DYNAMICS OF ANNUAL RADIAL INCREMENT OF SCOTS PINE (*Pinus sylvestris* L.) GROWING IN FOREST ECOSYSTEMS ON THE SHORES OF LAKES

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Abstract

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The dendrochronological research of Scots pine (*Pinus sylvestris* L.) growing in the vicinity to kettle lakes Kreivasis (closed lake) and Duobulis (flowing lake) was carried out in 2000-2002. The study is aimed to estimate the influence of water level fluctuations to the formation of radial increment of trees and to create series of radial increment of *Pinus sylvestris* L. trees growing on the shorelines and in control stands.

It was estimated that annual radial increment of pines growing on the shorelines of lake Kreivasis slightly negatively correlates (r = -0.21; P = 0.95) with the increase in water level. During the humid period, when water level remains high for quite a long time, many pine trees growing in the lakeshore zone die. The increase of radial increment of pines on the shorelines of Kreivasis is typical during the periods with small amount of precipitation (in 1932, 1937–1939, 1964–1977, 1997–2002). The annual radial increment of the control stand of lake Kreivasis, the stand on the shorelines of lake Duobulis and its control stand have decreased in the periods with small amount of precipitation as well. There are plenty of nutrient substances (various sediments came into it together with the water and most of them settle down in the lake from higher waters) on the shores of the open lake Duobulis. Meanwhile on the shores of the flowing water lake Kreivasis only the remains of water plants are accumulated.

Key words: Scots pine, radial increment, closed and flowing water lakes, water level

Introduction

Forests as a unit of all plant layers together with living organisms belonging to various taxonomic groups and abiotic components of ecosystem occurring in the habitat make up an ecosystem of an average rank. Forests at lakesides are complicated ecosystems, the

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biotic (species of plants, animals and other organisms) and abiotic (relief, climate, etc.) components of which vary with respect to both space and the time. In addition, forest is directly related with the problems of environment and consumption of natural resources: sustainable development of ecosystems, preservation of biological diversity, and increase of production. It is very important to estimate how the limiting factors of anthropogenic and natural origin influence the condition of ecosystems. Data on ecosystem functioning are necessary to compare them with respect to changes in time and environment as well as indicate extreme limits of ecological amplitudes of plant species and communities.

As far as annual tree rings accumulate information about phenomena taking place in forest ecosystems and their environment (Fritts, 1987; Eckstein, 1989), they can serve as the natural monitors (Schweingruber, 1989). Information provided by tree-ring width and structure allows objective evaluation of changes taking place in the natural environment and in specific forest ecosystems (Schweingruber, 1989, 1996; Lovelius, 1997; Stravinskiene, 2002 etc.). Thus, lately dendrochronological studies are more and more broadly applied for the environmental state assessment and forest research, for the indication of environmental state changes, for the assessment of efficiency of anthropogenic rearrangements in forest ecosystems, even for the reconstruction of past climatic conditions.

Application of dendrochronological methods in forest research allows to estimate the efficiency of forest drainage, fertilization, felling, to determine retrospectively seed years of the former forests and to foresee them in the future, to forecast mass diseases and invasions of pests in the forests. These methods can serve for the estimation of natural environmental state and climatic background dynamics, including the impact of lake water level fluctuations to the formation of annual radial increment of trees growing at lakesides. Up till now very few studies have been devoted to radial increment studies of stands growing on shorelines of lakes.

Present dendrochronological study is aimed to estimate the dynamics of annual radial increment, the influence of water level changes on the formation of Scots pine (*Pinus sylvestris* L.) radial increment and to create dendrochronological series for sample (growing on the shorelines) and control stands.

Material and methods

Experimental material for the dendrochronological analysis on the shorelines of kettle lakes Kreivasis and Duobulis (Utena and Rudesa forest districts in Utena forest enterprise, Moletai region, Lithuania) was collected in 2000-2002. Both lakes, which have formed on a hilly morainic relief in the post-glacial period by thermokarsten processes, are located next to each other. Lake Kreivasis is a closed water lake; i.e. it has no sources or tributaries, and is sustained only by surface water, while Duobulis is a lake with flowing water and a small amount of nutrient substances. 90, 85, 65 and 60 year-old one-storey pine forests of 0.7-0.9 stocking level growing on the shorelines in *Pinetum vaccinio-myrtillosum* forest types were chosen as research objects. Density of sample and control forest stands is 0.7, prevailing Kraft class – II, mean height – 25 m and mean stem diameter – 25-30 cm.

Seeking to ascertain the influence of water level on radial increment of trees growing in the environment of lakes of different types, drilled material was taken from trees growing at places closest to water – over-water terrace (0.5-1.0 m above the lake water level). Seeking to eliminate the influence of various exogenous factors on radial increment, control stands growing in higher parts (2.0-3.0 m above the lake water level) of the over-water terrace were chosen as control stands. Tree growth altitude was established at root collar by the means of geometric levelling.

Wood samples (boreholes) were taken using Pressler's borer in accordance to the methods of collecting experimental material for dendrochronological research (Stravinskiene, 1994). In the coastline pine stands of lake Kreivasis there were taken 30 and farther from the lake 30 control samples, while in the coastline pine stands of lake Duobulis – respectively 25 and 25 control samples of Scots pine (*Pinus sylvestris* L.). The total amount of wood samples is 110. The level NIL-2 to run a level of every tree growth site within the accuracy of 1 cm was used. Four soil profiles were taken and described.

Tree ring widths were measured using a LINTAB tree – ring measuring table with a TSAP 3.14 computer programme (measurement accuracy – ± 0.01 mm). Dating quality control was performed by using the COFECHA 3.00P program. Tree ring series of asynchronous growth or with possible dating problems were eliminated from the next stages of the research. Each tree ring series obtained from an individual tree was indexed separately. The indexing was carried out in two stages (Holmes, 1994). By using a negative exponential curve and a liner regression as well as after applying the spline function, age curve was removed. The programme CHRONOL from the ITRDB Program Library compiled in the University of Arizona by R.L. Holmes was used for the analysis of the obtained primary data. By using the COFECHA programme the cross-dating quality control was performed. Local chronologies for each sample and control stands were constructed as biweight robust means (Cook et al., 1990). Using the CHRONOL programme, tree age trend was eliminated.

For de-trending, chronology computation and statistical analysis of the ARSTAN programme was used. For the statistical analysis (correlation, regression), the programme STATISTIKA (Vencloviene, 2000) has been applied.

Results and discussion

Dynamics of Scots pine radial increment on the shores of lakes

Humidity is one of the most significant exogenic factors, influencing tree growth, especially those, occurring in coastline stands. To investigate the impact of water level fluctuations upon the radial increment of pine growing on the shorelines, the data on Kreivasis and Duobulis lakes water level measurements obtained in 1977–2001 were used. Observations of water level were carried out in summer time. According to the data of observation, the amplitude of Kreivasis lake water level ranged from 154.17 m to 155.07 m, while in lake Duobulis – from 152.67 m to 153.00 m above sea level (Fig. 1). The highest water level of lake Kreivasis was registered in 1992 and in lake Duobulis – in 1994.

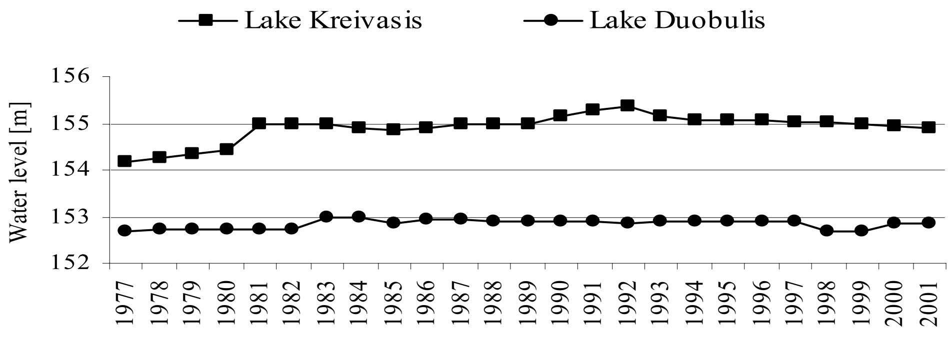

Fig. 1. Long-term water level fluctuations of Kreivasis and Duobulis lakes

Dendroecological research has revealed that the annual radial increment of pines in the coastline of lake Kreivasis slightly negatively correlates ($r = -0.21$; $P = 0.95$) with the increase in water level.

This relationship can be expressed by a simple equation:

$Y = 2907.9 - 18.30\,x$;

where Y – indices of annual radial increment, %; x – the altitude of lake water level, m.

During the humid, period when the water level remains high for quite a long time, many pine trees growing on the coastline die. The decrease of annual radial increment was observed in the periods 1927-1930, 1941-1944, 1952-1955, 1962, 1979-1989, 1992-1993, 1996 (Fig. 2).

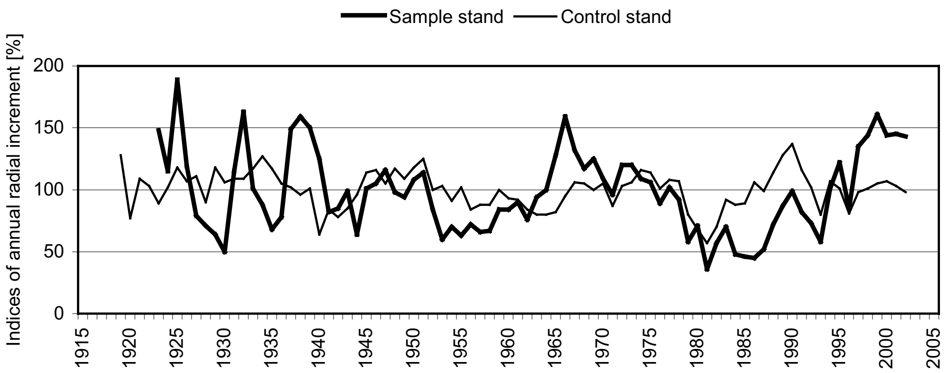

Fig. 2. Dynamics of annual radial increment dynamics of Scots pine (*Pinus sylvestris* L.) stand growing on the shorelines of lake Kreivasis and in control stand.

It shows that with the increase of water level in the lake, groundwater level on the coastline stands has increased. If groundwater level keeps higher for a longer period, the roots of trees in the coastline start growing under anaerobic conditions. Reduced aeration worsens the conditions of normal growth. It is reflected in lower annual radial increment. A distinct impact of water level dynamics was registered in the radial increment of a part of sample trees on the shorelines of lake Kreivasis ($r = -0.63$–-0.87; $p < 0.05$). In 2001 these trees grew 0.33–0.96 m above the lake water level. The correlation of annual radial increment of control trees in the environment of lake Kreivasis with water level fluctuations was low and positive.

A well-defined increase of radial increment of pines nearby Kreivasis lake is typical during the periods with small amount of precipitation (in 1923–1925, 1932, 1937–1940, 1965–1969, 1972–1973, 1997–2002). Annual amount of precipitation was rather low in these periods.

Annual radial increment of the control variant of Kreivasis lake sample stands as well as that of control pines in lake Duobulis environment was decreasing in the periods when the amount of precipitation was lower. In 1910, 1935–1936, and 1945 radial increment of trees became higher when the amount of precipitation increased. It seems likely, that the periods of dominating cold winters, springs and cool summers negatively influenced the formation of radial increment (1929, 1940–1941, 1953, and 1979). The fluctuations of pine annual radial increment in the coastline and control stands of lake Duobulis are presented in Fig. 3.

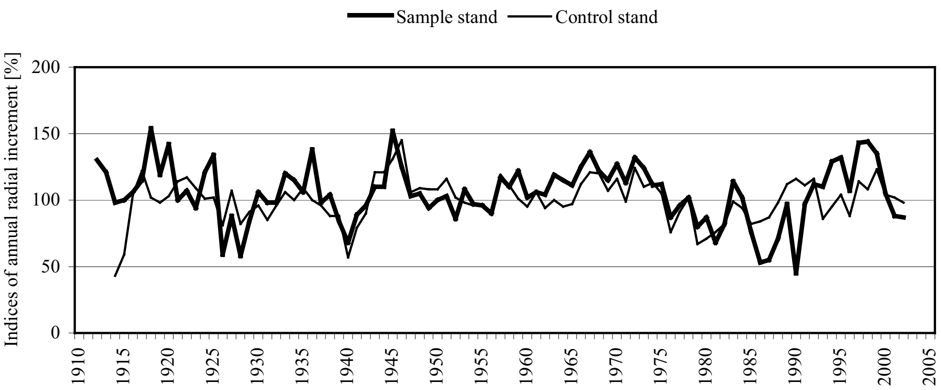

Fig. 3. Dynamics of annual radial increment of Scots pine (*Pinus sylvestris* L.) forest stand growing on the shorelines of lake Duobulis and in control stand.

The succession that is taking place in the environment of lake Kreivasis is not stable. Trunks of decomposed Scots pine trees occur abundantly in the bogged-up coastline. In wet (humid) periods, when high water level is sustained for a sufficiently long time, a lot of pine trees growing on the shorelines die. Degradation of this ecosystem is characteristic in humid periods, recovery – in dry periods.

Annual radial increment of the control stand of Kreivasis lake, of the stand at Duobulis lakeside and its control stand has decreased in dry periods with small amount of precipitation as well.

Chronologies of Scots pine radial increment

Synchronous fluctuations of radial increment of trees determined by dendroecological and dendrochronological study and expressed in chronologies enlarge the possibilities of this field in ecology science. Tree ring chronologies of high precision reflect past ecoclimatic changes. It can be used as one of methods to estimate the condition of forest ecosystems and for the indication of natural environmental condition changes (Stravinskiene, 1997, 1998, 2002)).

The chronology of radial increment indices of sample pine stand growing in the coastline of lake Kreivasis is presented in Table 1.

T a b l e 1. Chronology of Scots pine (*Pinus sylvestris* L.) sample stand growing on the shorelines of Kreivasis lake 0.5–1.0 m above the lake water level

Decade	Year									
	0	1	2	3	4	5	6	7	8	9
	Indices of annual radial increment [%]									
192	–	–	–	148	115	189	119	79	71	64
193	50	115	163	101	88	68	78	149	159	150
194	125	82	85	99	64	101	105	116	98	94
195	108	114	84	60	70	63	72	66	67	84
196	84	90	76	94	100	128	159	132	117	125
197	109	96	120	120	109	106	90	102	92	58
198	71	36	57	70	48	46	45	52	72	87
199	97	82	74	58	101	122	85	135	144	161
200	144	145	143	–	–	–	–	–	–	–

The chronology of the control pine stand (Table 2) growing at Kreivasis lakeside 2.0–3.0 m above the lake water level covers a 84-year period, starting in 1919 and lasting till 2002.

T a b l e 2. Chronology of Scots pine (*Pinus sylvestris* L.) control stand growing at lakeside Kreivasis 2.0–3.0 m above the lake water level

Decade	Year									
	0	1	2	3	4	5	6	7	8	9
	Indices of annual radial increment [%]									
191	–	–	–	–	–	–	–	–	–	128
192	77	109	103	89	102	118	107	111	90	117
193	106	109	109	116	127	116	105	102	96	101
194	64	84	78	85	96	114	116	105	117	109
195	118	125	100	103	91	101	84	88	88	100
196	93	92	84	80	80	82	95	106	105	100
197	105	87	103	106	116	114	101	108	107	80
198	68	57	70	92	88	89	106	99	114	128
199	137	116	102	80	107	101	81	98	101	105
200	107	103	99	–	–	–	–	–	–	–

Two next chronologies reflect the annual radial increment dynamics of pine trees growing on the shores of lake Duobulis. Chronology of sample pine stand growing 0.5–1.0

m above the lake water level chronology includes a 90-year period – since 1912 till 2002 (Table 3).

T a b l e 3. Tree ring chronology of Scots pine (*Pinus sylvestris* L.) sample stand, growing in the coastline of Duobulis lake 0.5–1.0 m above the lake water level

Decade	Year									
	0	1	2	3	4	5	6	7	8	9
	Indices of annual radial increment [%]									
191	–	–	130	121	98	100	106	116	154	119
192	142	100	107	94	121	134	59	88	58	84
193	106	98	98	120	118	106	138	98	104	84
194	68	89	96	110	110	152	126	103	105	94
195	100	103	86	108	97	96	90	117	110	122
196	102	106	104	119	115	111	125	136	122	115
197	127	113	132	124	111	112	87	96	102	80
198	87	68	82	114	102	76	53	55	71	97
199	45	97	112	110	129	132	107	143	144	135
200	105	88	87	–	–	–	–	–	–	–

The chronology of radial increment of lake Duobulis control stand growing 2.0–3.0 m above the lake water level reflects Scots pine growth in 1914–2002 (Table 4).

T a b l e 4. Chronology of Scots pine (*Pinus sylvestris* L.) control stand at lakeside Duobulis growing 2.0–3.0 m above the lake water level

Decade	Year									
	0	1	2	3	4	5	6	7	8	9
	Indices of annual radial increment [%]									
191	–	–	–	–	43	59	104	122	102	98
192	103	114	117	109	101	102	81	107	82	91
193	96	85	96	106	100	109	100	96	88	88
194	57	79	90	121	121	131	145	106	109	108
195	108	116	102	98	96	96	91	119	111	101
196	95	106	94	100	95	97	112	121	120	107
197	116	99	124	110	113	105	76	91	102	67
198	71	76	82	99	94	82	84	87	98	112
199	116	111	116	86	95	104	88	114	108	123
200	104	102	98	–	–	–	–	–	–	–

As it was noticed by authors (Fritts, 1987; Lovelius, 1997; Juknys et al., 2002; Stravinskiene, 2002, etc.) who have analysed the relationship between radial increment of trees and the processes taking place in their environment, the main reason that influenced tree growth rate (tree ring width) is the integrated influence of complex factors. It comprises both internal (genetic peculiarities, hereditary characteristics) and external (nutrients, light, warmth, humidity, aeration, etc.) factors that are important for tree radial growth.

Conclusions

1. Humidity is one of the most significant factors predisposing tree growth in the coastlines of lakes. Slight negative impact (r = -0.21; P = 0.95) of the increase in water level on annual radial increment of Scots pine trees growing in the coastline of lake Kreivasis was established. The decrease of annual radial increment was observed in the periods 1927–1930, 1941–1944, 1952–1955, 1962, 1979–1989, 1991–1993 under humid conditions. A lot of pines growing in the coastline zone die under humid periods, when high water level is held for a rather long period.
2. Scots pine radial increment of both control variants and that on the shoreline of flowing water lake Duobulis is supposed to be compared not with the lake water level, but with amount of atmospheric precipitation.
3. Particularly evident increases of Scots pine annual radial increment in the environment of lake Kreivasis were ascertained in the periods of lower precipitation amounts (1923–1926, 1932, 1937–1940, 1965–1969, 1972–1974 and 1997–2002).
4. Annual radial increment under lower precipitation amount decreased in the control variant of lake Kreivasis environment and in the coastline as well as in the control Scots pine stands of lake Duobulis.

Translated by the authors

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Stravinskiene V., Stasytyte I.: **Dynamika ročného radiálneho prírastku u borovice lesnej (***Pinus sylvestris* L.**) rastúcich v lesnom ekosystéme na brehu jazier.**

Dendrochronologický výskum u borovice lesnej (*Pinus sylvetris* L.) rastúcej v blízkosti ľadovcového jazera Kreivasis (bezodtokové jazero) a Duobulis (odtokové jazero) sme uskutočnili v rokoch 200-2002. Prácu sme sústredili na odhad vplyvu kolísania hladiny vody na vytvorenie radiálneho prírastku stromov a na vytvorenie skupiny stromov *Pinus sylvestris* L. na brehu a na kontrolných porastoch.

Vypočítali sme, že ročný radiálny prírastok borovice rastúcej na brehu jazera Kreivasis mierne negatívne koreluje (r = -0.21, P = 0.95) so zvýšením hladiny vody. Počas vlhkého obdobia, keď hladina vody ostáva dosť dlho vysoká, odumiera veľa borovíc rastúcich v brehovej zóne. Zvýšenie radiálneho prírastku borovíc na brehu jazera Kreivasis je typické počas obdobia s nízkymi zrážkami (roky 1932, 1937-1939, 1964-1977, 1977-2002). Ročný radiálny prírastok kontrolného porastu na jazere Kreivasis, porastu na brehu jazera Duobulis a jeho kontrolného porastu sa znížil aj v obdobiach s nízkymi zrážkami. Na brehoch odtokového jazera Duobulis je veľa výživných látok (rôzne sedimenty prichádzajú spolu s vodou a väčšina z nich sa usadí). Na brehoch jazera Kreivasis sa akumulujú iba zvyšky vodných rastlín.