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Examining circannual rhythm of tree phenology on individual and community scales in the temperate zone of China

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Tree phenology in the temperate zone has recently caused extensive concern because it can sensitively indicate and feedback to climate change. However, most existing studies have focused on relationships between specific phenophases and preceding meteorological factors in terms of inter-annual variation but neglected their circannual rhythm. Whether the circannual rhythm exists in different plant species and phenophases at individual and community scales and how a phenophase date can influence the occurrence date of the same phenophase after a one-year-cycle remains unknown. Hence, we analyzed the recurrence intervals of the start date of leaf unfolding and the end date of leaf fall of Salix matsudana, Ulmus pumila, Populus simonii and Prunus armeniaca at individual scales from 1981 to 2012, and the one-year cycles at community scales from 1982 to 1996 using correlation analysis and spectrum analysis as well as the corresponding daily photoperiod, temperature and precipitation data. Results show that multiyear mean recurrence intervals of the start date of leaf unfolding for the four species are between 363.6 and 366.8 days with standard deviations ranging from 2.2 to 14.2 days, while multiyear mean recurrence intervals of the end date of leaf fall are from 363.6 to 368.3 days with standard deviations between 2.9 and 17.1 days. Inter-annual variation of the circannual rhythm in phenological dates are smaller than that of the circannual rhythm in the first and last dates of threshold temperatures. Moreover, an earlier occurrence date of a phenophase in the current year may corresponds to a longer recurrence interval, and consequently leads to a later occurrence date in the next year, and vice versa. The negative feedback mechanism may slightly counterbalance the advancing and delaying trend resulting from climate warming. With respect to community phenology, phenological frequency curves show two bell-shaped sub-cycles within a year corresponding to spring and autumn phenological changes. Meanwhile, pentad mean photoperiod, air temperature and pentad accumulative precipitation display a dominant cycle of about 365 days. Thus, the circannual cycle of community phenology are synchronized with the circannual climatic cycle. Further analysis shows that the phase position of changing rate in photoperiod and air temperature in northern stations is earlier than that of spring phenological frequency, while the phase position of changing rate in photoperiod and air temperature in southern stations is earlier and later than that of spring phenological frequency, respectively. Contrarily, the phase position of changing rate in photoperiod and air temperature in northern stations is earlier and later than that of autumn phenological frequency, respectively, whereas the phase position of changing rate in photoperiod and air temperature in southern stations is earlier than that of autumn phenological frequency. Overall, the circannual rhythm of tree phenology at individual and community scales is the result of long-term adaptation of trees to environment. Here, photoperiod plays an important role in regulating tree's endogenous biological clock for growth and senescence, while temperature is crucial for adjusting specific phenological occurrence dates of trees, so that they can survive during cold season and use resources efficiently.