

Conference Paper

New Approach on Organizing the Monitoring of Macrophytobenthos in the Russian Arctic

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Abstract

The minimum number of samples was estimated based on the studies of the distribution of macrophytobenthos. The existing norms of three replicates per sampling station do not always allow to obtain reliable average values. The collection of a large number of samples, especially seasonally, will lead to significant changes in the studied community. It is recommended to put into practice the use of the method of photographing the areas of particular size along transects for further analysis using special software. It is proposed also to amend the existing regulatory documents on sampling of macrophytobenthos in the Barents Sea and other seas of the Russian Arctic. In particular, it is worth making the most of landscape surveys and mapping. The developing of a monitoring system for species diversity and macrophytobenthos distribution in the seas of the Russian Arctic is justified in regard to the monitoring of the community state, including that considering the climate change.

Keywords: species diversity, macroalgae, landscapes, biomass, monitoring

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Received: 24 December 2019

Accepted: 9 January 2020

Published: 15 January 2020

Publishing services provided by
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Selection and Peer-review under
the responsibility of the
BRDEM-2019 Conference
Committee.

1. Introduction

Algae are a key biological element for assessing the ecological status of coastal waters within the European Water Framework Directive 2000/60/EC. The guidelines of the European Water Framework Program and the marine strategy concern the assessment of environmental quality in estuarine and coastal ecosystems. This law requires that the environment quality has to be determined in an integrative manner using several biological elements (phytoplankton, benthos, algae, ichthyofauna) together with physicochemical elements (including pollutants). A methodology has been developed that integrates all this information into a unique quality assessment using the example of the water bodies in Italy [1].

Algae inhabiting the polar latitudes are characterized by the structural features and resilience that allow them to exist in harsh environmental conditions, in particular, they have strongly pronounced resistance to cold and darkness [2]. Despite these

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peculiarities, their biomass is extremely low, and the climatic changes significantly affect the algal communities in the polar latitudes [3]. For example, the biomass of kelp algae, primarily *Laminaria solidingula*, as well as *Saccharina latissima* and *Alaria esculenta*, together with related species, averages only 0.067 kg m² in the Beaufort Sea, Alaska [4]. In the Russian Arctic, macroalgae form a vegetation cover only along the Murmansk Coast, they are noted eastwards off only in some areas with the most suitable substrates [5]. Arctic algal communities are mostly sparse; therefore, it is necessary to minimize the seizure of algae so as not to harm both their populations and the ecosystem as a whole in studies of any kind. It should be noted that today there is practically no data on the rate of restoration of algal communities after damage, in particular after total destruction in a small area, although this is a common practice during the quantitative sampling [6]. The use of more gentle monitoring methods has been actively discussed since the beginning of 2000s [7, 8].

The method of quantitative accounting of algae is constantly being improved, but its essence does not change. Samples are taken using a frame of 50 cm × 50 cm. A methodology was proposed for accounting from a site of 40-cm wide and lasing through the whole littoral [9]. However, this method is designed for determining the commercial reserves of the algae and does not allow to perform the comparison between different communities.

In this paper, we will focus on the control and conservation of macrophytobenthos of the northern Russian seas in regard to the environmental protection and biodiversity conservation. Benthic algae in the coastal communities are often not considered as a key or/and vulnerable component of the ecosystem. The regulatory documents and traditions existing in Russia involve the collection of the three macrophytobenthos samples from each station using a frame of 0.25 m² in littoral and 1.0 m² in sublittoral. It is assumed that the researcher will obtain a larger number of samples as necessary [10, 11].

The present study is devoted to assessing the applicability of the standard method for monitoring of macrophytobenthos in the seas of the Russian Arctic using the Kola Bay of the Barents Sea as an example. The study aims to estimate the minimum number of samples necessary to identify significant differences between communities in time and space and to propose a possible way to improve monitoring of algal littoral communities based on these data. The area of our research was not chosen by chance to solve these problems. The Kola Bay is an area of intensive economic development, fishing and trading ports, military ports, and various facilities are concentrated here, oil and coal are loaded here; there are three large cities with a population of about 500

thousand people (Murmansk, Severomorsk and Polyarny). All these factors undoubtedly require monitoring the state of the ecosystem [12]. The authors have been studying and monitoring macrophytobenthos in the Kola Bay for almost 20 years, and this has prompted us to critically rethink the methods and approaches applied.

2. Methods and Equipment

2.1. Methods

The biomass and abundance of *Fucus vesiculosus* L. and *Fucus distichus* L. on the littoral of the Kola Bay of the Barents Sea was used as a primary data for calculating the minimum representative sample size. The algae were sampled each hydrological season (spring, summer, autumn and winter) in 2007--2009 in the area of Abram-Mys located in the southern arm of the bay (Figure 1).

Three sub-samples have been obtained from each station in the middle and lower littoral. In the central and northern arms of the bay, the studies were performed at 9 sites in June 2013, three sub-samples per station have been obtained on each littoral level. Samples were taken by the standard, widely applied method of accounting areas, using a 50 cm × 50 cm frame [10, 11]. All thalli whose holdfasts were inside the frame were considered belonging to the sample. A total of 171 samples were collected and processed. Biomass was calculated as kg m⁻² with an accuracy of 1 g. The abundance was calculated as the number of plants per m².

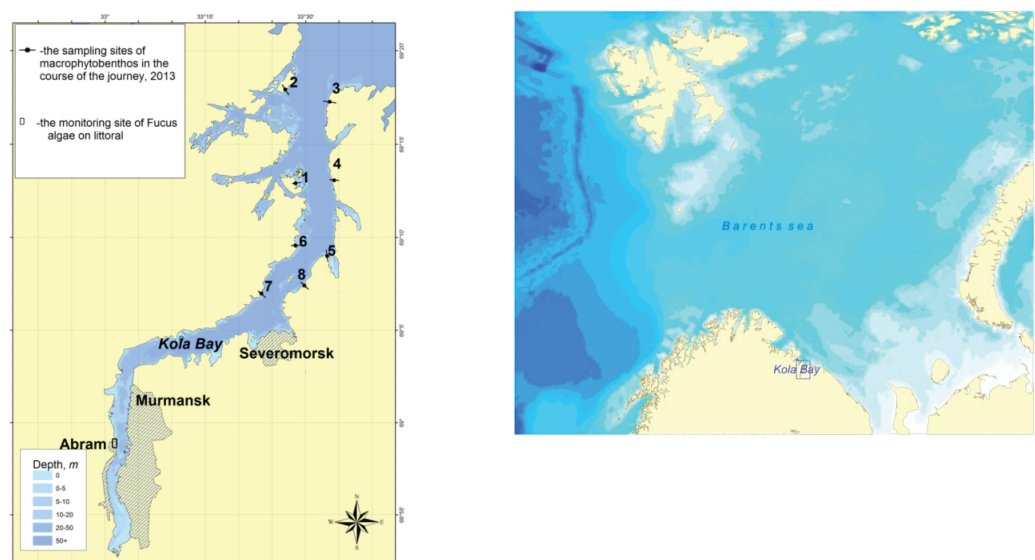


Figure 1: Research area and sampling method in the Kola Bay.

In order to calculate the required number of frames, the following formula was used [13].

$$n = \left(\frac{t}{\Delta} \right)^2 (s_1^2 + s_2^2) \quad (1)$$

where n is the required number of frames for the analyzed samples, t is the normalized deviation at $\alpha = 0.05$, Δ is the confidence interval at $\alpha = 0.05$ obtained from previously available data, s^2 is the variance for the sample.

3. Results

The number of samples must substantially exceed three in order to identify the minimum existing differences between stations (Table 1). On average, the number of sub-samples required for a representative sample for assessing *Fucus* biomass ranged from 8 for *Fucus distichus* up to 15 for *F. vesiculosus*. In regard to the algae abundance, the number of samples is even higher, from 9 needed for *F. vesiculosus* up to 28 for *F. distichus*. The area of one sample is 0.25 m² and, accordingly, to obtain data showing changes in the community over time, it is necessary to eliminate the algae community from the area of 2 to 7 m².

The required number of samples for comparing communities of different parts of the bay shore varies from 8 up to 59 (Table 2). These study sites vary significantly in species composition, habitus, and community growth conditions [5, 14]. It is not surprising that the biomass of each species of studied algae at the sampling sites varies greatly between particular samples, for example, at the site no. 8-2, the biomass of *F. vesiculosus* in the sub-samples was 0, 0, and 8,160 g. The mosaic distribution of furoids is characteristic of the littoral of the Murmansk Coast, algae often grow in groups of several or even several dozen plants. The variance in the sample may be very large (Table 2), which makes it difficult to compare the community between the sampling sites.

As a result, the number of samples required for comparing *Fucus* biomass between communities and for assessing population dynamics in the littoral of the Kola Bay varies greatly, but always amounts to more than 8 samples per station (sampling site), reaching up to 59 samples that cover almost 30 m². In this regard, at least two problems arise. First, it is initially difficult to estimate the sample size, which will allow a researcher to operate with data using parametric analysis methods, since the variation within even one sampling site between the sub-samples is very large. Secondly, the desire to monitor algal communities most fully using the standard methods leads to the collection of a large number of samples, which inevitably results to the devastation of

TABLE 1: Biomass and abundance of two *Fucus* species in the southern arm of the Kola Bay (Abram-Mys, the Barents Sea) in 2007--2009.

Parameter	Autumn 2007	Spring 2008	Summer 2008	Autumn 2008	Winter 2009	Spring 2009	Summer 2009
<i>Fucus vesiculosus</i>							
<i>B</i>	13.5	10.2	6.7	6.5	1.7	4.7	1.8
<i>s</i> ²	3.76	10.9	20.15	4.04	2.34	4.98	0.72
<i>n</i>	11±4						
<i>Fucus distichus</i>							
<i>B</i>	4.1	6.3	5.2	0.83	0.72	3.13	2.45
<i>s</i> ²	0.07	7.43	11.43	1.25	1.38	8.74	5.14
<i>n</i>	8 ±2						
<i>Fucus vesiculosus</i>							
<i>N</i>	1,421	1,492	2,148	1,628	1,176	848	632
<i>s</i> ²	370,533	625,296	88,752	170,944	636,304	144,592	82,288
<i>n</i>	9 ± 2						
<i>Fucus distichus</i>							
<i>N</i>	297	192	137	135	91	277	148
<i>s</i> ²	41,029	2,224	4,069	28,037	805	14,565	16,752
<i>n</i>	19 ± 9						

Note. *B* is the average biomass obtained from three samples, kg m⁻²; *N* -- abundance, ind. m⁻²; *s*² -- the variance for the sample; *n* -- the required number of samples at $\alpha = 0.05$.

very large areas of the littoral. Eliminating the dominants that form the morphology of the littoral macroalgae community from the areas covering up to dozen square meters is unacceptable in terms of preserving the natural environment.

4. Discussion

We have revealed the inefficiency of using the standard method of accounting areas for monitoring littoral algal communities. Three samples recommended often do not reveal all the differences between stations, despite those are revealed by other parameters, such as average individual change of thallome biomass, discharge of receptacles, and changing the age structure of the community. This method is also extremely ineffective in analyzing the species composition of the community, since most species grow very sparsely on the coast and it is necessary to study specific biotopes to observe them [15, 16]. At the same time, collecting a large number of samples may bring disastrous consequences for the algal communities [6]. The restoration rate of *Fucus* communities was assessed experimentally on the littoral of the Murmansk Coast, the Yarnyshnaya Bay [17]. The algae were removed totally from several 1-m² sites characterized by various

TABLE 2: Biomass of fucoids on the littoral of the Kola Bay in June 2013 (site no. refers to Figure 1).

Species	<i>F. vesiculosus</i>		<i>A. nodosum</i>		<i>F. distichus</i>	
	<i>B</i> , g	<i>s</i> ²	<i>B</i> , g	<i>s</i> ²	<i>B</i> , g	<i>s</i> ²
1-2	0.96	2,108,229	4.21	1,776,144	1.74	6,371,121
1-3	--	--	--	--	0.26	113,200
2-2	--	--	--	--	4.97	560,405
2-3	--	--	--	--	0.01	546
3-1	0.19	16,017	0.06	9,565	--	--
3-2	0.02	1,360	--	--	--	--
4-1	0.98	137,701	--	--	--	--
4-2	0.86	192,976	2.83	14,984,197	--	--
7-1	5.61	22,840,101	--	--	--	--
7-2	--	--	2.58	12,336,400	1.92	385,989
6-1	3.79	7,571,712	--	--	0.02	901
6-2	--	--	2.58	12,336,400	3.51	1,000,261
5-1	9.44	1,408,368	--	--	0.60	748,048
5-2	0.48	691,200	--	--	6.90	10,613,776
8-1	4.55	8,101	1.73	8,951,077	0.21	90,597
8-2	2.72	22,195,200	--	--	5.38	19,223,557
<i>n</i>	35±21		8±3		38±21	

Note. *B* is the average biomass obtained from three samples, kg m⁻²; *s*² -- the variance for the sample; *n* -- the required number of samples at $\alpha = 0.05$.

conditions in the relatively pristine area of the bay. After four years, the biomass and species composition have not been fully recovered yet. This indicates the particular need for a more gentle approach to the collection of algological material and the inability to use standard accounting sites to collect data annually or seasonally. Uptake of a significant part of the vulnerable community will alter the species ratio, which is one of the important features of the studied ecosystem, as it is underlined in a number of studies [18, 19].

On the one hand, it is necessary to develop a monitoring network to solve these problems, as well as to preserve the species diversity of algae in the Arctic seas and to monitor their changes under the influence of global climatic change [20]. On the other hand, the methods of such monitoring should do the least damage to vulnerable ecosystems and allow the researches to receive the necessary amount of information at optimal costs meantime. A detailed mapping of vegetation with an estimate of the biomass and the number of dominants may serve as an alternative to the classical sampling performed at least every year or even frequently, i.e. every season. The proposed method for mapping marine bottom vegetation and the photobank developing to store the digital information about the monitoring sites seems to us to be the least invasive

and low cost compared to standard hydrobiological monitoring methods developed before the period of rapid climatic changes.

A method of SCUBA photographing of the accounting areas was developed to monitor the benthic communities of coral reefs [21, 22]. The technique uses a camera with a special tripod and a software for image analysis. The modified method was tested again on the coral reefs and proved its effectiveness. The method can provide high accuracy for detecting temporary changes in coral communities, suitable for scientific research, it has an advantage in storing of the permanent records for follow-up research and public information, shorter fieldwork, and larger study areas.

An environmental quality index representative of the ecological state of rocky shores may be also obtained using the databases on the spatial distribution, GIS, and available information on the features of rocky-coastal communities as indicators of water quality. This index meets fully the requirements of the European Water Framework Directive 2000/60/EC; it is expressed as the ratio between the observed values in the estimated sector of the coast and the expected value in the zone of the reference state with the same substrate and coast morphology (environmental quality factor, EQR). This index has been used successfully to describe algal communities off the coast of Catalonia, the northwestern Mediterranean Sea [23]. In addition, the mapping of littoral may serve not only for macrophyte research under the scenario of recent climate change [24]. There is a methodology used for monitoring water quality based on cartography of littoral and upper-sublittoral rocky-coastal communities [23, 25].

Considering our results and the emerging issues discussed above, we propose an alternative approach to monitoring algal communities characterized by sparse distribution as is observed in the biotopes of high latitudes. We argue that reliable monitoring of the brown macroalgae communities using computer analysis of photographic material is possible due to the large size of *Fucus* algae and their clear morphological features. The essence of the monitoring methodology comprises several steps. First, the detailed studies are carried out in the area to be controlled, this helps to reveal the differences between a particular community and the adjacent ones [26]. Second, the detailed map of vegetation is being prepared, including the types of algal communities, average biomass of phytobenthos, and the locations of findings of protected and rare species. Third, the detailed map is developed on the basis of quantitative samples obtained by the method of accounting areas aligned along vertical transects. The number of samples for this mapping is based on previously obtained data on the variation of biomass in communities of this type, but must cover in total no more than 5% of the community area to make the least damage to the ecosystem. Since there is no experimental data on

what proportion of damage will be critical for the functioning of a particular ecosystem, we propose to use firstly this value and to perform additional studies on this issue. The fourth step is be the photographing of communities with superimposed frames of 1.0 × 1.0 m or 0.5 × 0.5 m or along a marked transect. At this stage, it is critically important to determine the exact geographical coordinates. There may be as many photographed frames as you like without affecting the observed communities. Based on the materials obtained, the projective cover is evaluated digitally for each species and for the total community. Later, the researcher performs only photographing and description every season, possibly with sampling for the species composition. Repeated quantitative sampling may be performed in a few years if there will be visible changes of the community, such as reduction in projective cover, change in the ratio of mass species, a noticeable change in the size of the thalli of large species, etc. Therefore, such monitoring approach has a minimal negative impact on the algae community. This method can be applied both on the littoral and the sublittoral using the SCUBA in the latter case. The application of this method will lead to developing of a detailed map of vegetation for the coastal areas, which will be also useful in many other researches, in particular, study of zoobenthos.

We tested the vegetation mapping on the coast of the Kola Bay of the Barents Sea earlier [5, 14]. During these studies, the maps of the types of macroalgae communities and of the distribution of macrophytobenthos, including that in terms of biomass, were developed for the littoral and sublittoral of the Kola Bay. The technique is quite simple and not laborious when using modern GIS technologies. Along the coast, photography was carried out during the period of low water. In all types of communities, the surveys were performed to collect the samples for the species composition and overall community description; this was done using the frames of 50 cm × 50 cm. Then the data were processed digitally, and the maps were developed. When comparing to our previous studies, it becomes clear that the mapping is relevant for the Kola Bay, since changes in the distribution of algal communities have already occurred in the historical past [26].

Mapping and compilation of the photobank may be relevant when monitoring hard-to-reach areas. During our research, we are dealing with very long sections of the coastline covering several hundred kilometers, so the observations are made very sporadically in the sparsely distributed communities. In this case, the comparison of the biotopes and their inhabitants in time obviously demands the exact GIS mapping and detailed descriptions.

5. Conclusion

The method of accounting areas has restrictions on use and is applicable only for obtaining data on the biomass of algae species with a fairly uniform distribution on the littoral. For a comparative assessment, a very large number of samples is necessary due to the uneven distribution of macroalgae in both littoral and sublittoral communities. Photographing and mapping, carried out by algologists, seems to be a good alternative for constant monitoring of algal communities.

Funding

This work was supported by the State Task of the Ministry of Science and Higher Education of the Russian Federation [AAAA-A17-117041210285-8] and a grant from the Russian Foundation for Basic Research [18-05-80058].

Acknowledgement

The authors would like to thank their colleague for their contribution and support to the research. They are also thankful to all the reviewers who gave their valuable inputs to the manuscript and helped in completing the paper.

Conflict of Interest

The authors have no conflict of interest to declare.

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