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Research Article

Fractal Analysis of Morpho-Physiological Parameters of Oxycoccus Palustris Pers in Oligotrophic Swamps of Western Siberia

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Abstract

The study considers changes in morpho-physiological parameters of Oxycoccus palustris Pers., a most wide-spread species of evergreen shrubs in oligotrophic bogs of Western Siberia, with regard to soil trophicity. The authors discuss the applicability of fractal mathematical principles for assessing morphological and physiological parameters and show that the studied parameters are invariant in nature, which enables applying fractal analysis methods to describe the way resources are distributed by plants in various environmental conditions. Work performed within the project No: 15-44-00028 «r-ural a»

Introduction

Western Siberia is well-known for its largest oil and gas deposits. Intensive oil and gas exploration and development have led to various changes in vegetation in the area, including substantial mechanical and chemical pollution. Various researchers [1-3] devoted their studies to the impacts of oil and gas development on local water, soil, vegetation and ecosystems. Oil pollution of this territory is quite tesselate in nature, since the areas of severe and average pollution randomly alternate with relatively clean areas. The contaminated areas are spread unevenly in oil and gas fields, and the majority of spills are usually located around pipelines and well pads [4,5].

Western Siberian lowlands are characterized by plain relief and precipitation exceeding evaporation. As for wetlands and bogs, their biomass is accumulated rather than decomposed, which results in an intensive bog formation and accumulation of undecomposed plants known as turf or bog muck [6,7].

The trophic nature of raised bogs is determined by oligotrophy resulting from low pH values and lack of oxygen in water-bearing turfs. Various anthropogenic contaminants originating from oil and gas development activities changed the mineral composition of wetlands, weakening the extreme oligotrophy of bogs. Natural populations of Oxycoccus palustris Pers. serve as edificators and dominants of oligotrophic bogs. This signifies that the species is well adapted to low supply of all nutrition resources considering a short growing season of the plant. This study considers changes in morpho-physiological parameters of Oxycoccus palustris Pers., a most wide-spread species of evergreen shrubs in oligotrophic bogs of Western Siberia, and correlation of these parameters with regard to changes in soil trophicity.

Methodology

Oxycoccus palustris Pers. was sampled in open wetland areas within the borders of Sphagnetum pinetofruticulosum association (Oxycocco-Sphagnetea Br.-Bl. et Tx. 1943 raised bog group, Sphagnetalia magellanici Kastn. et Floss 1933 order, Oxycocco-Empetrion hermaphroditic alliance).

The association has a high constancy of Oxycoccus palustris and significant amount of Carex globularis, Carex lasiocarpa, and Menyanthes trifoliata.

The relief of the studied area is flattened and hummock-ridge, without evident drains. The soils are turfy-gleyed, with the turf layer up to 1 meter.

According to the data of zoning held by K.E. Ivanov and S.M. Novikov in 1976, the area under study refers to the wetland territory of the Lyamin and Vakh rivers within the zone of convex oligotrophic bogs, which includes 3 subareas, including subareas of the Lyamin and Pim rivers, the Pim and Agan rivers, and the Agan and Vakh rivers. The sites for sampling Oxycoccus palustris Pers. are located in the Agan and Vakh rivers subarea [8].

The sampling was held at six locations over the area of 100 m^2, with 10 m^2 in distance from each other. We sampled the leaves from the middle layer of the plants and evaluated their amount and weight over the area of 25x25 cm. The procedure was repeated 6 times.

We used photocolorimetry to calculate the amount of nitrogen and phosphorus (see Voskresenskaya, 2006) and atomic absorption spectrophotometer MGA-915 to determine the amount of Fe, Cd, Cu, Pb, Mn, and Zn [9].

The amounts of flavonoids in extracts were evaluated titrimetrically by using rutin and tannins, while the content of free organic acids was calculated in equivalent of malic acid.

A digital video microscope HIROX KH-7700 (Japan) was applied to make anatomical and morphological measurements. The surface area of leaves was calculated using gravimetric method [10].

To gain statistic results, we used Statistica 11.5 software and MS XP Excel 2005.

Results and Discussion

According to the data on the soil's chemical composition (Table 1), oligotrophic bogs are characterized by significant tesselation. The concentration of some chemicals may differ by 5 times or more, i.e.

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Table 1: Morpho-physiological parameters in *O. palustris* populations.

Parameter	Locations					
	1	2	3	4	5	6
P, mg/g	1.3	1.8	1.5	3.48	2.5	2.6
N, mg/g	6.2	5.8	6.6	7.1	8.4	6.4
Cd, mg/g	0.48	0.464	0.428	0.934	0.798	0.577
Pb, mg/g	0.664	0.311	0.422	0.202	0.84	0.699
Cu, mg/g	1.54	1.863	1.828	0.768	3.019	0.975
Zn, mg/g	39.277	34.27	60.188	46.05	37.45	33.3
Flavonoids, %	1.51	2.46	2.37	2.26	1.046	1.28
Tannins, %	19.0	13.7	10.26	17	8.95	13.85
Organic acids, %	2.28	2.08	1.56	2.45	1.61	2.01
Organic acids (fruits), %	4.68	4.01	4.82	5.36	5.02	4.01
Amount of leaves on the plant	48.04	45.21	46.644	44.9	39.95	47.35
Leaf S, cm^2	0.24	0.27	0.337	0.455	0.233	0.032
Leaf S / plant, cm^2	1.12	0.96	1.174	1.318	0.782	0.119
Leaf length, cm	0.71	0.82	0.765	0.867	1.064	0.945
Leaf width, cm	0.25	0.29	0.279	0.369	0.286	0.386
Amount of plants over 0.25 m^2	62.22	39	49.222	76.25	161.5	99.75
Amount of plants over 1 m^2	239.22	156	192.556	304.889	218.5	401
Leaf thickness, mm	0.32	0.298	0.301	0.339	0.327	0.337
Cuticle thickness, mm	0.004	0.04	0.004	0.006	0.006	0.006
Upper epidermis thickness, mm	0.016	0.016	0.016	0.017	0.018	0.018
Lower epidermis thickness, mm	0.007	0.07	0.07	0.012	0.01	0.011
Columnar parenchyma thickness, mm	0.086	0.084	0.087	0.122	0.13	0.13
Spongy parenchyma thickness, mm	0.19	0.173	0.177	0.214	0.194	0.2
Conducting bundle length, mm	0.138	0.138	0.15	0.16	0.131	0.124
Conducting bundle width, mm	0.161	0.226	0.181	0.145	0.144	0.127
Weight of leaves, g	0.078	0.08	0.102	0.15	0.076	0.011
Plant weight, g	3.74	3.62	4.74	6.92	3.04	0.51
Plant weight/ m^2	894.75	564.33	911.96	2109.22	664.4	202.89

small areas of oligotrophic bogs may differ significantly in terms of nutrition.

The tessellate nature of soil has significantly affected all plant parameters under study (Table 1). We were unable to isolate any single parameter with a stronger response to the changing chemical combinations.

As indicated in some reference sources, invariability, i.e. manifestation of similar properties at different levels, is the major criteria when considering the eligibility of objects (including wildlife) and their correspondence to the principles of fractal formalism. Invariability of the area under study can be evaluated via various traditional indicators [11,12]:

N – total volume of samples;

p_i – index of species diversity;

Mq – moments of distribution for substances distributed over classes;

q – order for the moment of distribution.

Fractal formalism criteria are observed at the following stages of fractal analysis [13]:

1. Evaluation of indicators for N, the number of particular class representatives, for Mq, moments of distribution for substances distributed over classes at different values of q, order for the moment of distribution.

2. Logarithms of the above parameters for all samples involved.

3. Selection of linear and quadratic dependence models between N and Mq logarithms using regression analysis methods for various values of the moment of distribution.

5. Evaluation of the multifractal spectrum for the samples under study.

Based on the data, we calculated correlation coefficients, N, p_i, and Mq. The order for the moment of distribution (q) was set within the range (-3 – q - +3) recommended by some researchers [13]. These procedures were applied in respect of the data presented in Table 1. We analyzed both vertical data series (cumulative values of morpho-physiological parameters of plants at each location) and horizontal data series (changes in individual morpho-physiological parameters depending on the sampling location).

This dependence is described with the following linear equation: y = 3.94x + 0.8. With the moment of distribution equaling -1, the graph is as follows (Figure 1):

We found that with various negative q values the general trend of the graph is preserved. However, if the moment of distribution q is less than -1, there is a nonlinear component in the log N values exceeding 0.25 (Figures 2 and 3):

When analyzing the horizontal data series shown in Table 1, we observed a similar pattern with positive distribution moment values. The data on the dependence of Mq logarithm from N logarithm is reflected in Figure 4.
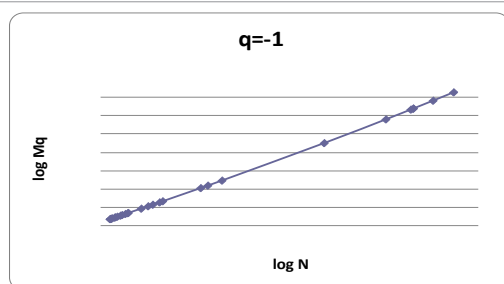
Figure 1: The dependence of Mq logarithm from N logarithm, with the moment of distribution equaling -1.
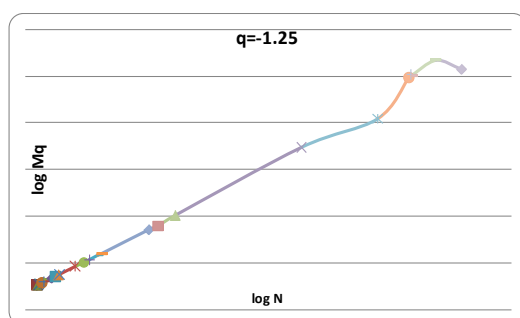

Figure 2: The dependence of Mq logarithm from N logarithm, with the moment of distribution equaling -1.25. This dependence is described with the following linear equation. **y = 5.64x + 0.67**
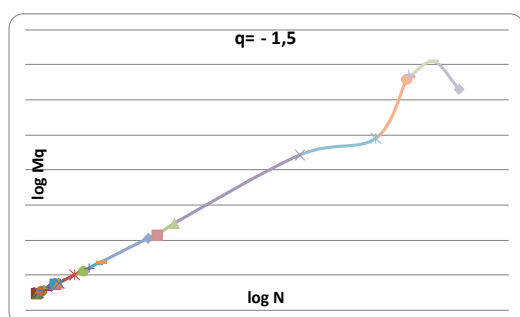

Figure 3: The dependence of Mq logarithm from N logarithm, with the moment of distribution equaling -1.5. This dependence is described with the following linear equation. **y = 7.55x + 0.49.**
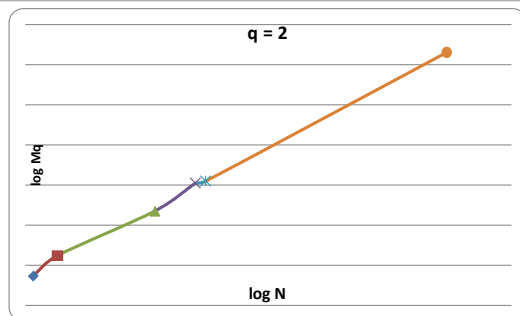

Figure 4: The dependence of Mq logarithm from N logarithm, with the moment of distribution equaling 2. This dependence is described with a following linear equation. **y = 2.15x – 0.297.**

The results showed invariable features in the dynamics of vertical data series reflected in Table 1 with negative q values, since, in this case, the graph reflecting the dependence of Mq logarithm from N logarithm shows the dependences which are close to linear. Thus, we can argue that the observed dynamics of morpho-physiological parameters of *Oxycoccus palustris Pers.* populations growing in oligotrophic bogs is invariant in nature.

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