



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

Usmanov IYu<sup>1</sup>, Yumagulova ER<sup>2</sup>, Ovechkina ES<sup>2</sup>, Ivanov VB<sup>3</sup>, Shcherbakov AB<sup>4</sup>, Aleksandrova VV<sup>2</sup> and Ivanov NA<sup>5</sup>

### 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»

### Keywords

Adaptation; Shrubs; Oligotrophic bogs; Morpho-physiology; Western siberia; Fractals; Invariability

### 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 tessellate 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 pills 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-Empetriton* 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<sup>2</sup>, with 10 m<sup>2</sup> 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 photocolourimetry 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 tessellation. The concentration of some chemicals may differ by 5 times or more, i.e.

\*Corresponding author: Dr. ES Ovechkina, Candidate of Biological Sciences, Bashkir State University- 450076, Russia, Tel: +7 347 273-48-42; E-mail: pinus64@mail.ru

Received: December 15, 2015 Accepted: December 23, 2015 Published: December 31, 2015

**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 <sup>2</sup>	0.24	0.27	0.337	0.455	0.233	0.032
Leaf S / plant, cm <sup>2</sup>	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 <sup>2</sup>	62.22	39	49.222	76.25	161.5	99.75
Amount of plants over 1 m <sup>2</sup>	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 <sup>2</sup>	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;

M<sub>q</sub> – 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 M<sub>q</sub>, 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 M<sub>q</sub> 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 M<sub>q</sub>. 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 M<sub>q</sub> logarithm from N logarithm is reflected in Figure 4.

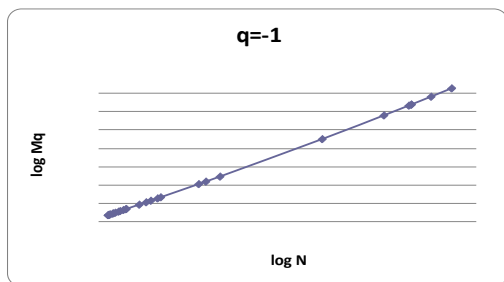


Figure 1: The dependence of Mq logarithm from N logarithm, with the moment of distribution equaling -1.

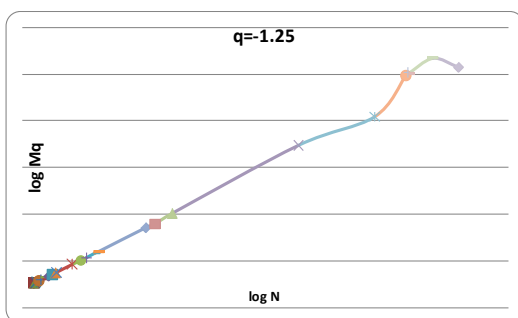


Figure 2: The dependence of Mq logarithm from N logarithm, with the moment of distribution equaling -1.25. This dependence is described with the following linear equation.  $y = 5.64x + 0.67$

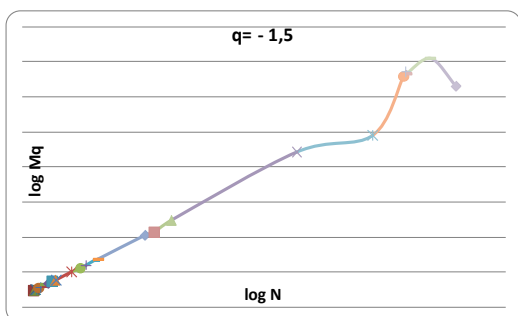


Figure 3: The dependence of Mq logarithm from N logarithm, with the moment of distribution equaling -1.5. This dependence is described with the following linear equation.  $y = 7.55x + 0.49$ .

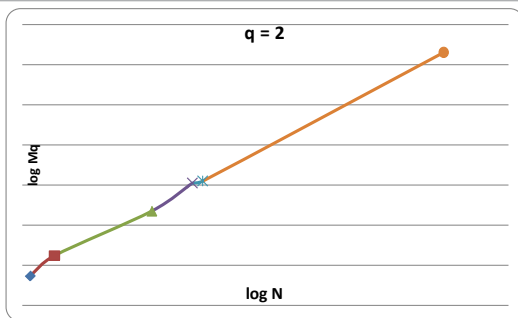


Figure 4: The dependence of Mq logarithm from N logarithm, with the moment of distribution equaling 2. This dependence is described with a following linear equation.  $y = 2.15x - 0.297$ .

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.

#### Reference

- Vasiliev SV (1998) Vozdeistvie neftegazodobyvayushchey promyshlennosti na lesnye i bolotnye ekosistemy Srednego Priobja. Novosibirsk.
- Shepelev AI, Shepeleva LF, Frolov VN, Mazitov RG (2005) In interexpo geo-sibir (proc. of interekspo geo-sibir. 10<sup>th</sup> International Exhibition and Scientific Congress.
- Shepelev AI, Shepeleva LF (2014) In mir nauki, kultury, obrazovaniya 6: 552-554.
- Usmano I, Ovechkina Yu, Yumagulova ES, Ivanov ER, Shcherbakov AV, et al. (2015) In vestnik nizhneartovskogo gosudarstvennogo universiteta. Bulletin of Nizhneartovsk State University 1: 79-86.
- Usmanov I Yu, Ovechkina ES, Shayakhmetova RI (2015) Vestnik nizhneartovskogo gosudarstvennogo universiteta 3: 84-94.
- Boch MS (1993) The flora and vegetation of bogs in the north-west russia and the principles of their environmental protection. Saint Petersburg: Nauka.
- Kulikova GG (1971) In vestnik MGU biologiya i pochvedenie. Bulletin of Moscow State University, Biology and Soil Science 2: 51-60.
- Bolota (1976) Bogs of western siberia and hydrological behavior. Leningrad: Gidrometeoizdat.
- Voskresenskaya OL (2006) An extended practical course on ecology: A reference book of Mari State University, Russia.
- Tretiakov NN (1982) A practical course on plant physiology. Moscow: Kolos.
- Dragavtsev VA (2005) Identified gene pool of plants and breeding. Saint Petersburg: VIR.
- Usmanov IYu, Yumagulova ER, Shcherbakov AV, Tsimbalyuk AI (2015) Procedure of the international conference "Problems of population ecology. VI Lyubishchev readings 2015" Togliatti.
- Gelashvili DB, Iudin DI, Rozenberg GS, Yakimov VN, Solntsev LA (2013) Fractals and multifractals in bioecology. Nizhniy Novgorod: Nizhniy Novgorod University, Russia.

#### Author Affiliation

Top

<sup>1</sup>Doctor of Biological Sciences, Nizhneartovsk State University, Russia

<sup>2</sup>Candidate of Biological Sciences, Nizhneartovsk State University, Russia

<sup>3</sup>Candidate of Pedagogical Sciences, Nizhneartovsk State University, Russia

<sup>4</sup>Candidate of Biological Sciences, Bashkir State University, Russia

<sup>5</sup>Postgraduate student, Nizhneartovsk State University, Russia