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Some of the features of *Fucus vesiculosus* L. in the intertidal zone of the Bolshoy Solovetskiy island in the White Sea

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Abstract. In 2014–2018 a study has been made on the development of bladder wrack (*Fucus vesiculosus* L.) coenopopulation in the tidal zone of the southwestern part of the Bolshoy Solovetskiy Island in the White Sea. During the observations, the dates of occurrence of germlings, dichotomy, air bladder, and receptacles on fucus thalli were established. The results of observations of *F. vesiculosus* development confirmed the data on the two peaks of germlings emergence. It was found out that the nature of fucus vegetative development in the first year of life is homophyadic. Further development of fucus in specific coenopopulations has its own biological features. The populations of *F. vesiculosus* are capable of renewal after 4 years. The results will be used to develop recommendations for the rational use of seaweed resources.

1. Introduction

Fucus vesiculosus L. is one of the dominant species of the coastal vegetation of the Solovetskiy Islands and, along with other representatives of the fucus algae (*F. distichus* L., *F. serratus* L., *Ascophyllum nodosum* L.) plays an important role in the functioning and production of the marine ecosystem in this area. With its unique chemical composition, *F. vesiculosus* is also a valuable resource object.

Biological peculiarities of the bladder wrack in the White Sea were studied in the 1960-1980s by Kuznetsov [1] and Vozzhinskaya [2]. Maksimova's [3, 4] research on this issue was the most detailed one. The data of the latter author was regularly used by us in monitoring of the state of fucus natural populations. However, in the study of *F. vesiculosus*, which grows in the southern part of the Solovetskiy Island, we paid attention to the inconsistency of some of our data and scientific information. In her works, Maksimova also noted that *F. vesiculosus* is an ecologically flexible species, capable of morphological modification depending on habitat conditions [4].

In this regard, the purpose of our research was to clarify the biological information about *F. vesiculosus*, necessary for the preservation and rational exploitation of this bioresource.

2. Materials and methods

Observations of the development of *F. vesiculosus* were conducted in 2014-2018 in the southwestern part of the Bolshoy Solovetskiy Island (Fig. 1).



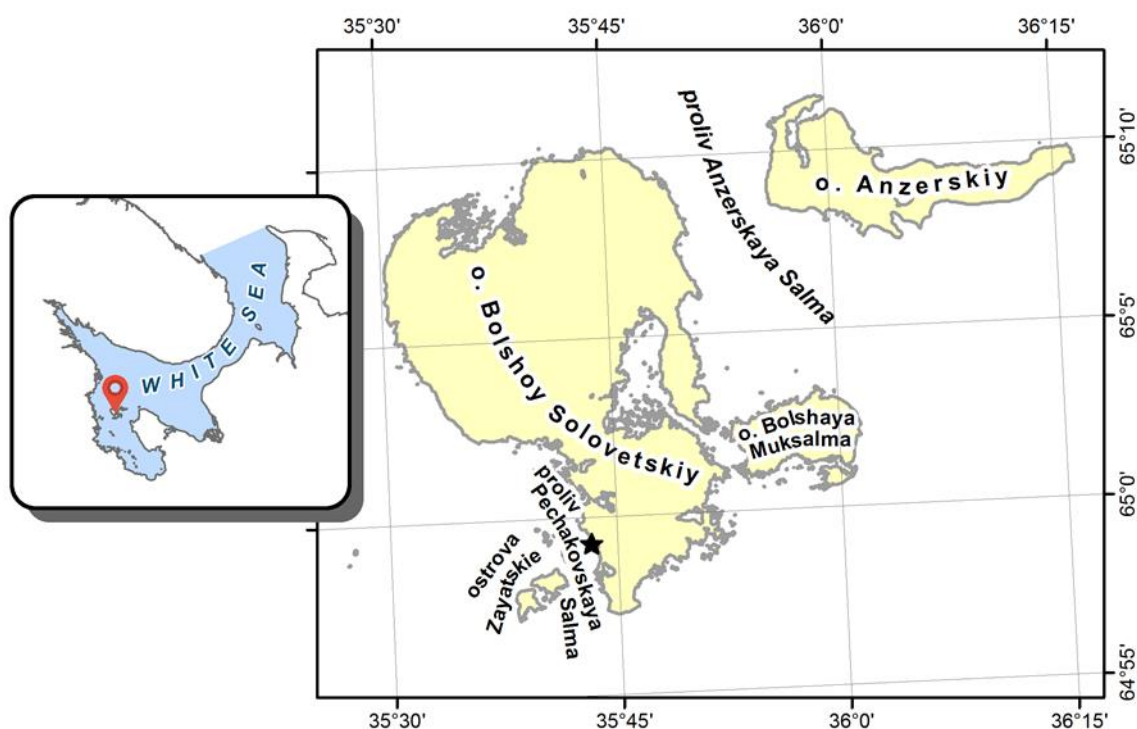


Figure 1. The map of the Solovetskiy Islands and location of the experimental site.

In the tidal zone we made a platform of 30 stones collected on the shore. The stones were laid on June 22, 2014 in the middle horizon of a slightly sloping stony-sand littoral zone, protected from waves. Annual measurements of fucus plants that settled on the rocky substrate were carried out in the second decade of June and September. In *F. vesiculosus*, the timing of the appearance of germlings, the formation of dichotomy, air bladders and their rows on the thalli, the changes in the length parameters were determined. In September 2015, young plants in the amount of 95 pieces were labeled with plastic numbered tags. In addition to measurements of labeled plants, at the same time 2-3 samples of seaweed were taken on the site with a frame of 0.01 m², or the seaweed was completely cut off from individual stones. A total of 1,800 *F. vesiculosus* specimens were examined. The obtained results were compared with Maximova's data, who studied the growth and development of *F. vesiculosus* in the littoral zone of the northeastern part of the Bolshoy Solovetskiy Island.

3. Results

A survey of the site in September 2014 showed that the surface of the stones was populated by germlings of *F. vesiculosus* 0.1-0.5 cm high. Sporophyte thalli had no signs of differentiation, i.e., they had no midrib and no holdfast.

In the second year (June 2015), the seaweed cover on the stones consisted of young unbranched focus thalli 0.1–3.1 cm high. Germlings with a height up to 1.0 cm dominated. These plants constituted 90% of the 303 studied thalli collected in 6 samples. Larger thalli 1.0-3.1 cm high made up 10%.

In September 2015, the height of the fucus thalli varied from 1.0 to 11.0 (14.7) cm. Most sporophytes (65%) remained unbranched. In some plants, 1-2 dichotomies were recorded (29% and 5% respectively). Some specimens had 3-4 dichotomies. Under the canopy of these young plants, new germlings were recorded.

In June 2016, the number of branches on labeled plants (age 1+ 2 years) ranged from 0 to 5. Sporophytes with 1-2 dichotomies prevailed (30% and 40% respectively). In September 2016, the

number of branches on labeled thalli reached 8, individual plants remained unbranched. Sporophytes with 3-5 dichotomies prevailed (17%, 22%, 19% respectively). The linear growth of young plants over the summer period (June-September) averaged 7.0 cm.

In 2017, observations were carried out only in June. All labeled fucus plants (age 2+ 3 years) had branchings, the number of which varied from 2 to 8. In 2018, by the end of summer, there were from 4 to 13 dichotomies on thalli. The linear growth of the thalli in the summer of 2018 averaged 3.1 cm.

Morphological structures such as air bladders (paired and unpaired) were first recorded on separate thalli of *F. vesiculosus* in June 2016. The age of these sporophytes was 1+ - 2 years. The studied fucus plants were characterized by the preliminary formation of paired or single cavities on the thalli, which were the basis for further air bladder formation. The presence of similar structures that preceded the bladders in young fucus plants was observed everywhere and in the natural settlements surrounding the site. In June 2017, plants with 1-2 rows of air bladders were registered on the site. The age of these sporophytes was 2 + - 3 years. In general, it was not possible to determine the exact number of air bladder rows formed during the study in most plants, since the lower air bladder rows gradually collapsed along with the leaf part of the thalli. Bladders remained on the middle or upper parts of the branches.

Fruiting plants on the site appeared in June 2016. However, such plants were sporadic. In June 2017, the share of plants with receptacles was 14%, and in June 2018 - 32%.

4. Discussion

Observations made at the site confirmed Maksimov's data that during the vegetation season in the White Sea, two generations of germlings - spring and autumn ones - are formed in *F. vesiculosus*. In spring, germlings appear in March-May, and in autumn - in July-August [3]. The "spring" generation appears from dormant sporophytes with stunted development and "compensates" for the high mortality rate (60–90%) of young thalli of the "autumn" generation, which occurs in late autumn [5].

The germlings found on the rocky substrate in the first year of our experiment (September 2014) were the "autumn" generation of *F. vesiculosus*. In June 2015, sporophytes of the "spring" generation were registered at the site. The presence of two different fucus generations was testified by the different degree of germlings development. The calendar age of the "spring" sporophytes in June 2015 was 1.5–3.5 months, of the "autumn" ones - 11-12 months. In the following years, germlings of both generations were constantly present at the site, the replenishment of which in the first four years was provided by the nearby fucus beds.

Our observations also confirmed Maksimov's data that in the first year of life a part of the fucus plants can form 1 dichotomous branching (sometimes 2 dichotomies), but more often the plants of 0+ do not branch. Dichotomies on thalli were recorded in September 2015 (in June all thalli were unbranched). Sporophytes with 3-4 dichotomies apparently belonged to the "autumn" generation of 2014; the age of these plants was 1.4-1.5 years.

Observations of the labeled plants have shown that in 1 + - 3+ years old fucus, the number of branches formed during the vegetation period is not sustainable. In this regard, in the same age group of plants, a different number of branches is registered. For *F. vesiculosus* of different ages, the same number of dichotomies was often observed (Table 1).

Table 1. Phases of the vegetative development of *F. vesiculosus* on the experimental site in the 2014-2018.

Experiment phases	Measurement date	Number of branchings	Thallus height, sm			Number of labeled plants
			Min.	Max.	Average	
1 st year (substrate colonization with germlings)	22.06.2014		substrate adding			
	10.09.2014	(0)	0.1	0.5	-	-
	13.06.2015	0(1) ^a	0.1	3.1	0.5±0.4	303 ^b
2 nd year	12.09.2015	0-3(4)	1.0	11.0(14.7)	5.7±2.4	95
	08.06.2016	0-4(5)	4.5	22.1	10.7±3.3	62
3 rd year	08.09.2016	(0)1-7(8)	5.0	36.0	16.8±6.8	58
4 th year	11.06.2017	2-7(8)	8.0	38.5	24.5±6.5	42
	08.06.2018	4-9(10)	20.0	57.0	36.8±10.3	20
5 th year	25.08.2018	(4)5-13	20.3	70.0	40.1±13.8	11

^a Single plants.^b Mass measurements.

According to Maksimova, fucus older than one year during the vegetation period (April-September) usually forms two new dichotomous branchings. Based on this statement, the author developed a method for determining the age of *F. vesiculosus* [3].

The results of the air bladder registration on the fucus thalli also did not correspond to earlier statements about the appearance of the first row of air bladders only in the fourth year of life. According to Maksimova, young *F. vesiculosus* plants do not form air bladders until the third year of life [3]. Our studies have shown that the timing of the air bladder appearance is specific for different coenopopulations of this species.

Data on the dimensional composition of *F. vesiculosus* at the site indicated an intensive vegetative growth of plants in the summer period. In the fifth year of the experiment (2018), when the fucus plants reached an age of 3.5–4 years, the algal cover on the site had a similar appearance to the nearby tangles of this species.

5. Conclusion

The observation results of the *F. vesiculosus* development, conducted on the littoral in the southwestern part of the Bolshoy Solovetskiy Island during 2014-2018 confirmed the scientific data on the timing of *F. vesiculosus* germlings emergence in the White Sea. The nature of vegetative development in the first year of life of the bladder wrack is obviously of the same type.

Further development of plants in specific cenopopulations of *F. vesiculosus* has its own biological features. Our study showed that in plants older than 1 year, the number of branches that form during the growing season is not stable. The formation of air bladders and their rows occurs in young fucus plants, which are younger than 3-4 years.

Fruiting in *F. vesiculosus* can begin as early as two years of age. However, for normal reproduction of the coenopopulation, the presence of plants of 3 years and older is necessary. In the conditions of the littoral, protected from waves, the populations of *F. vesiculosus* resume after 4 years.

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