Ecological and biotopic parameters and resilience of arctic bramble (*Rubus arcticus* L.) in Kirov region, Russia

**Yu V Gudovskikh¹, E A Luginina¹,³ and T L Egoshina¹,²**

¹ Russian Research Institute of Game Management and Fur Farming, Kirov, Russia
² Vyatka State Agricultural Academy, Kirov, Russia
³ E-mail: e.luginina@gmail.com

**Abstract.** Ecological-phytocoenotic features of *Rubus arcticus* L. were estimated near the Southern border of the range, ecological range of the species was also defined. According to the scale of soil humidity fluctuation the conditions’ range of the studied populations is wider than given by D N Tsyganov (1983). According to the complex of ecological scales, *R. arcticus* is a mesobiont species. Light-shading scale states euryvalent properties, and cumulative spectrum of soil scales shows its stenobiont features. Based on phytoindication data and according to the discomfort index, the most favourable conditions of edapho- and climatope for *R. arcticus* are formed in graminoid-mixed herbs wet meadow on forest aisle surrounded by birch-aspen bilberry forest and in spruce-birch mixed herbs-graminoid swampy forest. Hemeroby studies showed that the species has low resilience to human impact and can tolerate moderate anthropogenic influence.

1. **Introduction**

Traditional scientific investigations within the territory of Kirov region focus on macromycetes species composition [1,2], peculiarities of fructification and other resources parameters of wild growing fungi and berries [3-6], and the role of wild berries in game animals’ nutrition [7]. Population and coenotic parameters of wild species of non-wood forest berry plants are studied insufficiently, especially for rarer ones like arctic bramble (*Rubus arcticus* L.).

*Rubus arcticus* L. is a rootstock semi-subshrub, strictly polycentric species, optionally root sucker with unspecialized late morphological desintegration [8].

It’s a Eurasian-North American arctic-boreal species, spread in Northern and Eastern Europe, North-Eastern and Eastern Asia and North America [8-10]. In Russia it is marked in the North-West, North, and North-East of the European part, in Eastern and Western Siberia, Urals and Far East [11-15].

*R. arcticus* is protected in many regions of Russia, e.g. in the Republic of Bashkirie, Mary-El, Moscow and Yaroslavl regions [16-19]; enlisted in the Emerald Book of Russia [20]. The species is also marked in the 2019 IUCN Red list of Threatened Species (Least Concern ver. 3.1) [21] and in NatureServe Explorer database [22] as a species needing protection.

The aim of a study was to estimate the conditions of *R. arcticus* populations in proximity of the southern border of the range within Kirov region, Russia.

2. **Materials and methods**

The study included 12 coenopopulations (CPs) within Kirov region investigated in 2016-2018.
Descriptions of vegetative communities were accomplished with common methods [23]. Species taxonomy is given according to The Plant List database (http://www.theplantlist.org/).

Ecological parameters of the habitats were estimated by the species composition of the communities with the use of average class mark method by 10 amplitude scales of D N Tsyganov [24]: Tm — thermoclimatic, Kn — climate continentality, Om — ombro-climatic aridity-humidity, Cr — cryo-climatic, Hd — soil humidity, Tr — soil salt regime, Nt — soil nitrogen richness, Rc — soil acidity, fH — humidity fluctuation, Lc — light-shading.

Each factor was numerically estimated by ecological valence parameter (PEV) as a measure of coenopopulation’s adaptation to the variations of the ecological factor. The PEV value is a share of the grades’ range out of the full scale.

Realized ecological valence (REV) is a share of grades’ sum, which the CP covers within the factor’s scale, out the total number of grades in the scale [25].

Species tolerance to a combined effect of several factors was characterized by the tolerance index (It), or steno-eurybiont measure, as a share of PEV sum for investigated factors from the number of scales of the studied factors [25].

Ecological efficacy coefficient (Kec.eff., %), which presents the ratio of REV/PEV, shows the effectiveness of familiarization of the ecological space by certain CPs [25].

Discomfort index (D) based on ecological scales and phytocindication results [26], was also defined for each habitat:

\[ D = \frac{\sum_{i=1}^{n} Di}{n} \]

where D – discomfort index; Di – module of the difference between the value of the ecological factor in the given community and optimal value of the factor for a certain species in ecological scales; n – number of considered ecological factors.

Resilience to human impact was estimated by the hemeroby spectrum of the community [27-30] and apothyte parameter [31].

Statistics accomplished according to common methods and approaches proposed by G N Zaitsev [32].

3. Results and discussion
The study revealed that arctic bramble in southern taiga is usually found in herbaceous swampy birch forests with spruce, aspen and pine; in medium taiga – in herbaceous swampy forests, lime-grass-willow-herb swampy forests, and lime-grass-mixed-herbs cut-over areas from birch forests with spruce or mixed herbaceous forests.

Tree stand and undergrowth of plant communities is usually presented by *Betula pubescens*, *Betula pendula*, *Populus tremula*, *Picea × fennica*, and *Pinus sylvestris*. Tree stand age in the communities with *R. arcticus* varies from 15 to 90 years, crown density – from 0.2 to 0.7, height – 10 - 20 m.

Projective cover of *R. arcticus* in studied CPs ranges from 10% (in spruce-birch grassy and herbaceous-graminous swampy forests, lime-grass-mixed-herbs cut-over areas from mixed herbaceous forests, and on forest aisle in green-moss-cowberry pine forest with spruce and herbaceous swampy birch forest) up to 50% (in herbaceous birch forest with spruce and aspen, herbaceous aspen-spruce-birch forest, and spruce-birch forest with aspen and pine).

Total number of plant species revealed in 10 CPs reached 100, species richness of each CP varied from 9 to 32. *Deschampsia cespitosa*, *Pyrola rotundifolia*, *Rubus saxatilis*, *Vaccinium myrtillus*, *Poa nemoralis*, and *Gymnocarpium dryopteris* dominate in small-leaved forests with admixture of conifers (*Betula pubescens*, *Betula pendula*, *Populus tremula*, *Picea × fennica*, and *Pinus sylvestris*). Prevalence of *Poa nemoralis*, *Comarum palustre*, *Deschampsia cespitosa*, *Calamagrostis epigejos* is typical for young herbaceous aspen forests. *Vaccinium vitis-idaea*, *Rubus saxatilis*, *Fragaria vesca*, *Poa nemoralis*, *Pyrola rotundifolia* dominate in coniferous forests.
Different dominating species are marked on open swampy areas (graminaceous-mixed-herbs wet meadow, lime-grass-willow-herb swampy and lime-grass-herbaceous clear-cut areas): Comarum palustre, Calamagrostis epigejos, Geum rivale, Pyrola rotundifolia, Poa nemoralis, Deschampsia cespitosa, Epilobium angustifolium, Juncus bufonius, Stellaria nemorum, and etc.

Studied CPs are located in the interval between boreal (6.5) and sub-boreal (7.5) thermoclimatic parameters, which coincides with the actual studied sector of the species’ range. According to the climate continentality scale (Kn), studied habitats of the species fall in sub-continental and continental climatic zones (8–8.75). Ombro-climatic scale (Om) showing the ratio of precipitation and evaporation, places the studied CPs in conditions of sub-humid climate (8.5–9.0). By cryo-climatic scale (Cr) the species is found in conditions of moderate winters (6.5–7.75).

Analyses of the R. arcticus’ potential ecological valence (PEV) showed that, according to the climatic factors, the species is a mesobiont (It=0.50), i.e. has medium level of lability towards climatic factors, the species does not effectively use its potential to the environment soil factors.

R. arcticus in the study area realizes its maximum potential by thermoclimatic and cryo-climatic scales (14.43 and 14.0% correspondingly). The rest of the climatic scales show that ecological conditions of the studied habitats are medium from potentially possible (stated by Tsyganov). With the exception of thermoclimatic scale which values are close to the higher limit of the factor and are explained by the species location on the southern range border.

By soil humidity scale (Hd) the studied CPs were in hydration conditions from moist forest-meadow to wet forest-meadow (12.5–14.0). The scale range for soil salt regime factor (Tr) varied from 4.38 to 5.88 points (compliant to poor soils). By soils’ nitrogen richness scale (Nt) the species is found on soil from extremely nitrogen-poor (CPs 8 and 11; 4.0 points) to nitrogen-poor (CPs 1, 2, 3, 4, 5, 6, 7, 9, 10, and 12; 4.25 to 5.50 points), by soil acidity scale (Rc) the range is 4.0–7.0 (from low-acidity to high-acidity soils). It’s worth mentioning that according to the soil humidity fluctuation scale (Hi) the range of ecological conditions in studied CPs exceeds potentially possible borders and varies from relatively stable to moderately variable watering (4.0–6.0), which indicates the species’ high resilience towards soil humidity in the studied area. Ecological amplitude of the studied CPs with R. arcticus doesn’t exceed the species’ ecological range, according to the other soil scales.

Cumulative spectrum of soil scales presents the species as a stenobiont (It=0.33) which, consequently, has narrow ranges of adaptation to soil factors. Ecological efficacy coefficient (Kec.eff.) of the studied CPs varied from 16.78 to 67.0%, proving that the species does not effectively use its potential to the environment soil factors. Maximum ecological efficacy coefficient was revealed for soil humidity fluctuation scale (67.00%), minimum – for soil humidity scale (16.78%).

By light-shading scale (Lc) R. arcticus inhabits both open/semi-open areas and light forests (2.5–4.50). The species is an euryvalent (It=0.67) by lighting scale. Cumulative tolerance index reaches 0.46 (mesovalent species demonstrating medium lability level towards lighting).

Analyses of PEV in the system of D N Tsyganov’s ecological scales showed that by ombroclimatic scale factors (PEV=0.27), soil salt regime (PEV=0.32), and soil humidity fluctuation (PEV=0.27), R. arcticus is a stenovenal species capable of tolerating slight changes of the named factors, which are considered limiting and can possibly prevent the species expansion beyond its current range. Factors of thermo-climatic scale (PEV=0.41) and soil humidity scale (PEV=0.39) characterize the species as a semi-euryvalent, i.e. the variations of these factors are not limiting or strictly constraining the species’ growth. By cryo-climatic scale (PEV=0.60) R. arcticus acts as a semi-euryvalent and demonstrates broad range of resilience towards climatopical factors. Scale of climate continentality (PEV=0.73) and light-shading (PEV=0.67) characterize the species as a cryo-valent, realizing its ecological position to the full, which allows it to expand to new habitats. This explains high density and frequency of arctic bramble in both forests with different crown density level and tree stand composition, and open areas.

The value of discomfort index shows that the conditions of CP8 (lime-grass-willow-herb swampy cut-over area from herbaceous birch forest with spruce) and CP9 (spruce-birch swampy mixed-herbs-gramineous forest) comply with optimum ecological parameters for the species growth. The least
favorable conditions are marked in CP3 (herbaceous swampy aspen forest) and CP11 (forest aisle in green-moss-cowberry forest), where the highest values of discomfort index are defined (1.44 and 1.31 correspondingly).

The study of hemeroby revealed that in all CPs with *R. arcticus* oligo- and meso-hemerobic species prevail (38.1 and 41.9% correspondingly). The share of a-hemerobs is low - 0.17%. Relatively high share is occupied by b-eu-hemerobs – 18.4%. About 1.5% is a part of a-eu-hemerobic species. Polyhemerobs and meta-hemerobs were not marked in any of the studied communities.

The share of anthropotolerant species in plant communities with *R. arcticus* varies from 8.8 to 24.4%. Variability range of the apophyte index values lies within 9.6 - 32.3%. Relatively high parameters of anthropophobic species (75.6–91.2%) prove the species’ low resilience to human impact.

4. Conclusion
Arctic bramble in Kirov region is located on the southern border of its range and is usually found in herbaceous swampy birch forests with spruce, aspen and pine; herbaceous swampy forests; lime-grass-willow-herb swampy forests, and lime-grass-mixed-herbs cut-over areas from birch forests with spruce or mixed herbaceous forests.

Cumulative spectrum of soil ecological scales (by D N Tsyganov) presents the species as a stenobiont which has narrow ranges of adaptation to soil factors. *R. arcticus* is a stenothermal species according to ombroclimatic scale factors, soil salt regime, and soil humidity fluctuation, and capable of tolerating slight changes of the named limiting factors, which can prevent the species’ expansion beyond its current range.

*R. arcticus* has medium level of lability to climatope conditions and its studied habitats lie in subcontinental and continental climatic zones.

According to the hemeroby concept the species can only tolerate slight human impact.

References
[1] Kirillov D V, Perevedentseva L G and Egoshina T L 2011 *List of Agaric Macromycetes of Kirov Region* (Kirov) 64
[2] Stavishenko I V and Luginina E A 2015 *Mykology and Phytopathology* 49 41-9
[3] Egoshina T L and Luginina E A 2014 *Izvestia Samarskogo Sci Center RAN* 16 776-8
[4] Kislitsina A V and Egoshina T L 2016 *Vestnik Povolzhskogo State Technol Univ* 3(31) 77-86
[5] Egoshina T L, Kolupaeva K G and Raus L K 2006 *Plant Resources* 42 56-65
[6] Egoshina T L and Luginina E A 2008 *Vestnik Tverskogo Univ* 10 147-54
[7] Egoshina T L et al. 2017 *Izvestia Samarskogo Sci Center RAN* 19 255-60
[8] Zhukova L A and Belova S A 1997 *Ontogenetic Atlas of Medicinal Plants* (Yoshkar-Ola) 60-4
[9] Kuvayev V B 1990 *Ranges of Medicinal Plant of USSR: Atlas* ed V M Schmidt (Leningrad) 208
[10] Stjernberg T, Carlsson R, Haeggstrom C A and Haeggstrom E 2010 *Memoranda Soc. Fauna Flora Fennica* 86 54-8
[11] Vydrina S N, Kurbatskiy V I and Polozhiy A V 1988 *Flora of Siberia. Rosaceae* 8 (Novosibirsk) 200
[12] Makarov A A 2002 Medicinal Plants of Yakutia and Prospects of Use (Novosibirsk) 264
[13] Kravchenko A V 2007 *Conспект of Karelian Flora* (Petrozavodsk) 403
[14] Pospelova E B and Pospelov I N 2007 *Flora of Taimyr and Bordering Territories* (Moscow) 457
[15] Martynenko V A and Gruzdev B I 2008 *Vascular Plants of Komi Republic* (Syktyvkar: Institute of Biol. KomKNCUrO RAN) p 136
[16] Varlygina T I et al. 2018 *The Red Book of Moscow Region* (Moscow: Verkhovye) p 810
[17] Galeeva A Kh et al. 2011 *The Red Book of the Republic of Bashkortostan: Plants and Fungi* 1 384
[18] Baldaev Kh F et al. 2013 *The Red Book of the Republic of Mary-El. Plants Fungi* ed G A Bogdanova et al. (Yoshkar-Ola: Mary State Univ) p 324
[19] Anashkina E N et al. 2015 *The Red Book of Yaroslavl Region* (Yaroslavl: Akademia) p 472
[20] Belova Yu N et al. 2011-2013 Emerald Book of Russian Federation vol 1 (Moscow) p 308
[21] The IUCN Red list of threatened species 2019 IUCN Red list Unit Cambridge URL: http://iucnredlist.org
[22] An Online Encyclopedia of Life 2019 South Clark Street, Suite 930, Arlington, VA 22202 pp 655-67 URL: http://NatureServeExplorer.org
[23] Andreeva E N et al. 2002 Methods of Studies of Forest Communities (Saint-Petersburg: NIIKh Chemistry SPBGU) p 240
[24] Tsyganov D N 1983 Phytoindication of Regimes in the Subzone of Coniferous-Deciduous Forests (Moscow) 198
[25] Zhukova L A, Dorogova Yu A, Turmukhametova N V, Gavrilova M N and Polyanskaya T A 2010 Ecological Scales and Methods of Analyses of Plants’ Ecological Variations (Yoshkar-Ola) p 368
[26] Klimenko G O 2012 Proc. II Int. conf. Plants of the Red Book of Ukraine (Uman) p 107-10
[27] Ishbirdina L M and Ishbirdin A R 1992 Journ. of gen. boil. 2 211-24
[28] Frank D and Klotz S 1994 Biologisch-okologisch Daten zur Flora der DDR (Saale) p 167
[29] Steinhardt U, Herzog F, Lausch A, Muller E and Lehmann S 1999 Environmental Indices – System Analysis Approach (Oxford) 237-54
[30] Hill M O, Roy D B and Thompson K J 2002 Appl Ecol 39 708-20
[31] Jackowiak B 1993 Atlas rozmieszczenia roślin naczyniowych w Poznaniu (Poznan) p 409
[32] Zaitsev G N 1973 Methods of Biometric Studies. Mathematical Statistics in Experimental Botany (Moscow) p 256