Evolution of the Sprat (*Sprattus sprattus*, Linnaeus 1758) Population at the Romanian Littoral during 2008-2016 *(Aurelia Țoțoiu, Mădălina Galațchi, Cristian Sorin Danilov, Gheorghe Radu)*	"Cercetări Marine" Issue no. 47 Pages 205-221	2017

EVOLUTION OF THE SPRAT (*Sprattus sprattus*, LINNAEUS 1758) POPULATION AT THE ROMANIAN LITTORAL DURING 2008-2016

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ABSTRACT

Sprat is one of the fish species with high commercial importance in the Romanian marine area whose population is heavily influenced by the fishing effort exerted on it and by the evolution of environmental conditions. The paper is a synthesis of long-term data obtained by NIMRD "Grigore Antipa" Constanta mainly through National Data Collection Programs (NDCP) in the period 2008-2016, being partner of the National Agency for Fisheries and Aquaculture (NAFA). The main elements analysed are:
- dynamics of sprat catches and its share on fishing gears;
- evolution of fishing effort;
- distribution and biomass of fishing agglomerations;
- environmental conditions influence on the status and distribution of fishing agglomerations;
- structure on size classes of the catches;
- evolution of the growth parameters and natural mortality;

The presented data indicate seasonal changes of the distribution and biomass values, the fishing agglomerations being very much influenced of environmental conditions.

Key-Words: Romanian Black Sea area, catch, fishing effort, biomass, growth parameters, natural mortality, environmental conditions

AIMS AND BACKGROUND

Sprat (*Sprattus sprattus* L.,1758) is one of the fish species with high commercial importance in the Romanian marine area, being the second most abundant fish species after the anchovy and an important fisheries resource and prey species, whose population is heavily influenced by the fishing effort exerted on it and by the evolution of environmental conditions.

Marine pelagic species, usually inshore schooling, sometimes entering in the estuaries (especially the juveniles), and tolerating salinities as low as 4‰. In the daytime, it keeps to bigger depths and in the night, comes to surface (Ivanov et all., 1985; Radu et all., 2011). Forms important agglomerations and performs unregulated migrations between nutrition areas and spawning places determined by temperature conditions. In the spring exists a tendency of movement of the shoals toward coast and northwards and toward offing in the autumn, but are not exist specific migrations of spawning or feeding (Ivanov et all., 1985; Radu et all., 2011).

Mostly, adults tend to remain under thermocline, penetrating above its only in the spring and autumn. Juveniles occupy a large spread area at surface in the warm water (Ivanov et all., 1985; Radu et all., 2011).

The sprat wintering offing at depths of 80-100m; in April - May is nearing of littoral area in exploitable quantities, while in the summer avoids high water temperature performing migrations from coast to offing (Ivanov et all., 1985; Radu et all., 2011).

Sexual maturity attained at the age of 1 year when has about 7 cm. Spawning takes place in almost all the time year, but with maximum intensity in November – March, laying of eggs does in portions. Eggs are pelagic, in spherical shape. In winter, eggs are encountering both in the surface layer as well as in one of deep; in summer only at depths below 10m (2-50m) (Ivanov et all., 1985; Radu et all., 2011).

Maxima of recruitment and biomass occurred in the mid 1970s and mid 1980s. Maximum catch was recorded in 1989 (>100,000 tons), leading to highest fishing mortality after that the stock collapsed. The combination of low recruitment and excessive over-fishing was claimed to be the main cause of the collapse (Casey et all., 2009; Daskalov et all., 2009; Daskalov et all., 2010; Daskalov et all., 2011; Daskalov et all., 2012; Samson et all., 2013). In the mid 1990s the sprat stock started to recover and reached previous peak-levels recorded in the 1980s, but catches stayed relatively low because of the stagnated economies of Bulgaria, Romania and Ukraine (Casey et all., 2009; Daskalov et all., 2009; Daskalov et all., 2010; Daskalov et all., 2011; Daskalov et all., 2012; Samson et all., 2013). Consequently after 1995 the catches increased to levels comparable to the 1980s: 2001-2005 ~70 000 t. After the collapse in 1990 recruitment, biomass and catches of sprat started to increase showing a stable recovery by 2005 (Casey et all., 2009; Daskalov, 2003; Daskalov et all., 2009; Daskalov et all., 2010; Daskalov et all., 2011; Daskalov et all., 2012; Samson et all., 2013).

The analysis of the main population parameters (abundance, catch, fishing mortality) shows that the sprat stock has recovered from the depression in the 1990s due to good recruitment in 1999-2001 and the biomass and catches have gradually increased over the 1990s and early 2000s. The stock estimates, however, confirm the cyclic nature the sprat population dynamics (Daskalov et all., 2009; Daskalov et all., 2010; Daskalov et all., 2011; Daskalov et all., 2012). The year with relatively strong recruitment were followed by years of low to medium recruitment which leads to a relative decrease of the Spawning Stock Biomass (SSB). High fishing mortalities (F1-3) were observed in 1990-1994, 1998, and 2003.

In the recent period SSB has again decreased due to lower recruitment and high fishing mortality. Landings have initially (in 2001-2005) reached levels comparable to the 1980s but dropped again in 2006-2007. In 2008 the landing started to increase again due to expending Turkish fisheries that corresponded to a rise in fishing mortality. The short-term forecast indicates that present level of fishing is probably too high and at the present level of recruitment will affect negatively the SSB (Casey et all., 2009; Daskalov et all., 2009; Daskalov et all., 2010; Daskalov et all., 2011; Daskalov et all., 2012; Samson et all., 2013).

According to the results of the production model the MSY is estimated to be in the range of 44,442 t. Fmsy (ages 1-3) amounts to 0.53. Bmsy appears to be in the range of 128,000 t. (Casey et all., 2009; Daskalov et all., 2009; Daskalov et all., 2010; Daskalov et all., 2011; Daskalov et all., 2012; Samson et all., 2013).

EXPERIMENTAL

Data presented above are obtained through National Data Collection Program in the period 2008-2016, but NIMRD Constanta has also historical data (obtained from own projects) on qualitative and quantitative structure of the catches and landings, structure of fish populations, growth parameters and mortality rates, state of stocks, distribution of fishing agglomerations, spawning and recruitment intensity, etc.

The methodologies and techniques used both for data collecting, checking, processing and analyzing, and also for assessment of fish agglomerations were that usually accepted for Black Sea basin, and in compliance with international methodology.

The effort and catches data have been collected from fishing logbooks, fishing licenses and sales notes and cover fish species and fishing gear for all the active vessels. The information is based on exhaustive data reported in these documents. Also, another source of the data is through questionnaires, being used according to Romanian's legislation issued by NAFA laying down by the EU regulations. In collection of the data were involved all fisheries enterprises and fishery organizations from Romanian littoral.

Determination of the biological parameters of fish species of economic interest represent an important objective to establish demographic structure, growth parameters as well as others parameters necessary for recruitment study, mortality rate, abundance and biomass. Study of the biological parameters was made on catches obtained both passive and active fishing. The samples were analyzed in the institute laboratory. The following parameters were analyzed: length, weight, age, sex ratio, stage of gonad maturation. The length structures obtained from at-sea monitoring was complemented with the length structure from shore sampling.

The spatial distribution of the fishing resources is dynamic, changeable seasonally and sometimes pronounced enough from one year to the other one. For correctly assessment of the tendencies and changes occurred in the stocks abundance from one survey to the other one, or from one year to the other one, the standard fishing and assessment techniques were utilized, so that the results can be reproduced and compared. The sampling trawling on the Romanian continental shelf, together with the data obtained in the industrial trawling were used for to assess the fishing agglomeration biomass and distribution of main commercially interested demersal and pelagic species. The utilized method was swept area, for sampling was used the commercial pelagic trawl in the demersal variant. The following parameters have been taking into account: hauling speed; hauling time; horizontal trawl opening; qualitative and quantitative structure of the catch.

Also, for every survey at sea were recorded data on the state of the environment (wind, direction and intensity; temperature and salinity of water; zooplankton samples were taken, etc.).

RESULTS AND DISCUSSION

Evolution of the fishing effort

According to the data from the Fleet Register, at the beginning of 2008 the Romanian fishing fleet included 440 vessels operating in the Black Sea. Of them were 421 fishing boats with a total length less than 12m representing 95.22 % of all Romania vessels. In the last two years the number of fishing vessels decreased, being 151 vessels registered (2015), of which only 127 were active. The decline in the number of fishing vessels continued in 2016, with only 147 vessels, of which 121 were active (Fig. 1) (Radu et all., 2015; Totoiu et all., 2016).

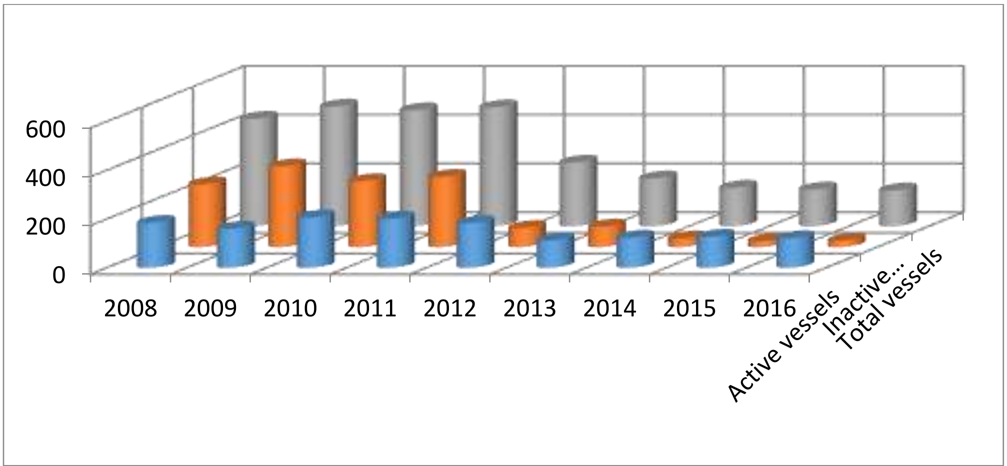

Fig. 1. Number of the active and passive fishing vessels.

In the Romanian fishery there are two types of fishing gears:
- for active fishery (beach seine; beam trawl; pelagic trawl)
- For passive fishery (long lines and bottom lines; gillnets for the Danube shad, turbot, mugilidae and gobies; sea pound nets; cages)

In 2016, the number of trap nets (32), turbot gillnet (2,631), shad gillnets (307), gobies gillnets (127), dogfish gillnets (138), beam trawl 16, pelagic trawl 4, long lines (77), etc. (Fig. 2).

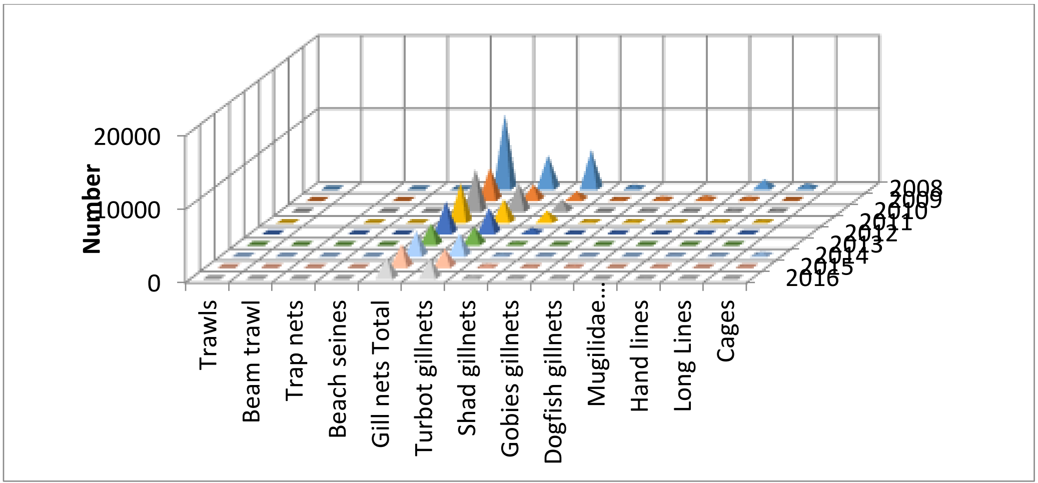

Fig. 2. Number of the fishing gears.

In sprat fishing, two fishing gears, pelagic trawl and pound net are used. During this period their number grew slightly, reaching at 6 trawls in 2014 and 33 pound nets in 2015 (Fig. 3) (Radu et all., 2015; Totoiu et all., 2016).

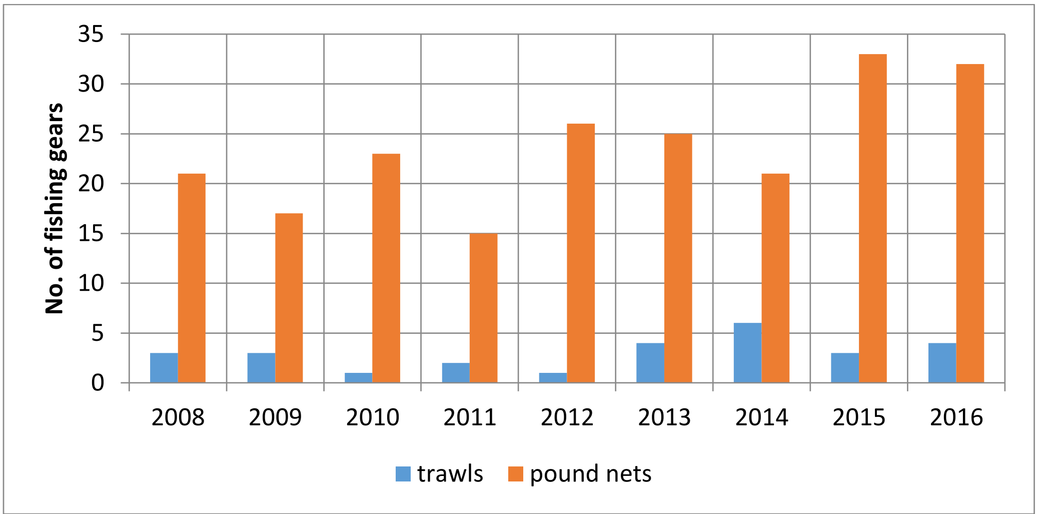

Fig. 3. Fishing effort for sprat at the Romanian littoral.

Dynamics of sprat catches

At the Romanian littoral, the level of capture and fishing efficiency oscillated from one year to other, function of the fishing effort (no. of vessels, no. of pound nets, effective fishing days etc.), evolution of hydro-climatic conditions, stocks status of the main fish species and anthropogenic factors (Radu et all., 2012; Radu et all., 2013; Radu et all., 2013; Radu et all., 2013; Radu et all., 2015; Raykov et all., 2011; Totoiu et all., 2016; Totoiu et all., 2016).

Total sprat catch decreased from 3198 t (1990) at 234 t (2008), that in 2016 reaching at only 49.3 tons (Fig. 4) (Radu et al., 2015; Totoiu et al., 2016).

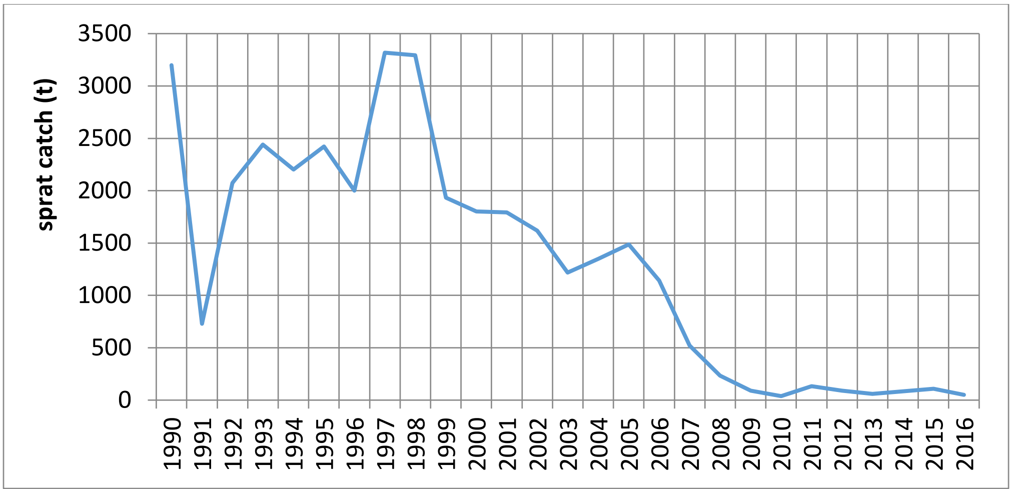

Fig. 4. Dynamics of the sprat catches in the Romanian Black Sea area.

Compared to the Black Sea sprat catch, the Romanian sprat catch is almost negligible, ranging from 0.04% to 1.1%. (Fig. 5) (Casey et all., 2009; Daskalov et all., 2009; Daskalov et all., 2010; Daskalov et all., 2011; Daskalov et all., 2012; Radu et all., 2015; Raykov et all., 2011; Samson et all., 2013; Totoiu et all., 2016).

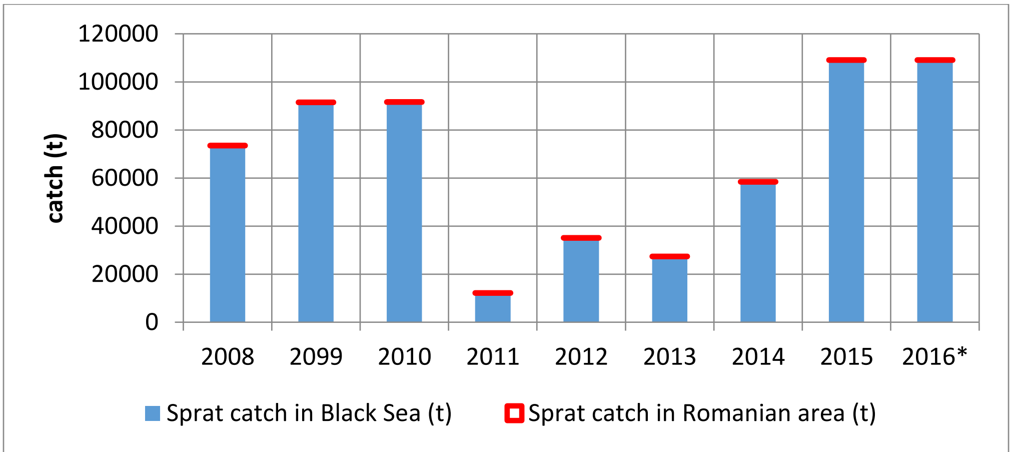

Fig. 5. Romanian catch for sprat compared with the catch of sprat for entire Black Sea.

In the analyzed period, the total catch from the Romanian littoral increased from 444 tons in 2008 to 6839 tons in 2016. The increase in catches was due to the *Rapana* species that entered in the fishery starting with 2012. At the same time, the sprat catches decreased from 234 tons at 49 tons (Fig. 6).

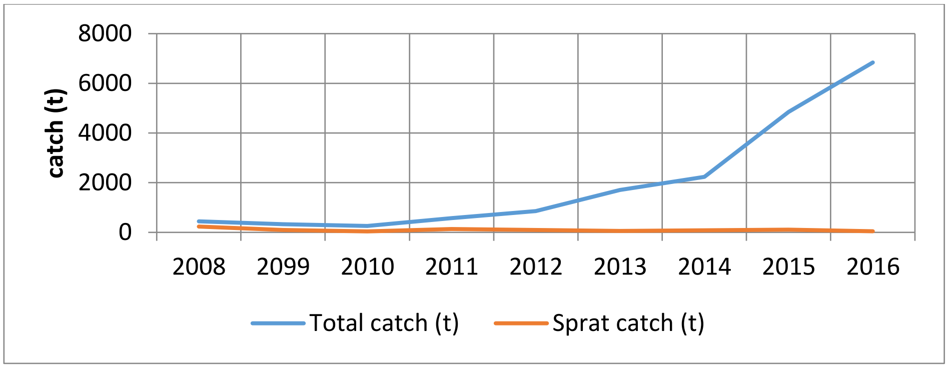

Fig. 6. Romanian catch for sprat compared to the total catch in the Romanian Black Sea area.

Analyzing the situation of sprat catches on the two types of gears (trawl and pound nets), it is noted that most catches were made with the pelagic trawl where almost 100% of the fished species was the sprat (Fig. 7). In the pound net catches, the sprat was between 5% and 30% (Fig.8) (Radu et all., 2012; Radu et all., 2013; Radu et all., 2013; Radu et all., 2013; Radu et all., 2015; Raykov et all., 2011; Totoiu et all., 2016; Totoiu et all., 2016).

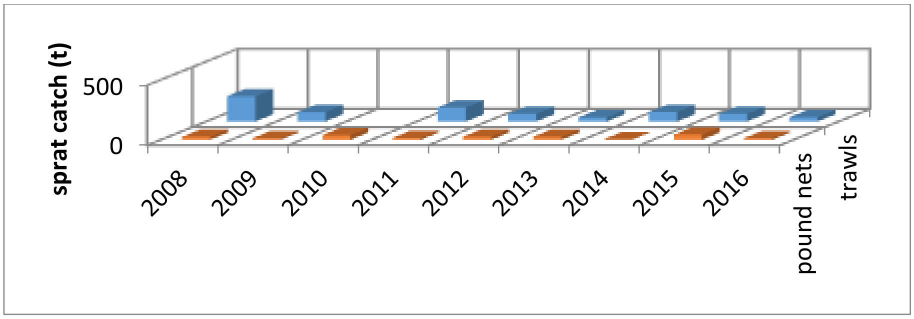

Fig. 7. Sprat catch (t) on fishing gears at the Romanian littoral.

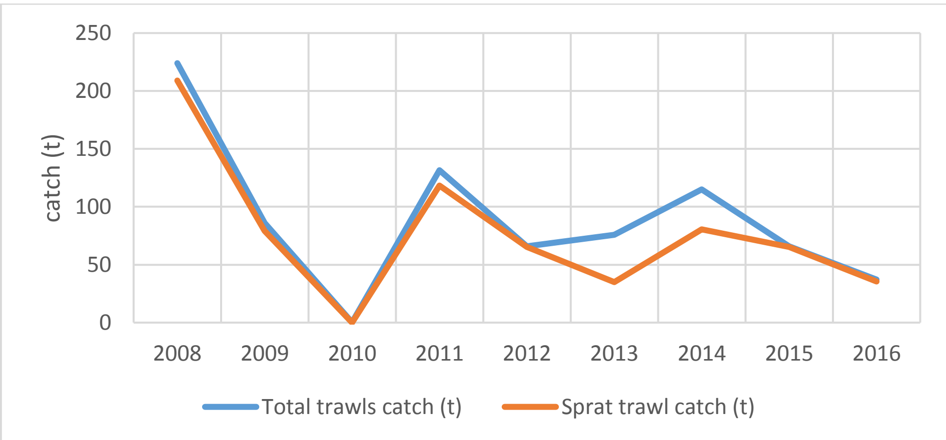

Fig. 8. Sprat trawl catch (t) compared with total trawl catch (t) in the Romanian Black Sea area.

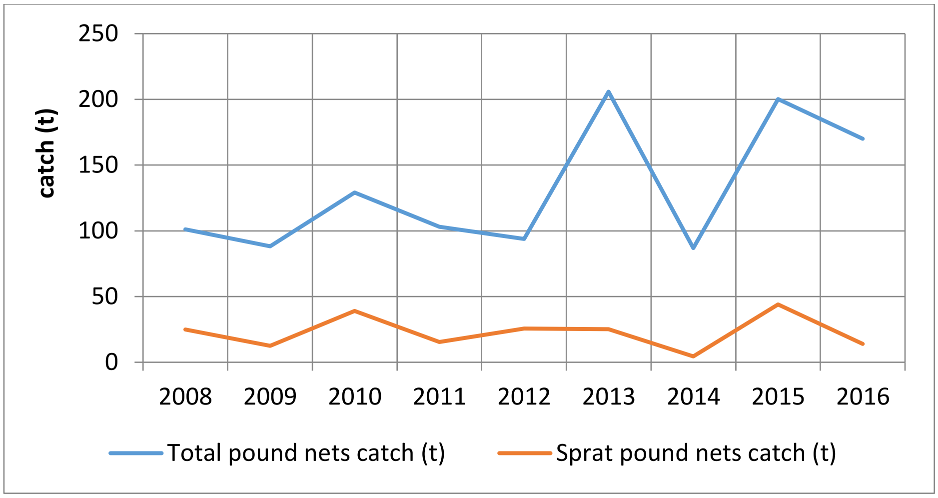

Fig. 9. Sprat pound nets catch (t) compared with total pound nets catch (t) in the Romanian Black Sea area.

Structure on size classes of the catches

In the analyzed period, the sprat had lengths comprised among 50 and 130 mm, the highest frequency pertaining to the individuals of 70-100 mm lengths (Fig. 10). The age corresponding to these lengths was 1;1+ - 3;3+, the ages 1;1+ - 2:2+ having a significant participation (Fig. 11).

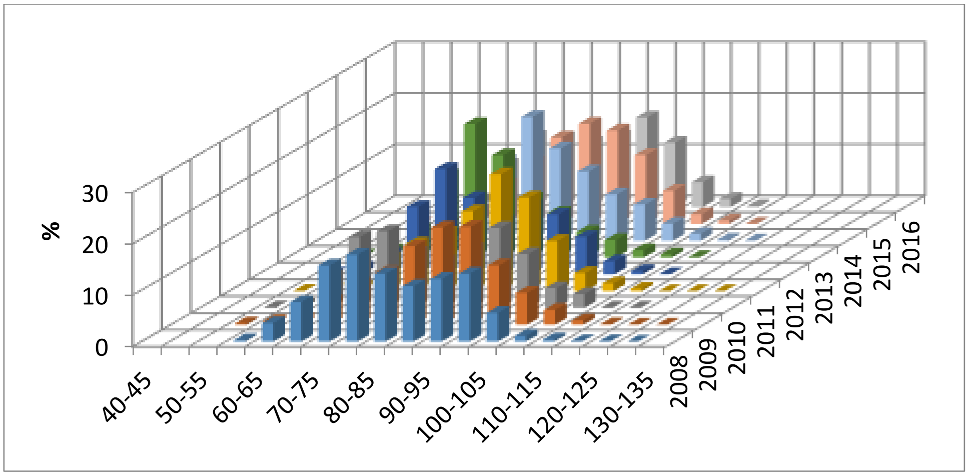

Fig. 10. Structure on length classes of the sprat at the Romanian marine area.

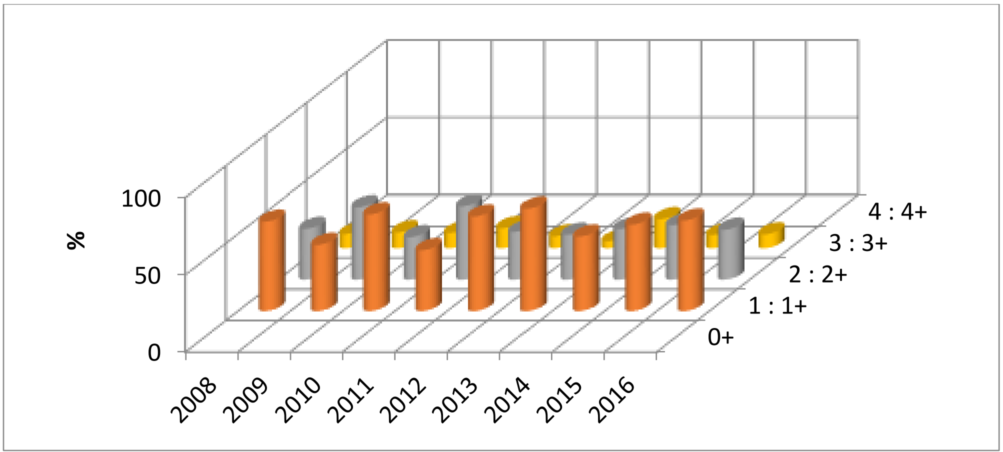

Fig. 11. Structure on age classes of the sprat at the Romanian marine area.

Evolution of biological parameters of sprat

In the period 2008-2016, the average length was about 8 cm (table.1) with average weight of about 3.5g (table. 2). The proportion of sprat specimens larger than the average size at first sexual maturation was about 50%, means that the population is in a pretty good state. (Fig. 12; 13). (Casey et all., 2009; Daskalov et al., 2009; Daskalov et all., 2010; Daskalov et all., 2011; Daskalov et all., 2012; Samson et all., 2013). Growth parameters and mortality rates for sprat at the Romanian littoral are presented in Table 3.

Table 1. Average length (mm) on age classes of the sprat (*Sprattus sprattus* L) from Romanian Black Sea area.

Years	0+	1 : 1+	2 : 2+	3 : 3+	4 : 4+	Average lengths (mm)
2008		75.910	93.760	101.630		84.130
2009		77.469	91.888	100.739		86.610
2010		74.800	92.860	98.709		75.300
2011		76.167	89.019	96.519		85.450
2012		73.468	89.370	97.356		80.180
2013		72.043	85.152	96.168		76.870
2014		76.378	86.983	95.815		81.168
2015		82.046	92.883	98.468		87.302
2016		73.189	87.223	94.841		80.136

Table 2. Average weight (g) on age classes of the sprat (*Sprattus sprattus* L) from Romanian Black Sea area.

Years	0+	1 : 1+	2 : 2+	3 : 3+	4 : 4+	Average (g)
2008		2.53	4.81	6.63		3.65
2009		2.88	4.67	6.21		4.06
2010		2.53	4.885	5.8976		3.53
2011		2.4367	4.1696	5.0865		3.6
2012		2.217	4.128	5.335		3.04
2013		2.3507	3.7495	5.4691		2.81
2014		2.612	3.875	5.088		3.759
2015		2.906	4.14	5.017		3.525
2016		2.29	3.74	4.82		2.986

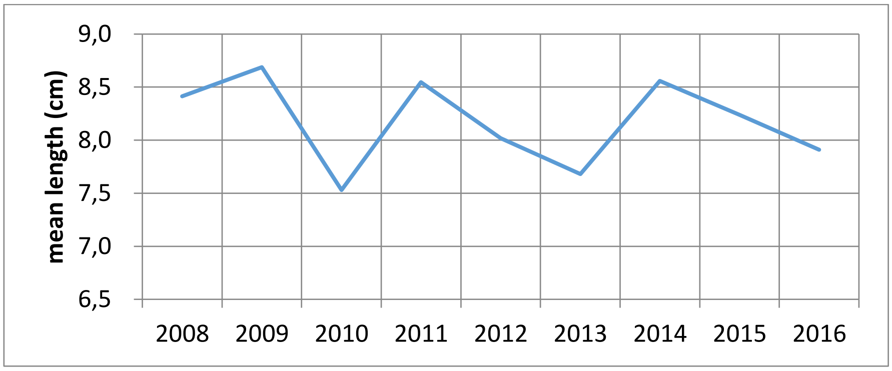

Fig. 12. The average length of the sprat at the Romanian littoral.

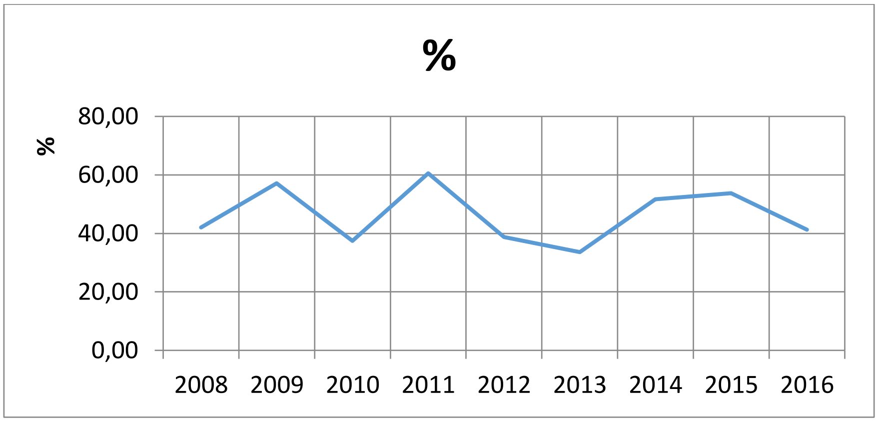

Fig. 13. The proportion of sprat specimens larger than the average size at first sexual maturation.

Table 3. Growth parameters and mortality rates for sprat at the Romanian littoral.

	VB_LINF	VB_K	VB_T0	M	Fc	Fmsy
2009	13.6	0.272	-1.19			
2010	12.6	0.534	-1.56	0.93		
2011	13.7	0.277	-1.16	0.498		
2012	12.1	0.349	-1.17	0.683	0.75	0.64
2013	12.1	0.341	-1.59	0.6932	0.446	0.64
2014	12.6	0.247	-1.58	0.498	0.45	0.64
2015	12.105	0.264	-3.22	0.569	0.5421	0.64
2016	11.578	0.275	-1.69	0.521		

Distribution and fishing agglomerations biomass

The spatial distribution of the fishing resources is dynamic, changeable seasonally and sometimes pronounced enough from one year to the other one. The biomass of the sprat fishing agglomerations oscillated at the Romanian littoral between 30000t and 114 000 tons (Fig. 14) (Radu et al., 2012; Radu et al., 2013; Radu et al., 2013; Radu et al., 2013; Totoiu et al., 2016; Totoiu et al., 2016). The environmental conditions existing to the Romanian littoral allowed formation and maintaining of very large agglomerations of gelatinous species, especially jellyfish (Radu et al., 2012; Radu et al., 2013; Radu et al., 2013; Radu et al., 2013; Totoiu et al., 2016; Totoiu et al., 2016). Because of jellyfish agglomerations, the spring - summer period in some years was extremely unfavourable for fishing with trawlers; Distribution and abundance of the two species (sprat and jellyfish) are opposite, jellyfish blocking setting up of the fish agglomerations in the surveyed area (Fig. 15, 16, 17) (Radu et al., 2012; Radu et al., 2013; Radu et al., 2013; Radu et al., 2013; Totoiu et al., 2016; Totoiu et al., 2016).

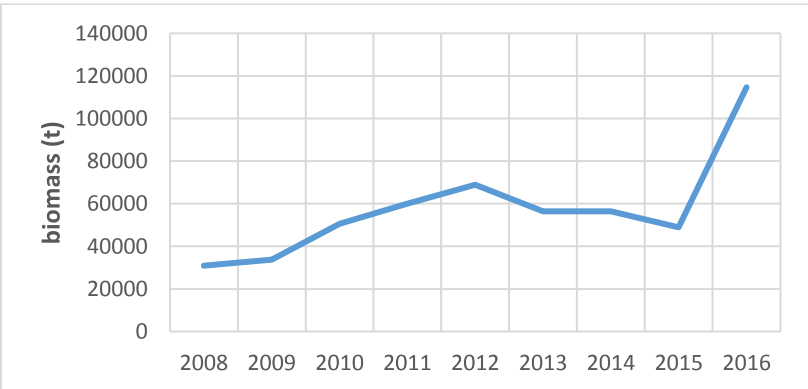

Fig. 14. The sprat biomass in the Romanian marine area.

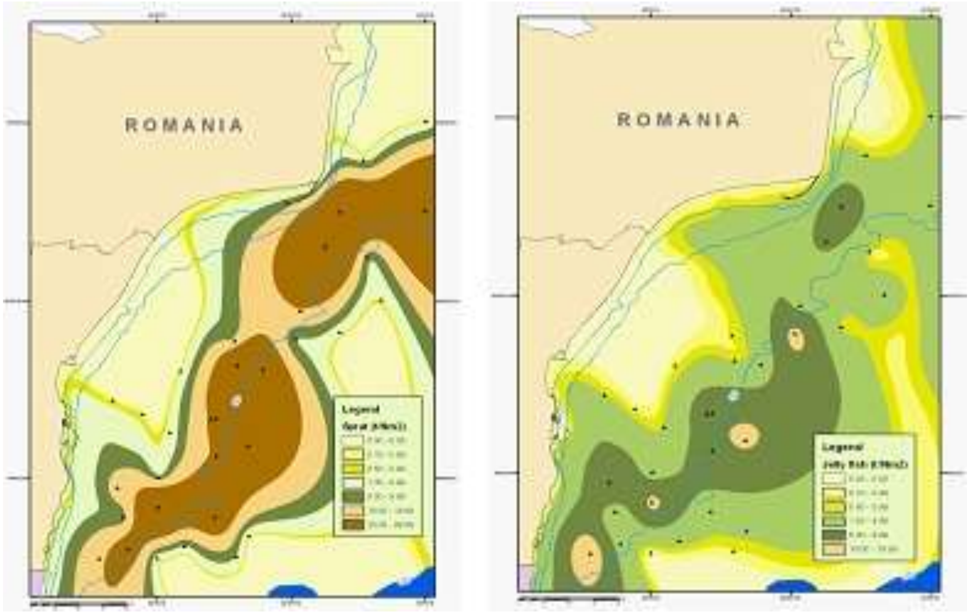

Fig. 15. Distribution and abundance of the sprat and jellyfish, spring 2012.

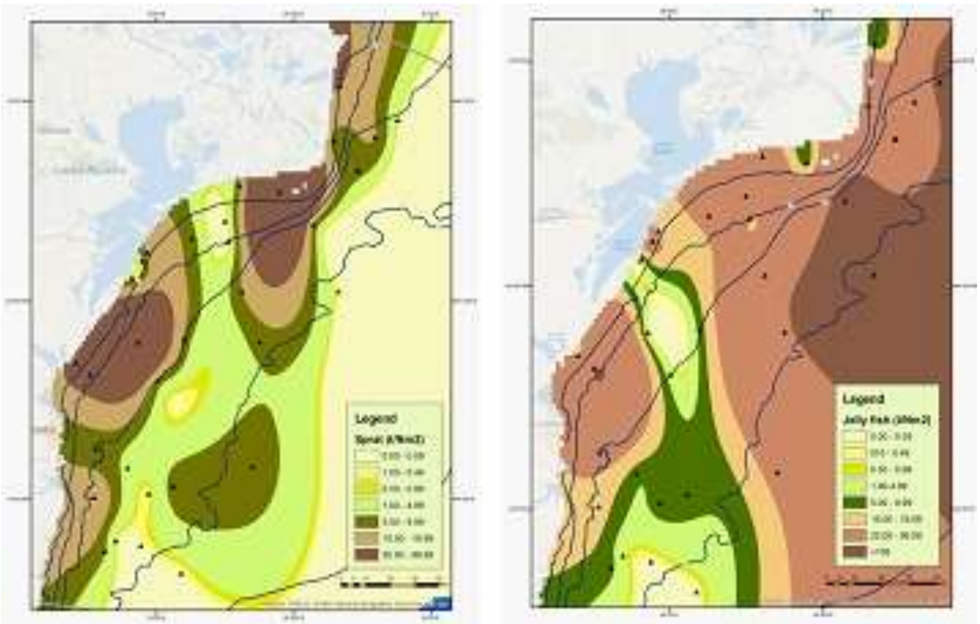

Fig. 16. Distribution and abundance of the sprat and jellyfish, spring 2013.

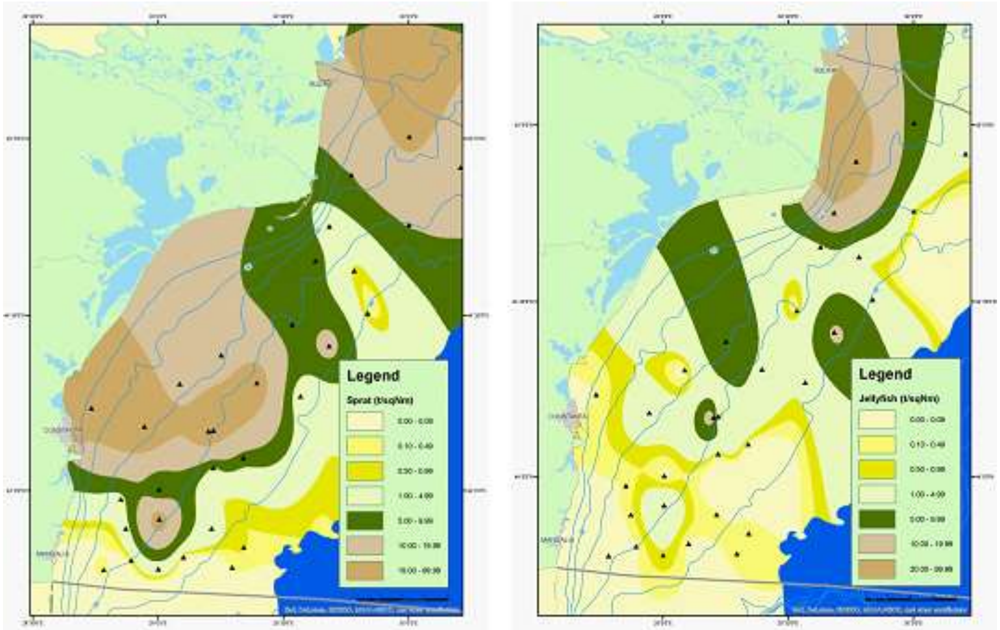

Fig. 17. Distribution and abundance of the sprat and jellyfish, spring 2015.

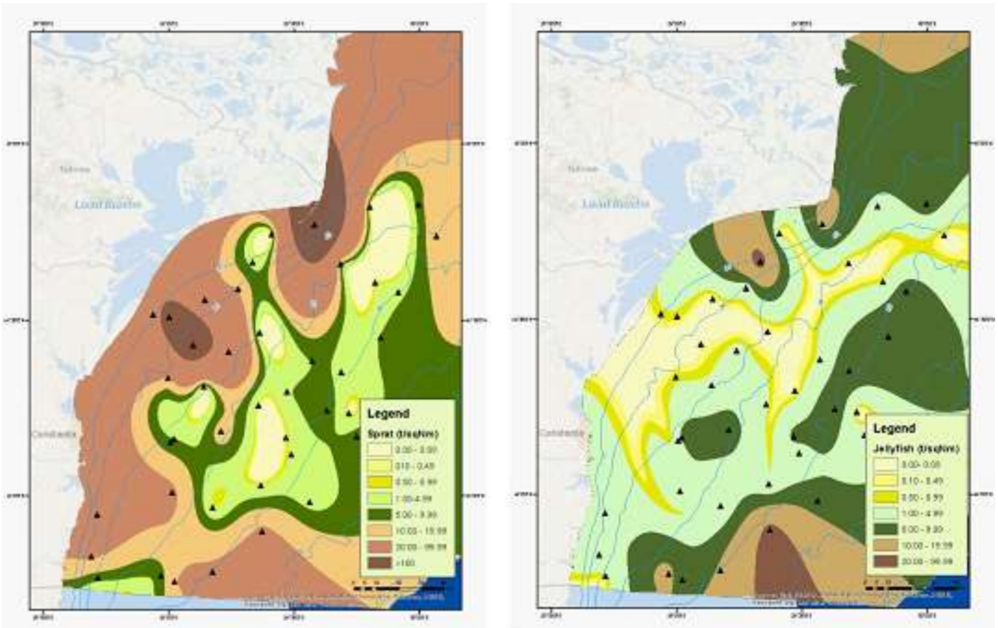

Fig. 18. Distribution and abundance of the sprat and jellyfish, spring 2016.

Influence of environmental conditions on the status and distribution of sprat

The reciprocal links between fish and the elements of the abiotic and biotic environment do not exist in isolation but are interdependent such that the variation of a system of links inevitably causes the variation of another system (Daskalov, 2003; Ivanov et all., 1985). Long-term research has confirmed that each species and each length/age group may have some specific and distinct reactions to the environment.
Feeding, metabolism and growth rates are affected not only by food availability but indirectly by water temperature. At a temperature outside the optimum limits, feeding is usually low. For sprat, which performs a feeding migration in the spring, the role of temperature is much more important, the phenomenon being conditioned by the development of planktonic organisms that are the basic food (Daskalov, 2003; Ivanov et al., 1985; Radu et al., 2011; Sarbu et al., 2016; Zaitsev et al., 1997).

The observations made over several years have shown that regardless of the particularities of other environmental factors, even though reaching optimal values, the sprat does not appear to the shore than when the water temperature has a certain value, namely approx. 7°C. It should be noted that these values are higher than those existing during wintering.

Although there are many articles describing the apparent relationship between fish behaviour, distribution and concentration of salinity, these relationships are not necessarily direct. Most often, salinity variations indicate the change in the condition of stability of water masses. The direct influence of salinity on most species can be considered minor.

The fishing of the sprat, one of species with the highest commercial importance, is largely determined by the frequency of cold currents of bottom. Being a cryophile fish that cannot withstand higher temperatures of approx. 16°C, it moves away from the shore at the beginning of the summer, and throughout this season it only returns with the upwelling phenomenon. One of the main factors that periodically affect the fish's availability in fishing is dominated by the currents, which in turn is influenced by the variations in time of wind intensity and duration.
In the transition season (March-April), but also in the warm season of the year, the winds had different directions and frequencies, favouring the migration of the agglomerations of fish to the shallow waters for feeding and reproduction.

Thus, the Nordic winds (N-NV-NE) by their action in time, pushing along the seashore, brackish water bodies generally rich in food, thus detecting an intense horizontal fish migration to the shallow waters of the shore.

Winds from the open sea (E-SE-S), the beginning may be beneficial for push to shore surface layer of water relatively warm, favouring feeding species confined waters less, but their actions over time will push to shore and colder waters will cause dispersion of food and fishery population migration to feeding. In addition, it will appear abundantly - the jellyfish - which will be caught in trawler vessels as well as in fixed shore-based installations (pound nets).

Winds from the land (western sector), push surface waters, more warmly, their place being taken by the deep cold waters, leading to the phenomenon of upwelling. Under these conditions, we are witnessing the dispersion of food and the fish population.

Through permanent observations, it was found that in situations with completely covered sky (8/8) and partially covered (5-7/8), both the feed and fishing concentrations are confined in the upper layers and the body water, as in the cases with clear sky and little covered (1-4/8), the food and fish agglomerations will be stationed on the bottom. Correlating the degree of coverage of the sky with water temperature from those layers we have a real mirror of fish concentrations for feeding migration.

By making a correlation between the presence and the degree of agglomeration of the sports with zooplankton biomass data, the low zooplankton biomass values for some periods explain the presence of rarefied sprat agglomerations in the area.

The survival of these species, in early stages of development, was negatively influenced by the continued deterioration of zooplankton trophic status and their consumption by clenophore *Mnemiopsis leidyi* and jellyfish *Aurelia aurita* (Radu et al., 2011; Zaitsev et al., 1997).

The presence in the waters of the Black Sea, in considerable quantities, of *Mnemiopsis leidyi* and *Aurelia aurita*, consumers of zooplankton, eggs and larvae, is thought to influence both the formation and distribution of fish agglomerations and the survival of larvae and juveniles (Radu et al., 2011; Zaitsev et al., 1997).

CONCLUSIONS

- sprat is one of the fish species with high commercial importance in the Romanian marine area;
- spatial distribution of the sprat fishing agglomerations is dynamic, changeable seasonally and sometimes pronounced enough from one year to the other one;
- for sprat, which performs a feeding migration in the spring, the role of temperature is much more important;
- sprat forms important agglomerations and performs unregulated migrations between nutrition areas and spawning places determined by temperature conditions.
- one of the main factors that periodically affect the fish's availability in fishing is dominated by the currents, which in turn is influenced by the variations in time of wind intensity and duration;
- the low zooplankton biomass values for some periods explain the presence of rarefied sprat agglomerations in the area;
- because of jellyfish agglomerations, the spring-summer period in some years was extremely unfavourable for sprat fishing with trawlers;
- sprat population is heavily influenced by the fishing effort exerted on it and by the evolution of environmental conditions;
- two fishing gears (pelagic trawl and pound nets) are used for sprat fishing;
- in the Romanian area, **total sprat catches decreased from 3198 t (1990) at 49.3t (2016;**
- the Romanian sprat catch is almost negligible, ranging from 0.04% to 1.1% from Black Sea sprat catches;
- most catches were made with the pelagic trawl where almost 100% of the fished species was the sprat;

- in the pound net catches, the sprat was between 5% and 30%;
- the proportion of sprat specimens larger than the average size at first sexual maturation was about 50%, means that the population is in a pretty good state.

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