Chapter 4
Europe

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Abstract Europe has a long tradition of systematic phenological data collection from a range of different environments. In recent times this data has proved invaluable in demonstrating the impact of climate warming on our natural environment together with providing a means by which to ground truth remotely sensed information. However, since the networks evolved in different countries with different traditions of data observation and collection aggregation at a continental scale is challenging. Here we provide a snapshot of some of the professional and citizen science-based national phenology networks, and describe a number of recently established pan-European initiatives to explore ways to establish a standardized framework for plant monitoring, data collection, quality control and transfer. Finally, we highlight areas such as species or groups of high value for nature conservation which require further research.

4.1 Introduction

While the longest written phenological record originates in Japan at the Royal court of Kyoto (the beginning of cherry flowering since 705 AD), the most vital and broadest tradition of phenological monitoring is found in Europe (Menzel 2002). In many countries long-term data sets exist, thus Europe is a particularly suitable region for investigating phenological changes or providing "ground truth" to satellite data. However, phenological information exists in numerous countries at a local, regional, or national level with quite different histories and traditions of observation. Thus, we are far away from a homogenous plant phenological data set at a continental level necessary for the applications indicated above, although new

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M.D. Schwartz (ed.), *Phenology: An Integrative Environmental Science*,
DOI 10.1007/978-94-007-6925-0_4, © Springer Science+Business Media B.V. 2013

initiatives, such as COST725 and the resulting PEP725 European phenological database, now offer structured, broad datasets. Unfortunately, it is impossible to provide a complete overview of European phenology here; however, current important national networks are compared to new schemes, such as Nature's Calendar, and to international initiatives (e.g. International Phenological Gardens, ICP Forests).

One of the oldest European phenological records is the famous Marsham family record in Norfolk 1736–1947 (Sparks and Carey 1995). Following Schnelle's (1955) historical overview, the first phenological network was then established by Linné (1750–1752) in Sweden. The first international (European) phenological network was run by the Societas Meteorologica Palatina at Mannheim (1781–1792), and a second famous one by Hoffmann and Ihne (1883–1941). Schnelle (1955) summarized the development of phenological observations in Germany as well as in other countries, such as (considering only European ones) Austria, Poland, Czech Republic and Slovakia, Russia, Finland, Sweden, Norway, United Kingdom, The Netherlands, Belgium, France, Switzerland, Spain, Italy, Greece and the former Yugoslav Republic through the middle of the last century. However, their subsequent history was very patchy.

4.2 International Networks

4.2.1 International Phenological Gardens

The International Phenological Gardens (IPG) is a unique phenological network in Europe, which was founded in 1957 by F. Schnelle and E. Volkert. Since then, it has been maintained on a voluntary basis, coordinated by a chairman (Chmielewski 1996). Manuals and annual observations have been published in the journal of the IPGs, the *Arboreta Phaenologica*. At present the network is coordinated by the Humboldt University Berlin (http://ipg.hu-berlin.de/). The core idea of this network was to obtain comparable phenological data across Europe by observing genetically identical plants (clones), which permanently remained at one site. Thus, the records are not influenced by different genetic codes of the plants and the variability and potential inaccuracy of the observations is reduced compared to data from the national phenological networks (Baumgartner and Schnelle 1976). In 1959, the first IPG started its observations in Offenbach (near Frankfurt am Main), Germany. Subsequently, additional IPGs were established with vegetatively propagated species of trees and shrubs at different sites across Europe. In 2002 about 50 IPGs record up to 7 phases of 23 plants species (~50 clones), in 2012 ~20 of them were still active and almost 50 new stations have been established since 2002. The network in Europe covers a large area from 38 to 69°N (Portugal to Scandinavia) and from 10°W to 27°E (Ireland to Finland), comprising different climate regions in Europe. Recent studies comprehensively analyzing the data of the IPGs revealed a lengthening of the growing season across Europe, provided the necessary ground truth to satellite data and CO_2 records, and linked the changed onset of spring to spring temperature and the North Atlantic Oscillation Index (NAO) (Menzel and Fabian 1999; Menzel 1997, 2000; Chmielewski and Rötzer 2001, 2002).

Most recently, following the example of the IPG, a new phenological network of arctic-alpine botanical gardens has been initiated by the Alpine Botanical Garden Schachen (Germany) including a new observation key for selected and propagated cloned alpine plant species (Schuster et al. 2011).

4.2.2 ICP Forests

Phenological observations are also made at Level II plots of ICP Forests. ICP Forests is the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests, which was launched in 1985 under the convention on long-range transboundary air pollution of the United Nations Economic Commission for Europe. ICP Forests monitors the forest condition in Europe using two monitoring intensity levels. The second level (so called Level II) has been operating since 1994 in selected forest ecosystems. On these plots, soil and soil solution chemistry, foliar nutrient status, increment, meteorological condition, ground vegetation and deposition of air pollutants are measured in addition to the annual crown condition assessments. On an optional basis, phenological observations are made to provide supplementary information on the status and development of forest tree condition during the year. Since 1999, additional phenological phases are recorded to determine the course of the annual development of forest trees, to explain possible changes in relation to environmental factors, and to utilize this knowledge in interpreting observed changes in tree condition. The ICP Expert Panel on Meteorology, Phenology and Leaf Area Index gives an additional focus on seasonal variations in phenology and LAI. Information about this network including the complete manual for phenological observations is available at http://www.icp-forests.org/.

4.3 National Networks

In Europe two major types of national (countrywide) phenological networks can be distinguished. In several countries, such as Albania, Austria, Czech Republic, Estonia, Germany, Poland, Russia, Slovak Republic, Slovenia, Spain, and Switzerland, the National Weather Services have been running (plant) phenological schemes during the second half of the twentieth century, and some networks already existed at the beginning of the twentieth century (see Schnelle 1955). In contrast to these “traditional” networks, “younger” networks have been (re) established recently.

Table 4.1 Basic identification information about the selected European phenological networks portrayed

Network contact	Internet	Current number of stations	Manual
Central Institute for Meteorology and Geodynamics, Austria	www.zamg.ac.at	~100	ZAMG (2000)
Czech Hydrometeorological Institute	www.chmi.cz	158 (46 forests, 84 crops, 28 fruit)	Guidebooks available
Slovak Hydrometeorological Institute	www.shmu.sk	221 (61 forests, 53 crops, 15 fruit, 92 com. phenology)	SHMÚ Bratislava (1988a, b, 1996a, b)
German Meteorological Service	www.dwd.de/phaenologie	~1,250 in the basic network plus approx. 400 immediate reporters	DWD (1991)
Estonian Hydrometeorological Institute	www.emhi.ee	21	EMHI (1987)
Environmental Agency of Slovenia	www.arso.gov.si/en/	61	Observation guidelines
MeteoSchweiz	www.meteoswiss.ch/	160	Meteo-Schweiz (2003)

4.3.1 Traditional Networks of the National Weather Services

Basic information concerning the phenological networks of selected countries, such as web site and network contact, number of observers, and species and phases, are listed in Tables 4.1 and 4.2. The recorded phenological information is used by the monitoring networks themselves or externally, primarily for research in agri-, horti-, and viniculture, forestry, ecology, human health, as well as for climatic evaluations and evaluation of potential global change impacts. In most cases, National Weather Services' phenological networks were intended to gather additional (integrated) climate information. Thus, observations of wild plants were used to monitor phenological seasons; agricultural observations of different crops and fruit trees mainly served to predict growing success, delivered data for modeling, and facilitated agro-meteorological consulting. Other purposes include the prognosis of onset dates, pollen forecasts, frost risk management, and monitoring of biotic damage.

The recent history (since 1950) and special characteristic of selected networks are quite similar: In **Germany**, the Deutscher Wetterdienst in 1949 and the Hydrometeorologische Dienst der DDR in 1951 took over the phenological network, which has been founded by the Reichswetterdienst in 1936 by combining different regional phenological networks. Since 1991, these networks are unified again, and the phenological network is managed by the Deutscher Wetterdienst (1991). At the same time, the observational program was adjusted. Similarly, in **Austria** and **Switzerland** phenological phases have been recorded continuously since 1951 in networks run

Table 4.2 Basic observation program information from selected European phenological networks portrayed (S species, P phases) (as 2002)

Network Contact	First (current) network	Wild plant + trees	Agricultural crops + farmer's activities	Fruit trees + grape vines
Central Institute for Meteorology and Geodynamics, Austria	(1928) 1951–today	15 + 9 S 7 P (68 P_{tot})	11 S 12 P (78 P_{tot})	5 + 1 S 9 P (26 P_{tot})
Czech Hydrometeorological Institute	(1923) 1986–today	45 S 26 P	19 S 33 P	14 + 1 S 16 / 2 P
Slovak Hydrometeorological Institute	(1923) 1986–today			
German Meteorological Service	(1936) 1951–today	30 S 59 P_{tot}	10 S 66 P_{tot}	10 S 32 P_{tot}
Russian Geographical Society		>102 S (wild plants, trees, crops, animals, AGROMET. EVENTS), >32 P		
Estonian Hydrometeorological Institute	1948–today	68[a] S 7 P	9 S 16 P	8 S 11 P

[a] The selection of native species is voluntary for the observers

by their National Weather Services. In Austria after the World War II, a new phenological network was established by the Zentralanstalt für Meteorologie und Geodynamik in Vienna, based on an older network started in 1928.

Unfortunately, the number of stations decreased from around 500 in the 1970s to 80 currently. The Swiss phenological observation network was founded in 1951 and initially consisted of 70 observation posts; the phenological observation program was slightly modified in 1996. The first phenological record in **Slovenia** is Scopoli's work *Calendarium Florae Carniolicae* from 1761. Modern phenology data collection started in 1950/1951 with the establishment of a phenological network within the Agrometeorological service, thus data are mainly used for research and applicable agriculture purposes. The recent network consists of 61 phenological stations, which are evenly distributed by a regional climatic key over the entire territory of Slovenia. The observations are carried out on species of non-cultivated plants (herbaceous plants, forest trees and bushes, clover and grasses) and of cultivated plants, such as field crops and fruit trees. In some portions of **the Slovak and the Czech Republic,** phenological observation was also conducted for a short time in the last half of the nineteenth century, but regular and managed phenological observation did not start until the twentieth century. From 1923–1955, the observational program comprised more than 80 plant species (crops, fruit trees, native plants), but also some migratory birds, insects, as well as agro-technical data. From 1956 to 1985 observations were made following the first instruction guide edited by the Hydrometeorological Institute, with an enlarged program including, for example, agro-meteorological observations and crop diseases. In 1985/86 a new system of phenological observation (including new guides) was instituted with three special sub-networks for field crops, fruit trees, and forest plants, and respective stations in regions with intensive agricultural production, in orchards and vineyard regions, and in forest regions. Three developmental stages (10, 50 and 100 %) are now observed.

In **Slovakia**, some historical stations were maintained in the (so called) "common" phenological network. In this network, general phenological observations (crops, fruit trees and grapevine, forest plants, migrating birds some agro-meteorological and agro-technical data) are made by volunteers, in contrast to the "special" networks, where experts (e.g., with agronomic education) do the recording. In 1996 the guides for the common and special observation of forest plants were modified. The species and scales of phenophases are now very close to those in use before 1985.

The former **USSR** area has many phenological observation programs supervised mainly by Russian organizations. The Russian Geographical Society started phenological studies in 1850s with more than 600 observers, mostly in European Russia. Today, the archive of this voluntary network in St. Petersburg is one of the most important phenological centers in Russia, with more than 2000 observation sites all over the former USSR area, and regional subprograms which have different observation manuals and species lists (Hydrometeorological Printing House 1965; Schultz 1981). The second important network is the Hydrometeorological Service's agrimeteorological observation program, organized by Schigolev in 1930, with a unique and strict methodology and very detailed observations of agricultural crops and some natural tree species, including climate parameters, such as soil temperature and moisture, and snow and precipitation, at the same site (Davitaja 1958; Hydrometeorological Printing House 1973). Today, the database at the central archive in Obninsk is not actively used, because the data is not digitized. Several other phenological observation programs exist that are run by the plant protection service, agricultural selection service, forestry department (Schultz 1982) or in Nature Conservation areas that use their materials for study and educational purposes (Kokorin et al. 1997).

In Estonia, the first scientific phenological observation program (with more than 30 observed species) was set up in the botanical garden of University of Tartu in 1869, by the Estonian Naturalists Society (Oettingen 1882). The Estonian Naturalist's Society started organized phenological studies in the 1920s/1930s and a broad observation program in 1951 (Eilart 1959). Today, the society is the most active voluntary observer of plant, bird, fish, phenology and seasonal phenomena in the country (Eilart 1968; Ahas 1999). The agri-phenological network of the Estonian Meteorological and Hydrometeorological Institute (started in 1948) used standard observation methods similar to those used in the former USSR (Hydrometeorological Printing House 1973; EMHI 1987). Their observation list consisted of agricultural plants, selected tree species, and main characteristics of the physical environment. Until the 1990s, 21 stations were still in operation (Ahas 2001), but that number diminished to 10 in 2001, and 6 in 2002.

In **Poland**, the Hydrometeorological Institute ran a phenological network from 1951 to 1990 composed of around 70 stations. In the manual by Sokolowska (1980), phenological observations are described, and the main results are reported by Tomsazewska and Rutkowski (1999). In **Spain**, the phenological network organized by the Spanish Meteorological Institute is characterized by an enormous number of stations, species, and phases, but less continuity of observations at single sites.

In general, the traditional phenological networks of the national hydrometeorological services can be characterized by their long-term continuous records which are ideal for climate change impact monitoring.

4.3.2 New Citizen Science Based Networks

The three examples of the British "Nature's Calendar", the Dutch "De Natuurkalender" and the Swedish National Phenological Network (SWE-NPN) stand as examples of phenological networks which have been set up recently, mostly run on the Internet, and organized by non-governmental organizations (NGOs), media, and research institutions. They include a lot of observations on animals (e.g., birds and butterflies).

A national phenological network in the **United Kingdom** was established by the Royal Meteorological Society in 1857. However, the subsequent development of British phenology was quite different from the continental central European countries, as annual reports were published only up until 1948. In 1998 a pilot scheme to revive a phenology network in the UK was started by Tim Sparks, research biologist at the Centre for Ecology & Hydrology in Cambridge, comprising both plant and animal phases. In autumn 2000 the Woodland Trust forces joined with the Centre for Ecology & Hydrology to promote phenology to a far wider and larger audience. In 2001 the number of registered recorders across the UK rose to over 11,700, and by August 2002 it was 16,809 and still growing, with around half of these being online observers. The Nature's calendar's website (http://www.phenology.org.uk) provides information about the species observed, an online list of observations, and graphic presentations of trends.

In February 2001, Wageningen University and the national radio program VARA Vroege Vogels (Early Birds) started a phenological monitoring network in **the Netherlands**, called De Natuurkalender. This network aimed to increase understanding of changes in the onset of phenological phases, also due to climate change, for human health, agriculture, and forestry. Other aims were to strengthen the engagement of the public in their natural surroundings and to develop interactive educational programs for school children and adults. The observation program includes over 100 species of plants, birds, and butterflies with at least one phenophase per species. The phenophases are clearly defined in an observation manual. Over 2000 volunteers subscribed to the program, and send their observations via the Internet, a paper form, or a special telephone line (Fenolijn) to the coordinators of the network. The observers and other potentially interested people are informed about the results of the observations by a weekly report during the radio program, which is followed by 500,000 people every Sunday morning. Furthermore, the network uses an interactive website to provide direct feedback to the observers.

The **Swedish National Phenological Network** (SWE-NPN) officially started in Jan 2010 to set up a nationwide, geographically dense phenology database (see http://www.swe-npn.se/). Equally to all other networks, its aim is to observe phenological shifts and to understand and predict how they will feedback on the climate system, ecosystem productivity and processes, and human health (pollen forecasts). The observation network is based on both professional field stations and community-based volunteers. Phenological observations are reported to the http://www.blommar.nu/ website, which offers ample feedback and outreach as well as data access tools. The SWE-NPN has meanwhile digitized all historical observational data (1873–1926) which were recorded on around 50 plants and 25 animals at more than 300 sites. It is intended to use them as a reference point for changing climatological and phenological conditions.

4.4 Other Networks

This rough overview of phenological networks leaves many regions in Europe blank, due to the lack of current phenological networks in those places (e.g., Portugal, Greece). Other countries only have local networks due to regional organized research structure (e.g., Italy), current networks that are run by other institutions (e.g. Finland METLA, Norway), or they mainly have historical networks (e.g. Norway, Finland). Thus, this overview does not claim to be exhaustive, and it is fairly certain that in many other countries, national or regional networks existed, or are still running.

An evaluation of the World Meteorological Organization (WMO) RA VI agro-meteorological questionnaire on phenological observations and networks revealed that from 28 replying countries only 6 countries (Belgium, Bosnia and Herzegovina, Denmark, Luxembourg, Portugal and the United Kingdom) had no regular (agro-meteorological) phenological network, whereas 22 countries (Armenia, Austria, Croatia, Czech Republic, Estonia, France, Germany, Hungary, Ireland, Italy, Israel, Latvia, Lithuania, Macedonia, Moldavia, Romania, Russia, Slovakia, Slovenia, Spain, Switzerland, Syrian Arabic Republic) have regular phenological networks (WMO 2000). However, following this WMO evaluation, the phenological observations, the applied observations methods, the structure of the networks, the coding systems, and the practical usage of data are highly diverse.

The French phenological network that started in 1880 under the care of Meteo France may represent observations “fallen into oblivion.” Phenological observations have been reported continuously up to 1960 for most stations adjacent to meteorological stations, but only three of them continued their observations after that date, with the last one stopping in 2002. The inception of this network was similar to other central European ones still in operation, as the observational program comprised perennial wild species including trees (25 species), crops (10), and fruit trees (8), and an instruction booklet was provided to observers to standardize observations. Observations are contained in archives, but have not been digitized. These data have not been analyzed, except at the very beginning of the network by C.A. Angot from Meteo France (in a few Annales du Bureau Central Météorologique) who mapped isolines of the onset of phenophases for the decade 1881–1891. Meanwhile France has set up a common system on all phenological information available at the national level (http://www.gdr2968.cnrs.fr/) including a so called "season observatory" unifying more than 27 laboratories and research organizations working on phenology (http://www.obs-saisons.fr/), such as INRA which started the Phénoclim network on fruit trees and grapevine.

The PhenoAlp project (www.phenoalp.eu) may serve as an example for recent transnational collaboration, here co-funded by the EU, to establish specialized networks in those areas currently not well covered.

The picture won't be complete without a hint to other environmental networks in which vegetative or reproductive phenology is monitored as auxiliary data. For example, at around 100 European and over 400 so called fluxnet research sites, carbon dioxide and water vapor fluxes are measured by eddy covariance method along with other environmental data such as leaf phenology (www.fluxdata.org).

4.5 Towards A Pan European Phenology

In order to overcome the diversity in phenological monitoring at the European scale, the COST725 action (Establishing a European data platform for climatological applications, 2004–2009) aimed to standardize and harmonize phenological observation schemes and guidelines and to unify data stored in different locations and in different formats (Koch et al. 2001). Thus, the succeeded in defining species and phases of common interest, to develop recommendations for monitoring and quality control, and to assign the BBCH code (Meier 1997) to all phases observed. Furthermore, in cooperation with WMO, WCDMP and WCP, COST725 developed guidelines for plant phenological observations. A common COST725 database was established and maintained comprising main parts of the historical data in a common format and with BBCH coding. Moreover, a complete overview of national and international European phenological networks including 30 contributions from all COST725 member states plus Croatia, Bosnia and Herzegovina, Montenegro and the International Phenological Gardens was published by Necovář et al. (2008).

The most important scientific achievement of COST725 was the first Pan European study of observed phenological changes comprising more than 125,000 time series of 542 plant and 19 animal species in 21 countries for the period 1971–2000 (see Fig. 4.1). The corresponding paper entitled 'European phenological response to

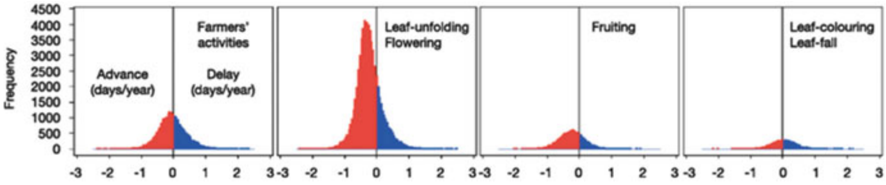

Fig. 4.1 Frequency distributions of trends in phenology (in days/year) over 1971 to 2000 for 542 plant species in 21 European countries (From Menzel et al. 2006; Rosenzweig et al. 2007, figure 1.6. on page 113)

climate change matches the warming pattern' (Menzel et al. 2006) received worldwide attention and was one of the backbones of the 4th Assessment Report of IPCC in 2007, demonstrating an attributable fingerprint of climate change in nature (Rosenzweig et al. 2007, 2008; see also Chapter 18 Plant Phenological Fingerprints). Out of the 29,000 time series of significant changes in natural and managed systems collated by IPCC, more than 28,000 were contributed by Europe, i.e. the COST725 publication of 2006 (AR4, IPCC, Summary for Policy Makers).

The successor of the COST725 action is the PEP725 database (www.pep725.eu) where 16 European meteorological network members (Austria, Belgium, Croatia, Czech Republic, Finland, Germany, Hungary, Ireland, Norway, Poland, Romania, Serbia, Slovak Republic, Slovenia, Spain, Switzerland) and 6 other partners have agreed to promote and facilitate phenological research by its database with unrestricted access for science, research and education. The database (2012) comprises 8.6 million records from almost 19,000 stations across 29 European countries, mainly since 1951.

4.6 Conclusions

The scientific community has a long list of requirements for monitoring. Long-term continuous data records of high quality are needed with good documentation, many auxiliary data, and often much more. Thus, special characteristics of the networks may be of interest to them. In general, observations are made by volunteers interested in nature, in special networks (Slovakia) or special stations (Germany, IPGs), or by experts. In the IPGs, observations are made on three specimens of each clone, whereas national network's rules describe how the observing area is defined and how the specimens have to be chosen in the surroundings of a phenological station. Constant specimens and locations are desired, however only in Slovenia are forest trees, shrubs, fruit trees, and vines permanently marked. All networks possess paper forms to note observations (even the new established networks in the UK and in the Netherlands do not want to exclude "offline" recorders and developed forms). The frequency of submitting forms varies from once a year to weekly to event-based data.

Data consistency and quality is difficult to evaluate. Most of the networks analyzed have monitoring guidelines, however they are very different, ranging from brand-new instructions, also available on the Internet (such as complete manual of ICP Forests, species and / or phenophase information of the Nature's Calendar or the German Weather Service) or substantial printed manuals (Germany Weather Service), to descriptions used since the beginning of the network (IPG). Quality control of the data mostly consists of only simple plausibility control. Accompanying disaster information does not exist at the moment, but could be available in the future (e.g., ICP Forests). The general data release policy varies as well, and in most cases data are open on an individual decision basis only.

Data formats are also quite different. In some countries older records still need to be digitized from paper, but most networks do have their data in files or databases. Nature's Calendar (with almost 50 % online observers) offers quick data access for registered observers and allows different kinds of data comparisons. In the National Weather Services' networks, observations on cultivated species are generally accompanied by information about varieties. However, associated data about the site (such as meteorology, soil, relief, and slope) are not available and (due to the coarse information about the station location) it is nearly impossible to gather exact auxiliary data.

Coding of phenophases following the BBCH code (Chapter 4.4, Biologische Bundesanstalt 1997) is a huge step forward in understanding phenophase definitions in different languages and making observations comparable.

Most recently, there is a clear tendency to complete long-term phenological monitoring in national networks by regional and/or experimental approaches in order to assess not only impacts of climate change on phenology, but to understand more about their triggers also under future conditions characterized by new, non-analog climates. In addition, it turned out that more species groups, e.g. of high value for nature conservation (endemic, invasive, protected) or community phenology (e.g. in grasslands), need further attention.

Acknowledgements I kindly thank my phenology colleagues from the COST 725 action, especially the chair Elisabeth Koch (Austria) as well as Rein Ahas (Estonia), Olga Braslavska (Slovak Republic), Isabelle Chuine (France), Zoltan Dunkel (Hungary), Elisabeth Koch (Austria), Jiri Nekovar (Czech Republic), Tim Sparks (United Kingdom), Andreja Susnik (Slovenia), and Arnold VanVliet (The Netherlands), for their valuable contributions.

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