Comparative review of phenological events observed by academician P.S. Pallas in Transbaikalia in the second half of the 18th century

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Abstract. This article analyses the phenological data about the flowering of some plant species obtained by P.S. Pallas in Transbaikalia during his academic expedition in 1772. For seven plant species, a noticeable shift in modern flowering phases to earlier dates is shown.

1. Introduction
The study of global climatic processes is currently one of the most important areas of natural science research. Climatic changes are most rapidly manifested in the continental regions. Over the past 60 years in Transbaikalia, the average annual air temperatures have risen by 1.8°C (1.2–2.7°C in different parts of the region, twice that across the planet as a whole) \cite{1}.

Consequently, the indirect proof of climatic changes is a time shift of various processes occurring in wildlife. A special role is played here by the materials of phenological observations, even though they are not always systemic in nature and usually cover relatively short periods of time. The most valuable information concerns distant time periods, even though they are usually fragmentary.

2. Materials and methods
This study was based on the information of academician Peter Simon Pallas about the dates of some phenological phenomena in Transbaikalia. This information was published by the author in the book "Journey through various provinces of the Russian state" \cite{2}. The described data were collected during his academic expedition in 1772 and represent the first phenological materials for the territory of Transbaikalia.

In his work, Pallas mentions about 50 plant species that he observed in Transbaikalia, but the exact flowering phase is indicated for only a few species, which were used in this work. Cited in the book by Pallas, the dates were recalculated considering the peculiarities of the Julian calendar.

The comparison of one-time (for one year) observations by Pallas with modern data was complicated by the fact that we do not know the peculiarities of the weather in spring-summer 1772. At the same time, the scientist's records do not contain any information about extreme weather conditions during his stay in Transbaikalia.
The data submitted by Pallas on plant phenology were compared with later data from the middle of the 20th century [3, 4] and late 20th to early 21st centuries [5]. Along with literary information, recent phenological data were provided, and as additional comparative material, phenological data on the flowering of plants in the Ulan-Ude Urban Area (Buryat Republic) were given [6].

### 3. Results and discussion

The first of the phenological observations of plant flowering on the territory of Transbaikalia was dated May 23, 1772. Pallas marked the beginning of flowering of the Daurian rhododendron (*Rhododendron dauricum*) near the city of Chita. The map "Seasonal dynamics of landscapes," which characterises the course of some phenological phenomena in the middle of the 20th century, provides somewhat earlier information about the beginning of flowering of this species—the middle ten days of May [3]—for the middle of the 20th century. According to modern data from Y.T. Rudenko [5], the average date of flowering of rhododendron in the vicinity of Chita falls on May 8 (averaged data over 47 years of observations). At the same time, the author noted that in the first half of this period, the average date of flowering of rhododendron fell on May 12, and in the second half of this period, on May 5. In some of the warmest years, flowering began much earlier, up to April 22 (in 2009) [5].

**Table 1.** Comparative phenological data on the flowering of plants mentioned by P.S. Pallas.

| Species                  | Phenophase         | Location and date (Pallas, 1772) | Location and date (middle of XX century) | Location and date (end of XX–beginning of XXI century) |
|--------------------------|--------------------|----------------------------------|-----------------------------------------|-------------------------------------------------------|
| *Rhododendron dauricum*  | Beginning of flowering | Chita, May 23                    | Chita, the middle ten days of May       | Chita, May 8                                           |
| *Androsace incana*       | Active flowering   | Tura River, May 27               | –                                       | Nerchinsky Zavod, May 12                                |
| *Arctogeron gramineum*   | Active flowering   | Tura River, May 27               | –                                       | Nerchinsky Zavod, May 12                                |
| *Armeniaca sibirica*     | Beginning of flowering | Ilya River, May 28              | –                                       | Chita, May 14                                           |
| *Prunus padus*           | Beginning of flowering | Onon River, early June          | Chita, May 31st; Onon River, May 25     | Chita, May 17                                           |
| *Stellera chamaejasme*   | Beginning of flowering | Tsagan-Nor Lake, around June 8  | –                                       | Chita, June 6                                           |
| *Stellera chamaejasme*   | Beginning of flowering | Borzya River, June 11          | –                                       | Chita, June 6                                           |
| *Malus baccata*          | Beginning of flowering | –                               | Chita, the first ten days of June      | Chita, May 25                                           |
| *Malus baccata*          | Active flowering   | Onon River, June 17             | –                                       | Chita, the first days of June                          |

On May 27, on the territory of the present Karymsky district, Pallas noted the mass flowering of two more early flowering plant species: *Androsace incana* (originally *A. villosa*) and *Arctogeron gramineum* (originally *Erygeron gramineum*). Regular phenological observations of these species in Transbaikalia are absent, but according to our data, the period of their mass flowering in the vicinity of Chita begins no later than the middle ten days of May. Active flowering near Nerchinsky Zavod (Nerchinsk-Zavodsky district) was recorded by us on May 12, 2014.

On May 28, Pallas marked the beginning of flowering of Siberian apricot (*Armeniaca sibirica*) (originally *Prunus sibirica*) along the Ilya River (modern Duldurginsky district). The average blooming date of this shrub in Chita was May 14 [5]. However, Chita is located 130 km to the north.
In early June (no exact date), Pallas noted the beginning of flowering of the bird cherry (Prunus padus). However, the researcher was in the valley of the Onon River (modern Duldurginsky or Akshinsky districts). In the late XX – early XXI centuries, the average date of the beginning of flowering of bird cherry in Chita fell on May 17 [5].

Additional data on the timing of the beginning of flowering of bird cherry are given in the Atlas of Transbaikalia [4]. For the city of Chita, the author (probably, according to data from the middle of the 20th century) specified the date as May 31, while for the Onon valley, it was May 25. Comparable dates were given by I.S. Kotov for Ulan-Ude, where in the period from 1930 to 1967, bird cherry began flowering in the last ten days of May – in the range from May 12 (1943) to June 3 (1966) [6].

Around June 8 (no exact date), Pallas, being on the territory of the modern Ononsky district (environs of Tsagan-Nor Lake), marked the beginning of flowering of the dwarf stellera (Stellera chamaejasme). Repeatedly, Pallas marked the blossoming of stellera on June 11 in the valley of the Borzya River (modern Borzinsky district). The beginning of flowering of this species near Chita (more than 200 km to the north) in the late XX – early XXI centuries fell on June 6 (averaged data for 32 years of observations) [5].

The following phenological observation was made by Pallas in Priononye (modern Olovyanninsky district) on June 17. The author noted the flowering of the Siberian crab apple (Malus baccata) (originally Pyrus baccata). Pallas described the phase of mass flowering. In this case, one can also assume a noticeable delay in the timing of flowering in comparison with the present. Rudenko marked May 25 as the average date for the beginning of apple blossoming in Chita (about 100 km to the north) for the city of Chita, but also for its environs.

Similar dates (May 31 to the beginning of flowering) were given by Kotov for this species in the Ulan-Ude area [6]. However, in most observation years, flowering had already ended by mid-June (the end dates were from May 30 to June 24). Of 38 years of observations (1930–1967), in only 5 years did the end of apple blossoming fall within the last 10 days of June. The Atlas of Transbaikalia for the city of Chita (probably based on materials from the middle of the 20th century) gives somewhat later dates for the beginning of apple blossoming (the first ten days of June) [3].

4. Conclusions
A comparison of modern data on the timing of flowering of seven different plant species with that given by Pallas for the 2nd half of the 18th century showed that in each case a shift to earlier dates occurred, ranging from two days (dwarf stellera) to at least two weeks (Daurian rhododendron, bird cherry, Siberian apricot). Considering that most of the species Pallas indicated were in geographically more southern points than the ones we adopted for comparison (Chita and its environs), presumably, the real shift in phenological dates would be even more significant. Furthermore, phenological dates available for Transbaikalia in the middle of the 20th century were intermediate. The presented comparative materials were in good agreement with the available data on the increase in average temperatures occurring over the past several decades.

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