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Stocks, Distribution and Population Parameters of Turbot (*Psetta maxima* L.) in front of the Bulgarian Black Sea Coast in 2006

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Abstract: Turbot exploited biomass in front of the Bulgarian Black Sea coast was estimated by the swept area method in spring and autumn-winter, 2006. Turbot stock biomass was calculated at 447 tons in spring and 1441 tons in autumn-winter. The considerable disparity between the two assessments was associated mainly with differing vessel and gear selectivity, but method limitations, weather conditions and species spatial and temporal distribution could have also contributed. High values of catch per unit effort and catch per unit area were registered in the areas off the capes Kaliakra, Galata and Emine. The size structure of catches encompassed length classes between 26.5 and 77.5 cm with numerical dominance of individuals with total length between 38.5 and 56.5 cm. The age of caught specimens ranged between 1 – 9 years. Turbot growth rate was estimated by von Bertalanffy growth function. The food spectrum of turbot included representatives of molluscs, crustaceans and fishes. The most important food components during both investigated seasons were fishes, mainly whiting.

Key words: turbot, stock assessment, population parameters, food spectrum

Introduction

Turbot (*Psetta maxima* L.) is important target for the commercial fisheries in the Black Sea. It belongs to the so called "local" fish species making only limited migrations to and off the coast related to the reproduction and the feeding. Being accessible for fishing almost throughout the year, turbot represents a valuable resource. Its stocks have been intensively exploited since the 1950s by means of bottom trawling and gillnet, however since 1984 bottom trawling has been banned. The changes in turbot stocks are highly dependent on the fishing pressure, as well as on the Black Sea ecological state. The first studies on turbot stocks off the Bulgarian coast were specifically focused on its sustainable exploitation (Martino, Karapetkova 1957). Further investigations on turbot stocks and population parameters were undertaken by Karapetkova (1961), Stoyanov *et al.* (1963), Nikolov 1967, Ivanov and Beverton (1985), Ivanov and Karapetkova (1979), Prodanov *et al.* (1997), Prodanov and Mikhailov (2003), however stock assessment by direct methods has not been conducted since 1992 until the present survey.

The aim of the current study is to assess the exploitation biomass of turbot stocks by the swept area method and investigate some population parameters of turbot in front of the Bulgarian Black Sea coast in 2006.

Study Area

Two subsequent studies were carried out in spring and autumn-winter, 2006. The southern and the northern regions of the Bulgarian Black Sea area were investigated separately. The research area was divided in three strata according to depth: stratum 1

(35-50 m), stratum 2 (50-75 m) and stratum 3 (75-100 m). Each stratum was divided into equal in size, not overlying rectangular fields with sides 5' Lat × 5' Long and area around 62.58 km² (measured by GIS software), large enough for a standard haul to fit within the field boundaries in meridian direction. At randomly chosen fields – 24 in spring and 37 in autumn, sampling by means of bottom trawls towed by fishing vessels was carried out (Fig. 1).

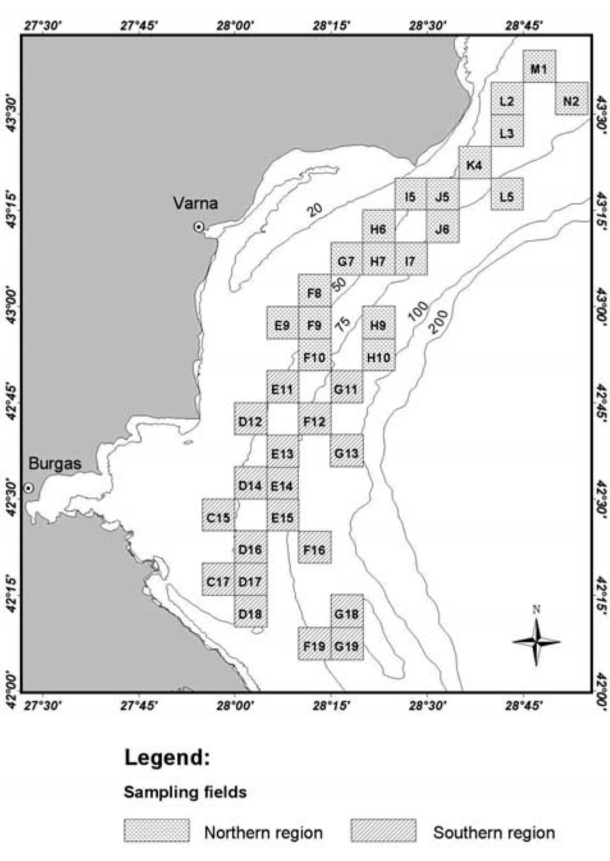

Fig. 1. Sampling area and plan of the sampling fields.

Material and Methods

A standard methodology for stratified random sampling was employed for the turbot stock assessment (Gulland 1966, Sparre, Venema 1998, Sabatella, Franquesa 2004, Zengin 2005). This method is based on bottom trawling across the seafloor (area swept) and is widely used as a direct method for demersal fish stock assessment. The seabed area covered during a single haul represents a basic measurement unit, which although very small compared to the total study area is deemed representative since turbots do not aggregate in dense assemblages (Martino, Karapetkova 1957). The fields are grouped in larger sectors – so called strata, the geographical and depth boundaries of which are selected according to the density distribution of the species under study.

During the spring study two different fishing vessels were used in the northern and southern areas, while during the autumn-winter study only one ship was involved. The employment of the same fishing vessel and trawling gear at both regions ensured the consistency of methodology (fishing effort) and comparability of the results between regions during the autumn study. The dimensions of the bottom trawl employed were as follows: head rope length – 26 m; net "eye" – 10x10 cm and effective part of wing spread – 10-12 m. At both regions lugs were carried out only during daylight with single haul duration 120 - 180 min at trawl speed 1.8 knots. Measurements and sampling on 616 individuals for length, weight, sex and age structure was made during both studies, food spectrum was also investigated.

For determination of the turbot growth rate, the von Bertalanffy (1938) function was used (Spare, Venema 1998, Hilborn and Walters 1992):

$$(1)\ L_t = L_\infty \{1 - \exp[-k(t - t_0)]\}$$

$$(2)\ W_t = W_\infty \{1 - \exp[-k(t - t_0)]\}^n$$

where: L_t, W_t are the length and weight of the fish at age t years; L_∞, W_∞ - asymptotic length and weight respectively, k , t_o –parameters.

The relationship between length and weight by ages was calculated as follows:

$$(3)\ W_t = qL_t^{\,n}$$; where: q , n – parameters.

For estimation of turbot condition, the Fulton's Index (K) was applied (Ricker 1975).

The diet composition of turbot was determined from stomachs fixed in 4 % formalin. The food components were divided in taxonomic groups and identified to the lowest possible taxonomic level. For each component the share in the total abundance and biomass was determined and the occurrence frequency was calculated. The most important diet component was determined according to the index of relative importance (IRI), (Pinkas *et al.* 1971) and for estimation of the importance of each food item among the stomach contents IRI expressed on a percent basis (Cortes 1997) was also calculated.

(4) $IRI = (\%N+\%W)*\%F$

$$\%IRI_i = \frac{100*IRI_i}{\sum_i^n IRI_i}$$

where: N – percentage of a food item by number;

W – percentage by weight;

F – percentage by frequency of occurrence.

Results and Discussion

Biomass

During the spring study 135 turbot specimens with a total weight of 249 kg were yielded from 24 hauls with an overall duration of 55 hours. The mean catch per unit effort (CPUE) in the northern region was 6.75 $kg.h^{-1}$, while in the southern it was only 0.19 kg h^{-1}. Highest catches per unit effort were yielded off c. Galata at depth 50-75 m.

During the autumn-winter survey the sampling network was expanded, which increased the precision of the obtained results. The study comprised 37 hauls with a total duration of 85 hours. Turbot individuals caught came to 481 with a total weight of 853 kg. The mean catch per hour in the northern area amounted to 9.89 $kg.h^{-1}$ and in the southern region – 10.23 $kg.h^{-1}$. The distribution of CPUE in autumn-winter in the entire Bulgarian Black Sea area is represented on Fig. 2. It is evident from the figure that turbot was spread over the entire area at depth 40-90 m. The largest catches per hour were yielded in front of c. Kaliakra (J5), c. Galata (H6, G7) and c. Emine (F12) with values in the range of 20-35 $kg.h^{-1}$. In both regions the maxima were situated around the 50 m isobaths. There is a decreasing pattern of CPUE to southerly waters. Decreased yields per hour were also observed with depth, with low catches in the order of 1-10 $kg.h^{-1}$ below 75 m. The results revealed that in front of c. Kaliakra study turbot formed significant assemblages during autumn-winter probably due to favourable conditions and abundant food resources in the area.

The mean catch per unit area (CPUA) in the northern region in spring arrived at 98.28 $kg.km^{-2}$ at

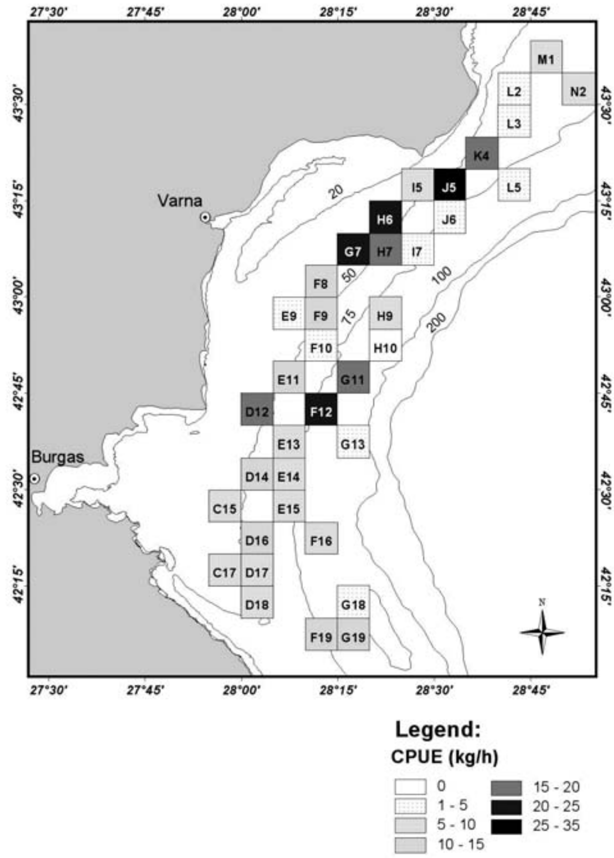

Fig. 2. Distribution of turbot CPUE in the Bulgarian Black Sea area during autumn-winter, 2006.

depth 35-50 m, 170.19 $kg.km^{-2}$ at depth 50-75 m, and 94.88 $kg.km^{-2}$ at depth 75-100 m. In autumn-winter the mean CPUA in the above strata were 339.5 $kg.km^{-2}$, 266.96 $kg.km^{-2}$ and 35.07 $kg.km^{-2}$ respectively. The CPUA distribution over the Bulgarian Black Sea area during the autumn – winter is represented on Fig. 3. It is evident from the figure, that CPUA in the northern region was higher compared to the southern region. In the northern region CPUA reached a maximum of 875 $kg.km^{-2}$ and the mean yield at depth 40-50 m was around 340 $kg.km^{-2}$. In the southern area the maximum value of CPUA was 380 $kg.km^{-2}$ and the mean CPUA at similar depth was 243 $kg.km^{-2}$.

According to the results obtained for the spatial distribution of CPUA a continuous area can be outlined from c. Kaliakra to c. Emine distinguished with higher catches than the rest regions. This zone is narrower to the north, ranging between 40-60 m depth and becomes wider to the south reaching depth 80 m in front of c. Emine and c. St. Atanas. CPUA pattern during spring shows a zone of higher yields along the line between c. Kaliakra and Byala, however the spring maximum is shifted to greater depth around the 75 m isobaths.

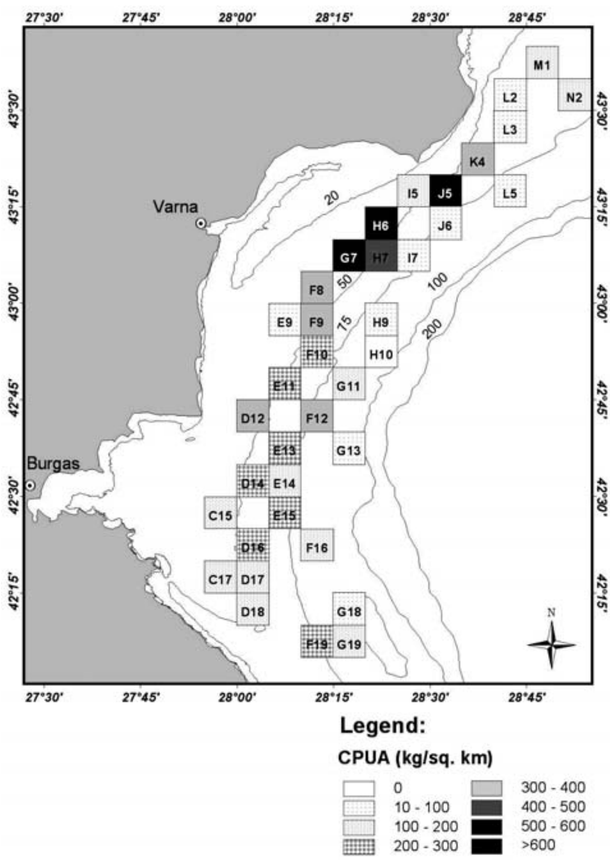

Fig. 3. Distribution of turbot CPUA in the Bulgarian Black Sea area during autumn-winter, 2006.

Turbot exploited biomass in swept fields was calculated on the basis of the catch per unit effort (CPUE) and catch per unit area (CPUA), determined according to the methodology. The area per strata and calculated turbot biomasses in study area are given in Table 1. The average values of CPUA with standard deviations by strata and regions are given on Fig. 4.

The exploitation biomass of turbot in spring was calculated at 447.38 tons, however due to less efficient vessel and fishing gear used in the southern region we deem that the stock was underestimated and the actual value was probably higher. The autumn-winter survey demonstrated that turbot stock in the southern region is comparable to that in the northern region and the biomass was calculated at 735 tons and 706 tons, respectively. Because of method limitations, gear efficiency, spatial distribution of turbot and poor weather conditions (rough sea and currents) during cruises, we consider that the actual turbot biomass was higher than the estimated.

Table 1. Biomass of turbot exploitation stock in the Bulgarian Black Sea, 2006.

Region	Stratum	Fields	Area km^2	$\overline{Ca}$ kg/km^2	Biomass (tons)
Spring					
North	1	14	876.11	98.28	86.10
	2	24	1501.91	170.19	255.61
	3	17	1063.85	94.88	100.94
Total		55	3441.87	128.61	442.65
South	1	7	438.06	0	0.00
	2	14	876.11	1.51	1.32
	3	21	1314.17	2.59	3.40
Total		42	2628.34	1.80	4.73
Autumn - Winter					
North	1	14	876.11	339.52	297.46
	2	24	1501.91	266.96	400.40
	3	17	1063.85	35.07	37.30
Total		55	3441.87	213.59	735.16
South	1	15	938.69	243.45	228.52
	2	20	1251.59	223.52	279.76
	3	23	1439.33	137.33	197.66
Total		58	3629.61	201.43	705.94

Population parameters

The investigated population parameters of turbot include length frequency, age structure, sex ratio, growth rate and condition factor.

Turbot length in catches during both studies ranged from 26.5 to 77.5 cm. The length frequency represented on Fig. 5, shows that the majority (75.88%) of specimens had absolute length within 38.5-50.5 cm in spring and 38.5-56.5 cm in autumn-winter. Individuals longer than 62.5 cm were rare. The mean length of individuals was 46.71 cm during spring and 47.10 cm during autumn-winter. The observed average lengths were lower than those, reported by Karapetkova (1961), which were 48.8 and 50.5 cm for the respective seasons. Inconsistent gear selectivity could possibly explain the difference, however reduction of turbot total length due to high level of exploitation during last several decades and altered ecological conditions in the Black Sea could be also supposed.

The size structure of catches during the spring and autumn-winter cruises was analysed. The size classes were selected according to the requirements of the FAA (2006) – the individuals with absolute length less than 45 cm are considered as small and those with length > 45 cm – as standard.

During the spring study the ratio between

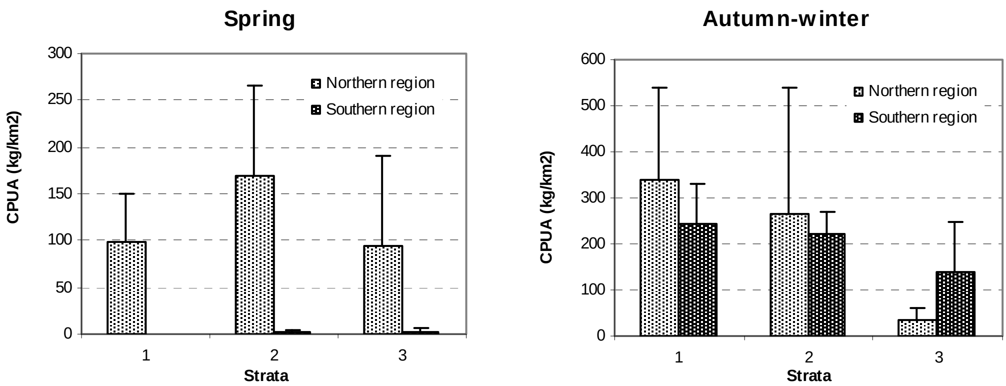

Fig. 4. Average CPUA (kg/km^2) by strata with standard deviations by regions and by seasons in the Bulgarian Black Sea area in 2006.

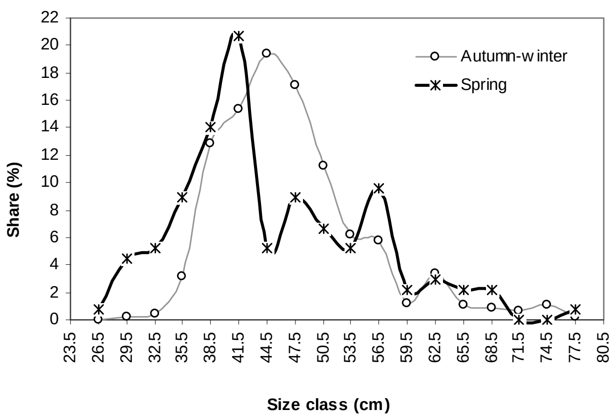

Fig. 5. Length frequency of turbot caught in the Bulgarian Black Sea area in 2006.

small and standard individuals in catches was 54.07:45.93 % in the northern region, while in the southern region the ratio was not calculated due to very few individuals yielded. Size class ratios at sampling fields during the autumn-winter study are given on Fig. 6, where the circle diameters are proportional to the total turbot abundance in catch at the respective field. The figure makes obvious that in the northern region standard individuals clearly predominated over the small with a ratio 76.14:29.86 %, while in the southern region the proportion was inverted to 44.70:55.30% in favour of the small individuals.

The sex ratio of male to female individuals was 48.89:51.11% during the spring study and 46.15:53.85% during the autumn-winter study. The length frequency by gender (Fig. 7) shows that individuals of absolute length < 40.5 cm were predominantly male, in size groups 44.5 - 56.5 cm the share of females increased and individuals larger than 65.5 cm were only female. The results reveal that females attain larger size and respectively weight compared to males.

The age composition of turbot catches during both studies encompassed 1-1+, 2-2+, 3-3+, 4-4+, 5-5+, 6-6+, 7-7+, 8-8+ and 9+ -years old individuals. The age structure was dominated by individuals 1-3 years old during the spring study and by 2+-4+ -years old during the autumn-winter study (Fig. 8).

Turbot growth rate was estimated by the von Bertalanffy growth function (VBGF) applied on the data for average lengths and weights by age groups for each gender. The values of the parameters in VBGF, which describe the linear and weight growth, are given in Table 2. The obtained results manifest, that the rela-

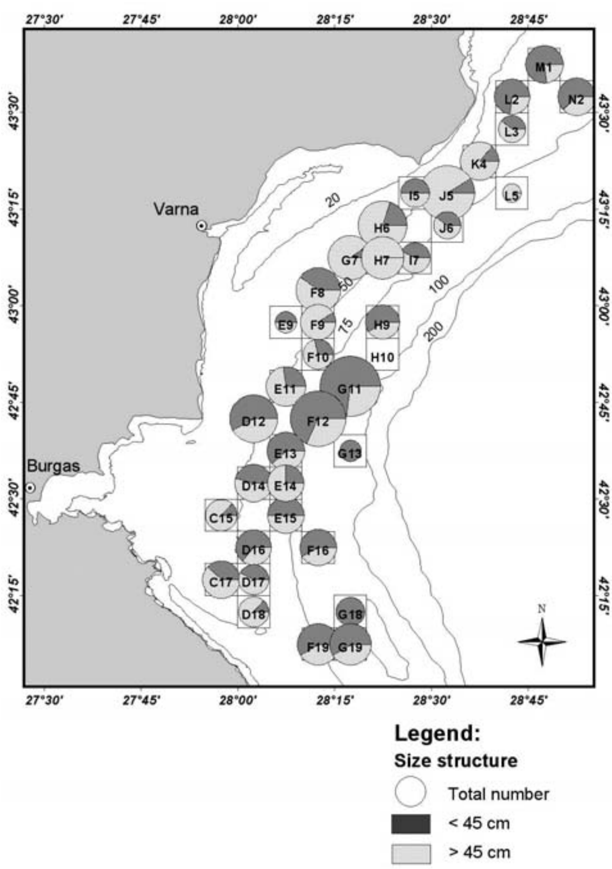

Fig. 6. Size structure and total abundance of turbot catches at swept fields during autumn-winter, 2006.

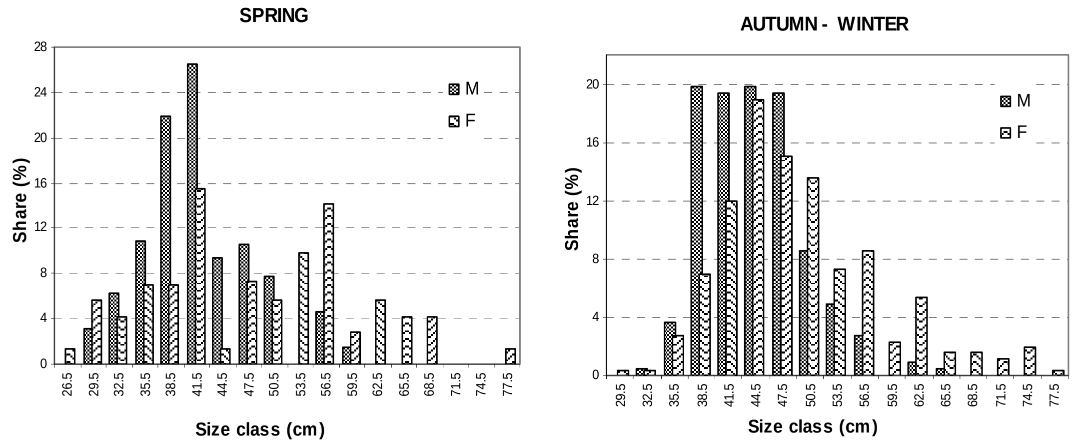

Fig. 7. Length frequency of turbot catches by gender and by seasons.

tionship between turbot lengths and weights for both sexes is allometric. The estimated asymptotic lengths of female individuals are higher than those of males and females reach higher total lengths and weights.

The Fulton's Index (K) was used as a measure of the physiological state of turbot. Fig. 9 represent the changes in Fulton's condition factor with age for both genders by seasons. Fig. 9 indicates that Fulton's condition factor in turbot decreases with age and is lower in males for which it ranges from 1.54 to 1.86 during spring and from 1.59 to 1.72 during autumn-winter. In females, it varies between 1.66 to 1.86 in spring and from 1.69 - 1.80 in autumn-winter season.

Food spectrum

Diet composition of turbot during spring and autumn-winter studies included representatives of molluscs, crustaceans and fishes. During both studies, 164 stomachs were examined, out of which 110 were empty (67%) and 54 contained prey (33%). The prey items found in the stomachs included whiting (*Merlangius merlangus*), sprat (*Sprattus sprattus*), horse mackerel (*Trachurus mediterraneus*), piked dogfish (*Squalus acanthias*), red mullet (*Mullus barbatus*), shad (*Alosa pontica*), gobies, sand shrimp (*Crangon crangon*) and molluscs (*Cerastoderma glaucum, Mytilus galloprovincialis, Modiolula phaseolina*).

The most important diet component, determined according to the Index of relative importance (IRI) in both seasons comprised fishes (Table 3), mainly whiting. Second significant component was the sand shrimp and the molluscs had insignificant share in turbot diet.

The observations showed that the food spectrum of turbot was very limited – only 6 species during autumn-winter and 8 species in spring. In comparison Bulgurkov (1965) described 5 fishes, 3 molluscs and 3 decapods in turbot diet composition with major importance of whiting in a study carried out in winter-autumn during the 1960s in the

Table 2. Values of parameters in VBGF for both genders and by seasons.

Parameters	Seasons			
	Spring		Autumn-winter	
	M	F	M	F
L_∞ (cm)	94.661	80.689	108.27	110.59
r^2	0.93	0.97	0.95	0.97
k	0.133	0.244	0.069	0.095
t_0	-2.514	-1.255	-5.340	-2.602
q	0.00007165	0.00003196	0.00003826	0.000028
n	2.62	2.85	2.78	2.88
W_∞ (kg)	48.275	9.027	6.92	87.28
r^2	0.98	0.97	0.94	0.97
k	0.052	0.226	0.139	0.044
t_0	-3.644	-1.451	-3.879	-3.701

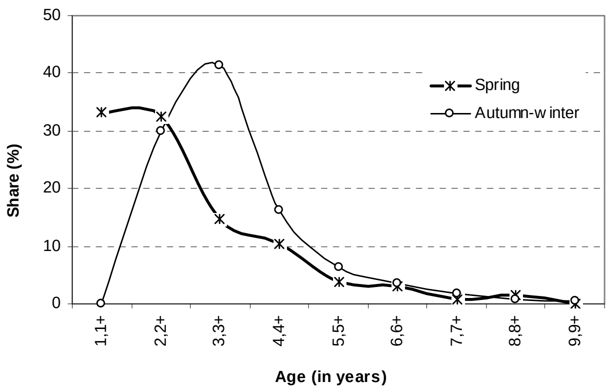

Fig. 8. Age structure of turbot catches by seasons in 2006.

southern Bulgarian Black Sea region. The current study confirmed that fishes represented the main turbot food, especially the whiting and among the decapods the sand shrimps were frequent. One small individual of piked dogfish was found in a turbot stomach, a species which has not been reported until now as prey for turbot.

Conclusions

The major findings of this study can be summarized as follows:

- Turbot exploited biomass in the Bulgarian Black Sea area was estimated approximately at 447 tons in spring and 1441 tons in autumn-winter 2006, however the actual biomass is deemed higher;

- The areas in front of the capes Kaliakra, Galata and Emine were distinguished by high catches;

- The size of turbot in catches included length classes between 26.5 and 77.5 cm, the majority of individuals being of length 38.5-56.5 cm;

- The age of turbot in catches varied between 1 and 9 years;

- The relationship between turbot length and weight is allometric for both sexes. According to von Bertalanffy growth function, females attaining higher length;

- The Fulton's Index decreased with age for both sexes and it was lower for males with values 1.54-1.86 in spring and 1.59-1.72 in autumn-winter. For females it varied between 1.66-1.86 in spring and between 1.69-1.80 in autumn-winter;

- The food spectrum of turbot included an assortment of molluscs, crustaceans and fishes, the latter being the most important component with dominance of the whiting.

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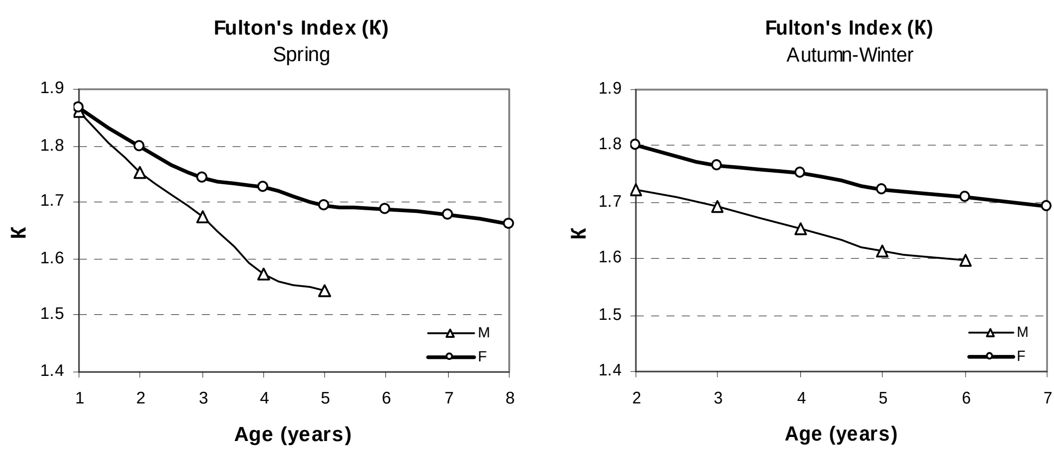

Fig. 9. Relationship between Fulton's Index and age of turbot by genders and seasons.

Table 3. Diet composition of turbot.

Season	Number of prey species	Prey groups			
		Mollusks	Crustaceans	Fishes	Unidentified
Spring	8	IRI%=2.08	IRI%=13.19	IRI%=84.02	IRI%=0.071
Autumn-winter	6	IRI%=0.03	IRI%=4.15	IRI%=95.82	

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Улови, разпределение и популационни параметри на калкана (*Psetta maxima* L.) по българското Черноморско крайбрежие през 2006 г.

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(Резюме)

Изчислена е експлоатационната биомаса на калкана чрез метода на площите пред българския бряг на Черно море през пролетния и есенно-зимния сезон на 2006 г. Биомасата на запаса от калкан е оценена на 447 тона през пролетния и 1441 тона през есенно-зимния сезон. Наблюдаваните различия в оценките се дължат на особеностите на метода, уловитостта на риболовния уред, климатичните условия и пространствено-времевото разпределение на вида. Наблюдавани са високи стойности на уловите в акваторията пред н.Калиакра, н. Галата и н. Емине. Размерната структура на уловите обхваща линейни класове от 26.5 до 77.5 см, като с най-висока численост са индивидите с абсолютни дължини между 38.5-56.5 см. Уловените индивиди са на възраст между 1 и 9 г. Хранителият спектър на калкана включва представители на мекотелите, ракообразните и рибите. Най-значимият хранителен компонент и през двата изследвани сезона са рибите, като доминира меджидът.