuals caught (99 exp.) oscillated between 19.0 and 70.0 cm and the weight between 133 and 6700 g. Of the fished and measured specimens, 15 were juveniles (15.15%), 38 were in the range 40.0 - 50.0 cm (38.38%); 28 exemplars in the range 51.0 - 60.0 cm (29.28%), and 18 in the range 61.0 - 70.0 cm (18.19%). Females predominated (43.75% /49 specimens), compared to the males (38.54% / 36 exp.), the rest of 17.71% / 15 juveniles. The total catch of turbot was 236.135 kg, with the following productivity: 2.39 kg / individual; 5.76 kg / haul; 5.76kg / hour of trawling. In the 42 sample trawlings made with the demersal trawl, on a surface of 17,800 Km², the average values of the catches were of about 0.241 - 0.464 t/Km² (Figure 1).

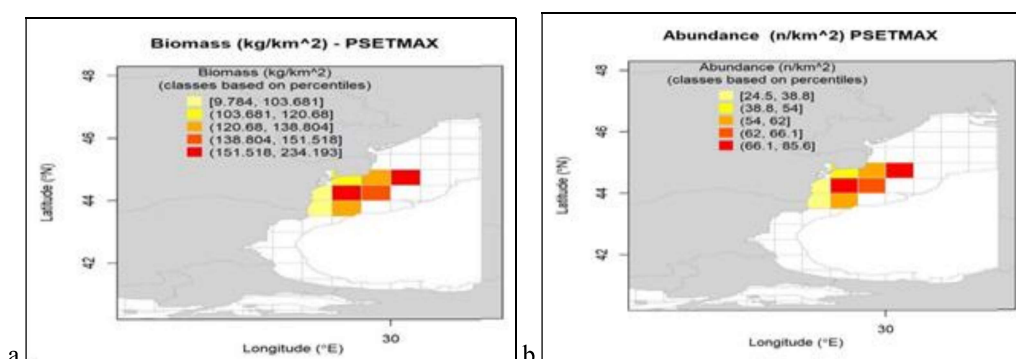


Fig 1. Spatial distribution of biomass (a) and abundance (b) for turbot in spring season 2019

The maximum values were recorded in the Sf. Gheorghe – Gura Portita (Strata 50 - 70 m) and Periboina - Constanta (Strata 30 - 50 m) sectors. The estimated biomass for turbot crowds, in the research area, was about 2,748.4 tons (Figure 1a, Table 1) and the abundance values by Km² oscillated between 24.45885 – 85.60597 number of individuals, with mean abundance value of 54.85373 no./km² (Figure 1b).

Table 1. Assessment of turbot agglomerations (tons), in May 2019, in the Romanian area

<i>Depth range (m)</i>	<i>0 - 30</i>	<i>30 - 50</i>	<i>50 - 70</i>	<i>Total</i>
Investigated area (Km ²)	2,260	6,300	9,240	17,800
Variation of the catches (t/ Km ²)	0-0.241	0-0.349	0-0.464	0-0.464
Average catch (t/ Km ²)	0.126	0.130	0.150	0.135
Biomass of the fishing agglomerations (t)	309.47	644.43	1116.69	2070.58
Biomass extrapolated for the Romanian shelf (t)				2,748.38

The analysis of the structure by lengths and weights of turbot population during the survey highlighted the presence of mature specimens and a high homogeneity. The lengths of turbot individuals were within the limits of classes of length 19.0-70.0 cm/133–6700 g. The dominant classes for length frequency combined (LFD combined) were 45.0-63.0 (Figure 2), for females length frequency were dominant classes between 51.0 -63.0 (Figure 3a), compared to males were the dominant classes were 41.0 -50.0 (Figure 3b). The average body length was 49.9 cm and the average weight 2351 g.

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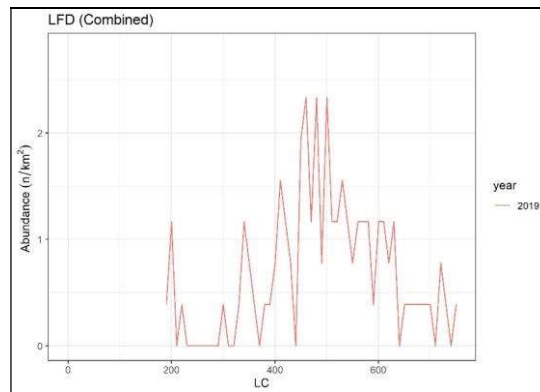


Fig. 2. Length frequency distribution of combined specimens of turbot, in spring season, in 2019

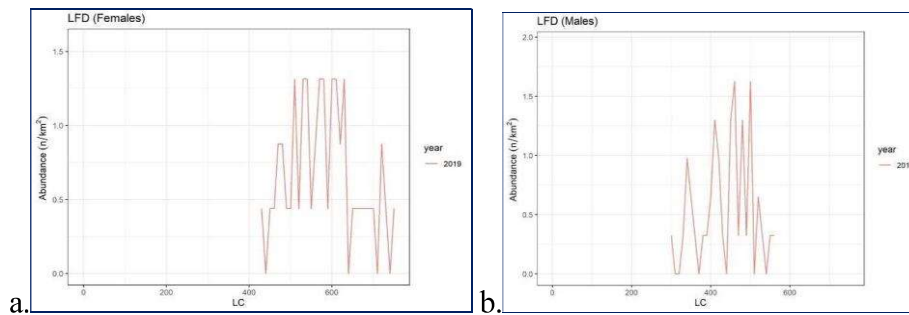


Fig. 3. Length frequency distribution of turbot females (a) and males (b), in spring season, in 2019

The Mean Individual Weight (MIW) classes oscilated between 0.4, 2.048 kg to 2.919, 3.578 kg with highest values recorded in Sf. Gheorghe – Sahalin areas in strata 50-70m (Figure 4).

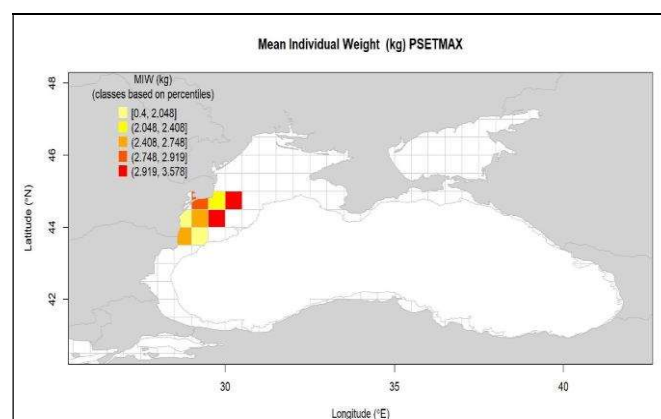


Fig. 4. Distribution of turbot MIW classes across the surveyed area in spring 2019

The abundance index of recruits has been recorded values between 24.45885 to 97.83539 no./km², the highest value was shown in Sf. Gheorghe area in strata's 30-50 m and 50-70 m, the mean value for the entire studied area was 10.98074 no./km² (Figure 5a). For the spawners the abundance index values were 24.45885 to 122.29421 no./km², with a medium value of 21.60579 no./km² (Figure 5b).

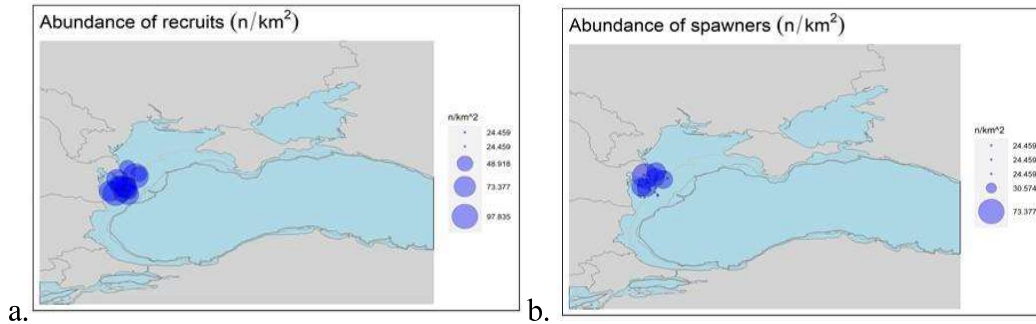


Fig. 5. Abundance of recruits (a) and spawners (b) (n/Km²), in spring season, in 2019

Highest density of turbot specimens have been recorded in depth range 50-60 m, that suggest in the time of the survey 17 may – 3 june 2019 (10 working days, prolonged due to weather conditions) and analyzing the specimens that the most of the turbot population spawned and returned to deeper waters (Figure 6).

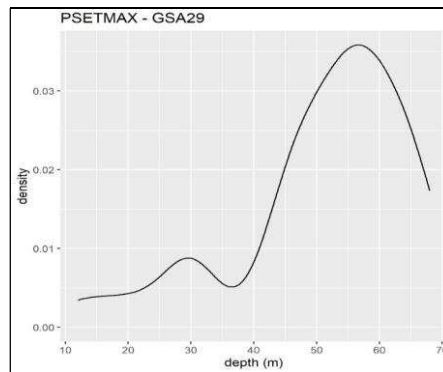


Fig. 6. Density of turbot specimens in accordance with the water depth (m), in spring season, 2019

Autumn season 2019

The total length of turbot specimens oscillated between 13.0 and 77.0 cm and the weight between 50 and 7700 g. Of the fished and measured specimens (101 exp.), 29 were juveniles (30.21%), 24 were in the range 40.0 – 50.0 cm (25.0%), 23 exp. In the range 51.0 – 60.0 cm (23.96 %), and 20 exp, 61.0 -70.0 cm (20.83%). Females predominated (43.75% / 42 specimens), compared to the males (38.54% / 37 exp), the

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rest of 17.71% were juveniles (17 specimens). The total catch of turbot recorded was 213.42 kg, with the following productivity: 2.22 kg / individual, 5.21 kg / trawl, 5.21 kg / hour of trawl. In the 41-sample trawling made with the demersal trawl, on a surface of 17,060 Km², the average values of the catches were of about 0.101-0.137 t / Km². The maximum value was recorded in Sf. Gheorghe – Periboina sectors, in depth strata 30-50 m (0.137 t/Km²). The estimated biomass for turbot crowds, in the research area was **2,485.37** tons (Figure 7a, Table 2), and the abundance values by Km² oscillated between 32.6118 – 77.45302 number of individuals, with mean abundance value of 59.12708 no./km² (Figure 7b).

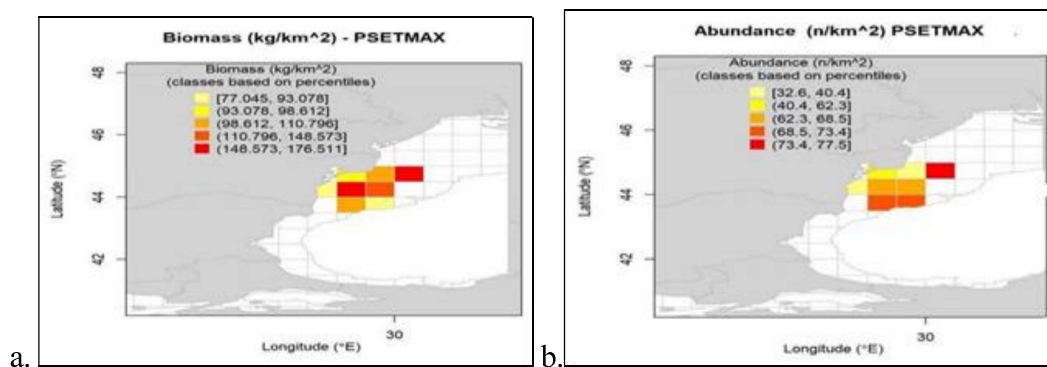


Fig. 7. Spatial distribution of biomass (a) and abundance (b) for turbot in autumn season 2019

Table 2. Assessment of turbot agglomerations (tons), in November/December 2019, in the Romanian area

<i>Depth range (m)</i>	<i>0 - 30</i>	<i>30 - 50</i>	<i>50 - 70</i>	<i>Total</i>
Investigated area (Km ²)	2,740	7,270	7,050	17,060
Variation of the catches (t/ Km ²)	0-0.255	0-0.260	0-0.358	0-0.464
Average catch (t/ Km ²)	0.101	0.137	0.127	0.122
Biomass of the fishing agglomerations (t)	249.990	676.88	947.96	1874.83
Biomass extrapolated for the Romanian shelf (t)				2,485.37

The lengths of turbot individuals were within the limits of classes of length 13.0 - 77.0 cm / 50 – 7700 g. The dominant classes for LFD combined were 50.0 - 66.0 cm (Figure 8), for female's classes 53.0 – 66.0 cm (Figure 9a), respectively for males 47.0 – 52.0 cm (Figure 9b). The average body length was 47.83 cm and the average weight 2274 g.

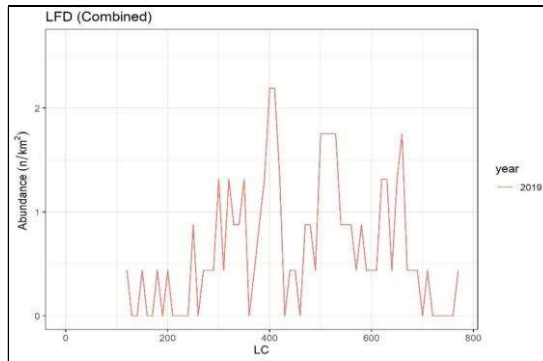


Fig. 8. Length frequency distribution of combined specimens of turbot, in autumn season, in 2019

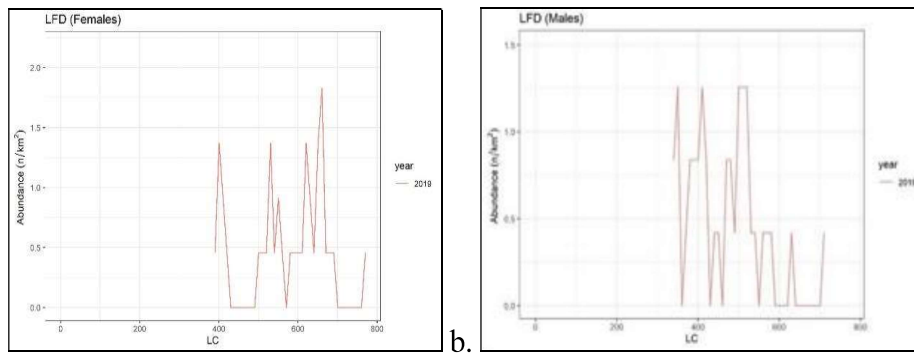


Fig. 9. Length frequency distribution of turbot females (a) and males, in autumn season, in 2019

The Mean Individual Weight (MIW) classes oscilated between 1.05-1.639 kg to 3.047-3.632 kg with highest values recorded in Baia Mamaia - Constanta, strata 0-30 m and Sf.Gheorghe-Sahalin in strata 30-50 m (Figure 10).

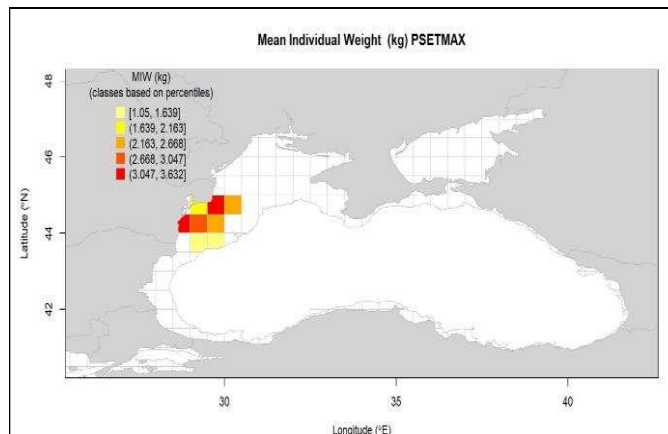


Fig. 10. Distribution of turbot MIW classes across the surveyed area in autumn 2019

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For autumn survey the abundance index of recruits has values between 24.45885 to 97.83539 no. / km², the highest values were recorded in Sf. Gheorghe, Mangalia, and Est Constanta areas in strata's 50-70 m, the mean value for the entire studied area was 26.248852 no./km² (Figure 11a). For the spawners the abundance index values were 24.45885 to 73.37654 no./km², with a medium value of 14.42892 no/km² (Figure 11b).

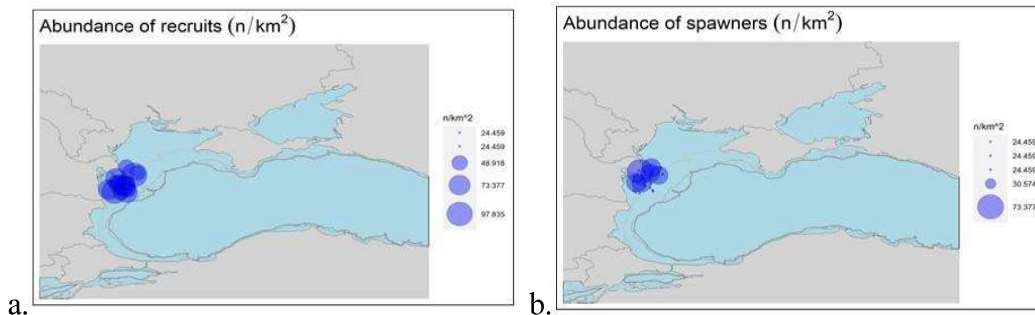


Fig. 11. Abundance of recruits (a) and spawners (b) (n/Km²), in autumn season, in 2019

Highest density of turbot specimens have been recorded in depth range 50-60 m, that suggest in the time of the survey 17 may - 3 june 2019 (10 working days, prolonged due to weather conditions) and analyzing the specimens that the most of the turbot population spawned and returned to deeper waters. Turbot density according to depth shows the population of turbot is in the depth range of 50-60 m (Figure 12).

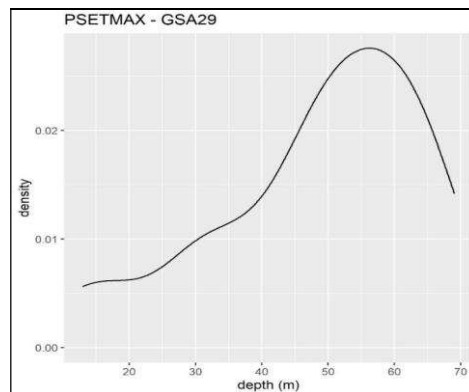


Fig. 12. Density of turbot specimens in accordance with the water depth (m), autumn season, 2019

Spring season 2020

The length of the individuals oscillated between 20.0 and 78.0 cm and the weight between 100 and 9100 g. From the total number of specimens (103 exp.), 21 were

juveniles (20.29%), 41 were in the range 40-50 cm (39.80 %); 26 exp in the range 51-60 cm (25.24%), and 15 exp in the range, 61-78 cm (14.57%). Females predominated (43.69% / 45 specimens), compared to the males (35.92% / 37 exp), the rest of 20,39% /21 were juveniles. Total catch of turbot was 254.62 kg, with the following productivity: 2.47 kg / individual; 6.36 kg / trawl; 6.36 kg / hour of trawl. The estimated biomass for turbot crowds, in the research a area, was of about **3,240.57 tons** (Figure 13a), the abundance recorded values of 6.1147 to 146.7531 number of individuals, with mean abundance value of 79.3214 no./km² (Figure 13b).

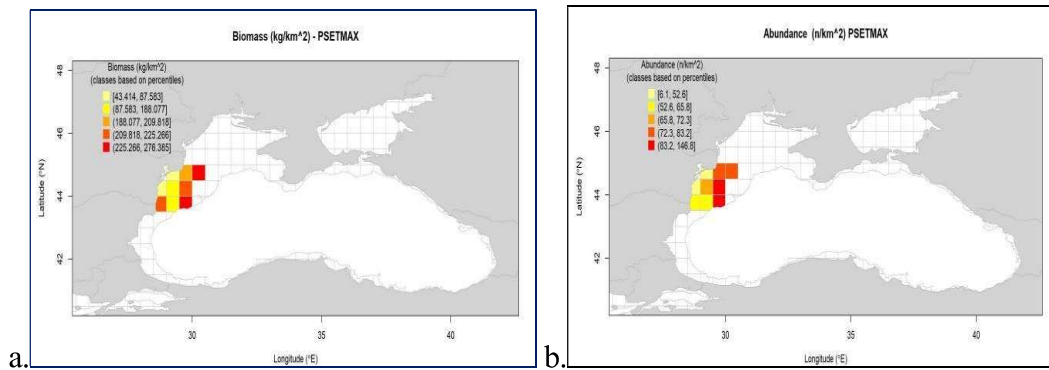


Fig. 13. Spatial distribution of biomass (a) and abundance (b) for turbot in spring season 2020

Turbot lengths recorded in the study were within the limits of classes of length 20.0 - 78.0 cm / 100 – 9100 g. The dominant classes for LFD combined were 40.0 - 65.0 cm (Figure 14), for female's classes 47.0 – 65.0 cm (Figure 15a), respectively for males 42.0 – 56.0 cm (Figure 15b). The average body length was 49.43 cm and the average weight 2472 g.

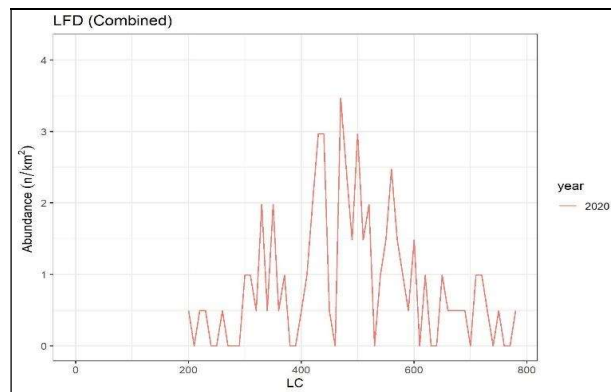


Fig. 14. Length frequency distribution of combined specimens of turbot, in spring season, in 2020

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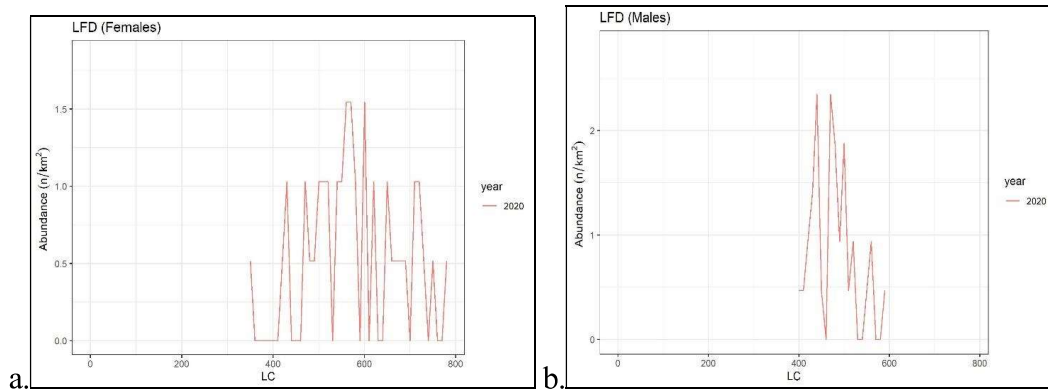


Fig. 15. Length frequency distribution of turbot females (a) and males (b), in spring season, 2020

Classes of MIW had values between 1.16-1.802 kg to 3.136-7.1 kg, biggest specimens have been observed in sectors Constanta strata 30-50 m, 50-70 m, and Mangalia in depth range 30-50 m (Figure 16).

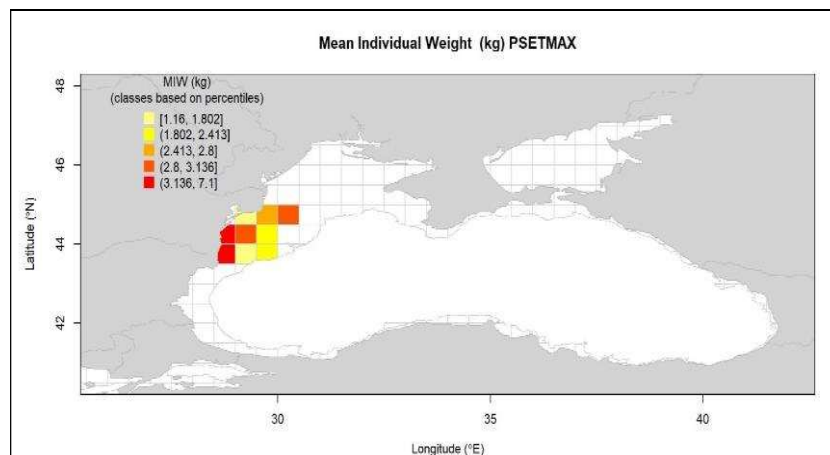


Fig. 16. Distribution of turbot MIW classes across the surveyed area in spring 2020

Abundance index of recruits for spring survey 2020 has values between 24.45885 to 97.83539 no./km², the highest values were recorded in Sf. Gheorghe, Mangalia, and Est Constanta areas in strata's 50-70 m, the mean value for the entire studied area was 25.07032 no./km² (Figure 17a). For the spawners the abundance index values were 24.45885 to 73.37654 no./km², with a medium value of 24.45885 no./km², sectors Sahalin, Baia Mamaia, Est Constanta, Mangalia in depth range 50-70 m recorded the highest values (Figure 17b).

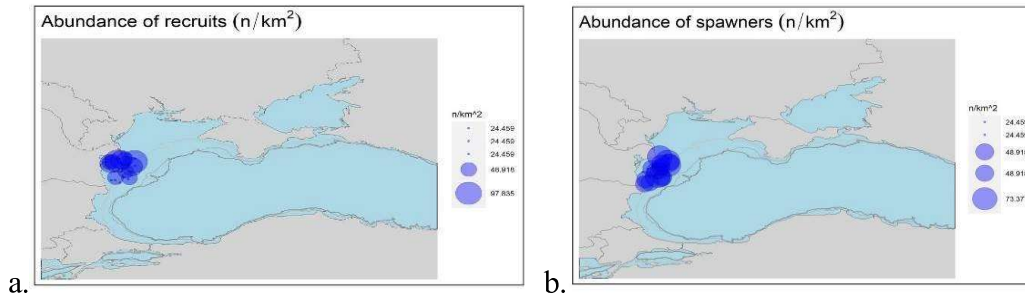


Fig. 17. Abundance of recruits (a) and spawners (b) (n/Km^2), in spring season, in 2020

Turbot density according to depth shows the population of turbot is in the depth range of 40-60 m (Figure 18).

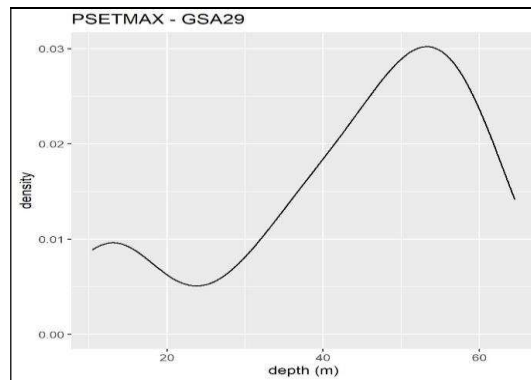


Fig. 18. Density of turbot specimens in accordance with the water depth in spring season, 2020

Autumn season 2020

Total number of specimens caught was 121 exp. with lengths between 19.0 and 74.0 cm and total weight from 77.5 and 8200 grams, from which 27 were juveniles (22.31%), 42 were in the range 40-50 cm (34.71%), 35 exp. in the range 51-60 cm (38.93 %), and 17 exp, 61-70 cm (14.05%). Females predominated (41.32% / 50 specimens), compared to the males (36.36% / 44 exp), the rest of 22.32% / 27 juveniles. The total catch captured by turbot was 284.630 kg, with the following productivity: 2.35 kg/individual, 7.11 kg/trawl, 7.11 kg/hour of trawl. The surface covered in the 40 hauls made was 12,830 Km^2 , average catches recorded were about 0.111 - 0.431 t/ Km^2 . Highest values of biomass were recorded in sectors Sulina - Sf. Gheorghe sector (10-30 m) and Chituc – Mangalia sectors (50 – 70 m). Estimated biomass for turbot was **3,588.42 t** (Figure 19a), and the abundance oscillated between 0.00 - 366.8827 number of individuals, with a mean abundance value of 88.2932 no./ km^2 (Figure 19b).

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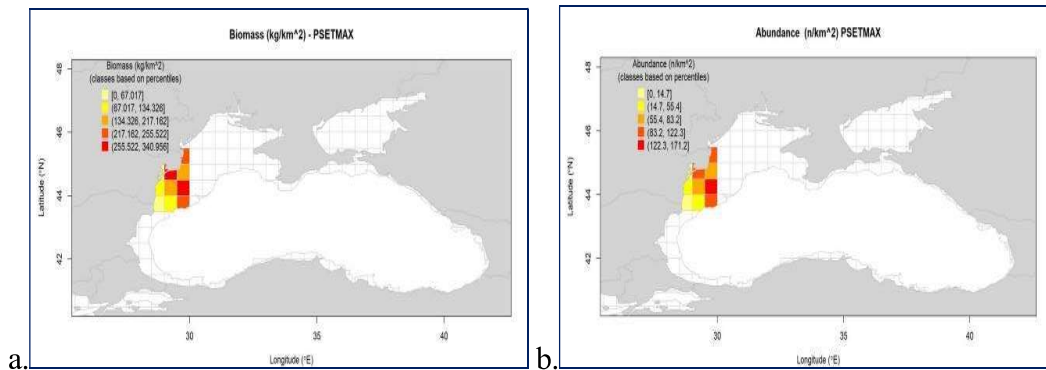


Fig. 19. Spatial distribution of biomass (a) and abundance (b) for turbot in autumn season 2020

The lengths of turbot individuals were within the limits of classes of length 19.0-74.0 cm /77.5-8200 g. The dominant classes for LFD combined were 40.0 – 68.0 cm (Figure 20), for females 56.0-68.0 cm (Figure 21a) and for males 40.0 – 51.0 cm (Figure 21b). The average body length recorded was 47.69 cm and the average weight 2222 g.

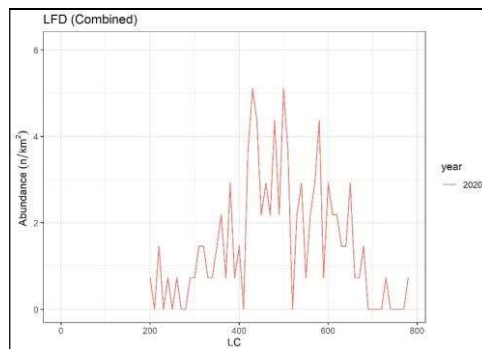


Fig. 20. Length frequency distribution of combined specimens of turbot, in autumn season, 2020

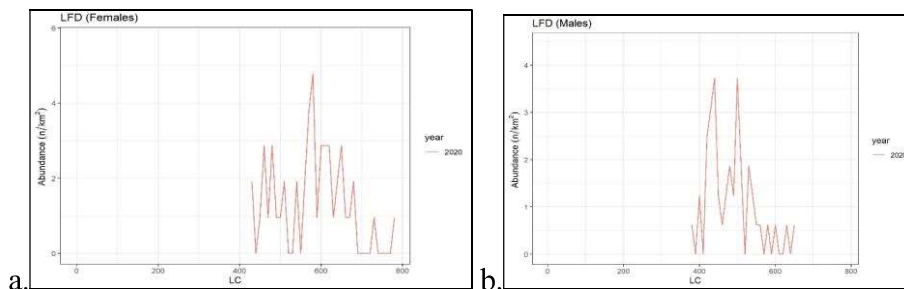


Fig. 21. Length frequency distribution of turbot females (a) and males, in spring season, in 2020

During the survey the classes of MIW had values between 1.709, 1.994 kg to 3.215, 4.567 kg, biggest specimens have been observed in sectors Constanta strata 30-50 m and Mangalia in depth range 30-50 m and 50-70 m (Figure 22).

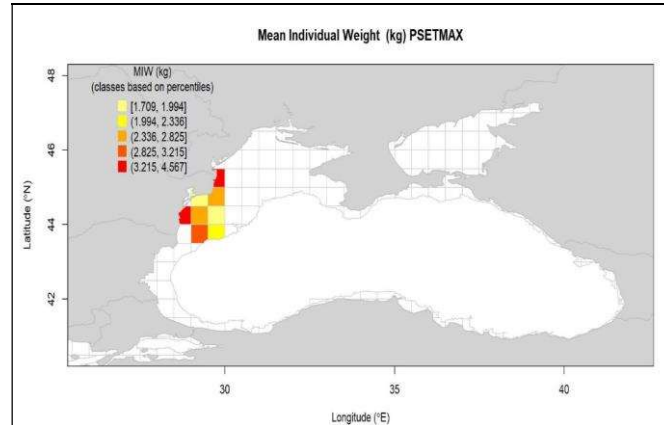


Fig. 22. Distribution of turbot MIW classes across the surveyed area in autumn 2020

Abundance index of recruits for autumn survey 2020 has values between 24.459 to 220.13 no./km², the highest values were recorded in Sahalin, Zaton and Est Constanta areas in strata's 30-50 m and 50-70 m, the mean value for the entire studied area was 28.73915 no./km² (Figure 23a). For the spawners the abundance index values were 24.459 to 195.671 no./km², with a medium value of 46.12194 no./km², sectors Sahalin, Zaton, Est Constanta in depths range 30 – 50, 50-70 m recorded the highest values (Figure 23b). Turbot density according to depth shows the population of turbot is in the depth range of 30-60 m (Figure 24).

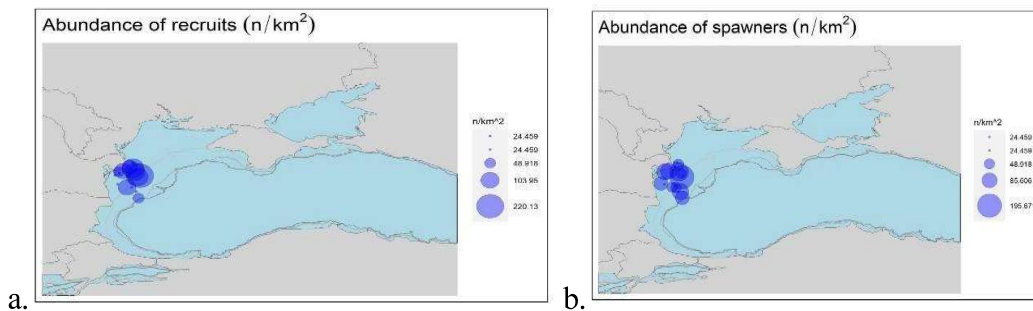


Fig. 23. Abundance of recruits (a) and spawners (b) (n/Km²), in autumn season, in 2020

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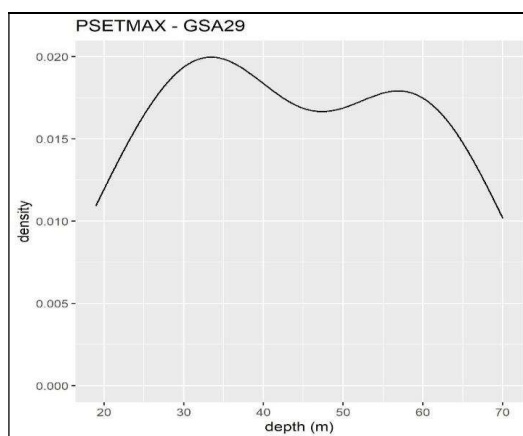


Fig. 24. Density of turbot specimens in accordance with the water depth (m), in autumn 2020

Age structure

The age composition of turbot catches in spring survey 2019 indicates the presence of individuals from 2 to 7 years old. Most of the individuals caught are 3 years old (39.5% of all specimens analyzed), followed closely by those of 4 years old (19 %), 5 years old (14 %) and 2 years (11.6%), (Figure 25). And the age composition of turbot catches in autumn survey 2019 indicates the presence of individuals from 2 to 6 years old.

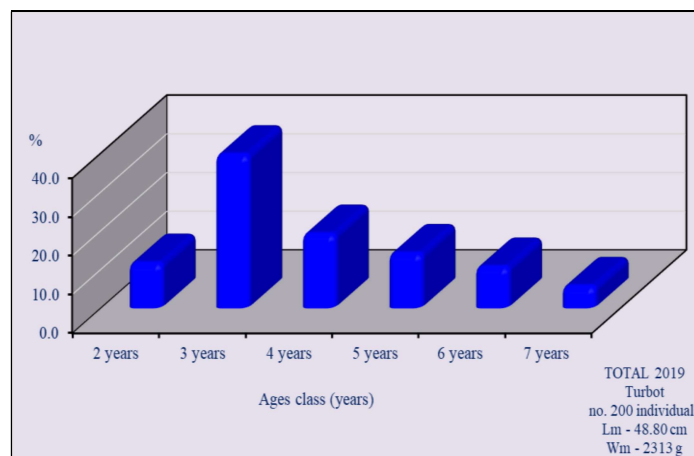


Fig. 25. Structure by age composition of turbot, during the spring survey 2019

The individuals caught are mainly 3 years old (52.0% of all specimens analyzed) and 4 years old (17.04%) and 5 years (16%), followed closely by those of 6 years old (9.0%) and 7 years old (6.0 %), (Figure 26).

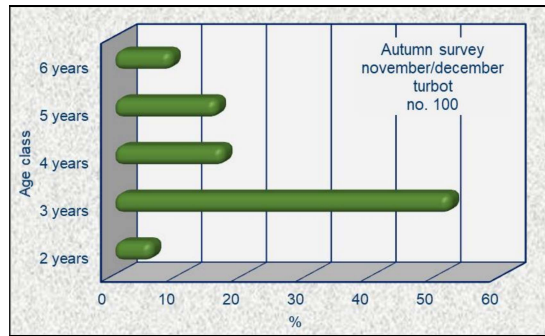


Fig. 26. Structure by age composition of turbot, during the autumn survey 2019

For the spring survey 2020 the turbot catches has recorded the following age composition composed of individuals from 2 to 7 years old, dominant were 3 years old (31.5% of all specimens analyzed), followed closely by those 5 years old (25.1%), 4 years old (21.7%), 6 years old (8.90%), 2 years (6.4%) and 7 years (6.4%) (Figure 27).

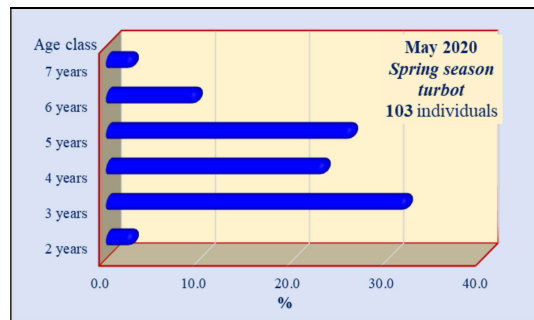


Fig. 27. Structure by age composition of turbot, during the spring survey 2020

Age composition of turbot catches for autumn survey 2020 indicates the presence of specimens from 2 to 6 years old, a high percent of the individuals caught are 3-year-old (32.0% of all specimens analyzed), 4 years old (30.04%) and 5 years (20.21%), followed by those of 6 years old (9.0%), 2 years old (6.0 %) and 7 years (2.39%) (Figure 28).

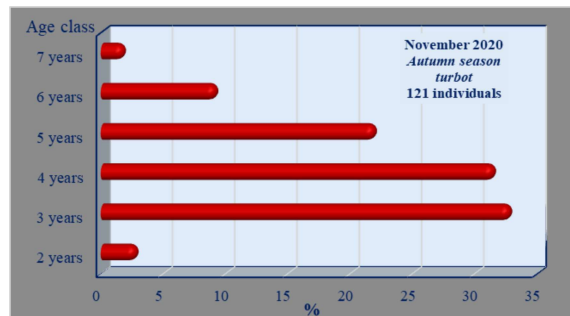


Fig. 28. Structure by age composition of turbot, during the autumn survey

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Estimation of turbot growth parameters has been made combined for both genders due to small numbers of specimens in which length and weight by age groups were used, the results are presented below in Table 3. The natural mortality coefficient of turbot in Romanian Black Sea area was calculated according to Pauly (1980) empirical equation.

Table 3. Growth, exploitation parameters and length-weight relationship - demersal surveys 2019-2020 in the Black Sea ($W = a \times L^b$ length-weight relationship, L_t - total length, W - weight, a and b - regression coefficients)

<i>Sampling year</i>	<i>Gear</i>	<i>L_∞</i>	<i>K</i>	<i>to</i>	<i>M</i>	<i>W = a x L^b</i>	
2019	Demersal trawl	81.05	0.315	-0.401	0.35	0.0385	2.795
2020	Demersal trawl	82.11	0.298	-0.428	0.33	0.0110	3.123

Predictions and possibilities for exploitation

Taking into account values of biomass resulted in last year with an increase in values of the general trend 2012-2020 (Figure 29) and the obtained maximum yield (MSY) - 329.048 tons for 2020, considering the precautionary approach and the specificity of the turbot population structure, we suggest a total allowable catch (TAC) of 164.524 tons in Romanian Black Sea region that can be sustainably exploited from the stock.

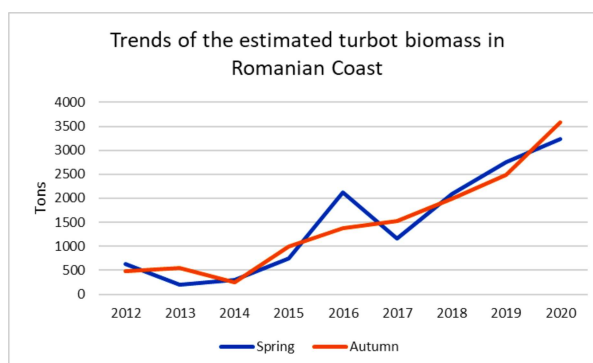


Fig. 29. Trends of the estimated biomass of turbot during demersal surveys

CONCLUSIONS

Based on the trawl survey results and assessment of the turbot stock the following conclusions have resulted:

- Highest biomass and abundance indices have been recorded in the north part of the Romanian Black Sea coast.

- Length frequency distribution combined of the turbot caught during the surveys was between 40.0 - 68.0 cm, for the females 47.0 – 68.0 cm and for the males 40.0 - 56.0 cm.

- Age composition was comprised from ages 2 to 7 years, dominant were age classes 3 and 4 years.

- The recommended TAC for Romania should not exceed 164.524 tons.

- All obtained results show an improvement of the turbot stock in the last years with values of biomass that are increasing every year.

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Conflict of interest.

The authors declare that they have no conflict of interest.

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