AN INTERNET APPLICATION FOR ARCHIVING SPRING PHENOLOGICAL OBSERVATIONS COLLECTED BY A NETWORK OF OBSERVERS

UN'APPLICAZIONE INTERNET PER L'ARCHIVIAZIONE DI OSSERVAZIONI FENOLOGICHE PRIMAVERILI RACCOLTE DA UNA RETE DI OSSERVATORI

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Abstract
The number of studies concerning the analyses of biological and climatic data is increasing year after year due also to the attention focused on global climate change impacts on species distribution and phenology..
As regard the project "Gilia – Spring Signals", issued by the Institute of Biometeorology of Florence, an Internet application system was developed and used to record phenological data which had been collected by a network of observers. This paper describes the architecture of the system and the criteria used for the network creation and for the data classification. Four years of phenological data are presented and discussed, particularly data related to first arrival sighting of Barn swallow (*Hirundo rustica L.*).

Keywords: Phenology, Biometeorology, Migration, Barn swallow.

Riassunto
Il numero di studi riguardanti l'analisi di dati biologici e climatici sta aumentando anno dopo anno particolarmente a causa dell'attenzione rivolta all'impatto del cambiamento climatico globale sulla distribuzione e la fenologia delle specie.
*Nell'ambito del Progetto "Gilia – Segnali di Primavera, realizzato dall'Istituto di Biometeorologia di Firenze, è stata sviluppata un applicazione internet utilizzata per registrare dati fenologici raccolti da una rete di osservatori. Questo articolo descrive l'architettura del sistema e i criteri utilizzati per la creazione della rete e per la classificazione dei dati. Sono presentati e discussi quattro anni di dati fenologici, in particolare i dati relativi al primo avvistamento dell'arrivo della rondine (*Hirundo rustica L.*).*

***Parole chiave** : Fenologia, Biometeorologia, Migrazione, Rondine.*

Introduction
A large number of studies has been carried on on the influence of climate change on phenology, which is defined as the study of the relation between environmental parameters and the periodic life-cycle events that regulate plant and animal lives. Long and homogenous phenological data series uniformly distributed to the study area are absolutely necessary to identify these kinds of impacts. This activity is extremely challenging because of the practical and economic difficulties that must be faced. A fundamental study, made by a European network of 21 different countries (Menzel 2006), is based on a series of 125,000 observations of 561 species concerning plants and animals as a result of 30 consecutive years of monitoring activity. Unfortunately, Italy did not take part in the network because of the lack of continuity of phenological studies. Recently, however, Italian researchers have made an attempt to fill this gap.
Since 2006, a group of Italian phenologists and crop modelers has promoted a monitoring network called IPHEN, Italian Phenological Network (http://www.ucea.it/iphen/). Species selected were two varieties of grapevine (*Vitis vinifera L.*), chardonnay and cabernet, and the spontaneous species Elderberry (*Sambucus nigra L.*). Phenological data are recorded every 15 days during the vegetative season and compared with predictions made by a growth-simulation model that is based on air temperature as a driving variable.
Another approach, commonly widespread in northern European countries, is based on collecting direct observations through a network of observers that can be solely composed by volunteers keen on nature. For example, Woodland Trust, an English Organization founded by the Royal Meteorological Society, has formed a network of voluntary observers and has created a web site where all publications and results related to phenology and climate change are published (http://www.naturescalendar.org.uk/) and since 1951 the Deutscher Wetterdienst (DWD) has managed a phenological network that nowadays counts about 1400 people who send their observations using postcards (http://www.dwd.de).
In this way, a complex and expensive job can be done easily, even in a large area. Thanks to the affiliation of these interested "detectives," it guarantees continuity in time.

Material and methods

In 2003, the Institute of Biometeorology set a new research line called "Climate Observatory" to study the global climate change effects on plants and animals. Gilia is a project on climate change and phenology that started in 2004. The aim of the project is to collect phenological observations in order to create a database useful for doing research on climate change impacts. Italy has been selected as the study area.

In the first year of activity, timing of spring migration of birds was chosen to be the phenological event observed. "Migration" means a regular seasonal journey between two regions performed by species which thereby reproduce and survive more efficiently than if they stayed in one place all year. The timing, duration and route of migratory movements are partly determined by the climatic conditions of the wintering and breeding grounds, as well as by the meteorological conditions faced during the flight. Some studies looked into the relation between spring migration timing and NAOI North Atlantic Oscillation Index (Mads *et al.* 2002, Anssi *et al.* 2004, Jonzen *et al.* 2002) and other climate indices (Cotton, 2003), while other ones analyze how climatic conditions of the wintering grounds (Gordo, 2005) or of the breeding sites (Sparks, 1998) affect the migration. The influences of meteorological variables, mainly wind and rain, during the migration flight are also widely studied (Shamoun-Baranes *et al.* 2003, Schaub *et al.* 2004).

Among seasonal migrant species, Barn swallow (*Hirundo rustica L.*) was selected because, as many other seasonal migrants breed in temperate areas of Northern Europe (Jonzen et al 2006), usually migrates from Africa to Europe in the spring and from Europe back to Africa in the fall. Habitually, Barn swallow starts its migration from the wintering grounds in March when the warm season, favorable for breeding, starts in Europe and one of its migration routes, which is the shortest path between Africa and Europe, passes through Italy.

Since 2004 we have formed a monitoring system based on a network composed of people belonging to environmental and birdwatching organizations in order to collect first arrival sighting observations. They helped us to gather data from every part of Italy at low cost. Considering that Barn swallow can cover a long route in a day, we decided to use, as the spatial measuring unit, the provincial administration areas. The temporal scale was chosen on the basis of the usual habits of observers, such as birdwatchers who make their observations during the weekend. A good compromise seemed to be the use of a 10 days scale: where n°1 represents the period from the 1^{st} to the 10^{th} of January, n°2 represents the period from the 11^{th} to 20^{th} of January and so on.

The observers recorded place and time of the first arrival of Barn swallow. Data recorded were converted to the spatial and temporal selected scales and processed to produce and update a map published on the internet every 10 days. Birdwatchers used to send their observations through e-mail, sms and mms.

Since 2005, we have decided to increase the number of species and phenological events observed. We have selected events related to the springtime, such as the beginning of plant blossoming, the first arrival and the first song of the birds and the end of hibernation for other animals. In addition, we decided to improve the system by creating an internet application and extending the network by choosing events easily identifiable by anyone. For this purpose we created a web site, http://www.gilia.ibimet.cnr.it/, as a tool to receive data and to show results and other information related to climate change. The web site is only in the Italian version at the moment, and it is divided into three sections: Phenology, Climatic Data, News and Publications. The phenological section contains a selected number of species and the related phenological events on springtime. Each species is presented with a brief description and with a set of fields that the user can fill with related data and then send to the system. There is also a link to a phenological map of the event that is updated regularly. The climatic section displays monthly and seasonal analysis of the meteorological data gathered by 32 Italian weather stations of the Italian Air Force (data are distributed by the World Weather Watch Program of the WMO freely for research purposes) and gridded maps of precipitation derived by data available on GPPC project site. Finally, the last part presents a list of selected news and documents related to the impact of climate change on life. Web site architecture is structured on three levels (fig. 1). The first one is the html code used to publish the page content in the correct format. The second level is a dynamic one which is made by php instructions that allows one to retrieve data from a database, through the sql language, according to the parameters indicated by the user. The dynamic component is also useful to retrieve climatic data and to select news and articles published on the site. For example, if a user asks for Spring 2007 cli-

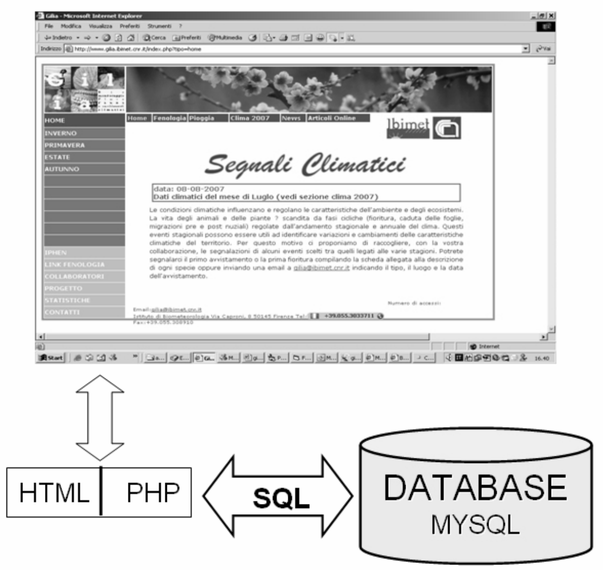


Fig. 1 - Logical architecture of the internet application system for collecting phenological data

Fig. 1 - *Architettura logica dell'applicazione internet per la raccolta dei dati fenologici*

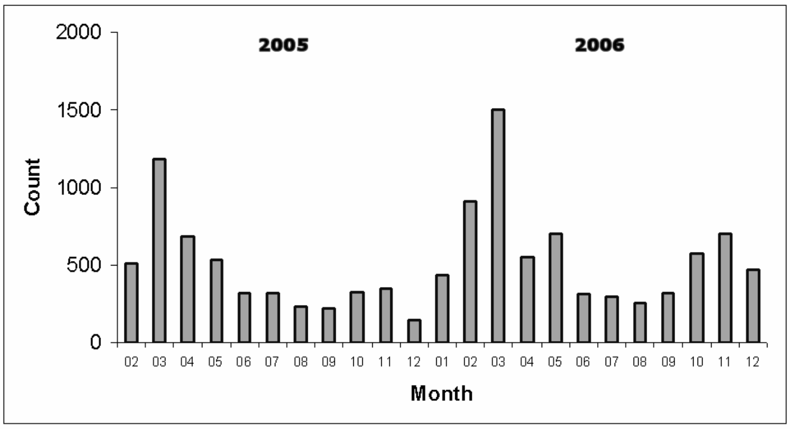


Fig. 2 - Number of accesses per month to the web site during 2005 and 2006
Fig. 2 - *Numero di accessi al sito per mese durante il 2005 e il 2006*

matic data, the server processes the database and shows the mean and the extreme values for the requested period, as well as monthly graphs of air temperature, relative humidity and precipitation. The use of dynamic php linked to the database is also the basic resource for the implementation of the form for collecting observations that represent the core of the system. In fact, the user can easily send his observations, which are then automatically recorded on the database, by compiling a predefined form.

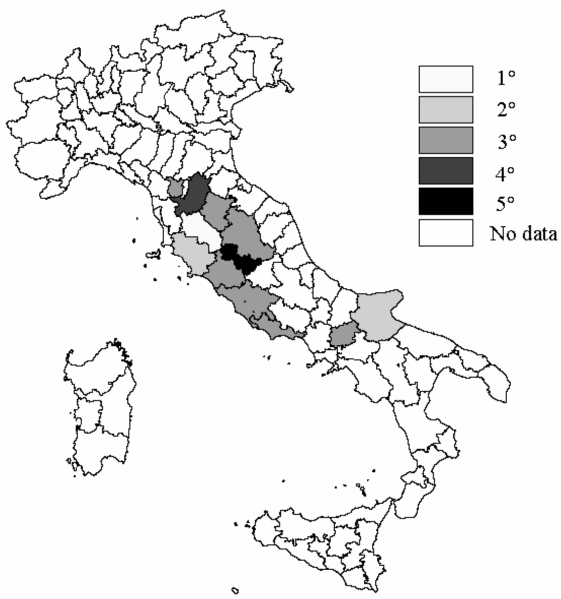


Fig. 3 Phenological map of blossom onset of Silver wattle (*Acacia dealbata*) for the year 2005.
Legend:
1° = 1st-10th Jan; 2° = 11th-20th Jan; 3° = 21st-30th Jan; 4° = 31st Jan-9th Feb; 5° = 10th-19th Feb.
Fig. 3 - *Mappa fenologica della fioritura della Mimosa (Acacia dealbata) per l'anno 2005.*
Legenda:
1°= 1-10 Gen; 2° = 11-20 Gen; 3° = 21-30 Gen; 4° = 31 Gen-9 Feb; 5° = 10-19 Feb.

Results

In 2004, only the first sighting of Barn swallow was monitored; while from 2005, 10 new events were added. Tab. 1 shows data collected during the period 2004-2007 and the number of observers that joined the activity. The maximum number of observers participating and data collected was reached in 2005 when the number of phenological events was extended. A specific tool for calculating the monthly frequency of access to the homepage was used to monitor the number of visitors. Both 2005 and 2006 (fig. 2) show a clear seasonal trend with two peaks: one major maximum during March and the other less pronounced in November, indicating a significant rising of people interest towards nature and its changes during springtime. The significant increase of clicks was also influenced by the advertising we did during the end of January. Data collected on the beginning of plant blossoming was not sufficient to trace significant phenological maps. Silver wattle (*Acacia dealbata*) reached a maximum of 25 observations during 2005, while in 2007 the observations recorded were only 12 (fig. 3).

Among all the species, Barn swallow reached the higher number of observations. The maximum was reached in the first year of activity. Since 2006, the number of observations has decreased.

During the last four years, 2005 was the coldest winter, and February, in particular, was characterized by an air temperature anomaly of -2°C in almost every part of

Tab.1 - List of the phenological data collected for each monitored species and total number of the observers for each year
Tab.1 - *Elenco dei dati fenologici raccolti per ogni specie monitorata e numero totale degli osservatori per anno*

species	2004	2005	2006	2007
Apis mellifica	-	11	3	2
Prunus avium	-	21	12	8
Forsythia	-	20	17	10
Lacerta muralis	-	16	4	6
Prunus dulcis	-	8	9	3
Leucanthemum vulgare	-	24	7	4
Turdus merula	-	16	3	3
Acacia dealbata	-	25	15	13
Prunus persica	-	19	8	11
Erinaceus europaeus	-	7	5	-
Hirundo rustica	61	58	41	46
Total	**61**	**225**	**124**	**106**
Observers	61	115	65	53

Italy, while Winter 2007 was characterized by a positive strong anomaly. First arrival sightings of Barn swallow collected during these years are shown on fig. 4a, 4b. Every province was marked by grey tones representing the ordinal number of the group of 10 days in which observations were made. The difference in tonality, clearly visible by comparing the two maps, shows that Barn swallows arrived earlier in 2007 than in 2005. We calculated also the frequencies of first arrival on the basis of 10-day groups for both years (fig.5). Both years had a maximum between the 12th and the 21st March; but prior to that period, 2007 observations always exceeded 2005 observations. Furthermore, in 2005 there were also observations in April, while there weren't any observations in April 2007. This dynamic is well underscored by a graph showing the progress of the arrival estimated as the cumulative percentage of the first arrival observed during the first part of the year (fig. 6). The shape of the curves is similar, but 2007 migration starts and ends earlier.

Discussion and conclusion

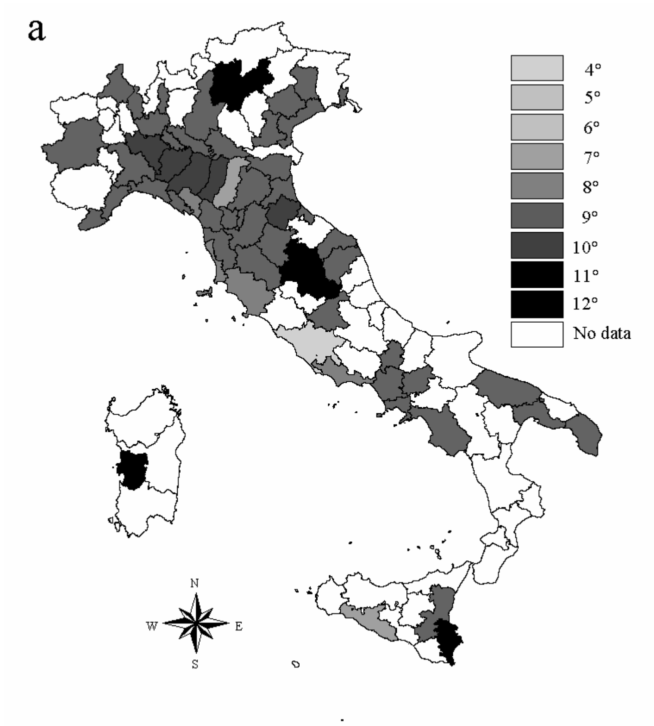
Showing data on the map using the provincial administration areas as the spatial measuring unit is sufficient to represent migration phenology, but its use for tracking the beginning of plant blossoming is inadequate. In fact, plant phenology is strongly influenced by local climatic conditions, so information about position and other characteristics, such as elevation and distance from the sea, are also relevant. The temporal scale based on 10-day groups is a good way to represent phenological data at geographical scale. In this way, phenological maps are easily understood, while for other kinds of analyses, the exact day of the year is important.

At present, our data series is not long enough to investigate the relation between phenology and climate and on global climate change impacts. Anyway, Barn swallow series can give some qualitative information about that topic. The results show that the shift of migration was affected by high-temperature anomalies recorded in our country. However we need to collect further data during next years in order to reach excellent results. During our four-year activity, we had to face the problem of preserving and increasing the network of observers.

An internet site, easy and cheap to create, represents a powerful tool for collecting data from observers scattered in a large area. At the same time, internet is a collection of so many pages that it is very difficult to come across the information without knowing of its existence. So advertisement through communications means, other than internet, must be considered a key aspect.

Finally, the monitoring protocol must be improved. Monitoring activity should guarantee a better temporal and spatial coverage of the observed events.

Therefore we need to extend and consolidate the network of observers because this data series can be very important for future phenological studies.



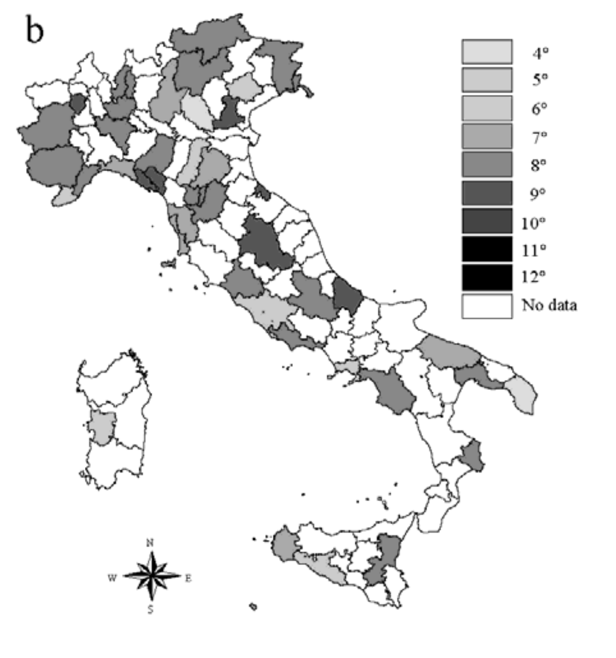


Fig. 4 - Phenological map of first arrival of barn swallow (*Hirundo rustica L.*) for the year 2005 (a) and 2007 (b). Legend:
4° = 31^{st} Jan-9^{th} Feb; 5° = 10^{th}-19^{th} Feb; 6° = 20^{th}-1^{st} Mar;
7° = 2^{nd}-11^{th} Mar; 8° = 12^{nd}-21^{st} Mar; 9° = 22^{nd}-31^{st} Mar;
10° = 1^{st}-10^{th} Apr; 11° = 11^{th}-20^{th} Apr; 12° = 21^{st}-30^{th} Apr.

Fig. 4 - *Mappa fenologica del primo avvistamento della rondine (Hirundo rustica L.) per l'anno 2005 (a) e per il 2007 (b).*
Legenda:
4° = 31 Gen-9 Feb; 5° = 10-19 Feb; 6° = 20-1 Mar;
7° = 2-11 Mar; 8° = 12-21 Mar; 9° = 22-31 Mar;
10° = 1-10 Apr; 11° = 11-20 Apr; 12° = 21-30 Apr.

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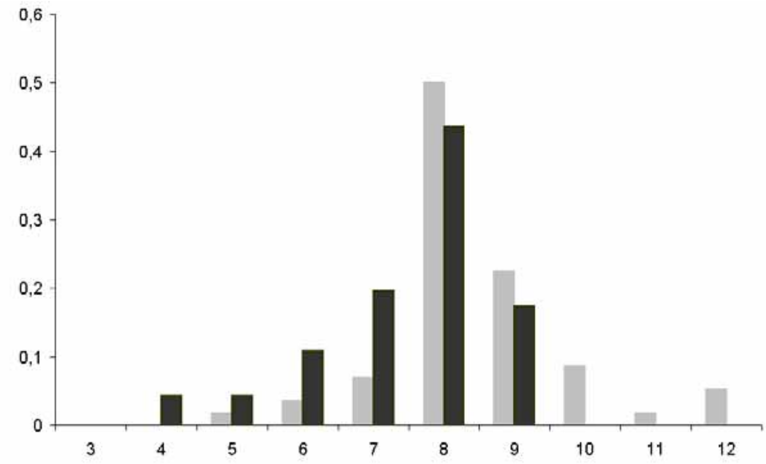

Fig. 5 - Frequency of observations during a period of ten days in 2005 (grey bars) and 2007 (black bars) expressed as percentage of the total observations collected for each year.

Fig. 5 *- Frequenza delle osservazioni per ogni 10 giorni nel 2005 (barre grigie) e nel 2007 (barre nere) espresso come percentuale delle osservazioni totali raccolte nell'anno.*

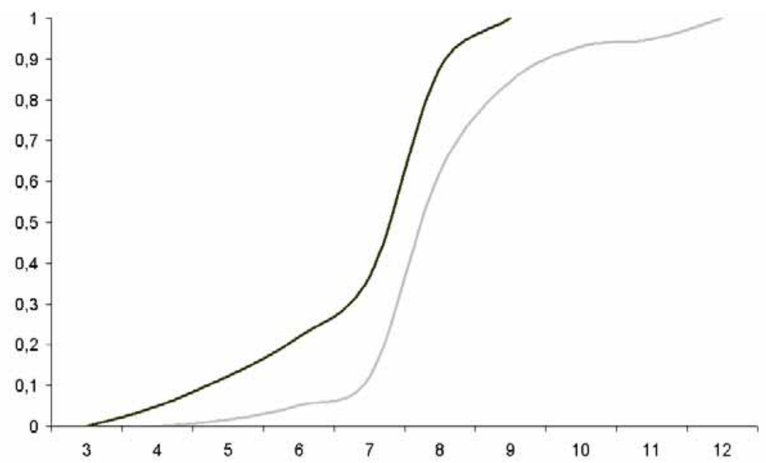

Fig. 6 - Ratio between observations collected from the 21st January and total observations in 2005 (grey line) and 2007 (black line).

Fig. 6 *- Rapporto tra le osservazioni raccolte a partire dal 21 gennaio e le osservazioni totali nel 2005 (linea grigia) e nel 2007 (linea nera).*