Rožnovský, J., Litschmann, T., (eds): Mendel a bioklimatologie. Brno, 3. – 5. 9. 2014, ISBN 978-80-210-6983-1

Early onset of spring phenological phases in the period 2007-2012 compared to the period 1931-1960 as a potential bioindicator of environmental changes in The National Nature Reserve Boky (Slovakia)

Jozef Zverko[1], Jaroslav Vido[1], Jana Škvareninová[2], Jaroslav Škvarenina[1]

1) *Department of Natural Environment, Faculty of Forestry, Technical university in Zvolen, ul. T. G. Masaryka 24, 960 53 Zvolen, Slovakia*
2) *Department of Applied Ecolog, Faculty of Ecology and Environmental Sciences, Technical university in Zvolen, ul. T. G. Masaryka 24, 960 53 Zvolen, Slovakia*

Abstract

Plants phenology responses is a reliable marker of the climate conditions. Since we see significant changes of regional climate patterns, serious question of phenological responses to this change is in the place. Because of this, our case study aims on comparison of spring phenophases onset in The National Nature Reserve (NPR) Boky in the period 2007 – 2012 with the historical records of the surrounding areas between years 1931 – 1960. We evaluate four woody plant species i.e. European cornel – *Cornus mas L*., Blackthorn – *Prunus spinosa L*., Hawthorn – *Crataegus monogyna L*., European hazel – *Corylus avellana L*. and two phenological phases: flowering and unfolding. Our findings show significant shifts of spring phenophases onset to earlier dates. Thus the result imply significant influence of changed climate conditions on earlier onset of spring phenophases of above mentioned woody plants in the NPR Boky.

Key words: Phenology, climate change, old-growth forest, NPR Boky, Slovakia

Introduction

Phenological response of plants is a reliable marker of changing climate conditions (Chmielewski et Rötzer 2001). It is because of the physiological reaction of plants to seasonal and inter-annual changes of climatological factors i.e. air temperature represents as sum of daily temperature, insolation, precipitation and many others (White et al. 1997). Long-term systematic observation of the phenophases gives a possibility to estimate shifts in phenophases onset or end, what allows to assess an influence of changing climate conditions on the nature especially on the nature reservations (Bauer et al. 2014, Schwartz et al. 2003). However long-term phenological observations in natural reservations were previously carried out relatively rare. Therefore we have relatively weak information from many unique natural reservation i.e. NPR (National Nature Reservation) Boky located in the Kremnické vrchy mountains (Central Slovakia).

To fill this gap, phenological observations has started in the last decade (since 2007) in the NPR Boky (Pálešová 2009). However, although the phenological observations has been established, until now only six years of phenological observation were carried out. In addition, no reference phenological historical records from this specific natural reservations are available. The present paper try to solve this challenge with comparison of the available historical phenological observations around the area to our relatively short-term phenological records in the NPR Boky. Although we understand that the phenological observations in the NPR Boky has been carried out only for few years what is methodically imprecise, comparison with historical records brings scientific interesting findings regarding to plants phenological responses to changing climate conditions in this very unique piece of central European wild nature.

Materials and methods

Characteristics of the NPR (National Nature Reservation) Boky.

NPR Boky (area 176.49 hectares) is located on south oriented steep slopes of the Kremnické Vrchy Mountains near village Budča. Altitude range is between 280 – 589 m a. s. l. The NPR was declared in 1964 in order to protect one of the northernmost sites of thermophilic and xerophilous plant and animal species with the occurrence of interesting geomorphological formations: sea stone, rubble and Devil's Rock Mushroom Rock. The most valuable forests with Turkey oak (Quercus cerris L.) and other concomitant tree species have character of the old-growth forest (Korpeľ 1989). Illustration of the NPR Boky is depicted on Fig. 1

Fig. 1 Typical aspect of the old-growth forest ecosystem in the NPR Boky. In the middle of the figure is depicted our automatic weather station

Phenological observations

Phenological observations were carried out during the period 2007-2012 on research spot in NPR Boky located in the Kremnické vrchy mountains (central Slovakia). The research was carried out on forest trees of the following species: European cornel – Cornus mas L., Blackthorn – Prunus spinosa L., Hawthorn – Crataegus monogyna L., European hazel – Corylus avellana. Phenological observations were written down according to the guideline (Kolektív 1984) prepared by SHMU (Slovak Hydrometeorological Institute). This methodology is currently used for phenological monitoring of forest tree species in Slovakia.

Although observations were conducted during the entire growing season, we used only spring phenological phases (flowering and leaf unfolding) as average onset date within the period 2007-2012. It is because of the stronger influence of air temperature on plants spring phenological responses, comparing with remaining seasons. (Chmielewski et al. 2004, Sparks et Menzel 2002).

Historical phenological records were used from the study of Kurpelová (1972a,b). This study includes both phenological and climatological observations performed in Central Slovakia during the period 1931 – 1960. From the study we used average onset date of the phenophases between 1931 – 1960.

Climatological observations

Climatological observations at the locality Boky (512 m a. s. l.) were performed by automatic weather station EMS. Although the standard set of meteorological units (i.e. air temperature, precipitation, soil temperature, global radiation), only the air temperature was used because of the above mentioned major correlation of spring phenophases with air temperature. Also the findings of Zverko (2013) aimed on correlation between various meteorological units to the spring phenological responses of plants at the locality Boky indicates the major role of air temperature. As a reference station was used station Sliač (Slovak Hydrometeorological Institute) located 10 km northeast of our research stationary in Zvolenská kotlina walley (312 m a. s. l.).

Results

Historical temperature comparison

Since only 6 years of climatological and phenological observations carried out by our institution are available, we need to confirm suitability of reference station Sliač to our climatological observations at the station Boky by three steps. This comparison is also necessary because of the south oriented slope of the NPR Boky comparing to the reference station Sliač located in flatland area and also because of the different altitude.

First step aims to compare correlation of measured temperature between years 2007 – 2012 on the research spot Boky with reference station Sliač.

This comparison showed that measured temperature on our research spot Boky strongly correlates (R2=0,9989) with measured temperature at the station Sliač (Tab. 1, Fig. 2)

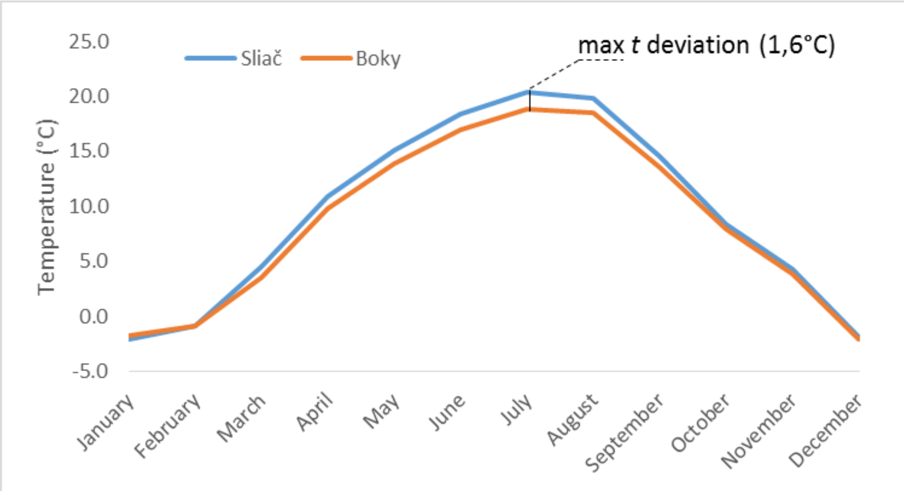

Fig. 2 Comparison between temperatures measured at the reference station Sliač and station at the research spot Boky (2007-2012)

Tab. 1 Average temperature at reference meteorological station Sliač and measured temperature at research spot Boky between years 2007 – 2012.

Station	Jan.	Feb.	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Sliač	-2.1	-0.9	4.6	10.9	15.1	18.4	20.4	19.8	14.6	8.4	4.3	-1.9
Boky	-1.7	-0.8	3.5	9.8	13.9	17	18.8	18.5	13.6	8	3.9	-2.1
Deviation	+0,4	+0,1	-1,1	-0,9	-1,2	-1,4	-1,6	-1,3	-1,0	-0,4	-0,4	-0,2

Correlation between these two stations allows to use historical records from the station Sliač for comparison of the two periods (1931 – 1960 and 1983 – 2012) in terms of discussion of increased temperature also in the area of our research spot Boky.

Thus the second step focuses on estimation of temperature increase comparing two periods 1931 – 1960 and 1983 – 2012 at the reference station Sliač.

Relatively strong temperature increase at the reference station Sliač has been found comparing this two periods (Tab. 2).

Tab. 2 Deviations of average monthly temperature at Sliač between the periods 1931 – 1960 and 1983 - 2012

Periods	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1931 - 1960	-4.4	-2	2.6	8.5	13.6	16.9	18.8	17.8	13.7	8.2	3.4	-1.1
1983 - 2012	-2.8	-1.3	3.4	9.5	14.5	17.4	19.5	18.8	13.9	8.5	3.2	-1.9
Deviation	1.6	0.7	0.8	1	0.9	0.5	0.7	1	0.2	0.3	-0.2	-0.8

Only during cold months November and December has temperature decreased. However comparison of the average monthly temperature within this two periods showed increase in temperature, especially significant during the months of spring phenophases (February to May).

The last step is to control whether the temperature during 2007 – 2012 is within the normal of 1983 – 2012 or whether the period 2007 – 2012 deviates from this long-term normal respectively. We see that the period 2007 – 2012 is not significantly deviated from the long – term normal of the period 1983 – 2012 (R2=0.998728) (Fig. 3). Thus our meteorological observations are not deviating from the long-term normal.

Based on the above presented three step test we argue, that our relatively short-term observations of climatological and phenological data from the locality Boky could be used in argumentation about the shift of spring phenological phases due to temperature increase in the previous decades.

Comparison of present phenological observations with historical records

As a source of historical phenological observation we used the publication of Kurpelová (1972 a,b). Because of the strong correlation in temperature values at the Sliač meteorological station (reference) with our station at Boky, we have used phenological observation from the Zvolen (2 km from Sliač station) as historical reference for our purpose. Phenological observations in Zvolen was carried out during the period 1931 – 1960.

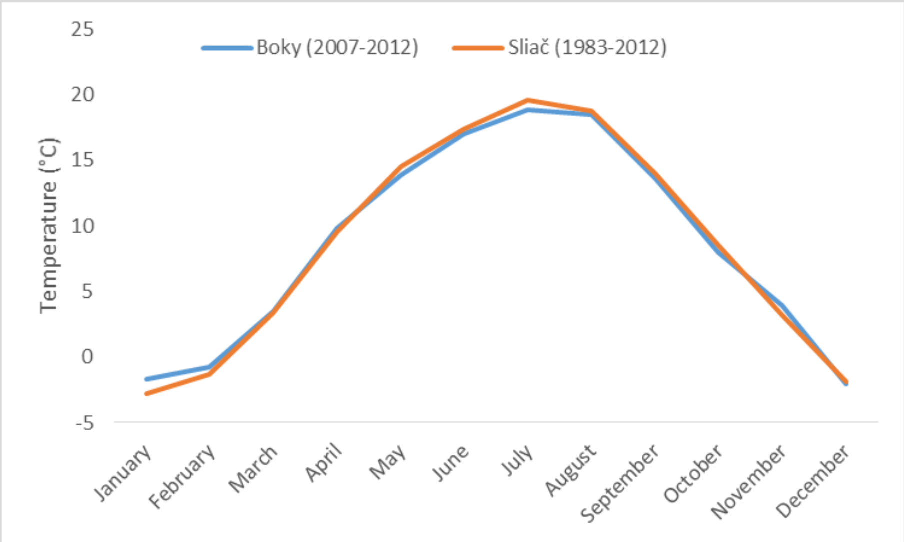

Fig. 3 Comparison between average monthly temperatures of the period 2007 – 2012 measured at the station Boky and long-term average temperature at the station Sliač (1983 – 2012).

Kurpelová et al. (1972) have detected average start day of the phase unfolding in Zvolen on April 18 for European Hazel and on May 4 for Blackthorn. Our findings from the locality Boky show that the average start day for European Hazel is on April 14 and for Blackthorn on April 17. This is a significant date shift what shows that the temperature increase in the last decades has strong influence on earlier onset of the unfolding in the area (Tab. 3)

Tab. 3 Detected average start day for phase unfolding at Boky within 2007 – 2012 and Zvolen 1931 – 1960

Locality	Hawthorn *Crataegus monogyna*	European hazel *Corrylus avellana*	Blackthorn *Prunus spinosa*	European cornel *Cornus mas*
Boky (2007 –2012)	April 9	April 14	April 17	April 21
Zvolen (1931 – 1960)	N/A	April 18	May 4	N/A

Significant shifts have also been detected comparing of the historical and present phenological observation of the flowering. Kurpelová (1972 a,b) found that the average start day of flowering in Zvolen in the period 1931 – 1960 was May 13 for Hawthorn, March 13 for European hazel, April 22 for Blackthorn and April 2 for European cornel. Our findings show that the flowering as well as the previously mentioned phase of unfolding started earlier in the period 2007 – 2012. On May 6 by Hawthorn, March 3 by European hazel, on April 13 by Blackthorn and on March 27 by European cornel (Tab 4).

Tab. 4 Detected average start day for phase flowering at Boky within 2007 – 2012 and Zvolen 1931 – 1960

Locality	Hawthorn *Crataegus monogyna*	European hazel *Corrylus avellana*	Blackthorn *Prunus spinosa*	European cornel *Cornus mas*
Boky (2007 – 2012)	May 6	March 3	April 13	March 27
Zvolen (1931 – 1960)	May 13	March 13	April 22	April 2

Discussion

Our findings indicate that the temperature increase has a significant influence on earlier onset of spring phenological phases of all the above discussed species. This facts correspond with findings of authors over the Europe. Sparks et al. 2005 indicate that in Sussex UK was the average start day of the flowering by Hawthorn on May 27 in the period 1980 – 1989 whereas in the period 1990 – 2000 flowering appeared on May 15. The same trend has been observed in Suffolk UK where the first flowering date of Hawthorn was observed on May 11 in the period 1930 – 1940, while in the period 1998 – 2005 shifted this date on April 28 (Sparks et al. 2006). The same trend is observed also on the continental Europe. Ahas et al. (2002) indicate significant speed up in spring phenological phases over the whole Europe in the last fifty years. The same situation has been detected in Swiss by spring phenophases of European hazel (Defila et Clot 2001). The most recent research of Pálešová et Snopková (2010) from the central Slovakia also confirmed that increased temperature in the last decades has significant influence on earlier onset of spring phenophases. Thus higher air temperature in spring months lead in earlier onset of spring phenological phases. Although we understand that our findings based only on six years of continual measurements and observations should be used in discussion of the climate change influence only very carefully, we see that the same trends are observed over the whole Europe. Therefore we argue, that if the temperature increase will continue in the area (Lapin et Melo 2004), early onset of phenophases comparing to the previous records will be a fact. This could bring problems and devastation to the ecosystems of the NPR Boky due to e.g. late frost situations (Dittmar et al. 2006).

Conclusion

Our findings confirm that the temperature increase has significant impact on earlier onset of spring phenological phases in all the discussed woody plant species. We understand that our climatological measurements were carried out only during six years what limits our findings as a significant signal of climate change impact. However our case study shows that increased temperature significantly speed up the onset of spring phenological phases. This facts with anticipated air temperature increase gives evidence that ecosystems in our study area will probably face this problem in the future. Thus our contribution show that early onset of spring phenological phases in the NPR Boky in the period 2007 - 2012 could be carefully discussed as a potential indicator of changing climate conditions. However to be sure we need to continue in climate and phenological observations in ecosystems of the NPR Boky.

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Acknowledgement

This contribution was supported by research grants of The Ministry of Education, Science, Research and Sport of the Slovak Republic: VEGA 2/0101/14, VEGA 1/1130/12,VEGA 1/0281/11, VEGA 1/0463/14 and by grant of the Slovak Research and Development Agency APVV 0423-10, APVV 0303-11 and APVV 0480-12.

Summary

Predkladaný príspevok sa zameriava na zhodnotenie posunu jarných fenologických fáz (kvitnutie a zalisťovanie) lesných drevín (drieň obyčajný – *Cornus mas L*., trnka obyčajná – *Prunus spinosa L*., hloh obyčajný – *Crataegus monogyna L*., lieska obyčajná – *Corylus avellana L*.) v národnej prírodnej rezervácií Boky (Kremnické vrchy) ako potenciálny bioindikátor zmien prostredia vo vzťahu ku klimatickej zmene. Výsledky poukázali na otepľujúci sa charakter klímy porovnaním období 1931 – 1960 a 2007 – 2012 resp. v prípade referenčnej stanice Sliač 1983 – 2012. To viedlo k skoršiemu nástupu vyššie spomenutých fenologických fáz všetkých lesných drevín signifikantne do skorších termínov u oboch sledovaných fenofáz. Aj keď si uvedomujeme, že naše pozorovania sú relatívne krátkodobé, dokazovanie vzťahov medzi referenčnou stanicou na Sliači a našou automatickou meteorologickou stanicou v NPR Boky nám dávajú silný argument, že zistené posuvy nie sú iba náhodilou fluktuáciou, ale náznakom trendu posunu jarných fenofáz vo vzťahu k neustále rastúcej teplote vzduchu v regióne. Avšak pre definitívne a štatisticky preukazné tvrdenie bude potrebné naďalej pokračovať vo fenologickom výskume v NPR Boky.

Contact:

Ing. Jaroslav Vido, PhD.

Department of Natural Environment, Faculty of Forestry, Technical university in Zvolen, ul. T. G. Masaryka 24, 960 53 Zvolen, Slovakia

+421 (45) 520 6215, email: vido@tuzvo.sk