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Ecological Characteristic of Brown Algae Communities – Potential Aquaculture Objects

Valentin Kapkov[1], Elena Shoshina[2], and Olga Belenikina[1]

[1]Moscow State University named by M. V. Lomonosov, Russia
[2]Murmansk State Technical University, Russia

Abstract

The benthic brown algae communities in coastal zone of southwest part of the Barents Sea have been studied. Research was carried out on the structure of benthic phytocenosis on the Murman coast in which edificators are brown seaweeds of the orders Fucales and Laminariales. The study focused on the dynamics of populations, size and age features against influence of the basic ecological factors on growth of commercial seaweeds - potential objects of mariculture. It is established that benthic phytocenosis on certain biotopes of littoral and sublittoral zones characterize by relativity high species diversity. The populations of commercial seaweeds form the multilevel structured benthic communities. The algae populations create topical, trophic and mediative connections which provide for steady stability of benthic communities. The use of plant community rather than individual algae species as biological indicators and biomonitors allows obtaining more complete information about the ecological state of benthic coastal ecosystem. The information collected can be used for the biological monitoring of marine bioresources in natural benthic communities, and also for cultivation of brown seaweeds under conditions of aquaculture.

Keywords: brown algae community, biodiversity, Barents Sea

Corresponding Author:
Valentin Kapkov
chelena45@mail.ru

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1. Introduction

In coastal ecosystems of northern seas, brown seaweeds are represented by wide species diversity and high population biomass. The commercial brown seaweed species found are from the orders Fucales and Laminariales of class Fucophyceae. On the Murman coast of the Barents Sea more than 60 species of brown seaweed grow forming a multilevel structured benthic community into which numerous populations of others hydrobionts are integrated, being well adapted for joint habitation under conditions which are periodically influenced by ecological factors. Long-living commercial brown seaweeds usually dominate in littoral and sublittoral phytocenosis, they have a long cycle of development, and they play the basic role in synthesis of primary production in coastal marine ecosystems [1--4].

There are huge stocks of seaweeds in Russia with biomass estimations by experts of 15-20 million tons. In contrast commercial stocks of brown seaweeds on the Murmansk coast are estimated to be 400-550 thousand tons [5]. With the anticipated continued anthropogenic pressure on coastal ecosystems where the commercial seaweeds grow, ecological conditions are not expected to improve in the foreseeable future [6]. Intensive harvesting of commercial seaweeds is expected to continue to reduce the naturally occurring stocks in the coastal zone of the sea. Effective monitoring of marine bioresources and further research on the cultivation of seaweeds in mono- and polyculture are necessary for the preservation of a steady harvest of seaweeds from natural and artificial sources in natural populations. Therefor development of new harvest and cultivation technologies of perspective species of seaweeds for the purpose of maximizing biomass with certain biochemical characteristics is required. Research on the biology and ecology of commercial species in natural populations, including studying the influence of ecological factors on the dynamics of growth and production of seaweeds [7, 8], and also knowledge of cultivation cycles, including optimum terms of seaweeds harvesting from plantations and technology of deep processing of received raw materials are necessary.

For the purpose of studying of biological and ecological features of commercial brown seaweeds, research on the spatial structure of natural phytocenosis in which they dominated has been carried out. Special attention was given to studying the size, age and generative structures of populations of fucoids and laminarian seaweeds, seasonal and long-term dynamics of their growth and influence of ecological factors on development of brown seaweeds.

2. Region and Methods

The research area was located in seven bays from Ajnovyh Islands (69˚79'05" N, 31˚50'58" E) to the Lumbovsky bay (67˚74'06" N, 40˚51'04" E) on Murman coast of the Barents Sea (Figure 1). Seaweed collections were made over the course of several years from littoral and sublittoral zones in bays of the specified areas. Samples were collected from vertical sections on 3-5 sample plots; from the littoral zone seaweeds were collected during outflow from frameworks 50x50 cm, in the sublittoral zone -- collections were made from frameworks 1x1 m using easy diving equipment. Seaweeds samples were divided by their age structure and biomass for the population of each seaweed species; measurements of lengths and weights of plants were collected along with the age of *Fucus* plants found on number of dichotomic branchings of thullus, and age of laminarians - on number of rings on stipe cuts. Statistical processing of the received data was by means of the software package «Microsoft Office Excel».

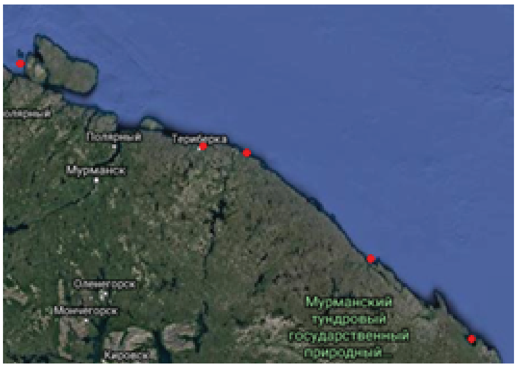

Figure 1: A sampling scheme on Murman coast of the Barents Sea.

3. Results and Discussion

It was established, that on Murmansk coast long-lived brown seaweeds form complex well-structured communities in which edificators are the basic commercial species. For the investigated region it is characteristic for species to exhibit a zonal distribution pattern of different species, with each species as a rule occupying a defined horizon or depth.

In the intertidal zone fucoids dominate: *Ascophyllum nodosum, Fucus vesiculosus, F. distichus* and *F. serratus,* forming the basic background of phytocenosis. Accompanying these fucoid species are various brown algae; *Pilayella litoralis, Dictyosiphon foeniculaceus, Stictyosiphon tortilis, Chordaria flagelliformis, Chorda filum, Elachista fucicola, Petalonia fascia, Stictyosiphon griffithsianus, Sphacelaria arctica* and red algae - *Palmaria palmata, Devaleraea ramentacea, Dumontia contorta, Membranoptera alata, Polysiphonia urceolata, Rhodomela lycopodioides, Polyides rotunda, Rhodochorton purpureum, Ceramium rubrum, Porphyra sp*. and other species. There are numerous microscopic epiphytes and endophytes. Green algae are also commonly found here: *Acrosiphonia arcta, A. flacca, A. sonderi, Monostoma grevillei, Protomonostroma undulatum, Spongomorpha lanosa, Cladophora rupestris*, *Ulvaria obscura*. Filamentous green algae *Ulothrix flacca, Urospora penicilliformis, Blidingia minima* occur in small amounts however by the end of summer they disappear. The biomass of associated algae, epiphytes and endophytes is small estimated at 10 times less than the biomass of dominating species. The ocean currents along the Murman coast promotes the domination in the intertidal community on boulders and pebbles by *Ascophyllum nodosum,* while in the high energy surf zone *Fucus vesiculosus* is the dominating species. The

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biodiversity of seaweeds increase in the transitive zone between the intertidal and sublittoral zones.

In the analysis of the vertical distribution of laminarians, it was found that they primarily occupy the top horizon of the sublittoral zone. With the conditions found on the Murman coast, surf on boulders, *Alaria esculenta* and *Saccharina latissima* were found to occupy the lower horizon of intertidal zone while in the bays protected from the surf on stony substratum laminarians grow at depths of 2-5 meters. Population of *Laminaria digitata* can occupy shallower depths, however maximum biomass for this species was found in the 5-7 meter deep horizon. On the open coast *Laminaria hyperborea* is the species that is a typically found [9]. Other accompanying species found in the laminarian communities include numerous algae species: red - *Ptilota gunneri, Odonthalia dentata, Phycodrys rubens, Euthora cristata, Fimbriopholium dichotomum, Palmaria palmata, Porphyra sp., Polysiphonia urceolata, Delesseria sanguinea, Turnerella pennyi,* brown - *Saccorhiza dermatodea, Desmarestia aculeata, D. viridis*, green - *Chaetomorpha melagonium, Acrosiphonia spp., Ulvaria obscura* and many other species, including various invertebrates species.

The wide range of ecological conditions found in the habitats studied results in high species diversities between the algal communities. The granulometric composition of the bottom was the determining abiotic factor influencing the distribution of seaweeds. On the rocky intertidal zone only a narrow strip of fucoids (*Fucus vesiculosus, F. distichus*) was found. In contrast, on boulder and stone substrate intertidal zones, in the same bays, fucoids form a wide strip of well-developed phytocenosis. The structure of sea floor sediments in many respects defines the mosaic distribution and density of populations of commercial seaweeds in the coastal sea zone.

The overall picture of phytocenosis structure of brown seaweed community distribution is characterized by the expressed vertical layers with various layers exhibiting seasonal variations in species of epithytes and in species of red, brown and green algae. The lower layer is occupied by cortical forms of red algae, colonizing a firm substratum shortly after the formation of bacterial and algae films. The following layer is formed by filamentous and blade-like species of red and brown seaweeds occupying free space on the substratum and thallus of cortical red algae. The dominating species in the community are represented by large brown and red seaweeds with numerous epiphytes with biomasses representing 40 % or more of the total community biomass. Found on fucoids living in open habitats there are numerous: brown algae *Elachista fucicola, Pilayella littoralis,* green filamentous algae, red algae *Palmaria palmata* on which, in turn, grow brown *Phloeospora brachiata*. In the closed bays, the diversity of epiphytes growing on fucoids increases considerably - all large specimens of fucoids are heavily colonized by seaweeds, small epiphytes and endophytes. *Fosliea curta* (characteristic epiphyte on open places) develops on the blade ends of *Laminaria*; on stipes of large long-lived *Laminaria* and *Alaria* there are red seaweeds, first of all, *Palmaria palmata* and *Ptilota plumosa*, also *Polysiphonia urceolata, Rhodochorton purpureum*, from brown - *Pilayella varia, Ectocarpus fasciculatus, Laminariocolax tomentosum* and others.

Typical associations of seaweeds on boulders in the littoral zone in the upper horizon were *Fucus vesiculosus* + *Ascophyllum nodosum*, on the middle horizon - *F. vesiculosus* + *F. distichus*, in lower horizon - *F. distichus* + *F. serratus* and *Palmaria palmata* + *Devaleraea ramentacea*. The maximum biomass of brown seaweeds was found on the lower (6700 g/m^2) and middle (5600 g/m^2) horizons. Thus the biomass of red seaweeds on the lower horizon was 6.5 times less, than on fucoids. On rocky littoral zone habitats in the upper horizon, associations of *F. vesiculosus* + *Porphyra umbilicalis* grew, with a biomass of 1300 g/m^2 and on middle horizon there were associations of *F. distichus* + *P. palmata* with a biomass 2100 g/m^2.

On boulder sublittoral zone the upper horizon was occupied with associations of *Saccharina latissima* + *Alaria esculenta* with an equal biomass of each species about 10500 g/m^2. At depths of 4 m, beds of *Laminaria digitata* were found with a biomass more than 13000 g/m^2 with accompanying brown seaweeds *S. latissima, Saccorhisa dermatodea* and red alga *Palmaria palmata*, however their biomass were found to be two-three times lower, than that of laminarians. On rocky sublittoral zones the upper horizon was occupied with associations of *D. ramentacea* + *A. esculenta* with insignificant inclusions of *S. latissima* and a biomass of 1200 g/m^2. Deeper beds of *L. digitata* + *A. esculenta.* with the maximum biomass more than 15000 g/m^2 at depths of 6-7 meters were found. The average values of plant biomass for commercial brown seaweeds of different age groups are shown in the Table 1.

In natural habitats the phytocenosis at different depths and with different species structure are often complementary. The factors limiting growth of thallus and resulting in low biomass of seaweeds are decreasing levels of solar radiation and water exchange. In addition, reduced biomass is associated with falling levels of biogene concentrations of nitrogen and phosphorus. Thus, for the cultivation of brown seaweeds in the pools isolated from the sea it is necessary to monitor for levels of biogenic elements in the environments. Where biogenic concentrations are low as compared to the open waters, they will need to be elevated as nitrogen and the phosphorus are necessary for intensive growth.

TABLE 1: Weight thalli (g) of commercial brown seaweeds of different age (year) in open bay.

Species	Weight (average and error of average), age, n -- number of plants							
	1	2	3	4	5	6	7	8
Saccharina latissima (n=176)	61±5	133±42						
Alaria esculenta (n=79)	188±54	260±26	328±64	510±96				
Ascophyllum nodosum (n=176)	5±2	7±1	54±11	148±42	238±104	254±50		
Fucus vesiculosus (n=153)	0,5±0,3	4±1	6±1	11±4	23±5	15±5		
Fucus distichus (n=88)	-	4±0,8	21±3	57±7	119±17	160±10		
Fucus serratus (n=111)	0,6±+0,3	1,2±0,6	6±1	17±3	33±9	110±52	256±82	340±86

Seasonal dynamics of live availability of sea plants is naturally interconnected with environmental factors [10]. The most important abiotic conditions for seaweeds on the Murman coast, with its transition between polar day and polar night, are light, temperature, and biogenic nutrient concentrations [11--13]. Optimal growth conditions for commercial species prevail in spring and summer. In July-August, weight accumulation of long-lived seaweed's species slow to a stop. In autumn and winter the processes of destruction prevail over growth processes with resulting loss of biomass. Seasonal dynamics of growth is shown represented by changes in biomass for *Laminaria* (Figure 2).

The age structure of populations of brown seaweeds in bottom phytocenosis varies considerably during the life cycle. For example, in the upper littoral zone in populations of *Ascophyllum nodosum* and *Fucus vesiculosus* there are plants in their first year of life. In contrast in low littoral zone seaweed populations, the senior age groups dominate. The development of plant communities in a coastal sea zone results from ecological succession over the course of consecutive seasons and from long-term changes in structure and species composition of seaweeds. The total abundance of seaweeds in phytocenosis varies considerably over the course of a year. In algal community succession, the biomass increases and interspecific communications between algae populations are established [14]. With increase of algal diversity during the spring-and-summer period, the structure and volume of the biological information of phytocenosis evolves and secures resistance towards the negative influence of ecological factors [15].

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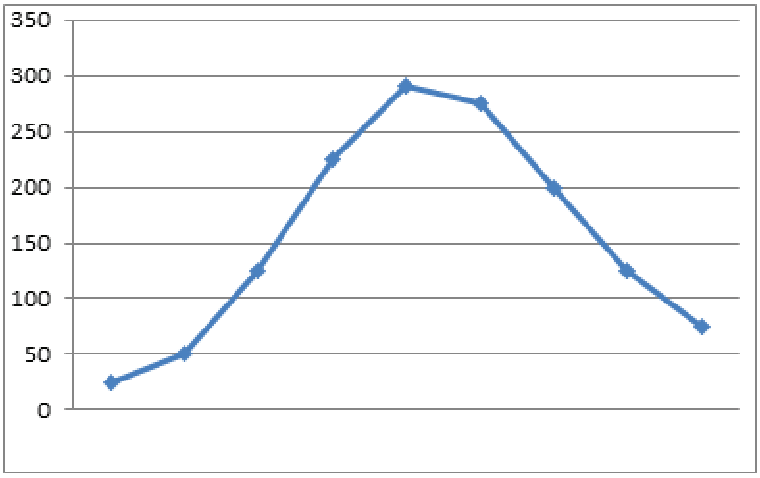

Figure 2: Dynamics of thallus growth of *Saccharina latissima* (March-November). On an axis of ordinate - weight in grammes, on an axis of abscisse -- months.

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4. Conclusion

The development of vegetative communities in coastal zone ecosystems results from seasonal and long-term ecological successional changes in structure and species composition of the seaweeds. The total abundances of seaweeds in phytocenosis structure vary over the course of a year. As the successional changes occur the seaweed biomasses increases with a corresponding establishment of interspecific communications between algae populations. The observed enlargement of species diversity expands structural relation with subsequent increase in volume of biological information accumulated in phytocenosis. That strengthens benthic community resistance towards the negative influence of ecological factors. The wide range of ecological conditions present in the study areas results in the observed high species diversity of seaweed's communities on the Murman coast of the Barents Sea. The abiotic factors most responsible for the observed distribution of commercial seaweeds are the presence of the firm substratum necessary for attachment, water depth which determines the levels of solar radiation reaching the plants, the temperature of the water including periods of its semidiurnal inflow and concentrations of biogenic elements during vegetative growth periods of the seaweeds life cycle. Biotic factors also play an important role in the regulation of population dynamics of seaweed growth. To elucidate the specifics of the interspecific relationships in the communities it is necessary to evaluate the metabolites present and their allocations in the environment. The use of plant community rather than individual algae species as biological indicators and biomonitors allows obtaining more complete information about the ecological state of benthic coastal ecosystem.

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