DATA ON 30-YEAR STAND DYNAMICS IN AN OLD-GROWTH BROAD-LEAVED FOREST IN THE KALUZHSKIE ZASEKI STATE NATURE RESERVE, RUSSIA

Maxim P. Shashkov[1,*], Maxim V. Bobrovsky[2], Vladimir N. Shanin[2], Larisa G. Khanina[1], Pavel Ya. Grabarnik[2], Miroslav N. Stamenov[2], Natalya V. Ivanova[1]

[1]*Keldysh Institute of Applied Mathematics of RAS, Russia*
[2]*Institute of Physicochemical and Biological Problems in Soil Science of RAS, Russia*
**e-mail: max.carabus@gmail.com*

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The article provides primary data on repeated tree measurements collected during two censuses on a permanent sampling plot (440 m × 200 m) established in the old-growth polydominant broad-leaved forest in the Kaluzhskie Zaseki State Nature Reserve (centre of European Russia). The time span between the inventories was 30 years, and a total of 11 578 individuals of ten tree, one shrub species, and several undefined tree species of three known genera were registered. During the surveys, tree identity, stem diameter at breast height (DBH) of 1.3 m, and life status (alive or dead) were recorded for every tree individual with DBH ≥ 5 cm. Additional attributes were determined for some individuals. Field data were digitised and compiled into the PostgreSQL database. An accurate data quality assessment, validation, and cleaning (with documentation of changes) have been performed before data standardisation according to the Darwin Core standard. Standardised data were published through the GBIF repository. From 1986 to 1988, 9811 individuals were recorded within the initial census, including 3920 *Corylus avellana* individual shrubs. *Corylus avellana* shrubs were recorded without measuring DBH. From 2016 to 2018, 7658 stems were recorded in the recensus, including 3090 living trees marked during the initial census, and 1641 other living trees reaching the DBH of at least 5 cm. *Corylus avellana* was not included in the recensus. Thus, over 30 years, about 65% of living tree individuals have survived, but the total number of living trees has not changed considerably. The mean diameter of shade-intolerant tree species (*Quercus robur*, *Fraxinus excelsior*, *Populus tremula*, and *Betula* spp.) has increased the most remarkably during 30 years. For these species, the increase in average diameter, along with the decrease in numbers, is associated with the death of young trees, presumably due to low illumination under the canopy. Contrastingly, shade-tolerant tree species (*Ulmus glabra*, *Tilia cordata*, *Acer platanoides*) increased in number, while their mean diameter increased slightly or even decreased, that evidences the successful regeneration of these species under the canopy. These data are relevant for investigating forest ecology questions at spatiotemporal scales as a model of natural succession.

Key words: Darwin Core, data quality assessment, GBIF, mesic temperate forest, permanent sampling plot

Introduction

Old-growth forests have a high conservation value. For instance, they act as refuges or sources of propagules for rare or threatened species, especially for forest species sensitive to human disturbance (Peterken, 1996; Sillet et al., 2000; Paillet et al., 2015; Liu et al., 2018). Furthermore, old-growth forests serve as an archive of past events allowing a better understanding of mechanisms of natural development after disturbances and successional dynamics of forest ecosystems (Kuuluvainen & Aakala, 2011; Král et al., 2014). The peculiarities of such forests are the abundant deadwood, presence of trees of various ages and diameters resulting from natural regeneration, numerous large and old trees, and a complex canopy structure consisting of multiple layers and heterogeneous mosaic of patches (Smirnova et al., 1988, 1989, 1990, 2017; Franklin & Van Pelt, 2004). A number of studies over the past two decades have shown that the proportion of old-growth forests has rapidly decreased across the world (Shorohova et al., 2011; Sabatini et al., 2018; Spracklen & Spracklen, 2021), whereas many of such forest tracts are still poorly studied.

This study focuses on *Quercus* mesic deciduous forests as distinguished in the European EUNIS habitat classification (Chytrý et al., 2020). Such forests have decreased their abundance significantly due to anthropogenic impacts during the last several centuries (Novenko, 2016) and now occur as isolated «forest islands» in the East European Plain.

We studied a unique uneven-aged old-growth stand that developed spontaneously over a long period probably after *Quercus robur* L. plantings in XVIII and XIX centuries, located in the Kaluzhskie Zaseki State Nature Reserve (e.g. Smirnova et al., 2017).

We have two main goals in our study: 1) to summarise and provide high-quality primary data on repeated tree measurements collected during two censuses on the permanent sampling plot in open access; 2) to investigate the long-term dynamics in tree species composition and stand structure of the broad-leaved forest over 30 years.

Material and Methods

Study area

The Kaluzhskie Zaseki State Nature Reserve is located in the northwest of the Central Russian Upland, in the southeast of the Kaluga Region, in the territory adjacent to the Orel Region and the Tula Region. The total area of the Kaluzhskie Zaseki State Nature Reserve is 185 km^2. The Protected Area consists of two separate parts, which are 12 km apart.

The Kaluzhskie Zaseki State Nature Reserve is located on a gently sloping upland, mostly at altitudes of 150–250 m a.s.l. The highest point is 275 m a.s.l. (Popadyuk et al., 1999). Long-term meteorological data are available for the nearest weather station Suhinichi (RSM00027707), ~ 65 km to north-north-west. There are continuous observations for 1977–2020. The average annual temperature is +5.5°C. The average annual precipitation is 635 mm (Veselov et al., 2021).

The Kaluzhskie Zaseki State Nature Reserve was established in 1992 to conserve the unique old-growth broad-leaved forests that were mostly undisturbed by cuttings and ploughing (Smirnova, 1994). The area has an old and diverse history of land use. «Kaluzhskie Zaseki» is a name that has been used since the XVIII century to designate a part of the Kaluga Province included into the Abatis belt beyond the River Oka of the Moscow State in the XVI and XVII centuries. The detailed history of the Kaluzhskie Zaseki State Nature Reserve area is described by Smirnova et al. (2017).

Field data collection

The permanent sampling plot with a total area of 88 000 m^2 (440 × 200 m) was established in 1986 in the southern part of the Kaluzhskie Zaseki State Nature Reserve (Fig. 1) by the team of researchers and students of Moscow State Pedagogical Institute under the leadership of Prof. Olga V. Smirnova and Dr. Roman V. Popadiouk. The plot is located within the oldest forest tract where the following species together form the overstorey: *Quercus robur*, *Fraxinus excelsior* L., *Tilia cordata* Mill., *Ulmus glabra* Huds., *Acer platanoides* L., *A. campestre* L., and also *Populus tremula* L., *Betula pubescens* Ehrh., and *B. pendula* Roth. Nowadays, *Quercus robur* individuals are more than 300 years old, while the maximum age of other tree species is more than 150 years. The cover of the overstorey is 60%, and the average cover of the shrub layer is 40% (Smirnova et al., 2017). *Corylus avellana* L. often dominates the shrub layer; estimates of entire individual shrubs age are more than 200 years, while the age of stems of a shrub are more than 50 years. *Euonymus europaeus* L., *E. verrucosus* Scop., *Lonicera xylosteum* L., and *Prunus padus* L. are common in the understory, alongside with the undergrowth of *Tilia cordata*, *Ulmus glabra*, *Acer campestre*, and *A. platanoides*. The average cover of the ground layer vegetation is 65%. *Aegopodium podagraria* L., *Asarum europaeum* L., *Lamium galeobdolon* (L.) L. subsp. *galeobdolon* Huds., *Pulmonaria obscura* Dumort., *Rabelera holostea* (L.) M.T.Sharples & E.A.Tripp, *Mercurialis perennis* L., *Milium effusum* L., *Dryopteris carthusiana* (Vill.) H.P.Fuchs, and other typical nemoral species are the most common. The nitrophilous species *Onoclea struthiopteris* (L.) Roth, *Filipendula ulmaria* (L.) Maxim., *Urtica dioica* L., and *Lunaria rediviva* L. also often occur. There are many spring-growing and spring-flowering perennial herbs: *Anemonoides ranunculoides* L. (Holub), *Ranunculus ficaria* L., *Gagea lutea* (L.) Ker Gawl., *G. minima* (L.) Ker Gawl., *Corydalis solida* (L.) Clairv., *C. cava* (L.) Schweigg. & Körte, *C. marschalliana* (Willd.) Pers., *Allium ursinum* L. often dominates.

The permanent plot is rectangular in shape and divided into 11 transverse lanes of 40 × 200 m; each lane, in turn, is divided into right and left sublanes of 20 × 200 m. A general view of the plot is shown on orthophotoplan (Fig. 2) built on imagery taken by the unmanned aerial vehicle Phantom 4. The results of the aerial photography analysis are not presented here. The image is used only as an illustration.

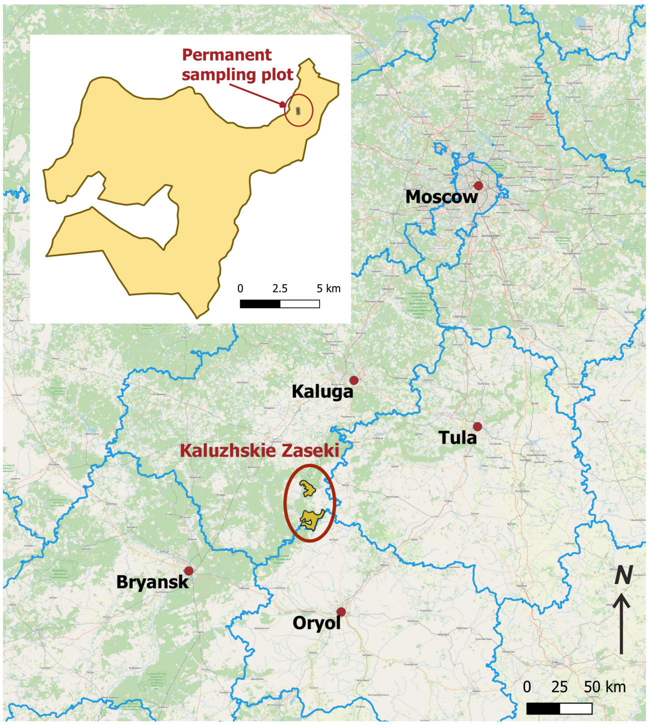

Fig. 1. Scheme of the study area showing the location of the permanent plot in the Kaluzhskie Zaseki State Nature Reserve. The administrative division is presented according to the Rosreestr via gis-lab.info from (Rosreestr, GIS-Lab. info, 2021). The background layer is from OpenStreetMap (OpenStreetMap contributors, 2015) via QGIS (QGIS Development Team, 2020).

During the first census in 1986–1988 (hereinafter – Census 1988), all tree stems (alive and dead) with the diameter at breast height (DBH) of 1.3 m of at least 5 cm were identified, measured, mapped, and marked in paint within the plot, as well as all *Corylus avellana* shrubs, for which the DBH was not measured. Standing dead trees (snags) were registered; fallen logs were included in the census as well. The following tree attributes were recorded for each individual stem: tree species, DBH and diameter at height of 0.3 m (for some alive stems and stumps), vitality (high, normal, decreased, low, dead, stump, fallen), origin (from seed or coppice), and ontogenetic stage (stage of biological age) (Table 1). There were distinguished young virginal (v1), virginal (v2), young generative (g1), middle-aged generative (g2), old generative (g3), sub-senile (ss), and senile (s) individuals (Smirnova et al., 2017). The age was determined for 292 trees by coring, and the height was measured for 1957 trees. The radii of crown projections were measured in 16 directions for 1915 trees. Individual shrubs of *Corylus avellana* were also included in the first census, but only the species identity, vitality, origin, and ontogenetic stage were recorded. Life status (alive or dead) was not explicitly recorded during the initial census. It was further derived from vitality in the course of the compilation of the database.

The local Cartesian co-ordinates were recorded for every individual stem using the following protocol for mapping tree positions within a sublane. The first measuring tape was placed along the line separating the adjacent lanes. The second measuring tape was placed in an orthogonal direction from the first tape to each tree trunk. Taking into account half of the stem diameter, the relative Cartesian co-ordinates of the centres of tree trunks were directly obtained, with the reference point set at the northwestern corner of the permanent sampling plot. This method is widely used by other forest ecologists (Reed et al., 1989; Hall, 1991). However, the recensus revealed many issues in these data.

The recensus was performed from 2016 to 2018 (hereinafter – Recensus 2018) under guidance of Prof. Maxim V. Bobrovsky. DBH and life status (alive or dead) for each tree stem were recorded. All newly detected trees (alive and dead) with DBH ≥ 5 cm were marked in paint and measured. An approximate location of these younger trees was marked on the tree location scheme of 1986–1988 (without using instrumental measurements). *Corylus avellana* individuals were not included in the recensus. The location of the plot borders was georeferenced with GPS Garmin S62.

Data processing and quality assessment

The data of the Census 1988 were digitised into the local database and stored in the DBF format. The process was guided by Sergey Chumachenko. Field notes apparently have not been preserved. Data quality assessment most likely was not conducted. Recensus 2018 data were digitised into spreadsheets, and subsequently all data were imported into the PostgreSQL database.

At the next step, we checked the data quality. According to the main principles of data quality (Chapman, 2005), we checked the semantic and structural consistency and completeness of the data. Exploratory analysis showed that not all tree attributes were obtained according to a strict and clear protocol and/or with appropriate accuracy and needed additional treatment. Therefore, we did not include the explicit tree co-ordinates into the dataset. Thus, below we provide the dataset and discuss the data on tree species composition, life status, and DBH. Other measured attributes are available upon request.

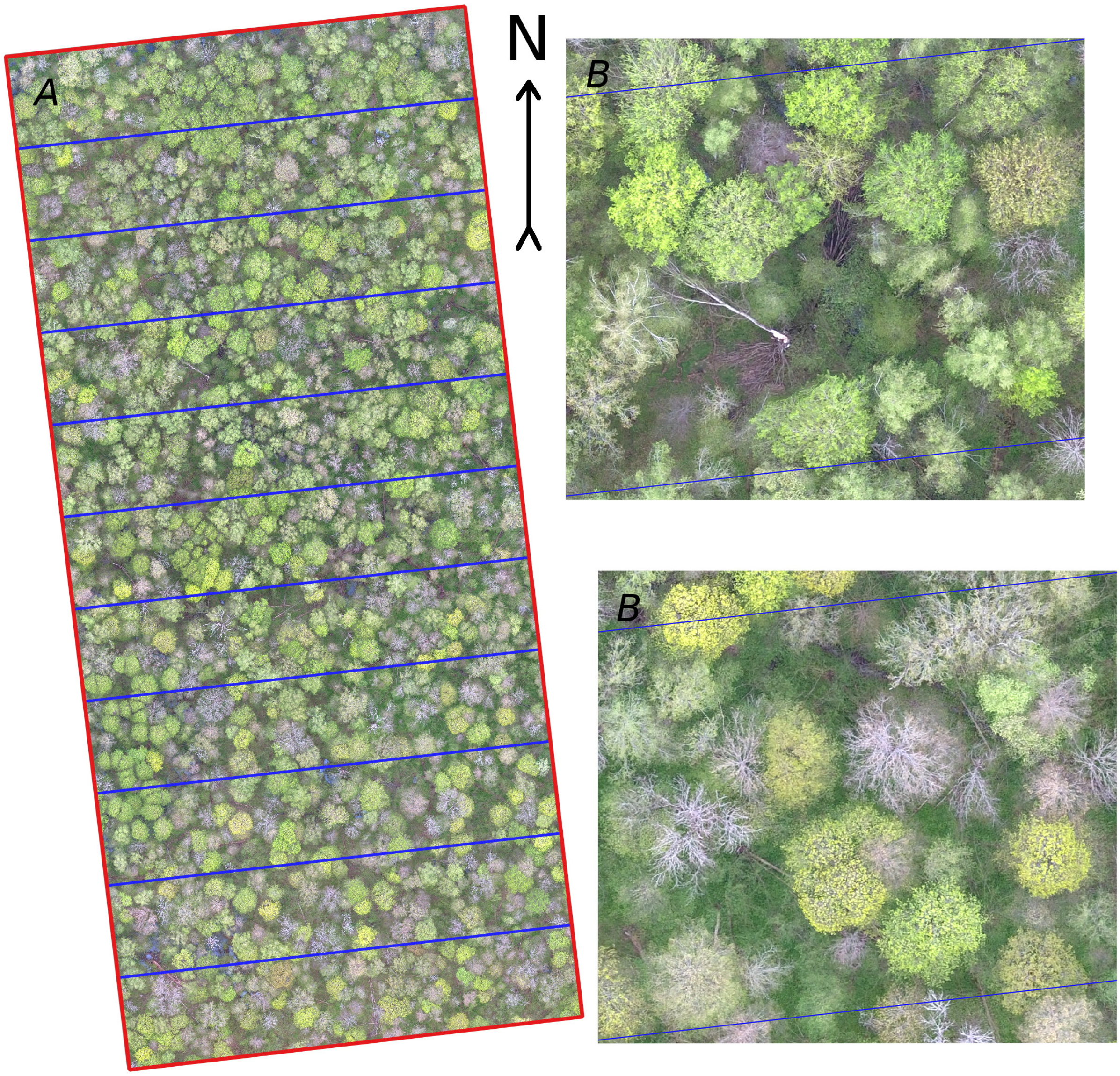

Fig 2. The overall view (orthophotoplan) of the sampling plot (A) composed of the aerial photographs series taken on 03.05.2018. Some trees are not yet fully foliated. The *Acer* spp. trees are flowering. The fragments of the orthophotoplan with canopy gaps and fallen trees are shown in larger scale on insets (B) to give an overview of the spatial heterogeneity of the sampling plot forest cover.

Table 1. Measurement attributes of trees on the permanent sampling plot

Measurement attributes (and units, where applicable)	Census 1988	Recensus 2018
Tree species identity*	yes	yes
Stem diameter at 1.3 m (cm)*	yes (without *Corylus avellana*)	yes
Stem diameter at 0.3 m (cm)	selectively (2350 trees)	no
Tree height (m)	selectively (1957 trees)	selectively (245 trees)
Tree age (years)	selectively (292 trees)	selectively (97 trees)
Life status*	yes (derived from vitality)	yes
Vitality	yes	no
Origin	yes	no
Ontogenetic stage	yes	no
Cartesian co-ordinates	yes	only for new trees (1767 trees)
Crown projection	selectively (1915 trees)	no

Note: * – features included in the GBIF dataset

For assessment of our data, we used the following criteria:

– Tree individuals with the same numbers within the sublane should have the same species identity in both inventories;

– DBH should increase or should not change (or decrease within permissible measurement accuracy);

– Dead trees counted in the first census should not be counted as alive in the recensus;

– Records with missing attributes (species, DBH, or life status) should be absent;

– Outliers in DBH measurements should be detected.

After determining errors and issues, all error instances and error types were documented and checked in the field. In total, 554 issues were resolved, and all changes were documented in the database. There were about 300 records for Recensus 2018 which have shown a DBH decrease from Census 1988. Such inconsistencies can be explained by bark roughness, irregular shape of the trunk and loss of bark between censuses due to tree death, while many old trees or those in suppressed condition have hardly grown during 30 years. Most of the negative differences were within 10–15%, but the flattened shape of the trunk of *Tilia cordata* can lead up to 30–50%. Nevertheless, some (20–30) cases of «DBH decrease» remained to be unresolved. Not being entirely sure whether these values of Census 1988 were measurement errors, we left them in the database. All original (verbatim) values were maintained and not lost in the data cleaning process. For data publishing, co-ordinates of trees were blurred, and the accuracy of location thus comprised 30 m.

Finally, we transformed our dataset according to the Darwin Core standard (Wieczorek et al., 2012) using Occurrence Core and Extended Measurement Or Facts. In our case, the Occurrence dataset class was preferable to the Sampling-event because we had to provide locations for each tree. One occurrence corresponds to one measured stem during the census, and each tree has a unique dwc: organismID. We used Event terms for specifying tree measurement to particular census (Fig. 3). The dataset was published through the Global Biodiversity Information Facility (GBIF) repository (Heberling et al., 2021). Data description is provided in Table 2.

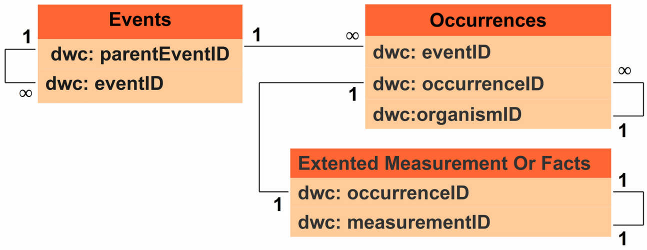

Fig. 3. The structure of the dataset published through GBIF. The relationship between events, associated occurrences and measurements are shown.

Data analysis

To characterise the long-term dynamics, we have considered the following aspects of the structural dynamics of tree stands.

1) Changes in tree species composition. For the assessment of tree species diversity, the Shannon diversity index was calculated for living trees using the «diversity()» function from the «vegan» package (Oksanen et al., 2020) in R (R Core Team, 2021). Statistical significance of the difference was estimated by the Hutcheson t-test using the «Hutcheson_t_test()» function from the «ecolTest» package (Salinas & Ramirez-Delgado, 2021) in R. Pielou's evenness was calculated as recommended by Oksanen (2020). We also calculated the reciprocal form of the Berger-Parker index (the ratio between the number of individuals of the most abundant tree species and the total number of individuals). In this case, a Berger-Parker value increases with increasing diversity and decreasing dominance by a single species or species group (O'Hara et al., 2007).

2) Changes in tree density and mean DBH. Numbers of living and dead trees (by species) were calculated for each census. Minimum, maximum, mean, and median DBH values, as well as the standard deviations, were calculated for living trees by species for each census.

3) Stem distribution of the main tree species per DBH class. The Kolmogorov-Smirnov test («ks.test()» function from the «dgof» package) was used to compare DBH distributions of living individuals of the main tree species between censuses.

Results

GBIF dataset

The published dataset (Smirnova et al., 2021) includes 17 469 data records related to 11 578 unique trees. The data are available in Darwin Core archive format (Wieczorek et al., 2012) through the GBIF portal, and have a Digital Object Identifier (DOI), linked with publishing Institution and data authors. The data are shared under the Creative Commons CC-BY 4.0 license.

Long-term stand dynamics

In total, ten tree species of nine genera (*Quercus robur*, *Fraxinus excelsior*, *Ulmus glabra*, *Acer platanoides*, *A. campestre*, *Tilia cordata*, *Populus tremula*, *Picea abies* (L.) H.Karst., *Sorbus aucuparia* L., *Prunus padus* L.), and one shrub species (*Corylus avellana*) were counted during two censuses. Another three taxa were identified only at the genus level: *Betula* L., *Salix* L., *Malus* Mill. As measured using the Shannon index, the temporal trend for species diversity was negative (Table 3). We found statistically significant differences between species composition in the two inventories ($p < 0.001$). The Pielou's evenness and Berger-Parker value also decreased. *Tilia cordata* was most abundant in terms of stem number during the census, followed by *Ulmus glabra*, *Fraxinus excelsior*, and *Quercus robur* (Table 3). By the recensus the tree species composition had changed (Table 4). *Tilia cordata* remained to be the most abundant species, but the number of *Ulmus glabra* has strongly increased, while the number of *Fraxinus excelsior* and *Quercus robur* has decreased.

Table 2. Description of the fields (Darwin Core terms) in the GBIF dataset

Darwin Core terms	Description
parentEventID	The identifier of the census (recensus).
eventID	The identifier of the fieldwork stage during the census and recensus.
samplingProtocol	Description of the methods used during the Event.
sampleSizeValue	The size of the sample plot (part of the plot) counted during the Event.
sampleSizeUnit	The unit of measurement of the size of the sample plot.
informationWithheld	List of measured tree attributes not included into the dataset.
dataGeneralizations	Actions taken to make the shared data less specific or complete than in its original form.
institutionCode	The name of the institution having custody of the information referred to in the record.
recordedBy	Field data collectors.
eventDate	Date of the census and recensus. Because we do not know exact dates of the initial census, «1988-09-01» was assigned for this event. Recensus was carried out during 4 fieldwork stages, and the corresponding dates were assigned to these events.
country	The name of the country.
countryCode	The standard code for the country (ISO 3166-1-alpha-2).
locality	The specific description of the place.
decimalLatitude	The geographic latitude (in decimal degrees, using the spatial reference system given in geodeticDatum).
decimalLongitude	The geographic longitude (in decimal degrees, using the spatial reference system given in geodeticDatum).
geodeticDatum	The spatial reference system upon which the geographic co-ordinates given in decimalLatitude and decimalLongitude are based.
coordinateUncertaintyInMeters	The horizontal distance (in meters) from the given decimalLatitude and decimalLongitude describing the smallest circle containing the whole Location.
coordinatePrecision	A decimal representation of the precision of the co-ordinates given in the decimalLatitude and decimalLongitude.
occurrenceID	The identifier of the measured tree in the census.
organismID	The identifier of the measured tree on the sample plot.
basisOfRecord	The specific nature of the data record (HumanObservation).
scientificName	The full scientific name of a measured tree.
taxonRank	The taxonomic rank of the most specific name in the scientificName.
occurrenceStatus	A statement about the presence or absence of a measured tree on the sampling plot. The «present» status was assigned for all trees counted during the census (alive and dead). In the recensus we considered as «present» all re-measured trees, and all new trees (alive and dead). Trees not counted in the recensus were assigned «absent».
measurementID	An identifier for the MeasurementOrFact.
measurementType	The title of the measurement (diameter at breast height, DBH).
measurementValue	The DBH value.

Table 3. Biodiversity indices calculated for living trees on the permanent sampling plot

Biodiversity indices	Census 1988	Recensus 2018
Shannon index	1.93	1.70
Pielou's evenness	0.93	0.78
Berger-Parker index	3.27	2.95* / 1.52**

Note: * – calculated for the most abundant species; ** – calculated for two most abundant species.

The mean DBH increased for *Quercus robur* (+18.8 cm), *Populus tremula* (+16.0 cm), *Fraxinus excelsior* (+13.3 cm), *Betula* spp. (+9.0 cm), *Tilia cordata* (+2.0 cm), and *Acer campestre* (+1.4 cm) (Fig. 4, Table 5). The mean DBH of *Acer platanoides* did not change. The mean DBH decreased for *Ulmus glabra* (-4.1 cm). The stem distribution per DBH (Fig. 5) significantly differed between both censuses ($p < 0.001$) for all species, except *Acer* spp. and *Tilia cordata*.

We also found the DBH for some trees (a total of 25 trees in the census and one tree in the recensus) to be lower than the threshold value of 5 cm (Table 4). This issue is most likely related to the erroneous inclusion of trees into the census based on the visual estimation of the DBH, while these trees were marked with a number first, and after the instrumental measurement, these trees were kept to preserve the consistency of numeration.

Table 4. Change of trees numbers over 30 years on the permanent sampling plot

Species	Census 1988		Recensus 2018		
	Living trees	Dead trees*	Living trees**	Lost trees***	New trees****
Quercus robur	561	804	194	1183	0
Fraxinus excelsior	629	37	241	455	20
Tilia cordata	1396	16	1606	241	418
Acer platanoides	321	16	368	54	83
Acer campestre	313	43	287	146	76
Ulmus glabra	663	85	1512	363	1031
Populus tremula	279	38	213	107	1
Betula spp.	402	43	316	129	0
Picea abies	0	0	2	0	2
Other species	144	77	38	203	10
Total	4708	1159	4777	2881	1641
Corylus avellana	3734	25	Not counted		

Note: * – trees, counted as dead during the census; ** – including new trees; *** – dead trees from the census, and trees counted as dead in the recensus; **** – new living trees counted during the recensus.

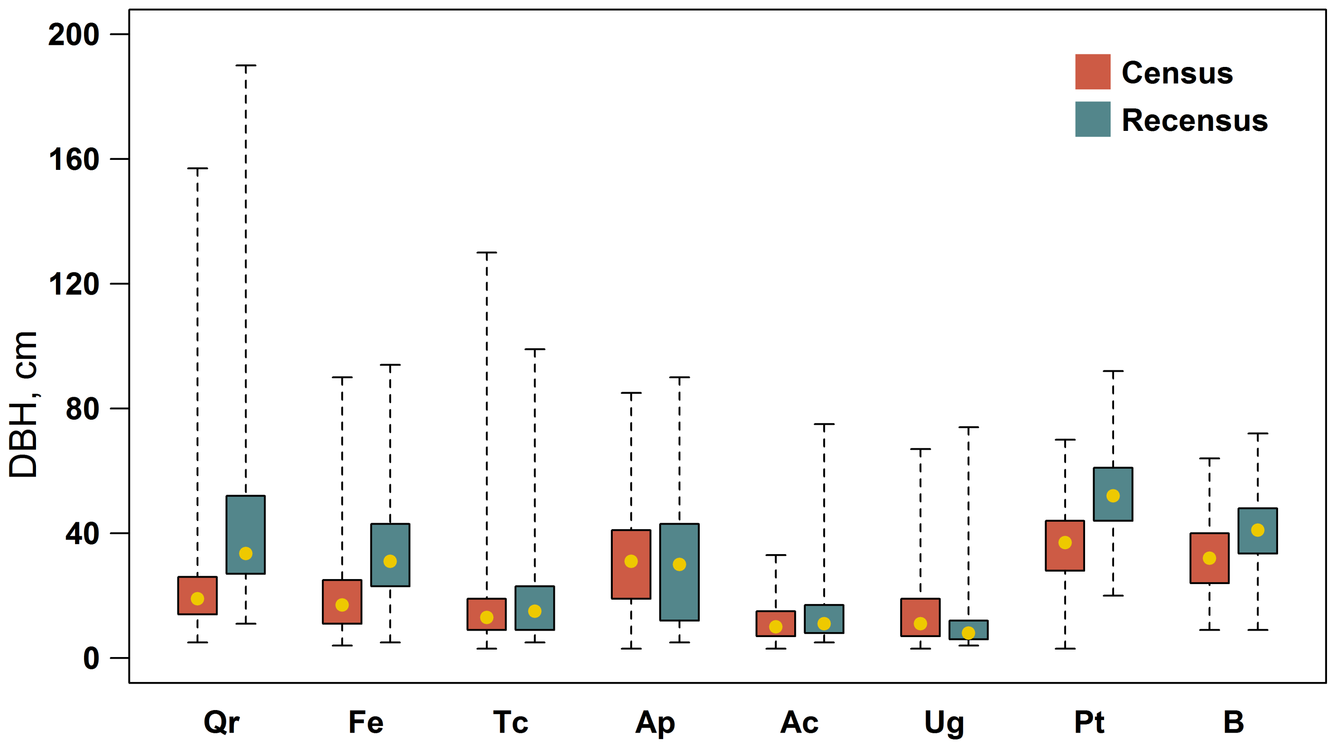

Fig. 4. Changes of living tree DBH values over 30 years on the permanent sampling plot. Designations of species names: Qr – *Quercus robur*, Fe – *Fraxinus excelsior*, Tc – *Tilia cordata*, Ap – *Acer platanoides*, Ac – *Acer campestre*, Ug – *Ulmus glabra*, Pt – *Populus tremula*, B – *Betula* spp. 1st and 3rd quartiles (boxes) and range (whiskers) are shown. Orange dots represent mean values.

Table 5. Change of living trees DBH over 30 years on the permanent sampling plot

Parameters	Qr		Fe		Tc		Ap		Ac		Ug		Pt		B	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
mean, cm	27.4	46.2	20.6	33.9	16.2	18.2	29.9	29.0	12.2	13.6	15.2	11.4	36.2	52.2	31.7	40.7
median, cm	19	34	17	21	13	15	31	30	10	11	11	8	37	52	32	41
SD, cm	25.0	30.8	13.1	17.2	11.2	12.8	14.6	17.6	6.7	8.6	11.7	9.5	11.5	12.9	11.1	11.1
min, cm	5	11	4	5	3	5	3	5	3	5	3	4	3	20	9	9
max, cm	157	190	90	94	130	99	85	90	33	75	67	74	70	92	64	72
N, ind.	554	194	611	238	1278	1599	313	368	297	283	652	1511	275	213	378	315

Note: 1 – census, 2 – recensus, mean – average DBH, SD – standard deviation, min – minimum DBH, max – maximum DBH, N – number of trees. Some N values differ from the number of trees in Table 3 because some DBH values were incorrect and therefore were not taken into account. Designations of species names: Qr – *Quercus robur*, Fe – *Fraxinus excelsior*, Tc – *Tilia cordata*, Ap – *Acer platanoides*, Ac – *Acer campestre*, Ug – *Ulmus glabra*, Pt – *Populus tremula*, B – *Betula* spp.

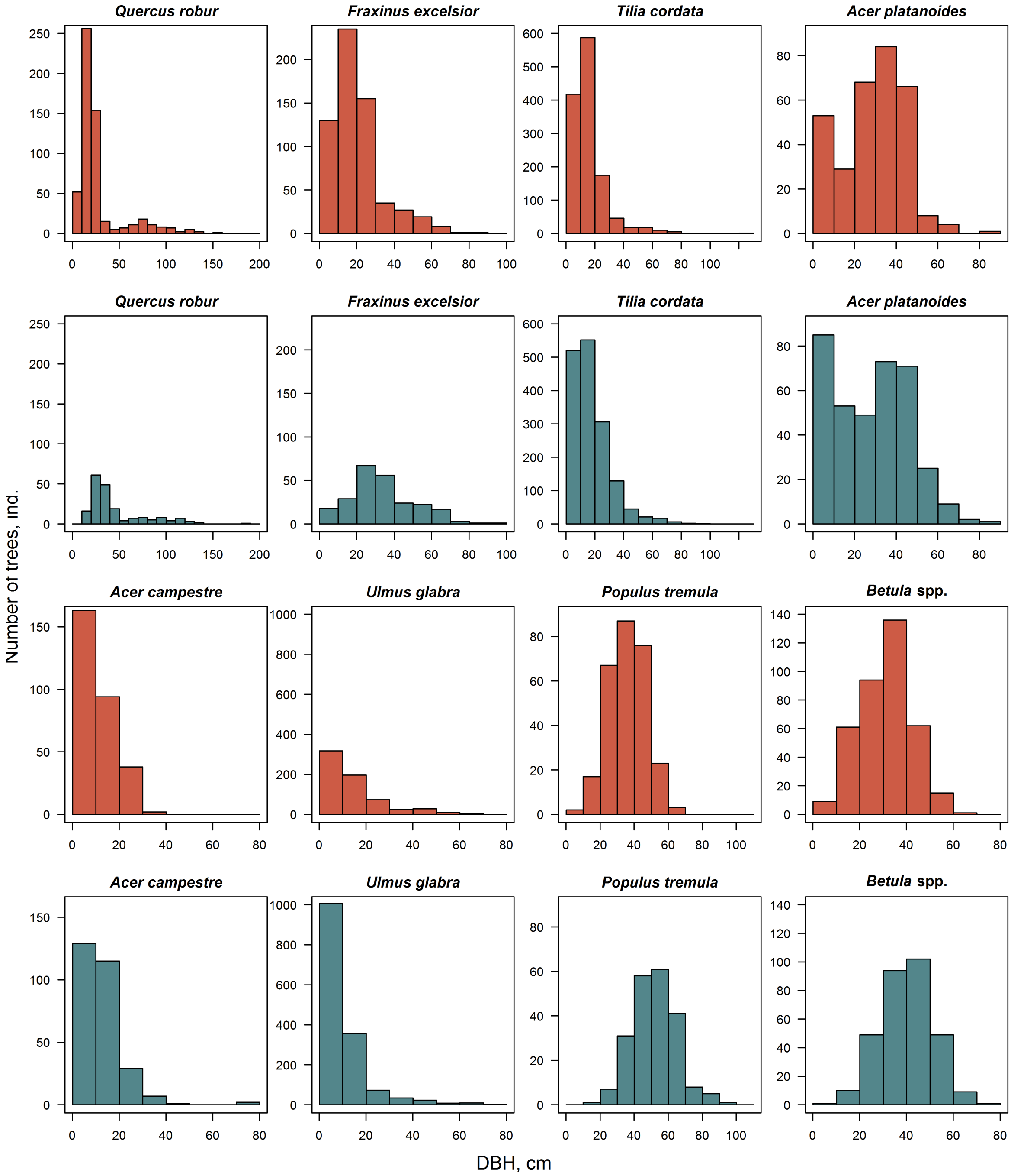

Fig. 5. Distribution of living trunks for the main tree species by DBH classes at the time of Census 1988 (red) and Recensus 2018 (blue) on the permanent sampling plot.

Discussion

Long-term stand dynamics

Our study showed the features of long-term tree stand dynamics on a permanent sampling plot established in an old-growth broad-leaved forest in the Kaluzhskie Zaseki State Nature Reserve. We found that about 35% of tree individuals died in 30 years, and a comparable number of new ones grew up. As a result, the species composition and species-specific diameter distribution were altered. We found that the tree species diversity decreased significantly. For all late successional shade-tolerant species (Smirnova et al., 1988, 1989; Evstigneev, 2018), a stable state of populations (for *Acer platanoides*, *A. campestre*) or an increase in their numbers due to an increase in the number of young individuals (for *Ulmus glabra*, *Tilia cordata*) was revealed. It is also supported by the results of the analysis of tree DBH changes. The mean diameters of *Quercus robur*, *Fraxinus excelsior*, *Populus tremula*, and *Betula* spp. have changed the most remarkably over 30 years, namely due to increasing in average diameter and decreasing in number, associated with young tree mortality. Such changes are expected for the pioneer shade-intolerant tree species, *Populus tremula* and *Betula* spp., which have no regeneration in broad-leaved forests due to low illumination under the canopy. A similar finding is also expected for *Quercus robur*, since many authors (Vera, 2000; Smirnova & Bobrovskii, 2001) assumed the impossibility of *Quercus* regeneration in a shady broad-leaved forest. Meadows associated with the activity of herd phytophages are assumed as a place for its sustainable renewal. The dynamics of the *Fraxinus excelsior* population is less clear than others: a slight increase in the number of young individuals was defined alongside with significant mortality of generative trees, which has become particularly noticeable in more recent years (especially in 2019–2021). The decline in adult individuals of *Fraxinus excelsior* may be related to the known spread in European Russia of the wood-boring beetle *Agrilus planipennis* Fairmaire, 1888, and/or the ascomycete fungus *Hymenoscyphus fraxineus* (T.Kowalski) Baral, Queloz & Hosoya, both of which are native to Asia (Straw et al., 2013; Musolin et al., 2017; Semizer-Cuming et al., 2019). The causes of the frequent death of *Fraxinus excelsior* trees in the Kaluzhskie Zaseki State Nature Reserve should be seriously investigated.

On the whole, similar results on the dynamics of tree populations were also obtained in the study of long-term woodland communities with silvicultural implications in the Białowieża Forest in Poland (Brzezieck et al., 2018). During the monitoring from 1936 to 2012, the density of the shade-tolerant trees *Tilia cordata* and *Ulmus glabra*, as well as moderately shade-tolerant *Carpinus betulus* L. increased. Simultaneously, the density of *Quercus robur* and *Fraxinus excelsior* showed a negative trend. The authors also noticed the declining occurrence and reduced roles of a large number of tree species over the 80 years of investigations.

Potential for data reuse

The establishment of permanent sampling plots in forests is crucial for accurate quantitative and qualitative assessment of forest resources on a regular basis. Modern data analysis methods need a large plot area because reliable data on population and spatial structure should be based on the measurement of many individuals (Wiegand et al., 2016). However, many forest census projects use sampling plots < 10 000 m^2 (Parish et al., 2010; Condit et al., 2014; Sekretenko & Grabarnik, 2015; Ovchinnikova & Ovchinnikov, 2016; Omelko et al., 2019; Sevko & Kotsan, 2020; Maslov, 2020; Manov & Kutyavin, 2021), and only a few researchers provide results for larger areas (Hubbell & Foster, 1983; Yamakura et al., 1995; Manabe et al., 2000), especially for the temperate forests (Liu et al., 2018; Omelko et al., 2019). Our data cover 88 000 m^2 and were initially used to investigate the tree population structure in old-growth broad-leaved forests (Smirnova et al., 1988, 1989). The datasets obtained from such plots can also be useful for calibration and validation of spatially explicit forest simulators in terms of species-specific growth rate, regeneration and survival depending on the local neighbourhood. For example, the data on diameter increment and crown projection size are intended to be used for parameter estimations for broad-leaved tree species in the crown competition model developed by Shanin et al. (2020).

An important restriction in the reuse of our data for quantitative analysis is the lack of reliable co-ordinates of trees. Our primary data included the local Cartesian co-ordinates for every individual stem, but the recensus revealed many issues in these data, and therefore we did not include the exact co-ordinates into the GBIF dataset. These data need to be re-measured using modern technologies for tree mapping, including ground-based (Liu et al., 2019; Calders et al., 2020) as well as remote methods (Mohan et al., 2017; Alonzo et al., 2018; Bennett et al., 2020; Medvedev et al., 2020; Ivanova et al., 2021).

To our best knowledge, there is no data repository for forest permanent sampling plots or individual tree attributes measurements, despite the rapid development of international forest research projects such as the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests – ICP Forests (Allegrini et al., 2009; Fischer et al., 2009), the Center for Tropical Forest Science network (Condit et al., 2014), and others.

Data on some types of individual tree attributes have also been summarised in a number of journal articles, local databases or websites. For example, Di Filippo et al. (2015) gathered the dataset of the maximum documented lifespan of broad-leaved trees from closed-canopy temperate forests in the Northern Hemisphere using tree-ring data and information from scientific literature or online databases. Ovaskainen et al. (2020) compiled various phenological and climatic events for a wide range of taxa (including tree species) recorded in 471 nature reserve sites in Russia, Ukraine, Uzbekistan, Belarus, and Kyrgyzstan between 1890 and 2018. Some information about tree morphological attributes is provided by the TRY Plant Trait Database (https://www.try-db.org), but the available data cover mainly tropical tree species (Thomas et al., 2017; Chacón-Madrigal et al., 2018; Williams, Nelson, 2018). The ICP Forests network includes > 6000 permanent observation forest plots throughout Europe and provides primary data for reuse on request. The HJ Andrews Experimental Forest and Long-Term Ecological Research Site, Oregon, USA (https://andrewsforest.oregonstate.edu/data) provides open-access to long-monitoring data (more than 60 years). In general, these data remain to be fragmented, and access is often limited or restricted.

The largest international infrastructure that provides free and open access to integrated biodiversity data is the GBIF, an important source of primary biodiversity data for scientific reuse. By August 2021, GBIF includes > 1.8 billion species occurrence records around the world (GBIF.org, 2021). More than 6000 peer-reviewed articles with the results of analysis of GBIF-mediated data have been published since 2003 (GBIF Secretariat, 2021; Ivanova & Shashkov, 2021). Although GBIF was initially based on the natural history collections community and was not intended to capture data about multi-species sampling event data (Guralnick et al., 2018), recent efforts have begun to develop an «Event Core», as well as new terms for census data mobilisation. Such practice makes it possible to present our dataset in Darwin Core fields without losing the original data structure and consistency. Our forest census dataset published through GBIF contributes to the development of open access ecological data and fills the gap in available forest biodiversity information from the Russian territory.

Conclusions

During this study we collected, combined, verified, cleaned, and exploratory analysed long-term tree census data on an old-growth broad-leaved forest stand in the Kaluzhskie Zaseki State Nature Reserve. Data were collected in the unique forest, which was mostly undisturbed by cuttings and ploughing. We found that over 30 years, about 65% of the living trees have survived, and a comparable number of younger individuals have replaced the dead ones. We also revealed changes in the tree community structure over time, mostly expressed through the partial replacement of light-demanding tree species by shade-tolerant ones.

The presented dataset is available through GBIF and addresses long-term dynamics stand structure, including tree species composition, DBH and life status. These data are relevant for investigating forest ecology questions at spatiotemporal scales as a model of natural succession.

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ДАННЫЕ ПО 30-ЛЕТНЕЙ ДИНАМИКЕ ДРЕВОСТОЯ В СТАРОВОЗРАСТНОМ ШИРОКОЛИСТВЕННОМ ЛЕСУ ЗАПОВЕДНИКА «КАЛУЖСКИЕ ЗАСЕКИ» (РОССИЯ)

М. П. Шашков[1,*], М. В. Бобровский[2], В. Н. Шанин[2], Л. Г. Ханина[1], П. Я. Грабарник[2], М. Н. Стаменов[2], Н. В. Иванова[1]

[1]*Институт прикладной математики имени М.В. Келдыша РАН, Россия*
[2]*Институт физико-химических и биологических проблем почвоведения РАН, Россия*
**e-mail: max.carabus@gmail.com*

В работе описаны первичные данные и результаты предварительного анализа измерений деревьев, собранные в ходе двух учетов на постоянной пробной площади (440 м × 200 м), заложенной в старовозрастном полидоминантном широколиственном лесу в государственном заповеднике «Калужские засеки» (центр Европейской части России). Первичный учет выполнен в 1986–1988 гг., второй перечет в 2016–2018 гг. Таким образом, продолжительность периода между учетами составила 30 лет. В учет включены все деревья с диаметром ствола ≥ 5 см. Всего на постоянной пробной площади отмечено 11 578 учетных единиц, относящихся к десяти видам деревьев, одному виду кустарников, а также трем родам, для которых не проводилось определение до вида. В ходе обследований для каждой учетной единицы определяли вид, измеряли диаметр ствола на высоте 1.3 м и указывали жизненный статус (живое или погибшее). Для некоторых учетных единиц указывали дополнительные характеристики. Данные обоих учетов были оцифрованы после полевых измерений. Для дальнейшей обработки в рамках проведенной работы они были организованы в базу данных в системе управления базами данных PostgreSQL. Поскольку данные первичного учета, по всей видимости, ранее не верифицировали, нами была выполнена оценка качества данных обоих перечетов общепринятыми методами; все внесенные исправления были документированы. После этого массив данных был стандартизирован в соответствии со стандартом Darwin Core и опубликован через репозиторий GBIF. Результаты анализа верифицированного массива данных показали, что при первичном учете на постоянной пробной площади было зарегистрировано 9811 учетных единиц, включая 3920 кустов *Corylus avellana*, которую учитывали без измерения диаметра. В повторном учете зарегистрировано 7658 учетных единиц, в том числе 3090 живых деревьев, отмеченных во время первичного учета, а также 1641 новое живое дерево, достигшее диаметра в 5 см. *Corylus avellana* не включена в повторный учет. Таким образом, за 30 лет на пробной площади сохранилось около 65% живых деревьев. При этом общее число живых деревьев существенно не изменилось. Также показано, что за 30 лет средний диаметр наиболее заметно увеличился у светолюбивых деревьев (*Quercus robur*, *Fraxinus excelsior*, *Populus tremula* и *Betula* spp.). У этих видов увеличение среднего диаметра вместе с уменьшением численности связано с гибелью молодых деревьев предположительно из-за низкой освещенности под пологом. Число теневыносливых деревьев (*Ulmus glabra*, *Tilia cordata*, *Acer platanoides*), напротив, увеличилось, а средний диаметр возрос незначительно или даже уменьшился, что свидетельствует об успешном возобновлении этих видов под пологом. Полученные данные актуальны для исследования динамики пространственной структуры лесов как модели естественной сукцессии.

Ключевые слова: Darwin Core, GBIF, мезофитные широколиственные леса, оценка качества данных, постоянная пробная площадь