Changes of Phenological Cycles in South Korea

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1. Introduction

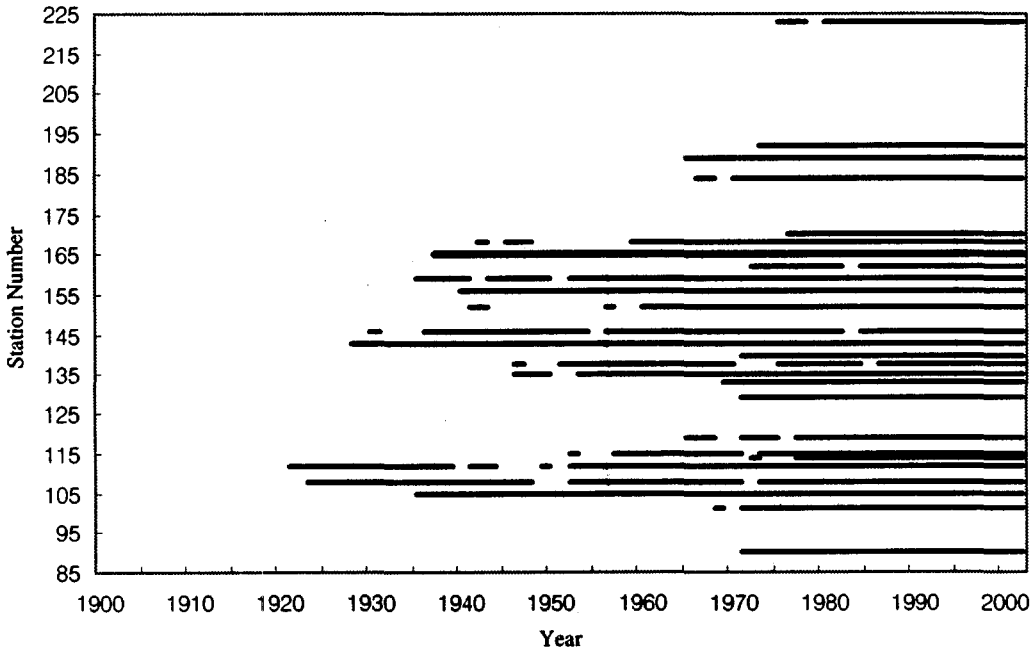
A recent rise in mean global temperatures suggests a shift in the temporal cycles of natural seasons. The impacts of warming trends can alter the temporal and spatial distribution of flora and fauna. Especially, phenological cycles are very sensitive to the occurrence of alternation of hot and cold seasons. Phenological calendars reflect the natural seasonality. In more detail, phenological cycles affects agriculture and human health (i.e. the amount of fruit production and allergies), as well as tourism industries like flower fairs or festivals. As the warming trend has been intensified in the 1990s, many fauna-related researches such as bird migration or its lay-egging (Sparks, 1999; McCleery et al, 1998) and insect life cycles (Roy et al, 2003) have been conducted in other countries. In addition, plant growth and flowering (Fitter et al, 2002, Defila et al, 2001) has also become one of highly spotlighted research topics in other countries in terms of global warming. For instance, the Global Phenological Monitoring (GPM) was initiated in 2002 as the result of this effort. The GPM started to gather the phenological data internationally in order to assess the impact of warming on the ecological cycles (http://www.dow.wau.nl/msa/gpm/). Nevertheless, in Korea, there are few researches focusingon the assessment of changing ecosystem in the process of global warming.

In fact, Korean Meteorological Administration has a solid long-term historical flowering dataset for several species recorded since the early part of the 20th century. Thus, this paper, based on the long-term flowering data, examined the timing of spring phenophases related to natural seasonal cycles such as sprouting, beginning of flowering, and full blooming during the last several decades in South Korea. Ultimately, this research may play an important role in supporting the GPM's program in that it offers a solid local report about Korean phenological trends to the Intergovernmental Panel of Climate Changes (IPCC). Even domestically, this research may be able to show the potentials of flowering data as a biological proxy indicator not only to evaluate the impact of global warming on the ecosystem but also to predict the magnitude of its changes.

2. Data and methods

Korean Meteorological Administration has observed the phenophase of standard trees planted in weather stations since approximately in the 1920s. Fig. 1 summarizes the period of flowering record for the Forsythia in each weather station during the 20th century as an illustration. There are some missing data because of Korean war or relocation or changes of observers so

that this research tried to summarize the general trend emerged in all of weather stations, because, even in the same area, the flowing time varies, having to do with its species, its number, and environment. This research converted the flowering date from month and day system into the Julian day scale and drew time series graphs. The species of flowers analyzed in this research are popular ones across the country: the Forsythia, the Azalea, and the Pear. In terms of climate components relevant to phenological cycles, temperature in February and March is known as the major factor to determine the onset of phenophase for the Forsythia and the Azalea. Additionally, the sunshine and rainfall also influence the determination of flowing time (http://www.weekend21.com/season/spring/2003_flower.hwp). Thus, this research intended to analyze the trends of daily maximum, daily mean, and daily minimum temperatures in January, February, March, and April at the first stage.



90	Sokcho	119	Suwon	146	Jeonju	170	Wando
101	Chuncheon	129	Seosan	152	Ulsan	184	Jeju
105	Gangneung	133	Daejeon	156	Gwangyju	189	Seogipo
108	Seoul	135	Chupungyeong	159	Busan	192	Jinju
112	Incheon	138	Pohang	162	Tongyeong	223	Chungju
114	Wonju	140	Gunsan	165	Mokpo		
115	Uleungdo	143	Daegu	168	Yeosu		

Figure 1. the period of flowering observation for the Forsythia in Korean Meteorological Administration

3. Natural seasonal cycles and flowering timing

According to the analysis of daily temperatures based on the threshold of natural seasonal cycles suggested by Lee (1973), Spring and summer started earlier in the year by 16-23 days and 7-13 days respectively, while autumn finished later by 6-26 days in the 1990s than in the 1920s. As a result, the period of winter in the 1990s was 22-49 days shorter than in the 1920s, while spring and summer became longer by 6-16 days.

Fig. 2 is an illustration of time series of flowering Julian date for the Forsythia since in the 1920s in six regions of South Korea. We can notice that it has spiral shape in the clockwise, which means the flowering time has become earlier in the late portion of the 20th century in Korea. The comparison of flowering Julian date between before and after 1990 shows that Forsythia (Azalea) flowered significantly earlier by 6 days (8days) (Table 1). The flowering time for the Pear shows slight earlier trends by 4days.

We also constructed a multiple regression model to predict the flowering date by using the number of Ice day (ID) and Frost day (FD) before flowering as follows:

$$\text{Forsythia Julian date} = 63.63 + 0.36 \times ID + 0.26 \times FD \qquad (R\text{-square: } 0.72)$$

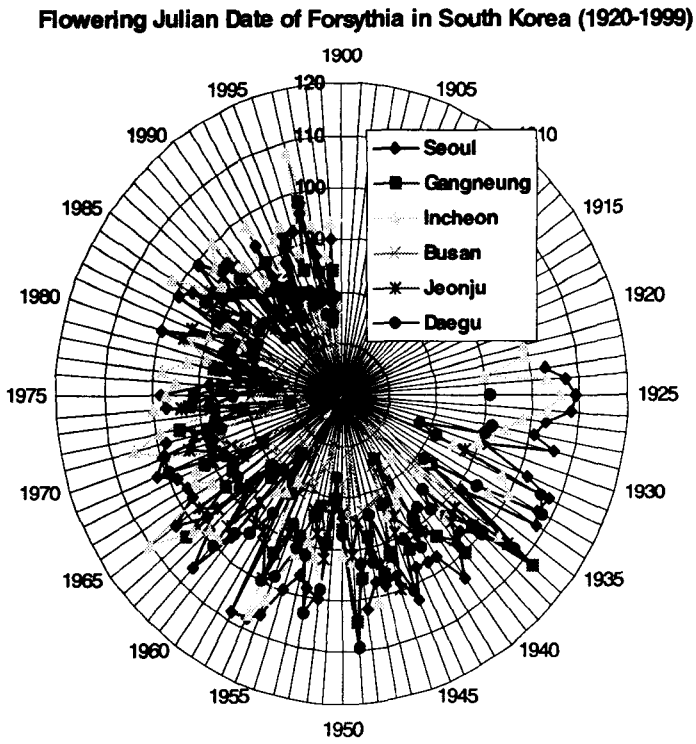


Figure 2. the change of flowering time of the Forsythia in South Korea during the 20th century

Table 1. the comparison of flowering Julian date before and after 1990 in South Korea

Components	Regon	Average*	S. D.**	Average	S. D.	Difference***
Forsythia	Gangneung	87.7	7.9	85.8	6.1	-1.9
	Seoul	97.7	8.0	87.8	6.7	-9.9
	Incheon	93.7	7.4	92.9	6.6	-0.8
	Daegu	88.7	9.2	77.6	4.2	-11.1
	Jeonju	88.8	8.0	84.5	6.1	-4.3
	Busan	77.5	6.4	73.9	4.1	-3.6
	Korea	89.4	9.9	83.8	8.4	-5.6

* Average: averaged date,** S.D.: standard deviation,*** Difference: Julian date before 1990 minus that after 1990

4. Conclusion

This research examined the changes of natural season and flowering date in South Korea during the 20th century. Major significant findings are as follows; First, the onset of spring in the 1990s became earlier by 6-23days compared with that in the1920s. Second, the flowering Julian date for each species became earlier in the 1990s (Forsythia: 6days, Azalea: 8days, and Pear: 4days) than in the previous decadesThird, we found the possibility to develop a prediction model of flowering time by using climate components.

For future studies, it is necessary to investigate the impact of urbanization on the earlier flowering. We should also develop a prediction model of domestic fruit production or of the occurrences of allergic patients in reference to the changes of flowering time.

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