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THE NEW DATA ON THE FOOD SPECTRUM OF *SARPA SALPA* (LINNAEUS, 1758) (SPARIDAE) IN THE BLACK SEA

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The first data on the food spectrum of the Mediterranean immigrant *Sarpa salpa* (Linnaeus, 1758) in the Sevastopol coastal area (the southwestern Crimea) are presented. Consumed species were identified in food bolus of one mature *S. salpa* specimen caught off the Kruglaya Bay in August 2023. As shown, the food spectrum covered 13 species of macroalgae. Out of them, red (Rhodophyta) and brown algae (Ochrophyta) predominated by diversity and mass, while the contribution of green algae (Chlorophyta) was minimum. To assess the effect of *S. salpa* (the species that feeds on phytobenthos) on macrophytobenthos communities and coastal ecosystems, regular monitoring of its population in the Black Sea area is required.

Keywords: *Sarpa salpa*, nutrition, macroalgae, Crimea, Black Sea

The Mediterranean invader *Sarpa salpa* (Linnaeus, 1758) was first recorded in the Black Sea in 1937 [Maiorova, Marti, 1938]. Until the XXI century, single specimens of this species were registered off the coasts of Bulgaria, Romania, Ukraine, Russia, Georgia, and Turkey [Guchmanidze, Boltachev, 2017; Öztürk, 2021]. Since 2001, it has become more common off the coasts of the Caucasus and Crimea, both singly and in schools up to a hundred individuals [Guchmanidze, Boltachev, 2017]. The natural range of *S. salpa*, an obligate benthic and pelagic phytophage, covers the eastern Atlantic Ocean and the western Indian Ocean [Carpenter, 2016]. This species is an object of commercial fishing and mariculture in the Mediterranean Sea [Şahinyilmaz, Yigit, 2015].

Previously, information on *S. salpa* diet in the Black Sea was provided based on a study of two individuals caught more than 70 years ago, with the identification of three genera of algae [Georgiev, 1954; Maiorova, Marti, 1938]. Therefore, the aim of the work was to obtain data on the salpa food spectrum and feeding characteristics in the coastal zone of the Sevastopol region (the southwestern Crimea).

MATERIAL AND METHODS

The composition of the food of an adult sexually mature specimen of *S. salpa*, a hermaphrodite, was studied. The fish was caught by a spearfisherman on 29.08.2023 at the entrance capes of the Kruglaya Bay, Sevastopol (44°60′73.51″N, 33°43′83.84″E) during the daytime at a depth of 19 m and at a water temperature in the bottom layer of +26 °C. The salpa occurred among a school of large *Diplodus puntazzo* (Walbaum, 1792).

The just-caught fish was identified using the guides [Carpenter, 2016; FishBase, 2024; Svetovidov, 1964; Vasil'eva, 2007]. Length–weight indicators were determined according to I. Pravdin [1966]. The general index of gastrointestinal tract filling (I, ‱) was calculated by the formula:

$$I = (m/M) \times 10,000\ ,$$

where m is the weight of the food bolus, g;

M is the weight of the fish, g [Rukovodstvo, 1961].

The fish and food items were weighted on an AXIS ADG500C electronic scale with an accuracy of 0.001 g. Mollusc species were identified according to [Opredelitel' fauny, 1972], and their names were updated following WoRMS [2024]. Macroalgae in the food bolus were identified according to [Zinova, 1967], and the species names were indicated taking into account nomenclatural changes [AlgaeBase, 2024].

Water temperature and depth were determined using a dive computer Suunto D4f (Suunto Oy, Finland) with an accuracy up to 1 °C and up to 1 m, respectively.

Information on macrophytobenthos of the Kruglaya Bay coast was obtained by us earlier (in the summer of 2017 and 2018). Sampling was carried out by the standard hydrobotanical technique [Kalugina-Gutnik, 1975]: a 25 × 25 cm recording frame was laid in four replicates at depths of 0.5, 1, 3, 5, 10, and 15–17 m (down to the lower boundary of the phytal zone). When processing samples, we determined the species composition of macrophytes and projective coverage, as well as biomass and abundance of cenosis-forming and mass species, with the contribution of epiphytic algae taken into account. Specific caloric content of algae was indicated according to B. Alexandrov [2001].

RESULTS AND DISCUSSION

Characteristics of the *Sarpa salpa* specimen and its habitat. The length–weight indicators of the *S. salpa* we examined (total length of 485 mm and weight of 1,700 g) (Fig. 1) are comparable to the maximum known for this species [Carpenter, 2016]. The index of gastrointestinal tract filling was 177‱.

The ichthyofauna of the Kruglaya Bay includes 42 to 57 species [Boltachev, Karpova, 2012; Hetman, 2017], and its high diversity is driven by environmental conditions and biotopic features. The coastal slope in the area where the salpa was found is characterized by a heap of stones and large boulders. Stony-block and rocky biotopes feature an *Ericaria–Gongolaria* phytocenosis (*Ericaria crinita* + *Gongolaria barbata* – *Cladostephus spongiosus* – *Ellisolandia elongata*), with a projective coverage of 70–90% and a high diversity of red algae (Rhodophyta), which is typical for this community in the Black Sea [Kalugina-Gutnik, 1975]. The highest biomass was recorded for brown algae (Ochrophyta): the values varied within 173–4,300 $g{\cdot}m^{-2}$. For red algae (Rhodophyta), biomass varied within 64–1,682 $g{\cdot}m^{-2}$, while for green algae (Chlorophyta), it did not exceed 12 $g{\cdot}m^{-2}$ [Cernysheva, 2019].

Phyllophora crispa phytocenosis (depth of 10–15 m) is confined to biotopes of shell rock and silty sands. Mosaic groups of *Zostera* seagrasses were observed only in certain areas of the Kruglaya Bay [Kovardakov, Prazukin, 2011].

Fig. 1. *Sarpa salpa* caught off the Kruglaya Bay, Sevastopol (29.08.2023)

Macroalgae of the food spectrum and feeding strategy. For the *S. salpa* examined, the food bolus weight was 30 g, and the wet weight of macrophytes *per* 1 kg of fish weight was 18 g. It is 1.4–1.7 times lower than values for this size–age group of salps in the Mediterranean Basin [Goldenberg, Erzini, 2014].

We found 13 species of macroalgae in the food bolus, including 2 Chlorophyta, 5 Ochrophyta, and 6 Rhodophyta (Table 1). The contribution of brown and red algae to the weight of the bolus reached 43.6 and 56.1%, respectively, while that of green algae did not exceed 0.3%.

In the *S. salpa* food bolus, the main component of red macroalgae was *Vertebrata subulifera* epiphytizing on *Ericaria* thallus (Table 1). A brown alga *E. crinita* occurred chiefly in the form of apical parts of branches with receptacles. The contribution of a green alga *Ulva rigida* and a calcified red alga *Corallina* sp. was minimum (Table 1). Representatives of the macrophyte epifauna – molluscs and a hydroid *Aglaophenia pluma* (Linnaeus, 1758) – were noted in insignificant quantities.

The features of the food spectrum composition that we revealed are consistent with the data on *S. salpa* diet in the Mediterranean Sea [Carpenter, 2016; Verlaque, 1990]. Thus, out of 138 identified species of macroalgae, a half also belonged to red algae, and the proportion of brown algae was similar to that obtained by us: 46.4 and 43.6%, respectively [Franco et al., 2015; Verlaque, 1990]. It should be noted that earlier, during the first catches of the salpa in the Black Sea, red algae were not found in its food [Georgiev, 1954; Maiorova, Marti, 1938].

The confinement of the salpa to the coastal zone of the Kruglaya Bay may be due to high biomass values of the dominant *Ericaria*–*Gongolaria* phytocenosis (687–4,611 $g \cdot m^{-2}$) featuring a significant contribution of *Ericaria* (up to 70–90%) and epiphytes (5–24%). The epiphytic synusium was dominated by *V. subulifera*, *Ectocarpus siliculosus*, *Sphacelaria cirrosa*, *Antithamnion cruciatum*, and *Chondria* representatives [Cernysheva, 2019] found in the salpa food (Table 1). The lower layers of phytocenoses at the entrance capes of the Kruglaya Bay are characterized by occurrence of the following lithophytes: *C. spongiosus*, *Carradoriella elongata* (Hudson) Savoie & G. W. Saunders, 2019, *Cladophoropsis membranacea* (Bang ex C. Agardh) Børgesen, 1905, *Gelidium crinale* (Hare ex Turner) Gaillon, 1828, *Gelidium spinosum* (S. G. Gmelin) P. C. Silva, 1996, *Osmundea pinnatifida* (Hudson)

Stackhouse, 1809, *Phyllophora crispa* (Hudson) P. S. Dixon, 1964, *Zanardinia typus* (Nardo) P. C. Silva, 2000, and other finely branched sciaphilous and soft coralline algae, also registered in the salpa food spectrum in the Mediterranean Sea [Cernysheva, 2019; Verlaque, 1990].

Table 1. Species composition, weight, and caloric content of food bolus components of *Sarpa salpa* (the Kruglaya Bay, 29.08.2023)

Taxon	Weight, g	Contribution, %	Specific caloric content, kJ·g^{-1}
Chlorophyta			
Lychaete echinus (Biasoletto) M. J. Wynne, 2017 (ep.)	0.05	0.17	18.92 / 25.26
Ulva rigida C. Agardh, 1823	0.03	0.1	13.79 / 17.37
Ochrophyta			
Cladostephus spongiosus (Hudson) C. Agardh, 1817	0.5	1.7	21.74 / 23.50*
Ectocarpus siliculosus (Dillwyn) Lyngbye, 1819 (ep.)	1.2	4.0	19.27 / 26.28
Ericaria crinita (Duby) Molinari & Guiry, 2020	10.3	34.3	16.46 / 18.00*
Sphacelaria cirrosa (Roth) C. Agardh, 1824 (ep.)	0.3	1.0	21.74 / 23.50*
Zanhlineardinia typus (Nardo) P. C. Silva, 2000	0.8	2.6	18.70 / 20.62*
Rhodophyta			
Antithamnion cruciatum (C. Agardh) Nägeli, 1847 (ep.)	0.05	0.17	20.46 / 22.94*
Chondria capillaris (Hudson) M. J. Wynne, 1991 (ep.)	1.4	4.67	16.99 / 18.61*
Chondria dasyphylla (Woodward) C. Agardh, 1817 (ep.)	0.8	2.7	16.99 / 18.61*
Corallina sp.	0.04	0.13	–
Laurencia obtusa (Hudson) J. V. Lamouroux, 1813 (ep.)	0.07	0.23	15.94 / 18.82
Vertebrata subulifera (C. Agardh) Kuntze, 1891 (ep.)	14.5	48.25	20.59 / 22.38
Mollusca			
Bittium reticulatum (da Costa, 1778)	0.041	0.01	–
Tricolia pullus (Linnaeus, 1758)	0.0028	0.009	–
Mytilidae gen. sp.	0.0003	0.01	–
In total	**30.08**	100.00	

Note: ep., an epiphyte. Specific caloric content is given according to B. Alexandrov [2001]: before the line, in terms of dry weight (DW); after the line, in terms of ash-free dry weight (AFDW). *, values for closely related species are provided. A dash denotes no data.

Since caloric content of red algae (Rhodophyta) in the food bolus of the studied specimen did not differ much, their predominance in the salpa diet could be associated with features of their chemical composition, *inter alia* their higher protein content (30–40%) compared to that for species of Ochrophyta (5–11%) and Chlorophyta (up to 20%) [Sukhoveeva, Podkorytova, 2006]. Moreover, red algae accumulate significant amounts of polysaccharides (up to 50–80%) and polyunsaturated fatty acids (eicosapentaenoic and arachidonic ones) occurring in fish tissues. The predominance of Rhodophyta in the *S. salpa* diet could be also governed by the fact that they were epiphytes (Table 1) with a high specific surface area the value of which positively correlates with their caloric content [Alexandrov, 2001].

The revealed features of the structure and distribution of macrophytobenthos in the coastal zone at the entrance capes of the Kruglaya Bay are important for assessing *S. salpa* feeding. The finding of an adult specimen in a warm layer (+26 °C) at a depth of 19 m may evidence for migrations from "pasture feeding" sites in dense macrophyte thickets at depths of 3–7 m to deeper layers, including the thermocline. According to mean long-term data [Troshchenko et al., 2019], in the Kruglaya Bay area, the core of the thermocline coincides with a depth of the salpa record. Such an adaptive strategy may also be associated with the rhythm of *S. salpa* feeding and the duration of digestion of polysaccharides that predominate in its food [Buñuel et al., 2020]. At the same time, fish can move hundreds of meters away from the coast without wasting much energy, and this resource is limited in species feeding on phytobenthos, especially with a carbohydrate type of nutrition [Verlaque, 1990].

Conclusion. For the first time, macroalgae were registered in the diet of the Black Sea *Sarpa salpa*; 13 species were identified. Red and brown algae accounted for 85% of species, and their contribution to the weight of the salpa food bolus was 99.7%. Regular monitoring of the state of *S. salpa* population in the Black Sea is required, especially under global climate change and processes of biota mediterranization: it will help in assessing the scale of the salpa effect on key cenosis-forming macrophyte species.

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НОВЫЕ СВЕДЕНИЯ О ПИЩЕВОМ СПЕКТРЕ *SARPA SALPA* (LINNAEUS, 1758) (SPARIDAE) В ЧЁРНОМ МОРЕ

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Представлены сведения о питании средиземноморского иммигранта *Sarpa salpa* (Linnaeus, 1758) в прибрежной зоне региона Севастополя (Юго-Западный Крым). Видовой состав компонентов пищевого комка определён по данным изучения одного экземпляра *S. salpa* — взрослой особи, отловленной на взморье бухты Круглая в августе 2023 г. Показано, что спектр питания сальпы охватывал 13 видов макроводорослей. Среди них по разнообразию и массе преобладали представители красных (Rhodophyta) и бурых водорослей (Ochrophyta), а вклад зелёных (Chlorophyta) был минимальным. Для оценки воздействия *S. salpa* — облигатного и активного фитобентофага — на сообщества макрофитобентоса и прибрежные экосистемы необходим регулярный мониторинг состояния популяции этого вида в бассейне Чёрного моря.

Ключевые слова: *Sarpa salpa*, питание, макроводоросли, Крым, Чёрное море