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Spatial and temporal structure of the *Acer negundo* L. cenopopulation in the forest parks of Yekaterinburg

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Abstract. The article is devoted to the study of the spatio-temporal structure of *Acer negundo* L. in the forest parks of Yekaterinburg on the basis of population and organism indicators. Eight fragments of ash-leaved maple cenopopulations in the Uktusky and Southwestern forest parks were examined. For the first time, a quantitative characteristic of the manifestation of organismal indicators in each ontogenetic state of maple was obtained. A feature of the spatial structure of the habitats of *Acer negundo* is its active introduction into cenoses in the forest parks of Ekaterinburg. An identical expansion of the species in the studied forest parks was established, however, there are also distinctive features of its habitat. In the course of the analysis of variance, the dependence of the dimensional parameters of the maple crown on changes in two factors (forest park, ontogenetic state) and their interaction was shown. The ability of the species to successfully adapt in fragmented and urbanized areas affected by recreational impacts and other forms of pollution and survive in a wide range of environmental conditions has been established.

1. Introduction

With an increase in the anthropogenic pressure on suburban forests, it is important to study the distribution of undergrowth species and their intraspecific differentiation for the conservation of biodiversity [1]. The study of the patterns of manifestation of size and growth parameters of trees in populations makes it possible to identify the features of the dynamics of their development and give a complete picture of the processes of adaptation of a given species to specific growing conditions [2–9]. The aim of this work is to study the ontogeny of their size indicators *Acer negundo* in the forest parks of Yekaterinburg.

2. Materials and methods

According to the botanical and geographical zoning of the Sverdlovsk region, Yekaterinburg is located in the southern taiga boreal forest subzone [10]. The study was conducted in 2021 in four fragments of cenopopulations (FTP) in Uktusky and four in the South-Western forest parks of Yekaterinburg (figure 1). To characterize ontogeny, standard methods were used [11–12]. The shares of trees of different ontogenetic states (i_m - immature, v - virginal, g_1 - young generative, g_2 - medium generative, g_3 - late generative, ss - subsenile) were calculated in the total sample size for each habitat (forest park).



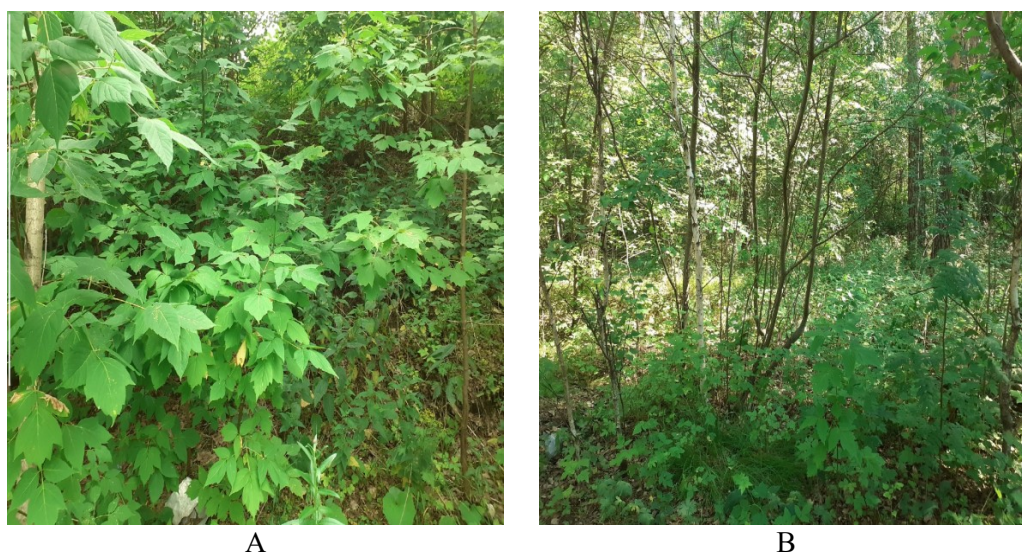


Figure 1. Invasions of the ash-leaved maple in the Uktusky (A) and Southwestern (B) forest parks.

The level of manifestation, the nature of variation, and differences in crown dimensional features were assessed: height H , diameters in two directions D_1 and D_2 , as well as calculated features of crown radius R , its projection area S , and volume V , depending on the forest park. The average values and standard deviations of crown features were analyzed depending on the ontogenetic state. We considered the nature of correlation and the general change in traits in accordance with the transition to subsequent ontogenetic states. To establish differences in growth parameters and their statistical significance, a two-way analysis of variance (ANOVA) was carried out, where the forest park and ontogenetic state acted as factors.

3. Results

As a result of the study, the density of ash-leaved maple in forest parks was established. In the Uktusky forest park, this indicator varied from 411 to 1011, in the South-West from 577 to 2744 pieces per hectare (table 1). According to the proportion of trees in different ontogenetic states in the total sample for two forest parks, one can speak about the time of existence of maple habitats, the direction and speed of their development (table 2).

Table 1. Characteristics of fragments of the *Acer negundo* cenopopulation in a forb pine forest.

Cenopopulation fragment number	Habitat		General density, ind./ha
	Composition	Tree stand Tightness of the tree canopy	
Uktus forest park			
1	10C	0.4	1011
2	8C2B	0.3	922
3	10C	0.2	411
4	7C3B	0.2	444
	$X \pm mx$	0.3	697
Southwestern forest park			
5	10C	0.5	2744
6	10C	0.4	577
7	10C+B	0.4	2044
8	10C	0.5	1244
	$X \pm mx$	0.4	1652

In the Southwestern forest park, the overwhelming majority of individuals are in the immature and virginal state; in the Uktus forest park, there are also medium and late generative (g_2 and g_3) species.

Table 2. Representation of shares of maple ontogenetic states in the forest parks of Yekaterinburg.

Forest park	j	im	v	g_1	g_2	g_3	Amount
Southwestern forest park	-	0.53	0.39	0.08	-	-	1.00
Uktus forest park	0.19	0.43	0.32	-	0.03	0.02	1.00

The data of table 3, which shows the average values and indicators of the variation of size traits, characterizing their level of manifestation and change in various ontogenetic states, show an increase in the size characteristics and the range of their change during the transition of individuals to the next ontogenetic state.

Table 3. Average values and indicators of variation (standard deviations) of dimensional traits of maple crowns for various ontogenetic conditions.

State	H, m	D ₁ , m	D ₂ , m	R, m	S, m ²	V, m ³
Southwestern forest park						
im	0.42±0.3	0.24±0.13	0.24±0.16	0.12±0.07	0.06±0.06	0.01±0.02
v	1.37±0.83	0.51±0.29	0.52±0.34	0.26±0.15	0.28±0.4	0.19±0.38
g_1	2.2±0.93	0.9±0.68	0.74±0.55	0.41±0.3	0.79±1.17	0.87±1.55
Uktus forest park						
j	0.12±0.04	0.13±0.05	0.1±0.04	0.06±0.02	0.01±0.01	0.001±0.001
im	0.42±0.22	0.28±0.13	0.22±0.1	0.13±0.05	0.06±0.05	0.01±0.01
v	1.68±1.5	0.87±0.93	0.76±0.92	0.41±0.46	1.16±3.74	2.31±10.67
g_2	8.5±1.79	5.18±1.29	4.67±0.98	2.46±0.42	19.43±6.31	55.38±23.89
g_3	6.55±0.45	4.57±1.97	4.16±1.74	2.18±0.93	17.66±12.78	40.46±30.4

The values of the traits (H and D₁) are sorted in ascending order within each ontogenetic state for a complete sample of trees (figure 2), including both forest parks, while a smooth increase in average values and a slight variation in traits in juvenile (j), immature (im) and virginal (v) states, and a significant increase in variation in the generative period, as well as at the end of the virginal.

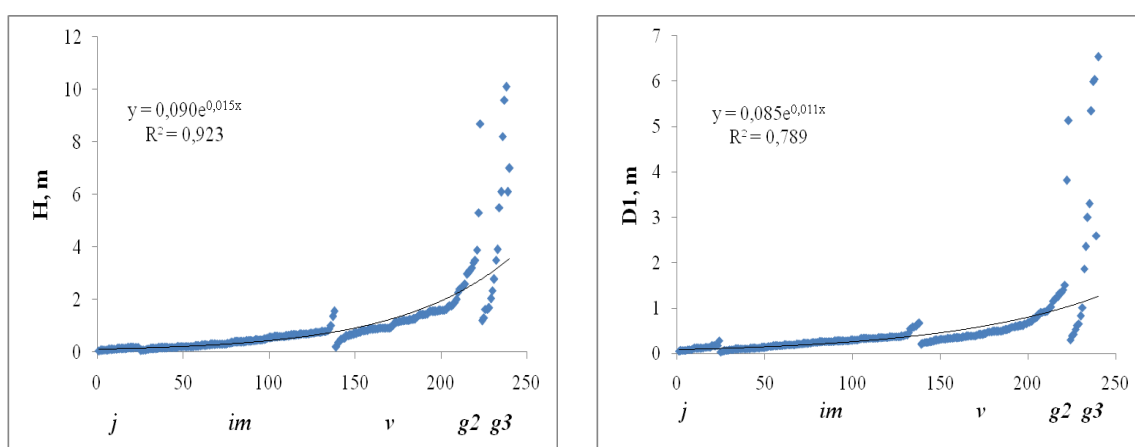


Figure 2. Changes in variation of heights H and diameters D₁ of maple crowns in different ontogenetic conditions.

In the habitats of the ash-leaved maple, the dependence of the size characteristics of the crown was revealed: quadratic D1 on H ($R^2=0.837$, $P<0.05$) and linear correlation of the diameters D_1 and D_2 ($R^2=0.919$, $P<0.05$) (figure 3).

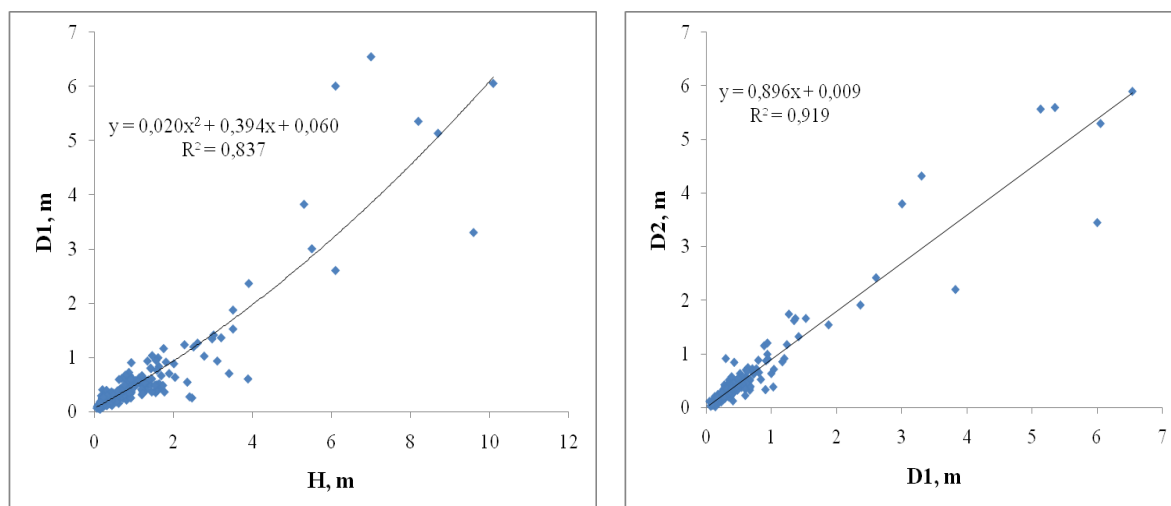


Figure 3. Graphs of dependence of heights and diameters in two directions of maple crowns in the total sample of all individuals.

Two-way analysis of variance (ANOVA), conducted on two factors: forest park and ontogenetic state, showed statistically significant differences ($p<0.001$) between samples of individuals both in terms of features characteristic of ontogenetic states and for two forest parks, the effect of the interaction of these factors is also significant (figure 4).

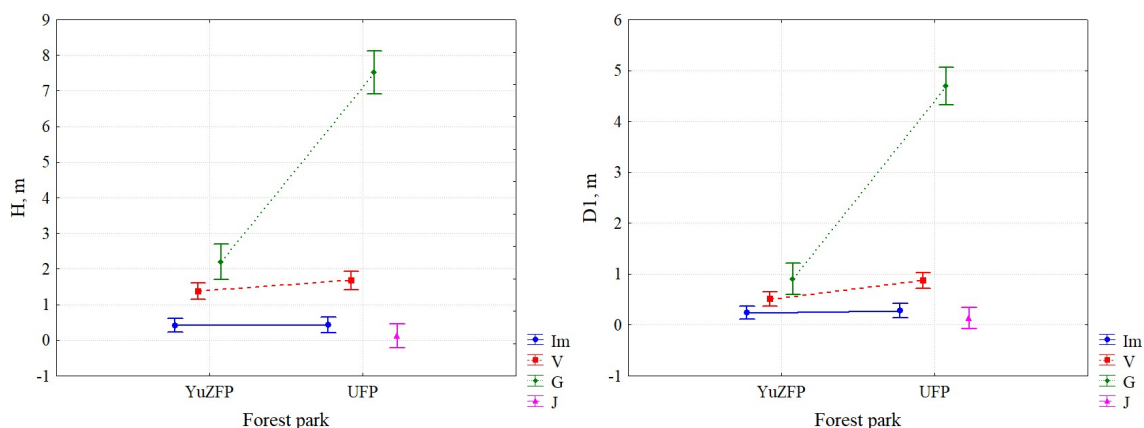


Figure 4. Graphs of manifestations of crown size traits illustrating the differences observed in forest parks and ontogenetic states of maple trees, according to the results of two-way ANOVA (letters: Southwestern forest park - YuZFP, Uktussky forest park - UFP, J, Im, V, G - the corresponding ontogenetic states).

4. Discussion

Ash-leaved maple grows in 12 forest parks of Yekaterinburg out of 15 on an area of 228 hectares, according to the GIS program of the AWP "Lesfond". 8 fragments of coenopopulations were studied in the same ecological and coenotic conditions of the Uktussky and Southwestern forest parks. According to the ratio of the numbers of ontogenetic states of individuals in 2 forest parks, one can

speak of their difference in composition. In all habitats, there is an increase in the average values of dimensional traits, as well as the ranges of their variation during the transition to the subsequent ontogenetic state, a particularly strong increase in variation is observed in the generative state. A quadratic dependence of crown diameters on heights was revealed, while the diameters in two directions are linearly interconnected. The results of the analysis of variance of changes in the dimensional characteristics of tree crowns depending on two factors: forest park and ontogenetic state indicate statistically significant changes in parameters when changing each of the factors, as well as their interaction. At the same time, in the immature state *im*, the parameters of individuals in the Southwestern forest park slightly exceed those in the Uktus forest park, in the virginal state *v*, on the contrary, and individuals in the generative state *g* of the Uktus forest park significantly exceed those in the Southwestern forest park. Thus, there are differences between the growth processes of maple individuals in the 2 cenopopulations studied, which are quantitatively manifested in the form of changes in the size characteristics of the crowns.

5. Conclusion

As a result of the study of the spatio-temporal structure of *Acer negundo* in the forest parks of Uktusky and Yugo-Zapadny, similar trends in the expansion of the species in these forest parks were established, as well as the features of manifestation and ranges of variation in the size features of the crown of maple trees in all habitats for each ontogenetic state, their differences and manifested effects two factors: there are statistically significant differences in the size characteristics of tree crowns, both in different ontogenetic states, and for each of the studied forest parks. The obtained ontogenetic and quantitative patterns of maple growth in habitats are of scientific interest, since they allow making a prediction regarding the further development of the species, and also contribute to understanding the fitness and development of this species in environmental conditions specific to the region.

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