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ORIGINAL ARTICLE

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# Plant development scores from fixed-date photographs: the influence of weather variables and recorder experience

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**Abstract** In 1944, John Willis produced a summary of his meticulous record keeping of weather and plants over the 30 years 1913–1942. This publication contains fixed-date, fixed-subject photography taken on the 1st of each month from January to May, using as subjects snowdrop *Galanthus nivalis*, daffodil *Narcissus pseudo-narcissus*, horse chestnut *Aesculus hippocastanum* and beech *Fagus sylvatica*. We asked 38 colleagues to assess rapidly the plant development in each of these photographs according to a supplied five-point score. The mean scores from this exercise were assessed in relation to mean monthly weather variables preceding the date of the photograph and the consistency of scoring was examined according to the experience of the recorders. Plant development was more strongly correlated with mean temperature than with minimum or maximum temperatures or sunshine. No significant correlations with rainfall were detected. Whilst mean scores were very similar, botanists were more consistent in their scoring of developmental stages than non-botanists. However, there was no overall pattern for senior staff to be more consistent in scoring than junior staff. These results suggest that scoring of plant development stages on fixed dates could be a viable method of assessing the progress of the season. We discuss whether such recording could be more efficient than traditional phenology, especially in those sites that are not visited regularly and hence are less amenable to frequent or continuous observation to assess when a plant reaches a particular growth stage.

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## Introduction

The bulk of recent evidence for the impact of climate change on biological systems comes from phenology, involving the recording of the dates when plants and animals reach a certain stage of their life cycle (Parmesan and Yohe 2003; Root et al. 2003; Walther et al. 2002). Whilst phenology is very simple to record, it does require frequent observation on the part of the recorder to provide accurate dates on which events took place. Recent work has detailed numerous examples of phenological advance, particularly in spring (e.g. Menzel and Fabian 1999). In addition to contemporary data showing changes in timing in recent decades, historic data can be very useful in identifying both long-term change and long-term susceptibility to one or more climatic variables (e.g. Sparks et al. 2000). This data collection can be complicated by recent lifestyle changes with people taking longer and/or more frequent holidays, and data collected as part of a schools exercise where recording can be interrupted by school holidays.

Some biological recording schemes in the UK (e.g. RSPB Big Garden Birdwatch http://www.rspb.org.uk/birdwatch, BTO BirdWatch Shortest Day survey http://www.bto.org/gbw/shortest-day/index.htm, Wild Flower Society Last Hunt http://rbg-web2.rbge.org.uk/wfsoc/frameworka.htm) record events around fixed dates or national or religious holidays. These can encourage mass participation, partly fuelled by the knowledge of a limited time contribution, and generate substantial amounts of information in a short space of time. As an example, the Big Garden Birdwatch attracted nearly 400,000 participants in 2005 whose only commitment was a one-hour birdwatch followed by submission of data by post or via the internet. Detection of change can also be revealed by examining photographs taken of the same subject in different years. Such photographic analysis can reveal changes in, for

**Table 1** The subjects of the photographs taken in the 1913–1942 period, and definitions of the development scores used

| Date | Subject | No. of years | Scores | Bulbs | Branches |
|---|---|---|---|---|---|
| January 1 | Snowdrop *Galanthus nivalis* | 30 | 1 | Not emerged | Firm bud |
| February 1 | Daffodil *Narcissus pseudo-narcissus* | 28 | 2 | Emerged, short shoots | Swollen/loose bud |
| March1 | Daffodil *Narcissus pseudo-narcissus* | 26 | 3 | Extending stems | Leaves starting to emerge |
| April 1 | Horse chestnut *Aesculus hippocastanum* | 30 | 4 | Flower buds visible | Leaves half emerged |
| May 1 | Beech *Fagus sylvatica* | 18 | 5 | In flower | Full leaf |

example, scrub development, sward height, tree growth, community composition and structure (Penuelas and Boada 2003) or glacial retreat (Thompson et al. 2002).

Might it be possible to combine these fixed-date and photographic elements to assess the progress of seasons? In this paper we utilise an existing resource, the photographic collection of John Willis, to examine the potential of fixed-date fixed-subject photographs in assessing seasonal progress and the influence of weather on this progress.

## Materials and methods

### Photographs and weather data

In *Weatherwise* (Willis 1944), John Willis presented a series of fixed-date, fixed-subject photographs taken between the years 1913 and 1942 as detailed in Table 1. These involved the image of the same plant or branch on the stated day. An example of two of the photographs is shown in Fig. 1. Unfortunately no scale was included in the image, and it is thus impossible to measure the height of the plant or the degree of swelling of the leaf bud, etc. Indeed, such a single measurement variable may be inappropriate when attempting to measure bud swelling in one year, for example, with leaf development in another. In the same book, Willis summarised monthly data for maximum shade, minimum screen, minimum grass and mean temperatures together with rainfall and sunshine. These were entered onto a computer and converted to metric measurements.

### Development scores

Scans of the photographs were shown (projected) to 38 colleagues at Monks Wood during a seminar. They were asked to assess rapidly (<10 s/photograph) these images according to a supplied five-point scale (see Table 1). Scores were made on anonymous recording forms; the only other information requested was whether the recorders considered themselves to be a botanist, and an indication of their grade. The latter were summarised into four categories, A–D; A the most senior and D the most junior.

### Analysis

For each year and date, means and standard deviations (SDs) were calculated across all recorders, and separately for the botanist/non-botanist and grade categories. The

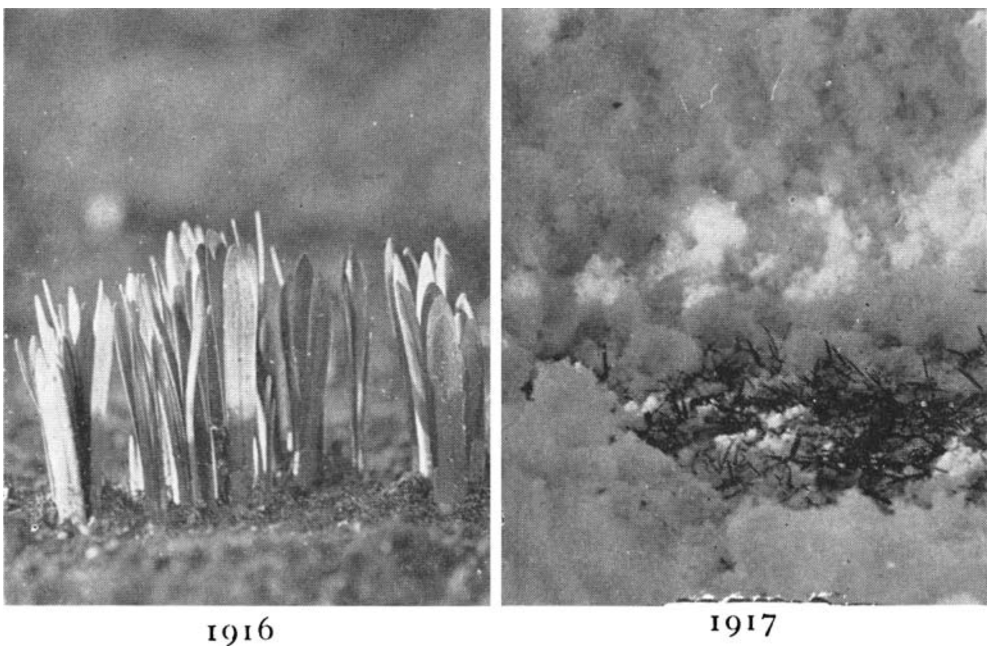


**Fig. 1** The Willis photographs of daffodil *Narcissus pseudo-narcissus* on 1 February 1916 and 1 February 1917. Mean January temperatures of the two years were 6.8°C and 1.7°C, respectively. Source: Willis (1944)

**Table 2** Correlations between mean development scores and preceding mean monthly temperatures, and results from stepwise regression

| | Correlations with mean monthly temperatures | | | | | | | Stepwise regression | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | Months | Combined response | $R^2$ | $P$ |
| Snowdrop | 0.13 | **−0.43** | 0.36 | | | | | Nov | −0.16 | 18.8 | 0.019 |
| Daffodil (1 Feb) | −0.13 | −0.18 | 0.30 | **0.84** | | | | Jan | 0.25 | 69.2 | <0.001 |
| Daffodil (1 Mar) | −0.23 | −0.15 | 0.26 | **0.72** | **0.87** | | | Jan, Feb | 0.35 | 80.7 | <0.001 |
| Horse chestnut | −0.29 | −0.25 | −0.09 | 0.24 | **0.43** | **0.71** | | Mar | 0.48 | 50.0 | <0.001 |
| Beech | −0.14 | 0.03 | −0.16 | 0.19 | **0.56** | 0.32 | 0.30 | Feb | 0.35 | 31.5 | 0.015 |
| Daffodil (Feb to Mar) | −0.24 | −0.11 | 0.04 | 0.03 | **0.60** | | | | | | |

Significant correlations are emboldened. For the stepwise regression the mean temperatures of the 3 months preceding the photograph were candidates for explanatory variables. The combined response indicates the predicted increase in development score for a 1°C increase in temperature in the selected months. At the bottom of the table correlations with the difference in development score of daffodil between 1 February and 1 March are presented

difference between daffodil scores on 1 February and 1 March was calculated from annual mean scores.

Annual mean scores for the whole group were compared to the weather data for the 3 months preceding the photograph, e.g. October–December for snowdrop and February–April for beech. Correlations with mean temperature were undertaken for preceding months, and stepwise regression was carried out with mean temperatures of the 3 months preceding the photographs as candidate explanatory variables.

Annual mean scores and standard deviations for the botanist/non-botanist groups were compared using 2-way ANOVA (factors: year and botanist/non-botanist). A similar comparison was made for the four grade categories. A regression of non-botanist score on botanist score was undertaken for each species/date combination to assess whether the slope differed from 1 (unity).

## Results

Correlations with weather from the three preceding months (not presented) revealed six significant correlations (out of a possible 15) for maximum shade temperature, five (of which one negative) with minimum screen temperature, four with minimum grass temperature and seven (of which one negative) with mean temperature. None of the correlations with rainfall were significant and only two with sunshine. The correlations with mean temperature were also invariably larger than the others and for these reasons only mean temperatures were considered in subsequent analyses.

All species displayed significant correlations with one or more mean temperatures of preceeding months (Table 2). In general, correlations with autumn temperatures tended to be negative (warm winters delaying growth) and those with months immediately preceding the photograph positive (warm weather encouraging growth, e.g. Fig. 2.). The (positive) correlation between snowdrop development score and December temperature failed to achieve significance. For beech, the previous month's temperature was not the strongest correlate. With the exception of daffodil (1 March), multiple regression models were restricted to a single month's temperature and all were significant, although that

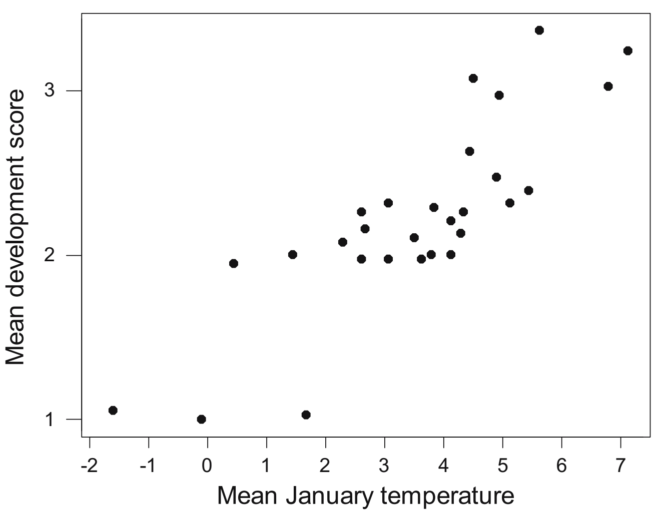


**Fig. 2** The mean development score of daffodil from photographs taken on 1 February plotted against mean January temperature

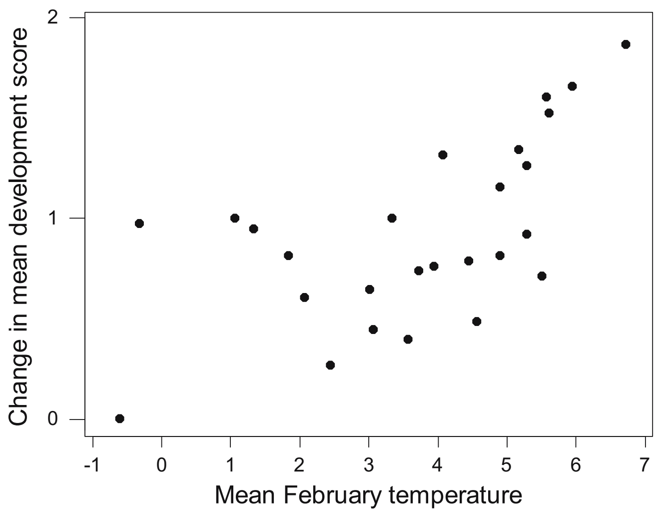


**Fig. 3** The difference between mean development scores on 1 March and 1 February for daffodil plotted against mean February temperature

**Table 3** Means of annual development scores and standard deviations (SD) for the botanist and non-botanist groups

| Subject | Botanists (*n*=16) | | Non-botanists (*n*=22) | | Significance between groups (*P*) | | |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Of means | Of SDs | Slope±SE |
| Snowdrop | 2.15 | 0.29 | 2.16 | 0.35 | 0.66 | 0.067 | 1.03±0.05 |
| Daffodil (1 Feb) | 2.23 | 0.29 | 2.22 | 0.42 | 0.70 | **0.001** | 1.02±0.03 |
| Daffodil (1 Mar) | 3.17 | 0.33 | 3.10 | 0.36 | **0.006** | 0.186 | 1.00±0.04 |
| Horse chestnut | 2.39 | 0.44 | 2.38 | 0.56 | 0.71 | **0.001** | 0.99±0.02 |
| Beech | 4.07 | 0.35 | 4.02 | 0.39 | 0.084 | 0.421 | 1.03±0.02 |

Differences between groups were tested using ANOVA. Regressions slopes of non-botanist scores on those of botanists are given in the final column. Significant results emboldened

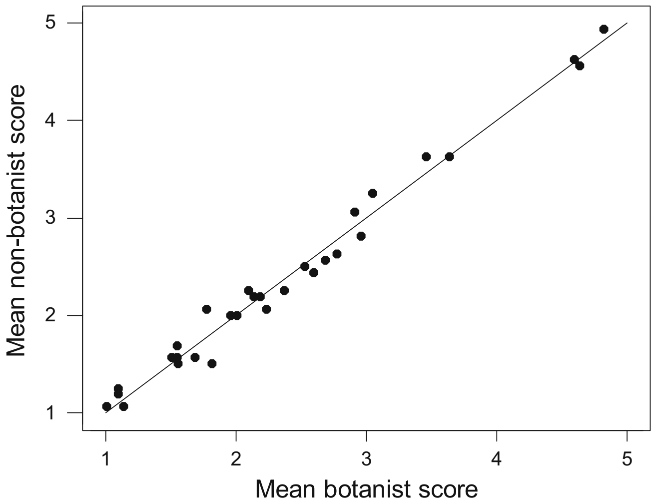


**Fig. 4** The relationship between mean botanist and non-botanist development scores for horse chestnut from 1 April photographs. A line of unity has been superimposed

of snowdrop had a negative coefficient suggesting warm weather in late autumn could delay development. The difference between the 1 February and 1 March development scores was positively correlated with mean February temperature (Table 2, Fig. 3).

Table 3 summarises the mean values and standard deviations in the botanist/non-botanist comparison. The mean values were close although the daffodil (1 March) mean score for botanists significantly exceeded that for non-botanists. There was greater disparity in mean SD with significant differences for daffodil (1 February) and horse chestnut and in all five species/date combinations SDs of the non-botanist group were larger. Regressions between the two groups produced slopes not significantly different from unity (Table 3, Fig. 4).

Table 4 summarises the results from the four grade categories. Whilst mean values are close, three reveal statistically significant differences. Four of the analyses of SDs have a significant group effect, although interpretation of differences is difficult as it is the second group (B) that appears most variable, except for beech where this group is least variable!

## Discussion

It is clear from this study that plant development relied heavily on temperature, particularly mean temperature. There were no significant correlations with rainfall and few with sunshine. Within the UK, temperature is likely to remain the driving force in plant development, except in extreme cases of water stress. Negative correlations with autumn temperatures emphasise that some plants require a chilling phase before breaking dormancy, as was shown with phenology by Sparks and Carey (1995).

With the exception of snowdrop, strong positive correlations were shown between preceding months' temperature and plant development, although with beech the correlation with temperature 2 months previously was the strongest. Of the seven flowering species considered by Sparks and Manning (2000) between 1965 and 2000, snowdrop appeared to be the least responsive to temperature at 3.8 days earlier per 1°C warmer. In contrast, daffodil appeared to have a response of 7.9 days earlier per 1°C warmer. Of particular interest is that these records were

**Table 4** Means of annual development scores and standard deviations (SD) for the four grade groups (A=most senior)

| Subject | A (*n*=6) | | B (*n*=8) | | C (*n*=14) | | D (*n*=10) | | Significance between groups (*P*) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Of means | Of SDs |
| Snowdrop | 2.24 | 0.30 | 2.19 | 0.41 | 2.13 | 0.28 | 2.12 | 0.24 | **0.003** | **0.001** |
| Daffodil | 2.26 | 0.24 | 2.22 | 0.56 | 2.21 | 0.24 | 2.23 | 0.33 | 0.55 | **<0.001** |
| Daffodil | 3.10 | 0.33 | 3.20 | 0.35 | 3.05 | 0.33 | 3.19 | 0.32 | **<0.001** | 0.892 |
| Horse chestnut | 2.31 | 0.30 | 2.36 | 0.66 | 2.40 | 0.47 | 2.41 | 0.44 | 0.104 | **<0.001** |
| Beech | 3.93 | 0.49 | 4.12 | 0.24 | 4.00 | 0.39 | 4.10 | 0.32 | **<0.001** | **<0.001** |

Differences between groups were tested using ANOVA. Significant results emboldened taken in Norwich, close to where Willis lived. Another local study reported in Sparks and Gill (2002) suggested a greater response in horse chestnut (4.8 days/1°C) than in beech (3.0 days/1°C). It is quite clear that these species have translated this temperature responsiveness into phenological advance in recent years as temperatures have increased, e.g. snowdrop (Sparks and Smithers 2002), daffodil (Sparks and Manning 2000), horse chestnut (Defila and Clot 2001; Sparks and Gill 2002) and beech (Sweeney et al. 2002).

Development scores between different groups were broadly comparable although some significant differences were revealed. This is a contrasting dilemma to that usually encountered in statistical analysis of too much variability. Here ANOVA models of mean scores had very low residual variability ($R^2$>98% for botanist/non-botanist comparisons and $R^2$>96% for comparisons between grades) and small differences between mean values were detected as statistically significant. Botanists were more consistent scorers than their non-botanical counterparts. Differences between grades were less easy to interpret but, as recording forms were anonymous, it was not possible a posteriori to identify individuals who may have contributed to greater variability in the B grade.

The use of fixed-date, fixed-subject photographs to produce development scores appears to provide a viable method to assess seasonal progress. The use of digital cameras and the internet provide options for low-cost mass participation exercises. Phenology requires regular monitoring of vegetation before the date of a specific phase (e.g. flowering, bud burst, leafing) is recorded. The use of a simple photograph on a fixed date may require less commitment and allow a greater number of sites to be assessed on the same day. Strictly speaking, the photograph is only necessary if the scores are centrally assessed or an archive is necessary, otherwise the person on the ground can record the development score.

Fixed date monitoring is widely practised; for example the 4 July (Independence Day) count of Monarch and other butterflies (http://www.naba.org), flower counts on the last day of October (Wild Flower Society), the Christmas Bird Count (http://www.audubon.org/bird/cbc/index.html), or bird watching on the last weekend in January (Big Garden Birdwatch). Plant development scoring would be simpler than all these because the subject is not mobile, and a simple rapid assessment rather than a count of observed species is necessary.

We recommend further assessment of the suitability of fixed-date scoring for monitoring the seasonal progress of plants. In particular, a comparison between traditional phenological recording (and its repeatability) with plant development scores would be both timely and valuable.

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