KnE Life Sciences

BRDEM-2019
International applied research conference
«Biological Resources Development and Environmental Management»
Volume 2020

Conference Paper

Seaweeds of Protected Area of Kandalaksha Bay - the Continuity Phytocenosis Guarantor

Galina Shklyarevich[1] and Elena Shoshina[2]

[1]Petrozavodsk State University, Petrozavodsk, Russia
[2]Murmansk State Technical University, Murmansk, Russia

Abstract

Ecosystems of the northern seas are highly productive and highly vulnerable requiring continued preservation of the shallow coastal marine zones. Research was conducted in the protected portions of the Kandalaksha Bay Kandalaksha State Nature Reserve of the White Sea. Here there are large shallow water areas among many large and small islands. These areas are characterized by having extensive coastlines with different types of intertidal zones. The highly varied nature of the coastal zones, with the unique conditions found in the different bays, creates peculiar regional and local hydrodynamic conditions. The abundant large and small rivers flowing into these areas provide a continuous flow of biogenic elements. These nutrients when combined with the steady flow of sedimentary material (as substratum for seaweeds) create favorable conditions for development of a variety of marine phytocenosis. Seaweeds of the protected reserve water of the Kandalaksha Bay may be the guarantor of phytocenosis continuity of the White Sea.

Keywords: seaweeds, diversity, Kandalaksha Nature Reserve, White Sea

Corresponding Author:
Elena Shoshina
shoshinaev@gmail.com

Received: 24 December 2019
Accepted: 9 January 2020
Published: 15 January 2020

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the BRDEM-2019 Conference Committee.

1. Introduction

72 species of seaweeds have been identified from the upper portions of Kandalaksha bay in the region of the Northern and Luvengsky archipelagoes [1]. In the detailed investigation of Porja inlet 49 species of seaweeds and 244 species of accompanying invertebrate species were identified [2]. The remoteness of the Kandalaksha State Nature Reserve waters which are far from human habitation and industrial complexes experience few anthropogenic influences and little or no pollution. In the protected reserve waters harvest of seaweeds from the seaweed beds or from the coastline after storms is completely forbidden. Long-term ecological monitoring research within the study area was carried out with special emphasis on phytocenosis. The purpose of our work was to carry out long-term continuous biological monitoring of the area within the shallow reserve water of the Kandalaksha Bay of the White Sea.

2. Region and Material

Continuous periodic sample collections were made from 1980 until present. A map of the Kandalaksha bay showing the protected territories of the Kandalaksha State Nature Reserve and our sample sites is shown in Figure 1. The shaded areas represent the sites with the most extensive intertidal zones with lengths ranging from 50 to 100 m conforming to the fluctuating shorelines. Within the text we have used the traditional names, found in hydrobiological publications for the settled species', as they reflect morphological features of the seaweed found in arctic ecosystems.

Samples were gathered annually from June -- September during periods of high water flow. Monitoring polygons exist in the Kandalaksha State Nature Reserve for tracking long-term changes in seaweed biomasses along with other hydrobionts such as, the bivalve molluscs, *Mytilus edulis*. Littoral zone seaweed sample collections were made by the authors. The sample plots sizes ranged from 0.1 $м^2$ down to 0.01 $м^2$. In the sublittoral zone, in depths ranging from 15-20 m, samples were collected under the guidance of authors by skin-divers using generally accepted collection methods. The most detailed studies of the region are in the Northern Archipelago and Porja Inlet where there are extensive shallow areas.

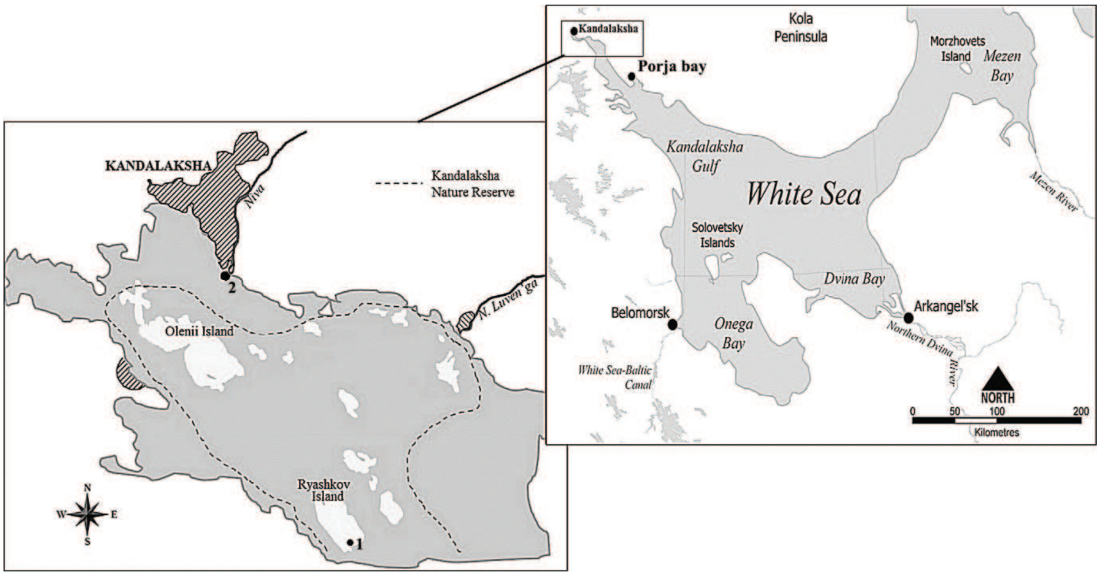

Figure 1: Map of the study sites showing the protected shallow water areas of the Kandalaksha State Nature Reserve.

3. Results and Discussion

Species diversity. The seaweed's flora of the White Sea and Kandalaksha bay is now well studied [3--7]. Because of climate change, there is considerable interest in accumulation of data on long-term dynamics of the biodiversity of species in many areas [8--10]. In Porja Inlet it was found that there are 30 % fewer seaweed species [2], than in the upper portions of Kandalaksha bay around the Northern Archipelago where 72 species, including 12 green, 27 brown and 33 red species of seaweeds were found [1]. There are varied habitats around Northern Archipelago for seaweed's growth. Around Rjashkov Island (Northern Archipelago) there are distinct seaweed habitats each with its own particular seaweed community. In some areas there are very weak currents with these areas usually having a mud-sandy bottom. In other areas there are narrow interisland channels with depths of 5-15 m and varied bottom type and rather weak currents. In the straits there are typically strong currents, a stony bottom and depths of 30 meters and deeper. In Porja Inlet the conditions for seaweed's growth are more homogeneous, as a whole than in the rest of the bay.

The biogeographical structure of seaweeds in the investigated area is typical for the White Sea: consisting of species with a wide distribution in the boreal and the arctic zones [7--8]. The seaweed's biodiversity in the bays and lips of the White Sea is correlated with the mode of water movement, its intensity and its salinity. The abundance of seaweed and their distributions depend primarily on the type of bottom which is present [8, 11]. The taxonomical composition of the seaweed flora of the White and Barents Seas represents a depleted flora of the Northern Atlantic. In the bays and inlets of the White Sea, with reduced water movement intensity and salinity of 20-25 ‰ or lower, some species which prefer higher oceanic salinity and water intensities are absent. In inlets of the White Sea, such as the Porja Inlet, euryhaline and boreal species predominate. Filamentous seaweeds of different groups have more wide spread distributions, preferring closed sites with lower salinities, shallow depths and with warm summer time water temperatures. Most of these algae have a growth form such that they are found laying directly on the sandy or mud bottom.

Littoral seaweeds. In moving from the open to closed parts of Porja Inlet the detritus layer on the surface of soft mud increases. In the lips of the second order the bottom can quite often be covered by a thick layer of necrotic biomass, consisting of a mix of detritus and portions of seaweed thullus and other seawood fragments. In regions with a longer lip, the bottom is more poorly washed leaving more decaying organic compounds which are colonized by hydrosulphuric bacteria. In the top sites of lips the detritus communities prevail where environment conditions are variable and where low salinities prevail. In the upper portions of Porja Inlet on soft mixed grounds one typically finds communities of green filamentous algae and infaunal' invertebrates. Green algae are represented by single-row filamentous or bushy forms, i.e. algae have strongly dissected thullus with an enormous surface area for absorption; these species (*Cladophora sericea, Chaetomorpha tortuosa, Enteromorpha prolifera, E. intestinalis*) are capable of existing in areas with a wide range of salinities (practically from 0 to 20-22 ‰). These seasonal seaweeds disappear in the second half of year when detritus communities and invertebrates again occupy the region.

In the open portions of the inlet on firm substrates, communities of large brown seaweeds are well developed, being dominated by fucoids (*Fucus distichus, F. serratus, F. vesiculosus, Ascophyllum nodosum, Pelvetia canaliculata*). These long lived seaweeds have their thallus heavily colonized by numerous seasonal epiphytes. Epiphytes most often found are brown algae from *Ectocarpus* and *Dictysiphon* genera, while to a lesser degree one finds red and green seaweed epiphytes. In the intertidal zone on stones, on the fucoids are colonized by brown algae and on soft grounds between the fucoids seaweeds are found green algae -- *Enteromorpha intestinalis, Enteromorpha spp., Rhizoclonium riparium, Cladophora rupestris, C. sericea;* brown -- *Ectocarpus confervoides, E. hiemalis, Chordaria flagelliformis, Dictiosiphon foeniculaceus, Stictyosiphon tortilis, Spacelaria plumosa, Chorda filum* and red algae -- *Ahnfeltia plicata, Devaleraea ramentacea, Ceramium rubrum, Polysiphonia arctica, P. nigrescens, Polyides caprinus, Rhodomela lycopodiodes, Hildenbrandtia prototypus*. This species assemblage represents a typical algal complex for low salinity (to 20-22 ‰) or fluctuating salinity sites in the White Sea. It has been noted that the seaweed communities in Porja Inlet form very productive communities at zero depths. These littoral zone communities are composed of mobile annual seaweeds with strong desiccation resistant thallus and having tolerances for a wide range of temperatures and salinities.

Sublittoral seaweeds. Fucoids seaweeds are the most widely distributed in the shallow upper portions of Porja Inlet. In the deeper (from 3--5 meters) sublittoral zones there are beds of laminarians and red algae. The dominating species as defined by having the highest biomasses are *Fucus vesiculosus* -- 1195±309 g/m^2 and *Ascophyllum nodosum* -- 3544±269 g/m^2. Thus present was *Fucus serratus* with biomass of only 278--489 g/m^2. Thallus of *Fucus vesiculosus, F. serratus* and *Ascophyllum nodosum* were found in the deeper zones with depths of 14--18 m. Seaweeds found in these deeper zones, areas deeper than 10 m, probably represent plants that were transported down from more shallow sites. For our analyses, it was difficult for us to distinguish the attached plants from those transported by currents. With the exception of the fucoids found in the shallow waters of Porja Inlet, the brown seaweed *Chorda filum* had the widest distribution. These brown seaweed communities are found in sites having a soft bottom with a pebble substrate and in regions closed off from other portions of the bay. Fucoid and laminarian communities characteristically occur in a mosaic pattern. Laminarians (*Laminaria saccharina* and *L. digitata*) are found at a wide range of depths ranging from the shallow 1.5--2 m zone down to the deeper 14--23 m zone. Other large brown seaweeds also having a mosaic distribution include Desmarestia aculeata which can be found in any location. *Alaria esculenta*, was not detected at any of our sampling sites not even in our open water sampling locations. Analyses of the vertical distribution of seaweeds revealed the following features: the majority of macrophytobenthic' seaweed species were concentrated in the shallow zones of Porja Inlet in depths from 0 to 10 m, in deeper zones seaweed occurrences sharply decline. For sublittoral communities, with the exceptions sited cited above, the dominating species were most often brown seaweeds -- *Sphacellaria plumosa, Chordaria flagelliformis, Dictiosiphon foeniculaceus, Stictyosiphon tortilis, Spacelaria plumosa, Chorda filum*, green alga -- *Cladophora rupestris, Cl. sericea; Chaetomorpha melagonium*, then red alga -- *Ahnfeltia plicata, Ceramium rubrum, Corallina officinalis, Phyllophora truncata, Polysiphonia arctica, P. nigrescens, Rhodomela lycopodiodes, Palmaria palmata* and finally others. *Phyllophora* is represented by two well expressed forms which in the White Sea are quite often marked as independent species. In the intertidal zone at zero depths is found *Phyllophora brodiaei* while in deeper zones one finds *Ph. interrupta*.The deep-water complex of red seaweeds is represented by a large list of species found in salinities of 20--27 ‰. Such seaweeds, as *Polyides caprinus, Euthora cristata, Lithothamnion polymorphum, Lithothamnion sp., Hildenbrandtia prototypus, Corallina officinalis, Phyllophora truncata, Ahnfeltia plicata, Palmaria palmata, Ptilota plumosa, Phycodris rubens, Polysiphonia urseolata, P. nigrescens, Rhodomella licopodioides* and *Odonthalia dentata* were commonly found at our deep sampling sites with depths ranging from 10 to 20 m. The shallow water limits for these red seaweeds species varied from 5 to 9 m. The seaweed species with the deepest distribution were the corticated algae (*Lithothamnion foecundum*).

Only two species were found to appear in 40 % or more of our sampling sites -- *Laminaria saccharina* and *Phyllophora truncata*. Only four other species were found at 21--40 % of our sampling stations -- *Laminaria digitata, Fucus vesiculosus, Corallina officinalis* and *Ahnfeltia plicata*. The majority of species are rare with occurances at less than 20 % of sampling stations.

Biometric data on the size and weight of the dominant species found that the average length of stipes for *Laminaria saccharina* was 16±4.7 cm, with average length of a blade -- 158±22.1 cm, and width of blade -- 34±4.2 cm. The average weight of *L. saccharina* thallus (Burnt island, depth 4 m) was determined to be 313±69 g (wet) or 92 g (dry). These values are typical for this species. The height of *Ahnfeltia plicata* fluctuated from 4 to 18 cm (on the average 10±0.7 cm), the average weight was 15±1.4 g (wet) or 8.8±0.7 g (dry). The biomass of various species from widely distributed communities is presented in Table 1.

Table 1: Biomass and stocks of some algae in communities.

Algae	Biomass, kg/m^2 (wet) in communities		
	A. nodosum+ F. vesiculosus+ Mytilus edulis	*F. vesiculosus +A. nodosum*	*A. nodosum+ +F. distichus*
Chlorophyta			
Enteromorpha sp.	0.00002	0.0045	0.02
Chaetomorpha sp.	0	0	0.008
Cladophora rupestris	0	0	0.05
Cladophora fracta	0.04	0	0
Phaeophyceae			
Pylaiella littoralis	0.001	0.0005	0.06
Ectocarpus sp.	0.0001	0.0001	0
Chordaria flagelliformis	0.001	0.001	0
Dictyosiphon sp.	3.7	0.0001	0.0001
Styctyosiphon subarticulatus	0.2	0.05	0
Scytosiphon lomentarta	0.01	0.03	0
Chorda filum	0.001	0.001	0.0002
Fucus vesiculosus	1.8	1.5	0.5
Fucus distichus	0	0	2.3
Ascophyllum nodosum	2.8	0.8	5.3
Phodophyta			
Porphyra sp.	0.0005	0	0.005
Phyllophora brodiaei	0	0.008	0.0002
Ahnfeltia plicata	0.0003	0	0.0002
Polysiphonia arctica	0.001	0	0
Polysiphonia nigrescens	0	0.001	0
Polysiphonia sp.	0	0	0.0005
Stocks of seaweeds in the most significant communities, Northern Archipelago (in tons)	14287	4688	336

The most wide spread community *Ascophyllum nodosum+Fucus vesiculosus+Mytilus edulis* was seen in about 29 % of all phytocenosis, being found on stony fractions in the lower intertidal horizon with seaweeds comprising 74% of the community biomass. The stocks of these seaweeds growing around the Northern Archipelago hold an estimated 14 thousand tons of biomass. This is the most productive community in the White Sea Kandalaksha Bay reserve. Another community found in the littoral zone around the islands of the Northern Archipelago (33 % of all its area) is dominated by *Fucus vesiculosus+Ascophyllum nodosum*. This phytocenosis occupies the middle intertidal horizon on stone-sandy beaches. Here seaweeds must overcome the hardship of life on a non-firm substrate, plus a longer duration of drying, therefore the average biomass of the dominant species is reduced by 3.5 times as compared to the previous community and with the total community biomass reduced 10 fold. The lower intertidal zone community on continuous stony and rocky substrate consists of dominant species *Ascophyllum nodosum+Fucus distichus* and occupies only 4.2 hectares or 1 % of the surveyed littoral zone. In this portion of the lower intertidal zone these species represent from 70 % to 100 % of the biotypes present. Some fucoid's species, living on rocky banks achieve a larger size than all the others seaweed biotopes with thallus of *A. nodosum* reaches in height of 1--1,5 m, and a base diameter of 3-4 cm. The biomass of the dominant seaweed's species in this community fluctuated from 2.5 to 8 kg/m^2 for *A. nodosum* and from 1.6 to 3 kg/m^2 for *F. distichus*. On average, the fucoid's biomass here was 7.85 kg/m^2, representing an estimated 336 tons of biomass. In the *A. nodosum+F. distichus* community we found the richest species diversity (12 species). Seaweeds in this community dominate the community representing 83 % of the general biota. Size characteristics of fucoids found in the Northern Archipelago are presented in Table 2. The data indicates that the abiotic conditions found in the Kandalaksha bay of the Northern Archipelago favor the fucoid species.

Table 2: Interannual variability of height of brown seaweeds (cm) in top of Kandalaksha bay (White Sea) in 2010 and 2018.

Species	*Fucus vesiculosus*	*Ascophyllum nodosum*	*Fucus distichus*
Reserved water area, Northen Archipelago, Rjakov Island			
Data 15.07.2010			
Average, M ± m	45.4 ± 2.0	55.9 ± 3.1	27.0 ± 2.1
Data 22.07.2018			
Average, M ± m	49.7±7.0	65.8±9.8	26.7±3.1
Not reserved water area, near Kandalaksha town			
Data 15.07.2010			
Average, M ± m	47.4 ±2.1	62,8 ± 3,1	61.5 ± 2.5
Data 23.07.2018			
Average, M ± m	45.3±9.3	55.7±15.3	47.5±9.9

4. Conclusion

Seaweeds of a coastal zone of the sea provide stable existence of benthos communities at anthropogenous influence [12--14]. The protected ecosystems of the Kandalaksha State Nature Reserve serve as a potential source for seaweed flora restocking for

Kandalaksha bay and for all the White Sea. Restocking of seaweeds can occur naturally by fragmentation and water current transport or by stage-by-stage moving to the new habitat. Some seaweed disperses through release of generative products. For example *Laminaria saccharina* by the end of the first year of a life after starting to form reproductive structures, can fragment and the fragments be transported by water currents for long distances while not stopping the reproductive process. Alternately, the reproductive products of *Ascophyllum nodosum* are carried by winds and water currents for long distances. Therefore, the algae protected in the Kandalaksha bay reserve should be considered as the guarantor for the safety of seaweed floral biodiversity in the White Sea. The problem of marine coastal zone protection is complex and interdisciplinary [15]. Researches on coastal ecosystems from degradation should proceed and develop taking into account modern climatic and anthropogenous changes [8--10].

References

[1] Shklyarevich, G. A. (1999). *Seaweeds and invertebrates in shallow water of Porja Inlet.* Apatity: Kola scientific center of Russian Academy of Sciences.

[2] Ninburg, E. A., Shoshina, E. V. (1986). Flora of seaweeds and their distribution in the inner part of Kandalaksha Bay. *Nature and economy of North,* vol. 14, pp. 60--66.

[3] Eds. Tsetlin, A. B., Zhadan, A. E., Marfenin, N. N. (2010). *Flora and fauna of the White sea: the illustrated atlas.* Moscow: Association scientific editions KMK.

[4] Smirnova, N. R., Mikhaylova, T. A. (2013). Seaweeds, living in area of Marine biological station of St. Petersburg State University. *Vestnik of Saint Petersburg University. Series 3. Biology,* № 2, pp. 12--22.

[5] Mikhaylova, T. A, Malavenda, S. S, Chalaman, V. V. (2014). Species structure of seaweeds on collectors for mussels cultivation in the White sea. *Vestnik of MSTU*, vol. 17, N 1, pp. 157--164.

[6] Mikhaylova, T. A, Naumov, A. D., Aristov, D. A. (2017). Composition and structure of macrophytobenthos of low part of photic zone of Kolvitza Inlet (Kandalaksha Bay, White Sea). *News of systematics of the lowest plants*, vol. 51, pp. 121--132.

[7] Mikhaylova, T. A. (2017). Checklist of Rhodophyta of the White Sea (the Arctic Ocean). *Botanica Marina,* vol. 60 (1), pp. 55--65.

[8] Berger, V., Dahle, S., Galaktionov, K., et al. (2001). *White Sea. Ecology and environment*. St.-Petersburg--Tromso.

[9] Filatov, N. N., Pozdnyakov, D. V., Johannessen, O. M., et al. (2005). *White Sea. Its marine environment and ecosystem dynamics influenced by global change.*

Chichester: Springer-Praxis Publishers.

[10] Matishov, G. G., Moiseev, D., Lyubina, O., et al. (2012). Climate and cyclic hydrobiological changes of the Barents Sea from twentieth to twenty-first centuries. *Polar biology*, vol. 35, N 12, pp. 1773--1790.

[11] Malavenda, S. V., Mitayev, M. V., Gerasimova, M. V., Malavenda, S. S. (2017). Fouling of coarse-clastic sediments with macrophytes depending on the rate of abrasion (Murmansk coast). *Doklady Earth Sciences,* vol. 474, N 1, pp. 557--560.

[12] Malavenda, S. V., Komrakova, D. G., Malavenda, S. S. (2013). Change of structure of littoral phytocenosis under anthropogenous influence. *Vestnik of MSTU,* vol. 16, N 3, pp.486--492.

[13] Voskboinikov, G. M., Makarov, M. V., Malavenda, S. V., et al. (2019). Role of sea algae-macrophytes in cleaning the coastal waters of oil product. *Laws of formation and influence of sea atmospheric dangerous phenomena and accidents on a coastal zone of the Russian Federation in the conditions of global climatic and industrial calls («the dangerous phenomena»). Materials of the international scientific conference.* Rostov to Don: The Southern center of science of the Russian Academy of Sciences, pp. 356--357.

[14] Dolotov, Yu. S., Filatov, N. N., Nemova N. N., et al. (2002). The study of dynamics of the water, suspended matter, anthropogenic pollution, and the ecosystem living conditions in the estuaries (by the example of the Karelian Coast of the White Sea). *Oceanology,* vol. 42, Supp. 1, pp. 135--147.

[15] Titova, G. D. (2014). Assessment of marine ecosystems services as a complex interdisciplinary problems on way to the decision. *Vestnik of Saint Petersburg University. Series 3. Biology,* vol. 3, pp. 46--57.