IRISH PHENOLOGICAL OBSERVATIONS FROM THE EARLY 20TH CENTURY REVEAL A STRONG RESPONSE TO TEMPERATURE

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ABSTRACT

Phenology, the study of the timing of recurring life cycle events, has gained global scientific recognition in recent years as it demonstrates how ecosystems are responding to climate change. However, in Ireland the systematic recording of phenological events has not been traditionally undertaken. Here we present some recently rediscovered historic phenological records, abstracted from the *Irish Naturalists' Journal* for the period 1927–1947 (with a gap from 1940 to 1945) and analyse them with respect to temperature data, sourced from Dr Tim Mitchell's Tyndall Centre webpage. We find that in many cases in Ireland spring phenological events, such as first flowering, first leafing and first observations of insects, show an earlier trend in response to increasing spring temperatures over the study period. In addition, we compare spring migrant bird arrival dates from the *Irish Naturalists' Journal* records with those abstracted from various published and unpublished bird records from the eastern region of Ireland for the period 1969–1999. We demonstrate that five out of the seven species analysed were recorded earlier in the more recent time period, and three of these were significantly earlier. These results illustrate the value of historic phenological data records for investigating and comparing past and present climate influences on species developmental behaviour.

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INTRODUCTION

Phenology is the study of the timing of recurring life cycle events in plants and animals (Schwartz 2003). These events, known as phenological phases, include the leafing and flowering of plants, migration and egg-laying dates of birds and the first appearance dates of insects. The timings of these phenophases are typically controlled by environmental conditions, such as temperature and day length (Linkosalo and Lechowicz 2006; Pudas *et al.* 2008). The study of phenology has gained scientific recognition in recent years as phenological trends show the responsiveness of species to climate change and, in particular, to changes in temperature. Phenological data from across Europe, including Irish data (Menzel *et al.* 2006) was used in the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report on Impacts, Adaptation and Vulnerability (Parry *et al.* 2007) to demonstrate the impact of climate change on life cycle events of both plant and animal species.

In Ireland, the systematic recording of phenological events has not traditionally been undertaken. However, phenological recording has a long history throughout Europe: for example, records go back over 300 years in the UK (Sparks and Carey 1995), over 250 years in Finland (van Vliet and de Groot 2001), over 120 years in Germany (Zimmerman *et al.* 2008) and over 130 in Estonia (Ahas 1999). Nonetheless, a 40-year-long dataset of phenological records exists for a suite of trees from four sites in Ireland. These sites form part of the Europe-wide International Phenological Gardens (IPG) network, and recording of dates of leaf unfolding, flowering, leaf discoloration and leaf fall are ongoing. Analysis of the datasets revealed their value as an indicator of climate change to demonstrate an advance in spring events in response to increasing spring temperature (Donnelly *et al.* 2004; 2006). Other sources of data have been identified as useful phenological records, such as bird migration dates from various local bird reports throughout Ireland.

The importance of systematic monitoring and recording of the timing of environmental events as a useful tool in climate change research has become increasingly recognised and is used extensively with this type of data in present day studies. In particular, historic phenological data from long-established networks have been widely used to demonstrate the impact of current environmental change on species and ecosystems (Menzel *et al.*

2006; Parry *et al.* 2007). Therefore, it is important to continue to support such networks and expand their geographical extent and species base to gain a more representative account of the impacts of climate change and other environmental changes on the environment.

We examined back issues of the *Irish Naturalists' Journal*, which has been published every year since 1925, to determine if phenological data existed. This journal is the official journal of the established Irish field clubs and covers all aspects of Irish natural history, including botany, zoology and geology. A series of phenological observations was identified and extracted for a wide range of plant and animal species together with records of crop cutting dates and dates of potato blight for the 1920s, 1930s and 1940s.

Here we examine these data from the first half of the twentieth century to determine if a response to temperature can be detected. In addition, we compare arrival dates of spring migrant birds from two different time periods (~1927–1947 and 1969–1999) to determine if recent arrivals are earlier than those in the historic record.

MATERIALS AND METHODS

PHENOLOGICAL DATA

Dates and location of a number of phenological phases (first flowering, first leafing of trees, arrival and departure of migrant birds, first bird song heard after January 1, first sighting of insects and agricultural events such as crop cutting and plant diseases) were extracted from the *Irish Naturalists' Journal* for the fifteen years for which they were published (1927–1939 and 1946–47; the gap from 1940–45 was due to World War II). Any species with fewer than ten years of records were omitted from analysis. Events relating to crop cutting are termed pseudo-phenophases as they are not biological but their timing is strongly influenced by environmental conditions. Dates were converted to days after December 31 and the mean for each event and year was calculated from all the different locations throughout Ireland.

The *Irish Naturalists' Journal* (1925–present) is the official journal of the established Irish field clubs. Contributors are predominantly science researchers, field club members and amateur naturalists. A number of issues are published annually on a wide variety of topics in geology, botany and zoology. Inspired by the phenological system operated by the Royal Meteorological Society of London, Arthur Stelfox initiated phenological recording in Ireland (Stelfox 1927) by requesting academics, naturalists and members of the public to record the timing of events in common Irish plants, birds and other forms of wildlife in the countryside. The activities listed by Stelfox included the leafing of trees, flowering of garden plants, harvesting of a variety of crops, the arrival and departure of birds in spring and autumn and the emergence of insects and bats from hibernation. The data collected were subsequently published in Phenological Reports in the *Irish Naturalists' Journal*. The datasets contained in these reports were used in this paper.

In order to make a comparison between phenological events in the first part of the twentieth century and those in the second part we examined first spring migrant bird arrival data from various published and unpublished bird records from the eastern region of Ireland for the years 1969–1999 (Cummins *et al.* 1970; 1972–1974; Hutchinson *et al.* 1971; Ruttledge 1971; Moore 1975; 1976; Mullarney 1976; Cooney *et al.* 1981–98, 2000) with those from the *Irish Naturalists' Journal*. Where at least ten years data existed in the *Irish Naturalists' Journal* for these migrant species the first observation per year for the eastern region of Ireland (Counties Louth, Meath, Dublin and Wicklow) was abstracted. Since the published and unpublished bird records consisted of absolute first sightings in each year, we extracted the equivalent metric from the *Irish Naturalists' Journal* for this analysis rather than a mean of all first observations. Records considered to be highly questionable for one of the following criteria were excluded from the analysis to ensure that the two datasets were comparable: a) dates completely outside the normal expected range of arrival dates as informed by standard contemporary references (Ussher and Warren 1900; Humphreys 1937; Kennedy *et al.* 1954); b) records likely to be of wintering birds rather than spring arrivals and c) records likely to be of breeding birds rather than spring arrivals. Expert judgement was used to make the latter assessments.

TEMPERATURE DATA

The Irish temperature data was sourced from Dr Tim Mitchell's Tyndall Centre web pages (http://www.cru.uea.ac.uk/~timm/climate/index.html). Three-monthly mean temperature values were used for the regression analysis, using the month in which the average date of the particular event occurred and the preceding two months. Thus an event occurring in April was compared to the mean temperature for February–April, and so on. This antecedent three-month period has been found to be important in influencing spring phenology (Estrella *et al.* 2007).

Statistical analysis

Regression analyses were carried out on the annual mean phenological data from the *Irish Naturalists' Journal* against three-monthly mean temperatures. Spring migrant arrival dates from the first part of the twentieth century and those in the second part were compared using a two sample *t*-test.

RESULTS

A total of 143 phenological events were recorded for at least ten years, with a total of 25,753 observations being made during this time. Regressions of phenological events against temperature are summarised in the appendix tables. Of all the events analysed, 123 produced negative regression coefficients, indicating earlier phenology at higher temperatures, and 75 (60%) of these achieved significance at the $P = 0.05$ level. Of the 20 events producing positive regression coefficients only two (10%) were significant. These related to the arrival dates of winter migrant birds and suggested later arrival in warmer autumns. The response to temperature and the proportion of significant relationships varied greatly between event types (Table 1). First flowering and first leafing dates appeared to be very sensitive to temperature with a mean response *c.* 8 days earlier for every 1°C increase in spring temperature. Nearly 80% of these relationships were significant. Bird-related variables had lower mean response rates to temperature: the four bird event types ranged from 0.7 days earlier to 5.5 days later with a 1°C increase in temperature. Fewer than 20% of these bird events were significantly related to temperature. Of the remaining two groups, both produced a similar mean response to the flowering/leafing events of *c.* 8 days earlier/1°C warmer. For insects, 40% of events were significantly related to temperature. The remaining group, dominated by pseudo-phenophases, and in particular agricultural events, had a similar proportion of significant relationships with temperature.

Figs. 1–6 provide examples of the negative relationships between event dates and temperature. They include examples of first flowering (lesser celandine, wood anemone), first leafing (hazel), first migrant arrival (northern wheatear), first insect appearance (speckled wood) and first breeding (common frog). With the exception of northern wheatear ($P = 0.021$) all showed a highly significant ($P < 0.001$) negative relationship with temperature.

First arrival dates of spring migrant birds in the eastern region of Ireland are shown in Table 2. Five of seven bird species were seen earlier in the more recent time period (1969–1999) and three of those were significantly earlier. Arrival dates in the 1969–1999 period were on average 6 days earlier than in the 1927–1947 period.

DISCUSSION

The data taken from the *Irish Naturalists' Journal* shows that the majority of the phenophases analysed demonstrated an earlier occurrence with increasing temperatures. In fact, as reported in Donnelly *et al.* (2006), the Irish response appears to be greater than that for Europe as a whole, where events were shown to occur an average of 2.5 days earlier for every 1°C temperature increase (Menzel

Table 1—A summary of the regressions of phenological events on three-monthly mean temperature for each event type. The number of events (*n*), the number of significant (*sig*) and nonsignificant (*Not sig*) regressions are followed by the mean and *SE* of the regression coefficients (days/1°C) in each event type.

Type of event	*n*	*sig*	*Not sig*	*Mean response*	*SE*
First flowering date	61	45	16	−8.0	0.5
First leafing date	8	8	0	−8.3	0.6
First arrival of summer migrant birds	16	1	15	−1.1	0.7
First spring birdsong	9	2	7	−3.5	1.7
Departure of summer migrant birds	7	1	6	−0.7	1.3
First arrival winter migrant birds	3	2	1	5.5	2.5
First insect	30	12	18	−8.0	1.6
Other	9	4	5	−8.1	1.8

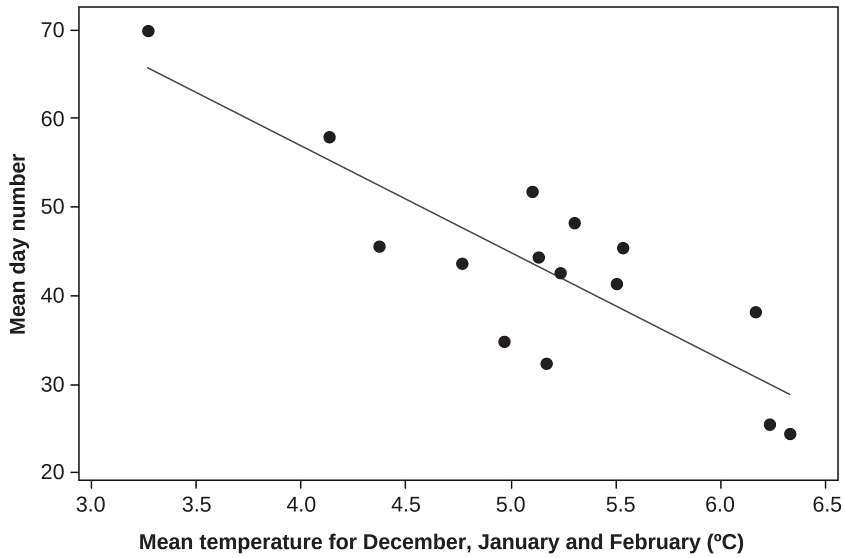

Fig. 1—Plot of mean day number of lesser celandine (*Ranunculus ficaria*) first flowering against mean December–February temperature (°C). The superimposed regression line estimates an advance of 12.1 days for each 1°C increase in temperature ($P < 0.001$).

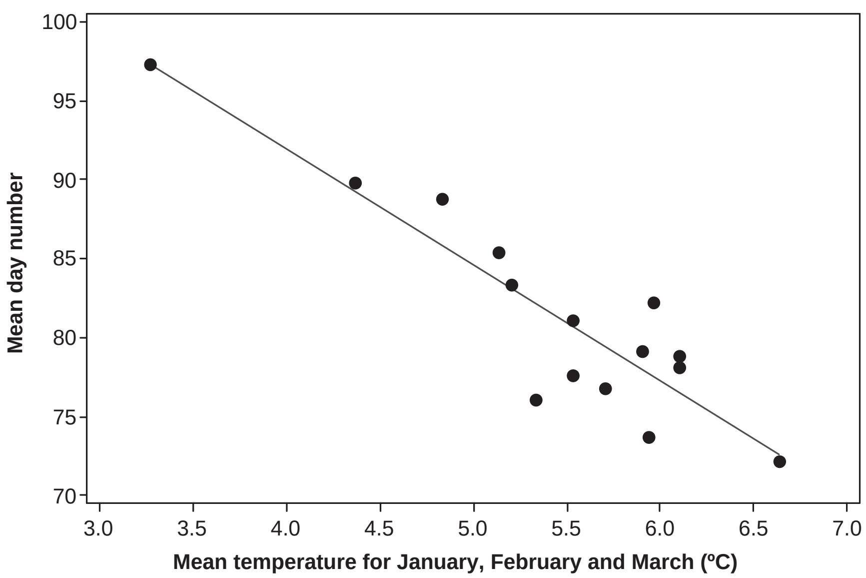

Fig. 2—Plot of mean day number of wood anemone (*Anemone nemorosa*) first flowering against mean January–March temperature (°C). The superimposed regression line estimates an advance of 7.4 days for each 1°C increase in temperature ($P < 0.001$).

et al. 2006). This temperature response was particularly apparent in plants, while the migrant birds did not exhibit such a strong response. This may not be surprising since it has been shown that birds are influenced by temperatures at other points along their migration routes (Ahola *et al*. 2004), while the data here has been analysed using Irish temperatures only. Despite this weaker response to temperature, we have also shown that some migrant birds are arriving in Ireland earlier now than they did in the first half of the twentieth century.

Population declines can sometimes mask earlier appearances of bird species as the organism is encountered less frequently and therefore early individuals can easily be missed (Tryjanowski *et al.*

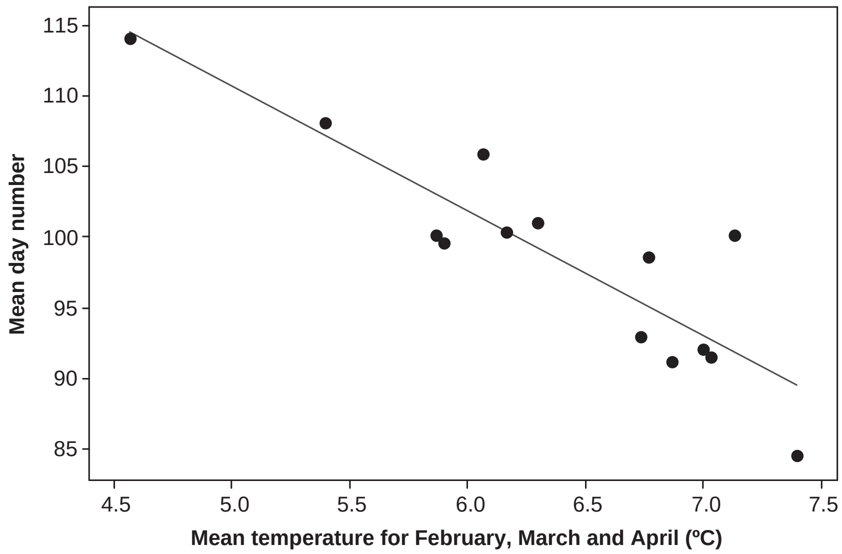

Fig. 3—Plot of mean day number of hazel (*Corylus avellana*) first leafing against mean February–April temperature (°C). The superimposed regression line estimates an advance of 8.8 days for each 1°C increase in temperature (*P* < 0.001).

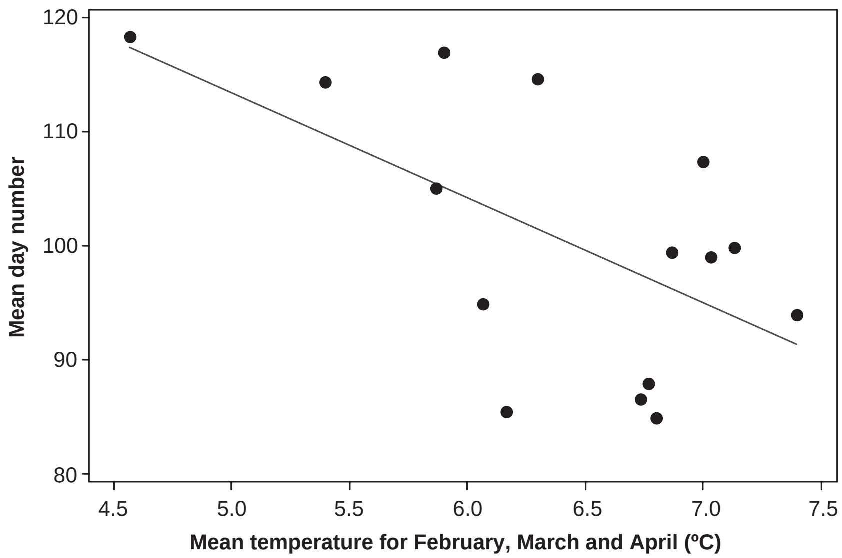

Fig. 4—Plot of mean day number of northern wheatear (*Oenanthe oenanthe*) spring arrival against mean February–April temperature (°C). The superimposed regression line estimates an advance of 9.2 days for each 1°C increase in temperature (*P* = 0.021).

2005). This could be particularly important in the case of the common cuckoo, for example, which is now much rarer than it was in the first half of the twentieth century.

We have used a rather broad-brush approach of comparing phenology with a three-month mean temperature up to and including the month in which the mean date was recorded. Improvements to the estimation of temperature responses might be possible if we were to target specific months or, in the case of migrant animals, temperatures they encounter in other parts of their life history. Alternatively, accumulated daily temperatures to each event may be used. Despite this, and the rather short duration (fifteen years) of the *Irish Naturalists' Journal*'s data, we have achieved

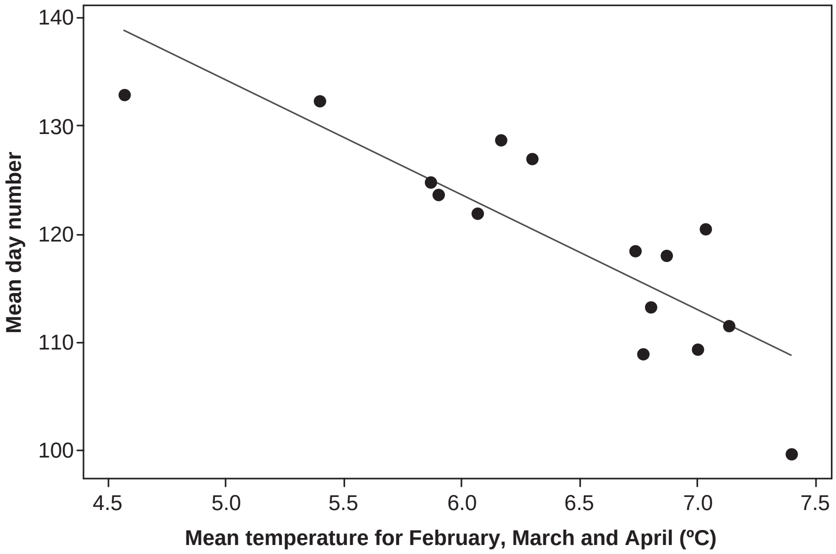

Fig. 5—Plot of mean day number of speckled wood butterfly (*Pararge aegeria*) first appearance against mean February–April temperature (°C). The superimposed regression line estimates an advance of 10.6 days for each 1°C increase in temperature ($P < 0.001$).

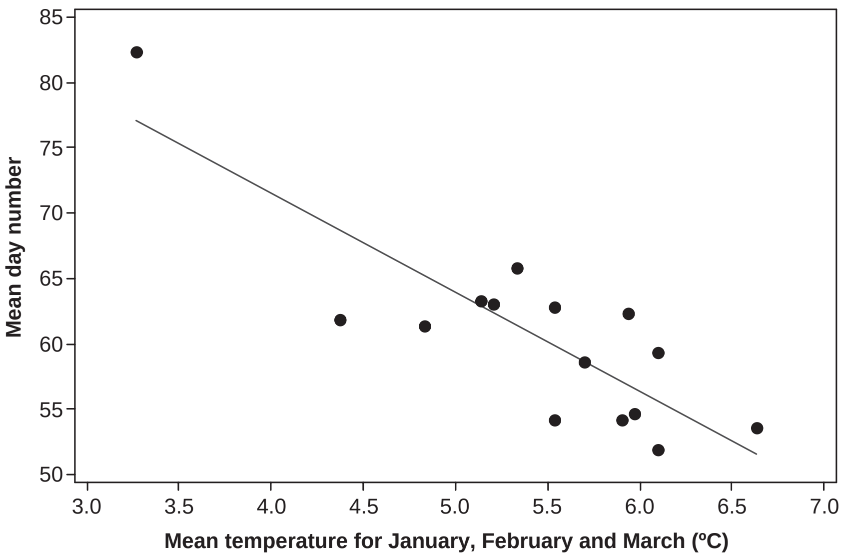

Fig. 6—Plot of mean day number of common frog spawn (*Rana temporaria*) first appearance against mean January–March temperature (°C). The superimposed regression line estimates an advance of 7.6 days for each 1°C increase in temperature ($P < 0.001$).

a very high level (*c.* 60%) of significant relationships between phenology and temperature. It is perhaps no great surprise that the better recorded events produced more significant relationships (rank correlation between total number of records and significance of regression on temperature $r_s = -0.393$, $P < 0.001$). In the current schemes to rejuvenate phenology in Ireland it would be appropriate not only to look at which events appear to be temperature responsive, but also to assess the potential popularity of different events. For example, in the *Irish Naturalists' Journal*'s data there were only 25 records of Holly Blue from 11 years but 413 records over fifteen years of lesser celandine.

It is clear from our results that not all species respond in the same way to increasing temperatures. This could cause a problem with asynchrony

Table 2—Mean first date (days after 31 December) of a subset of migrant bird arrivals from (*Irish Naturalists' Journal* 1927–1947) and various published and unpublished bird records from the eastern region of Ireland (1969–1999) and the *t*-test statistics comparing them.

Species	*Irish Naturalist mean first day*	*Eastern Ireland mean first day*	*t*	*P*
Common Cuckoo	109.1	110.1	−0.30	0.767
Common House Martin	**112.3**	**95.6**	**3.80**	**0.001**
Sand Martin	94.6	87.6	1.70	0.098
Sedge Warbler	**125.7**	**113.9**	**3.42**	**0.002**
Barn Swallow	**94.1**	**87.5**	**2.09**	**0.042**
Common Swift	115.5	114.5	0.42	0.680
Willow Warbler	93.1	95.5	−0.92	0.366

Species with a significant difference ($P < 0.05$) between the mean first dates are given in bold.

in food chains (Visser and Both 2005) if climate change continues as predicted. For example, if birds arrive in spring long after their insect food supply has hatched they will find themselves with less prey to feed on. Similarly, insects hatching before their food plants have leafed will encounter similar problems.

As stated in the introduction, phenological recording in Ireland has not traditionally been undertaken. This lack of long-term data is an obstacle to using such records to study how the environment is reacting to climate change. For example, while we have been able to use local bird report data to provide an up-to-date comparison to the migrant data abstracted from the *Irish Naturalists' Journal*, we have no equivalent for plants, so we cannot investigate whether these have become earlier in a similar way to a number of the birds. Given the greater temperature responsiveness of plants we would have expected a greater advance than in the birds. It is important that phenological data continues to be collected and we hope our demonstration of the responsiveness of phenology to temperature in Ireland may enthuse potential recorders. Historic data such as that uncovered in the *Irish Naturalists' Journal* can also play an important role in filling in the gaps in our phenological knowledge, and attempts should be made to discover and utilise any other data that may exist.

This paper has established that there has been advancement in phenological events in the Irish countryside during the twentieth century that is strongly correlated with increasing air temperatures. The range of species influenced is broad and includes insects, summer and winter migratory birds, aquatic and terrestrial flowering plants, and trees. Analysis of the data has also demonstrated the value of phenological recording in Ireland.

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APPENDIX

These tables summarise the species names, mean day number of occurrence (mean), regression coefficient (*b*) and significance (*P*) from a regression of mean annual day number on three-month temperature (period indicated in the months column, letters represent first letter of the month in a three-month series, i.e. OND = October, November and December and MAM = March, April and May). The total number of records (*N*) and the numbers of years of records (*n*) form the final two columns. Species with significant regressions ($P < 0.05$) are given in bold. Within each event type species are arranged in mean day order.

First Flowering

Species	*Latin name*	*mean*	*b*	*P*	*months*	*N*	*n*
Sweet-scented Butterbur	*Petasites fragrans*	−3.9	−6.8	0.074	OND	219	15
Snowdrop	***Galanthus nivalis***	**17.8**	**−5.6**	**0.016**	NDJ	**396**	**15**
Winter Aconite	*Eranthis hyemalis*	18.8	−6.0	0.067	NDJ	191	15
Yellow Crocus	***Crocus aureus***	**33.9**	**−9.2**	**<0.001**	DJF	373	15
Hazel (male)	***Corylus avellana***	**34.9**	**−8.7**	**0.026**	DJF	226	15
Hazel (female)	***Corylus avellana***	**43.1**	**−8.2**	**0.006**	DJF	270	15
Lesser Celandine	***Ranunculus ficaria***	**43.1**	**−12.1**	**<0.001**	DJF	413	15
Primrose	***Primula vulgaris***	**48.7**	**−9.4**	**0.024**	DJF	371	15
Yellow Coltsfoot	***Tussilago farfara***	**60.8**	**−8.0**	**<0.001**	JFM	337	15
Vernal Whitlow grass	***Erophila verna***	**65.9**	**−10.8**	**0.009**	JFM	103	15
Elm	***Ulmus* spp**	**74.4**	**−11.5**	**<0.001**	JFM	239	15
Almond	***Prunus dulcis***	**79.3**	**−11.7**	**<0.001**	JFM	96	15
Wood Anemone	***Anemone nemorosa***	**81.4**	**−7.4**	**<0.001**	JFM	341	15
Dog Violet	***Viola riviniana***	**81.6**	**−11.3**	**<0.001**	JFM	339	15
Common Butterbur	***Petasites hybridus***	**83.1**	**−6.2**	**0.036**	JFM	107	15
Larch	***Larix decidua***	**87.5**	**−7.4**	**0.003**	JFM	228	15
Marsh Marigold	***Caltha palustris***	**87.7**	**−8.8**	**<0.001**	JFM	306	15
Blackthorn	***Prunus spinosa***	**92.1**	**−11.9**	**<0.001**	FMA	421	15
Wood Sorrel	***Oxalis acetosella***	**92.4**	**−8.5**	**<0.001**	FMA	292	15
Poplar (unspecified)	***Populus* spp**	**98.0**	**−8.3**	**0.010**	FMA	58	14
Ground Ivy	***Glechoma hederacea***	**98.9**	**−9.0**	**0.001**	FMA	255	15
Cowslip	***Primula veris***	**102.0**	**−5.6**	**0.001**	FMA	260	15
Ash	***Fraxinus excelsior***	**105.5**	**−7.6**	**0.010**	FMA	196	15
Greater Stitchwort	***Stellaria holostea***	**108.9**	**−8.8**	**0.001**	FMA	305	15
Goldilocks	***Ranunculus auricomus***	**109.0**	**−8.6**	**<0.001**	FMA	115	15
Cuckoo-flower	***Cardamine pratensis***	**111.5**	**−7.0**	**<0.001**	FMA	342	15
Garlic Mustard	***Alliaria petiolata***	**111.9**	**−7.6**	**0.006**	FMA	145	15
Wild Hyacinth (Bluebell)	***Hyacinthoides non-scriptus***	**112.6**	**−7.7**	**0.001**	FMA	343	15
Germander Speedwell	***Veronica chamaedrys***	**116.1**	**−5.6**	**0.018**	FMA	260	15
Broad Leaved Garlic	***Allium ursinum***	**118.1**	**−7.2**	**0.008**	FMA	151	15
Cuckoo Pint	***Arum maculatum***	**118.7**	**−6.5**	**0.001**	FMA	237	15
Sea Pink	***Armeria maritima***	**119.1**	**−7.9**	**0.002**	FMA	**119**	**15**
Sea or Vernal Squill	*Scilla verna*	122.3	−16.9	0.269	MAM	31	12
Early Purple Orchis	***Orchis mascula***	**122.4**	**−9.7**	**0.007**	MAM	258	15
Horse Chestnut	***Aesculus hippocastanum***	**123.1**	**−14.6**	**<0.001**	MAM	339	15
Hawthorn	***Crataegus monogyna***	**129.0**	**−15.0**	**0.001**	MAM	395	15
Common Bugle	***Ajuga reptans***	**129.0**	**−8.3**	**<0.001**	MAM	172	15
Birdsfoot Trefoil	***Lotus corniculatus***	**132.3**	**−10.1**	**0.001**	MAM	**271**	**15**
Red Campion	*Silene dioica*	133.7	1.2	0.887	MAM	78	15
Bog Bean	***Menyanthes trifoliata***	**134.1**	**−9.2**	**0.034**	MAM	132	15

Species	*Latin name*	*mean*	*b*	*P*	*months*	*N*	*n*
Red Clover	***Trifolium pratense***	**134.9**	**−9.3**	**0.002**	MAM	280	15
Mountain Ash	***Sorbus aucuparia***	**139.7**	**−9.3**	**<0.001**	MAM	**193**	**14**
Ladies' Fingers	*Anthyllis vulneraria*	142.8	−6.8	0.127	MAM	121	15
White Clover	***Trifolium repens***	**145.6**	**−8.0**	**0.014**	MAM	236	15
White Ox-eye Daisy	***Leucanthemum vulgare***	**147.3**	**−7.2**	**0.003**	MAM	309	15
Yellow Iris	***Iris pseudacorus***	**151.3**	**−7.1**	**0.013**	MAM	**247**	**15**
Ragged Robin	*Lychnis flos-cuculi*	155.0	−3.7	0.309	AMJ	215	15
Yellow Water Lily	*Nuphar lutea*	158.7	−8.2	0.064	AMJ	110	14
Foxglove	*Digitalis purpurea*	159.7	−0.9	0.770	AMJ	199	14
Dog Rose	*Rosa canina*	161.9	−1.2	0.663	AMJ	303	15
White Water Lily	*Nymphaea alba*	162.1	−12.8	0.092	AMJ	75	14
Meadow Vetchling	*Lathyrus pratensis*	162.3	−1.9	0.434	AMJ	186	15
Tufted Vetch	***Vicia cracca***	**166.7**	**−13.5**	**0.030**	AMJ	**158**	**14**
Meadowsweet	*Filipendula ulmaria*	175.8	−3.2	0.157	AMJ	216	15
Harebell	*Campanula rotundifolia*	189.7	−4.0	0.117	MJJ	107	15
Black Knapweed	***Centaurea nigra***	**191.2**	**−7.2**	**0.015**	MJJ	**202**	**15**
Greater Bindweed	*Calystegia sepium*	193.7	−4.9	0.306	MJJ	170	15
Devils-bit Scabious	***Succisa pratensis***	**209.0**	**−5.3**	**0.031**	MJJ	**144**	**15**
Grass of Parnassus	*Parnassia palustris*	216.2	−2.9	0.680	JJA	72	15
Soapwort	***Saponaria officinalis***	**238.7**	**−18.8**	**0.002**	JJA	**31**	**14**
Ivy	*Hedera helix*	267.1	−1.6	0.473	JAS	196	15

First Leafing

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Horse Chestnut	***Aesculus hippocastanum***	**91.2**	**−9.7**	**0.001**	FMA	365	15
Larch	***Larix decidua***	**91.2**	**−10.1**	**<0.001**	FMA	239	14
Hazel	***Corylus avellana***	**98.6**	**−8.8**	**<0.001**	FMA	165	14
Elm	***Ulmus* spp**	**109.1**	**−8.6**	**0.013**	FMA	224	15
Beech	***Fagus sylvatica***	**112.5**	**−4.8**	**0.001**	FMA	293	14
Poplar (unspecified)	***Populus* spp**	**116.8**	**−9.7**	**<0.001**	FMA	103	14
Oak	***Quercus* spp**	**119.7**	**−6.6**	**0.003**	FMA	251	14
Ash	***Fraxinus excelsior***	**124.8**	**−8.0**	**0.019**	MAM	**257**	**15**

Summer Migrant Bird First Arrival

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Chiffchaff	*Phylloscopus collybita*	90.5	−1.6	0.135	JFM	267	15
Northern Wheater	*Oenanthe oenanthe*	100.6	−9.2	0.021	FMA	58	15
Willow Warbler	*Phylloscopus trochilus*	103.4	−1.2	0.350	FMA	230	15
Sand Martin	*Riparia riparia*	104.8	−0.9	0.651	FMA	169	15
Barn Swallow	*Hirundo rustica*	106.0	−0.1	0.883	FMA	465	15
Common Sandpiper	*Actitis hypoleucos*	113.5	0.7	0.460	FMA	64	15
Corncrake	*Crex crex*	116.3	−0.8	0.466	FMA	411	15
Common House Martin	*Delichon urbicum*	116.9	−1.0	0.370	FMA	218	15
Common Cuckoo	*Cuculus canorus*	117.6	−0.5	0.542	FMA	410	15
Arctic & Common Terns	*Sterna* spp	120.6	1.1	0.721	FMA	73	15
Common Swift	*Apus apus*	125.1	0.4	0.863	MAM	286	15
Sedge Warbler	*Acrocephalus schoenobaenus*	125.6	−1.1	0.589	MAM	67	15
Common Grasshopper Warbler	*Locustella naevia*	126.6	1.7	0.698	MAM	41	15

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Common Whitethroat	*Sylvia communis*	129.1	−2.9	0.192	MAM	134	15
Spotted Flycatcher	*Muscicapa striata*	138.0	−5.1	0.136	MAM	117	15
European Nightjar	*Caprimulgus europaeus*	142.8	2.8	0.622	MAM	26	13

First Bird Song Heard After Winter

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Song Thrush	*Turdus philomelos*	9.3	−5.6	0.107	NDJ	291	15
Great Tit	*Parus major*	20.3	6.0	0.143	NDJ	209	15
Mistle Thrush	*Turdus viscivorus*	20.3	−5.0	0.128	NDJ	212	15
Hedge Sparrow	*Prunella modularis*	29.6	−0.1	0.982	NDJ	207	15
Common Blackbird	***Turdus merula***	**36.0**	**−6.9**	**0.032**	DJF	**281**	**15**
Chaffinch	*Fringilla coelebs*	37.1	−0.9	0.662	DJF	231	15
Goldcrest	***Regulus regulus***	**45.7**	**−12.8**	**0.003**	DJF	**117**	**15**
Sky Lark	*Alauda arvensis*	56.4	−2.6	0.081	DJF	267	15
Yellowhammer	*Emberiza citrinella*	67.2	−3.8	0.097	JFM	156	15

Summer Migrant Bird Departure

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Common Cuckoo	*Cuculus canorus*	177.9	0.4	0.895	AMJ	167	15
Corncrake	*Crex crex*	209.2	1.3	0.743	MJJ	148	15
Common Swift	*Apus apus*	228.7	−0.1	0.920	JJA	172	15
Chiffchaff	*Phylloscopus collybita*	260.8	3.1	0.353	ASO	121	15
Sand Martin	***Riparia riparia***	**269.6**	**−7.6**	**0.042**	JAS	**69**	**15**
Common House Martin	*Delichon urbica*	270.1	−2.0	0.246	JAS	155	15
Barn Swallow	*Hirundo rustica*	278.6	−0.1	0.944	ASO	270	15

Winter Migrant Bird Arrival

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Grey Goose	***Anser* spp**	287.1	9.1	0.007	ASO	81	15
Redwing	***Turdus iliacus***	289.6	6.7	0.012	ASO	**103**	**15**
Fieldfare	*Turdus pilaris*	296.0	0.8	0.811	ASO	84	15

Insects first Observed

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Honey Bee	***Apis* sp.**	**72.1**	**−7.1**	**0.002**	JFM	**195**	**15**
Queen Bumble Bee	***Bombus* spp**	**79.7**	**−10.1**	**0.001**	**JFM**	**130**	**14**
Small Tortoiseshell	*Aglais urticae*	83.5	−7.4	0.070	JFM	263	15
Brimstone	***Gonepteryx rhamni***	**93.7**	**−10.7**	**0.030**	FMA	**36**	**12**
Queen Wasp	***Vespa* spp**	**96.4**	**−9.8**	**0.021**	FMA	**165**	**15**
Peacock Butterfly	***Inachis io***	**104.7**	**−13.6**	**0.003**	FMA	**186**	**15**
Small White	***Pieris rapae***	**109.5**	**−8.0**	**0.003**	FMA	**270**	**15**
Holly Blue	*Celastrina argiolus*	118.6	−8.4	0.120	FMA	25	11
Speckled Wood	***Pararge aegeria***	**119.5**	**−10.6**	**<0.001**	FMA	**152**	**15**
Green Veined White	***Pieris napi***	**119.8**	**−7.9**	**0.005**	FMA	**150**	**15**

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Orange Tip	***Anthocharis cardamines***	**122.0**	**−15.4**	**<0.001**	MAM	**271**	**15**
Painted Lady	***Vanessa cardui***	**124.6**	**−38.8**	**0.010**	MAM	**35**	**13**
Large White	***Pieris brassicae***	**124.7**	**−10.4**	**0.003**	MAM	**143**	**15**
Red Admiral	*Vanessa atalanta*	130.8	−17.6	0.268	MAM	61	14
Wall Brown	*Lasiommata megera*	134.7	−9.3	0.055	MAM	83	15
Small Copper	*Lycaena phlaeas*	144.4	−6.0	0.263	MAM	78	15
Common Blue	*Polyommatus icarus*	147.2	−9.1	0.257	MAM	75	15
Cinnabar Moth	*Tyria jacobaeae*	151.0	−7.8	0.124	MAM	110	15
Brimstone Moth	*Opisthograptis luteolata*	153.1	0.3	0.984	AMJ	47	13
Small Heath	*Coenonympha pamphilus*	156.8	1.3	0.730	AMJ	34	12
Ghost Moth	*Hepialus humuli*	161.1	0.2	0.982	AMJ	36	14
Six-spot Burnet	*Zygaena filipendulae*	171.1	−4.7	0.564	AMJ	40	13
Meadow Brown	*Maniola jurtina*	173.0	4.8	0.315	AMJ	119	15
Ringlet	***Aphantopus hyperantus***	**175.5**	**−15.5**	**0.003**	AMJ	**46**	**13**
Magpie Moth	*Abraxas grossulariata*	188.8	−9.0	0.154	MJJ	56	13
Dark-green Fritillary	*Argynnis aglaja*	194.1	1.9	0.743	MJJ	26	12
Ants flying	*Formicidae* spp	210.8	−15.4	0.061	MJJ	50	13
Red Admiral 2nd brood	*Vanessa atalanta*	223.4	6.6	0.384	JJA	70	14
Painted Lady 2nd brood	*Vanessa cardui*	229.3	10.6	0.223	JJA	36	12
Peacock Butterfly 2nd brood	*Inachis io*	232.2	−13.8	0.125	JJA	40	12

Other

Species	*Latin Name*	*mean*	*b*	*P*	*months*	*N*	*n*
Frog Spawn		**60.6**	**−7.6**	**<0.001**	JFM	**258**	**15**
American Gooseberry Mildew	*Sphaerotheca mors-uvae*	154.3	−1.6	0.896	AMJ	40	14
Wild Raspberries ripe	***Rubus idaeus***	**210.0**	**−21.0**	**0.027**	MJJ	**63**	**13**
Apple Scab	*Venturia inaequalis*	193.8	−9.7	0.262	MJJ	19	12
Potato Blight appeared	*Phytophthora infestans*	201.1	−6.5	0.481	MJJ	72	14
Oats cut	***Avena sativa***	**226.7**	**−6.2**	**0.044**	JJA	**146**	**14**
Wheat cut	*Triticum* spp	229.7	−7.2	0.073	JJA	84	14
Barley cut	***Hordeum vulgare***	**233.9**	**−8.0**	**0.034**	JJA	**52**	**14**
Hay cut		172.6	−5.4	0.164	AMJ	217	14