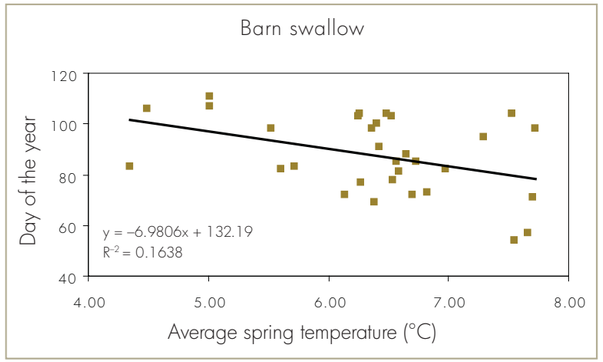

Figure 3: Arrival date (day of year) of the barn swallow in relation to spring temperature (average February to April temperature). As spring temperature increases the arrival time is earlier (negative relationship).

atmosphere because leaves photosynthesise for longer periods. There are currently no phenological models available for birds, but, based on historic records, we would expect the trend towards earlier arrival dates to continue, at least in the short-term. Survival will ultimately depend on an adequate food supply being available when they do arrive.

Observations of the timing of phenophases in both plants and animals have proven to be an effective way of demonstrating the impact of rising temperature on the natural environment. The development of phenological models has enabled projections to be made of what might be expected to happen in future as temperatures continue to rise. Further research is required on the interactions between interdependent phenophases to determine possible implications for ecosystem dynamics under a range of climate change scenarios.

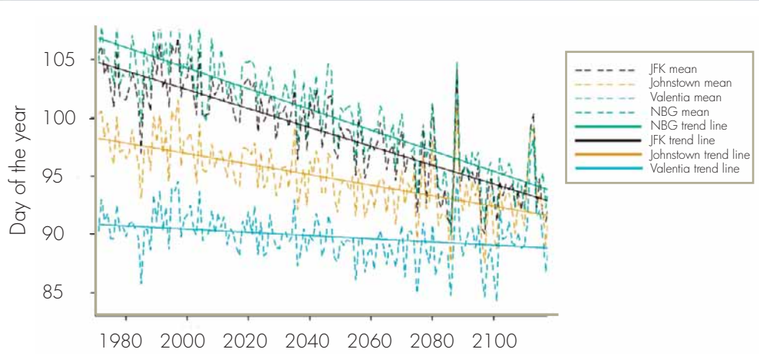

Figure 4: Phenological model output for the timing of birch tree leafing at four stations (JFK – John F. Kennedy Arboretum, Co. Wexford; Johnstown – Johnstown Castle, Co. Wexford; Valentia – Valentia Observatory, Co. Kerry; and NBG – National Botanic Garden, Glasnevin) in Ireland, 1950–2100.

Useful websites

Nature Watch (http://phenology.biodiversityireland.ie/)
Phenology at Trinity College Dublin (www.tcd.ie/botany/phenology)
Landscape scale phenology at University College Cork
(http://cmrc.ucc.ie/pages/research_project_page.php?project_code=phenology)
Greenwave – phenology for primary schools (www.greenwave.ie)
Biology.ie – phenology for secondary schools (www.biology.ie)
International Phenological Gardens network (www.agrar.hu-berlin.de/struktur/institute/nptw/agrarmet/phaenologie/ipg)
National Phenology Network, USA (www.usanpn.org)

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10th Scientific Statement

The impact of rising spring temperature on trees, insects and birds in Ireland

RIA Climate Change Sciences Committee

RIA

Detecting the impact of climate change, in particular rising temperature, on our natural environment can be a challenging task. In spring, increasing temperature is the overriding environmental trigger for plant and animal development in temperate regions, although other environmental parameters, such as precipitation and day length, play a role. The timing of leafing of trees, arrival of migratory birds and appearance of insects all signal the arrival of spring and are strongly influenced by local temperature. When spring temperature is higher than average these events will occur earlier in the year, and when spring temperature is lower than average, as was the case in 2010 and 2011, we expect to see these events occurring later in the season. The study of the timing of these life-cycle events in plants and animals is called phenology and the developmental events are referred to as phenological events, or phenophases for short.

Beech leaf unfolding
Photo: Markus Eugster.

Phenophases that occur in autumn, such as leaf colouring, leaf fall and bird departure are certainly influenced by temperature but the main environmental cue driving the timing of these events is shortening day-length.

By examining the timing of phenophases through time it is possible to determine whether temperatures were relatively higher or lower than usual. Phenology, in particular spring phenology, is sensitive to temperature and is therefore widely used as an indicator of temperature in climate change research. Indeed, the IPCC's 4th Assessment Report[1] used the results of a study[2] containing more than 100,000 phenological records from 20 European countries, including Ireland, to demonstrate to policy makers that climate change was having a detectable impact on the natural environment.

Where does the phenological data come from?

There are many long-established phenology networks throughout the world, such as the International Phenological Gardens (IPG) network, the Finnish Phenology Network and the phenology network established by the Royal Meteorological Society in 1875. Ireland is part of the IPG network, which was established in the late 1950s. A number of genetically identical trees, such as beech, birch, poplar and cherry, were distributed to more than 50 locations throughout Europe, and the timing of a range of phenophases, such as bud burst, leaf unfolding, flowering, fruiting, leaf colouring and leaf fall, were systematically recorded each year.

Arrival dates of migratory birds and appearance dates of insects are collected at various locations and published regularly. More recently, a series of National Phenology Networks (NPN) in the USA (USA-NPN), Sweden (SWE-NPN) and Ireland (IE-NPN), have been established to incorporate a wider range of species, including plants, insects and birds. In addition, 'citizen science' projects have been established to encourage the general public to collect phenological data on a range of common spring and autumn events such as the arrival of swallows, the appearance of the clouded yellow butterfly and leafing and leaf fall of birch. Members of the public are invited to record, on a website, the location and date on which they observe these phenophases. Nature Watch (http://phenology.biodiversityireland.ie/) is the recently established Irish website that, it is envisaged, will yield valuable data on which to conduct research in future.

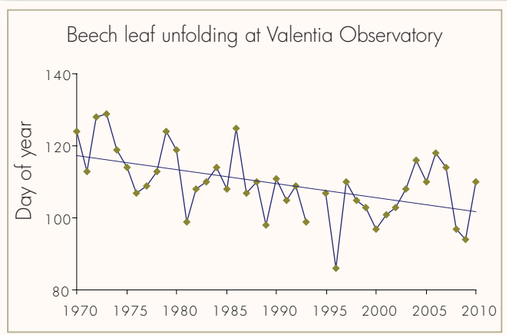

Figure 1: Timing (day of year) of beech leaf unfolding at Valentia Observatory 1970–2010.

What the data have revealed

Some recently analysed data from Ireland has shown that leafing of a range of tree species has steadily occurred earlier since the 1970s[3] (Figure 1).

In addition, the arrival time of sub-Saharan migrant bird species is also earlier[4] (Table 1) and insects such as the flame carpet moth are not only appearing earlier, but are also exhibiting a longer flight period (length of time between first and last sighting) (Figure 2). All of these advancing trends have been attributed, at least in part, to rising spring temperature. When spring temperature is relatively high these events occur earlier in the year (Figure 3).

The studies mentioned here have focused on individual groups of species. But if interdependent phenophases, such as bird arrival dates and insect (primary food source) appearance dates, respond differently to rising temperature, a mismatch in the timing between the bird and its food source may occur, which in turn may have detrimental implications for bird survival rates.

What does the future hold?

Phenological models, using output from global climate models, that predict bud burst dates of birch suggest that birch leafing will continue to advance (i.e. occur earlier) as spring temperature rises (Figure 4). There is every reason to believe that this response will also hold true for other temperate tree species. Earlier leafing can have positive and negative effects on forests and horticulture. Earlier leafing can result in trees being vulnerable to late frosts, which could have negative implications for the fruit industry. On the other hand, early leafing results in a longer growing season, because the leaves remain on the trees for longer. This, in turn, would ensure that more carbon dioxide (CO_2) is removed from the

SUB-SAHARAN BIRD SPECIES	TREND OVER TIME
Common cuckoo *Cuculus canorus*	Later
Common swift *Apus apus*	Earlier
Sand martin *Riparia riparia*	Earlier
Barn swallow *Hirundo rustica*	Earlier
Common house martin *Delichon urbicum*	Earlier
Whinchat *Saxicola rubetra*	Earlier
Northern wheatear *Oenanthe oenanthe*	Earlier
Common grasshopper warbler *Locustella naevia*	Earlier
Sedge warbler *Acrocephalus schoenobaenus*	Later
Common whitethroat *Sylvia communis*	Earlier
Willow warbler *Phylloscopus trochilus*	Earlier

Table 1: Trends in arrival dates of common summer migrants to Ireland over a 31-year period (1969–1999).

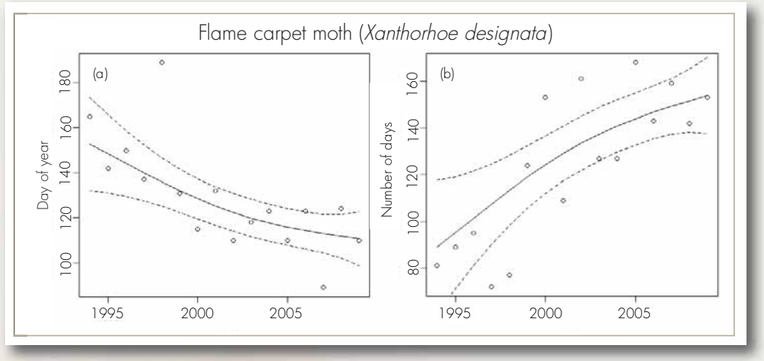

Figure 2: Flame carpet moth (a) appearance time and (b) flight period, Raphoe, Co. Donegal. Appearance time is getting earlier while the length of the flight period is extending. Dashed line represents the 95% confidence interval.

Barn swallow *(Hirundo rustica)*

[1].IPCC (2007) IPCC Fourth Assessment Report: Climate Change 2007. Available online at: http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

[2].Menzel, A., Sparks, T.H., Estrella, N., *et al.* 2006 European phenological response to climate change matches the warming pattern. *Global Change Biology* **12**, 1–8.

[3].Donnelly, A., Salamin, N. and Jones, M.B. 2006 Changes in tree phenology: an indicator of spring warming in Ireland? *Biology and Environment: Proceedings of the Royal Irish Academy* **106**B (1), 47–55. Available online at: http://www.jstor.org/stable/pdfplus/20728577.pdf

[4].Donnelly, A., Cooney, T., Jennings, E., Buscardo, E. and Jones, M. 2009 Response of birds to climatic variability; evidence from the western fringe of Europe. *International Journal of Biometeorology* **53**, 211–20.