Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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Report Series No. 23

Ireland's National Phenology Network (IE-NPN)

SSTI
Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

Environmental Protection Agency

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Climate Change Research Programme 2006–2013

Ireland's National Phenology Network (IE-NPN)

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Prepared for the Environmental Protection Agency

by

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Executive Summary

Everybody is familiar with idea of the first snowdrop or daffodil in spring, the first swallow of summer or the last rose. Phenology is the scientific study of the timing of these types of recurring life-cycle events in plants and animals. With long-term observations over decades, it becomes possible to identify important patterns between these events and the external forces which influence them. It also becomes apparent that plant and animals species show a high degree of interdependence with respect to the timing of these events.

As part of the EPA-funded project entitled 'Climate change impacts on phenology: implications for terrestrial ecosystems', Ireland's National Phenology Network (IE-NPN) was established to coordinate phenological activity throughout the country. The number of designated phenological recording sites was expanded to include International Phenological Gardens (IPG) sites and a series of native species gardens. The combined networks will enable comparison of the timing of phenological phases of a range of trees at a European level using the IPG data and at a national level using the native species. The number of sites across the country is continuing to evolve as some sites withdraw from the networks and others are added.

Ireland's National Phenology Network is also the contact point for collaboration with other similar networks around the world, such as the national phenology networks in Sweden (SWE-NPN) and the USA (USA-NPN), Nature's Calendar in the UK and many others. Research activity is a key focus of IE-NPN and a number of historic datasets have been identified and analysed in relation to temperature variables to determine if global warming has had an impact on plants, birds and insects in the Irish environment. In brief, an advance in the timing of key spring phenophases of plants (leaf unfolding of a range of trees), birds (arrival of spring migrants and departure of winter visitors) and insects (appearance and flight time of a range of moths) has occurred since the 1970s and this can be attributed, at least in part, to rising spring temperature. In addition, landscape phenology can be determined from remote sensing data to establish the start of the growing season, and historic data can be used in combination with projections of future temperature to simulate the timing of phenological events in future.

In recent years the involvement of the general public and school pupils in monitoring the environment has gained popularity. This has been achieved with the development of 'citizen-science' initatives. Citizen-science networks are used extensively in phenology research and provide valuable data by which to determine climate change impacts. These networks also help raise awareness among the non-scientific community of potential environmental threats. The *Nature Watch* website was established in collaboration with the National Biodiversity Data Centre to expand the range of species and the geographic area from which phenological data could be collected.

In conclusion, phenological activity in Ireland has proven extremely valuable in demonstrating the impact of climate warming on plant and animal development, and has also shown how future warming may result in an even earlier start to spring. The establishment of the IE-NPN was instrumental in co-ordinating both monitoring and research in phenology at a national level, and resulted in raising awareness of the value of phenology as an indicator of climate change.

The recommendations from this work are to continue to expand the number of designated phenological monitoring sites across the country and the range of species therein and to encourage further participation of the general public in the systematic monitoring of the environment.

1 History of Phenology in Ireland

1.1 What is Phenology and Why is it Important?

Each spring, buds begin to come alive on trees, flowers start emerging from the cold ground and many migratory birds commence their long journey from sub-Saharan Africa to arrive in Irish gardens – all these events mark the end of winter and the beginning of a new spring season. When spring temperature is warmer than usual, snowdrops burst out of the ground, leaves emerge earlier, and the swallow may also arrive earlier than is customary. On the other hand, when spring temperature is colder than usual (as was the case in the spring of 2011), all of these events are delayed slightly and it is considered a 'late' spring. The study of the timing of these recurring life-cycle events in plants and animals is called 'phenology' and the events themselves called 'phenological phases' or 'phenophases' for short (Fig. 1.1).

Research has shown that phenological development is closely regulated by climatic conditions, particularly temperature. Flowering of plants in spring, colour changes of leaves in autumn, bird migration and nesting, insect hatching, and animal hibernation are all examples of phenological events. Phenological research has recently gained recognition as an important tool in global change science

Having annual records of the date when bud burst of a particular tree occurred over its lifetime allows us to infer if spring temperature was warmer or colder than usual. Bud burst is usually early if the temperature is warm and late if the temperature is cold. Similarly, if we know the date of arrival of migratory birds we can infer what spring temperatures were like. This sensitivity to temperature makes phenology a useful indicator of temperature and is therefore an important tool in climate change research. Indeed, a study by Menzel et al. (2006) of over 100,000 primarily spring phenological records from 20 European countries – one of which was Ireland – was used in the Intergovernmental Panel on Climate Change's (IPPC) *Fourth Assessment Report* to demonstrate to global policy-makers that climate change was having a direct impact on our immediate environment.

In addition, in order to generate an interest in science in general, phenological networks offer the opportunity to encourage children and adults to make observations of their local environment and the way that it changes over the years. Phenology by its nature is a very simple tool to detect climate change and thus allows the consequences of what is perceived as a global problem to be investigated at a local level.

1.2 History of Phenology Recording in Ireland

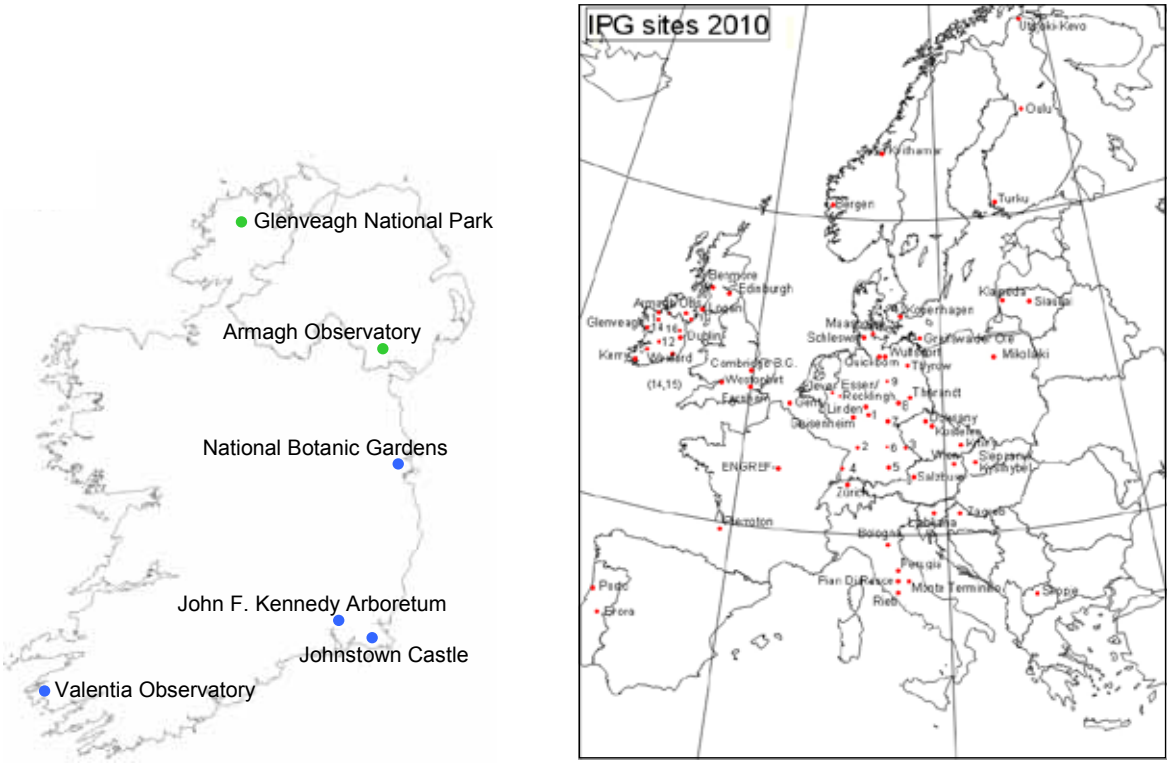
Inspired by the phenological system operated by the Royal Meteorological Society of London, Irish architect and naturalist Arthur Stelfox initiated phenological recording in Ireland in 1927 by requesting academics, naturalists and members of the public to record the timing of events in common Irish plants, birds and other

Figure 1.1. Various phenological phases of bud burst and leaf unfolding of aspen (*Populus tremula*). Image by Annelies Pletsers.

forms of wildlife in the countryside. These observations were recorded in phenological reports of the *Irish Naturalists' Journal*. A more systematic phenological recording method began in Ireland in the early 1960s as part of the Europe-wide International Phenological Gardens (IPG) network. This network was established in 1957 by Fritz Schnell and Ernst Volkert of the Deutsche Wetterdienst (the German weather service) and today comprises nearly 90 sites across 19 different European countries. Four IPGs were established in Ireland in the 1960s by Austin Burke, former director of the Irish Meteorological Service, in cooperation with the National Botanic Gardens and the Department of Agriculture. These sites are located at Valentia Observatory, Co. Kerry, John F. Kennedy Arboretum, Co. Wexford, Johnstown Castle, Co. Wexford and the National Botanic Gardens in Dublin (Fig. 1.2 and Table 1.1). Observations are made in line with the guidance provided by the co-ordinators in Berlin. Met Éireann (the Irish Meteorological Service) managed the collection and submission of observations until Frank Chmielewski of the Humboldt University rolled out a direct data-submission web interface in 2006. Little attention was paid to the analysis of the data collected until recently. In 2001 a study on 'Indicators of Climate Change' was commissioned by the Irish Environmental Protection Agency (EPA) and interest in this valuable phenological data was established as the relationship between spring phenology and temperature was recognised. The data from the IPG sites were employed as a useful spring warming indicator for Ireland (Sweeney et al., 2002; Donnelly et al., 2004 & 2006) and also contributed to the meta-analysis performed by Menzel et al. (2006), which showed that phenological events closely match climate warming in Europe over a 30-year period (1971–2000).

Two additional IPGs were established in recent years, the first in Armagh Observatory (2003) and the second in Glenveagh National Park (2007), both using the standard IPG species (Table 1.2). In addition, some native tree species have also been incorporated.

The formal collection of phenology data from the gardens meant that relatively long time-series were available from the 1960s. However, a search for earlier data revealed that back issues of the *Irish Naturalists' Journal*, which has been published every



(a) (b)

Figure 1.2. Location of the international phenological gardens (a) in Ireland pre-1960 (blue dots) and early 2000s (green dots) and (b) in Europe.

year since 1925, contained some useful data. 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. This analysis has shown that there was advancement in phenological events in the Irish countryside during the twentieth century which was strongly correlated with increasing air temperatures. In addition, the range of species influenced was broad and included insects, summer and winter migratory birds, aquatic and terrestrial flowering plants, and trees.

Table 1.1. List of species at each of the original International Phenological Gardens (IPGs).

Species	Valentia Observatory	John F. Kennedy Arboretum	Johnstown Castle	National Botanic Gardens	Glenveagh National Park	Armagh Observatory
Betula pubescens	1 (g)	3 (g,g,g)	3 (f,f,p)		1 (g)	1 (g)
Fagus sylvatica						
'Har'	2 (g,p)	1 (g)			1 (g)	
'Tri'	2 (p,g)	2 (g,g)		nl		
'Dud'	1 (p)				1 (g)	
'Dan'		2 (g,g)				
Fagus orientalis		2 (g,g)	1 (g)			
Populus canescens	3 (f,f,d)	2 (g,p)		2 (g,g)		
tremula	2 (f,f)			1 (g)	1 (g)	
alba			3 (g,g,g)			
Prunus avium			5 (p,p,d,d,d)			
'Bov'	2 (f,f)	3 (p,p,p)		2 (g,g)	1 (g)	
'Lut'	2 (f,f)	1 (g)		2 (g,g)		
Sorbus aucuparia	3 (f,f,p)	1 (g)	1 (p)		1 (g)	
'Tschechos'		3 (f)				
Tilia cordata	3 (g,g,g)	2 (g,g)	4 (g,g,g,g)	nl	1 (g)	1 (g)
Salix aurita	3 (g,g,g)	3 (g,g,g)	3 (g,d,d)	1 (g)		
aucutifolia	3 (g,g,g)			nl	1 (g)	1 (g)
smithiana	4 (f,f,f,g)	2(g,g)	3 (g,g,g)	1 (g)	2 (g,g)	1 (g)
viminalis	1 (g)	2(g,g)		1 (g)		1 (g)
glauca						
Ribes alpinum				3 (g,g,g)		1 (g)
Robinia pseudoacacia		1 (g)		1 (g)		
Pinus sylvestris	1 (f)			nl		
Picea abies			5 (p,p,p,p,d)	5 (g,g,g,g,g)		
'North'		3 (g,g,g)				
'Late'		3 (g,g,g)			1 (g)	1 (g)
'Early'		3 (g,g,g)			1 (g)	1 (g)
Corylus avellana		1 (g)		1 (g)	3 (g,g,g)	3 (g,g,g)
Forsythia suspensa		1 (g)		1 (g)	3 (g,g,g)	3 (g,g,g)
Syringa x chinensis		1 (g)		1 (g)	3 (g,g,g)	3 (g,g,g)
'Red Rothomagensis'						
Larix decidua					1 (g)	
Sambucus nigra					1 (g)	1 (g)
Quercus robur					1 (g)	

g: tree in good condition, visibly healthy plant; f: tree in fair condition, observations still reliable; p: tree in poor condition, no longer suitable for observation; d: tree dead, no longer under observation; nl: tree not located; number represents the number of each species present at each IPG.

Table 1.2. Location details of the International Phenological Gardens (IPGs) in Ireland.

IPG code	IPG station	Latitude	Longitude	Altitude	Start of recording
13	Valentia Observatory – Co. Kerry.	51°56'	10°15' W	14 m	1966
14	John F. Kennedy Arboretum – Co. Wexford.	52°20'	06°38' W	80 m	1966
15	Johnstown Castle – Co. Wexford.	52°18'	06°31' W	60 m	1967
16	National Botanic Gardens – Dublin.	53°22'	06°16' W	30 m	1966
112	Glenveagh National Park – Co. Donegal	52°02'	07°38' W	60 m	2008
118	Armagh Observatory – Armagh	54°35'	06°65'	64 m	2005

In 2003 a small network of Irish phenologists – Phenology in Ireland – was established to provide a forum for interested parties to facilitate collaborative links. The network had representatives from universities, Met Éireann, the Department of Agriculture, the National Parks and Wildlife Service and the general public. This network has now been subsumed into the newly established National Phenology Network (see below).

1.3 International Links

Ireland was an active participant in the European COST Action 725, 'Establishing a European Phenological Data Platform for Climatological Applications', which was established in October 2003 and ran for five years. During that time a number of scientific papers and reports were written and an active European phenology community was established. Two short-term scientific missions resulted in a PhD student from Trinity College Dublin (TCD) gaining training in the use of phenological models in Montpellier, France. This PhD was the first phenology-based thesis to be presented in Ireland and was based on a combination of experimental work and modelling. When COST Action 725 finished, the network of collaborators continued to work closely together and a pan-European phenology network was established with support from EUMETNET and the Austrian Federal Ministry for Science and Research.

1.4 The Need for a National Phenology Network in Ireland

The main catalyst for setting up a national phenology network was the need to co-ordinate phenology activity in Ireland in order to help determine the impact of climate change, in particular climate warming, on the Irish environment. Prior to 2008 all phenology research was carried out in a piecemeal manner and tagged on to other activities. However, several important scientific papers and reports were published on the back of the current research, which highlighted the need for a more cohesive approach to establishing a sustainable phenological network which would enable monitoring, assessment and prediction of phenological changes in the context of global climate change and the consequential implications for terrestrial ecosystems. In light of this, a large-scale phenology project, entitled 'Climate Change Impacts on Phenology: implications for terrestrial ecosystems', was established in April 2008 and ran until September 2011. The project was co-ordinated by TCD and funded by the EPA.

Some of the most important outputs from this project were:

- Establishing the Irish National Phenology Network (IE-NPN);
- Raising public awareness of the use of phenology in current climate change research in Ireland through media releases;
- Setting up a website to encourage the general public to record phenological events;
- Extending the number of sites where phenological events were being observed and incorporating native species into the mix;
- Developing phenological models to make projections of how climate warming may impact trees in future;
- Establishing a network of phenologists across the country and providing training for participants;
- Extending the network to include birds and insects;
- Conducting a range of experiments in which the environmental triggers of bud burst were determined;

- Hosting an international conference on phenology;
- Establishing a professional network of researchers both nationally and internationally;
- Publishing numerous scientific papers on a range of phenological topics.

1.5 Ireland's National Phenology Network (IE-NPN)

The role of the IE-NPN is to coordinate all phenology activity in Ireland and to encourage people of all ages and backgrounds to observe and record phenology of plants and animals across the country. Together with researchers the IE-NPN helps develop various ways of using these observations to support decision-making by citizens, managers, scientists and others. The network comprises a wide range of stakeholders, including researchers in various universities, members of the general public, the NBDC, Teagasc, Met Éireann, etc. Table 1.3 give an outline of the history of phenology in Ireland.

In addition, IE-NPN acts as the contact point for collaboration with other similar networks around the world, such as national phenology networks in Sweden (SWE-NPN), the USA (USA-NPN), Nature's Calendar in the UK and the Netherlands (De Natuurkalender) and many others.

Research activity is also a key focus of IE-NPN and a number of historic datasets have been identified and analysed in relation to temperature variables to determine if climate change has had an impact on plants, birds and insects in the Irish environment. Some of the findings are described in Section 4 below, but, in brief, an advance in the timing of key spring phenophases of plants (leaf unfolding of a range of trees), birds (arrival of spring migrants and departure of winter visitors) and insects (appearance and flight time of a range of moths) have occurred over the past 40 years and this can be attributed, at least in part, to rising spring temperature.

Table 1.3. History of phenology recording in Ireland at a glance.

1927–1947	Phenological reports in the *Irish Naturalists' Journal* provided plant, animal and farming activity observations for 15 years
1960s	Establishment of four International Phenological Garden (IPG) sites at Valentia Observatory, John F. Kennedy Arboretum, Johnstown Castle and the National Botanic Gardens
2003	Armagh Observatory establishes a phenology garden
2005	Biology.ie is established to encourage secondary-school children to make phenological observations
2006	Greenwave is established to encourage primary-school children to make phenological observations
2007	Glenveagh National Park establishes a phenology garden
2008	Climate change impacts on phenology project established in Trinity College Dublin (TCD) and funded by the EPA
2009	IPG network in Ireland expanded and 10 new sites are established. A native species network is also established and contains 18 sites
2010	*Nature Watch* website is launched in collaboration with the National Biodiversity Data Centre (NBDC) and encourages the general public to record phenological observations

2 Current Network of Participating Phenology Gardens

In 2008 there were six active IPGs in Ireland (Fig. 1.2b) but it was decided to expand the number of sites by adding an additional 10 gardens and also to set up a series of native species gardens.[1] This has allowed a more widespread geographical coverage of the country and also the observation of both native and non-native species. Making observations of non-native species enabled a comparison of results with other European countries; the monitoring of native species gave a better idea of what was happening to the Irish environment.

2.1 Location of Participating Gardens

The IPG sites (Fig. 2.1, Table 2.1) were chosen based on their proximity to available air temperature stations, and specimens were planted in spring of 2009 (Table 2.2). These trees require a period of two to three years acclimation before monitoring can begin.

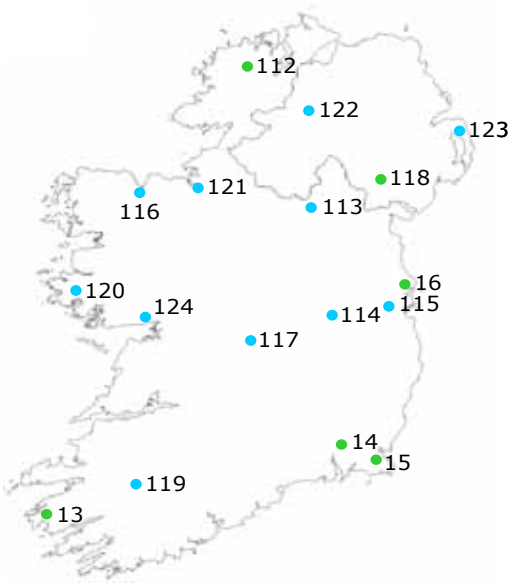


Figure 2.1. Illustrative map of International Phenological Gardens (IPGs) pre-2009 (green) and post-2009 (blue).

Table 2.1. Details of the additional International Phenological Gardens (IPGs) established in 2009. Note that 122 and 123 have since withdrawn.

IPG Site		Latitude	Longitude	Altitude	Start of recording
113	Ballyhaise College, Co. Cavan	54° 02'	7° 18' W	77 m	2011/12
114	Williamstown House, Co. Kildare	53° 21'	6° 57' W	103 m	2011/12
115	Carton Estate, Co. Kildare	53° 22'	6° 35' W	60 m	2011/12
116	Enniscoe House, Co. Mayo	54° 60'	09° 90'W	38 m	2011/12
117	Birr Castle, Co. Offaly	53° 05'	7° 54' W	55 m	2011/12
119	Millstreet Country Park, Co. Cork	52° 04'	9° 03' W	116 m	2011/12
120	Ballynahinch Castle, Connemara, Co.Galway	53° 30'	9° 45' W	26 m	2011/12
121	Markree Castle, Co. Sligo	54° 11'	8° 29' W	40 m	2011/12
122	Baronscourt,Tyrone, Northern Ireland	54° 42'	7° 22' W	64 m	2011/12
123	Mount Stewart, Down, Northern Ireland	54° 34'	5° 33' W	10 m	2011/12
124	National University of Ireland, Galway	53° 16'	9° 3' W	8 m	2012?

[1] Hazel Proctor, TCD, co-ordinated this expansion.

Table 2.2. List of species present at each of the added International Phenological Garden (IPG) sites in 2009. Species present at each garden. Numbers indicate how many specimens are at each Irish IPG.

Species	Ballyhaise College	Williamstown Garden	Carton Estate	Enniscoe House	Birr Castle	Millstreet Country Park	Ballynahinch Castle	Markree Castle	Baronscourt	Mount Stewart
Larix decidua	1	1	1	1	1	1	1			
Picea abies (early)	2	1	1	1	1	1	1	1	1	1
Picea abies (late)		1	1		1	1		1	1	1
**Pinus sylvestris*	1	1	1	1	1	1	1	1	1	1
Betula pubescens		1	1		1	1	1	1	1	1
**Fagus sylvatica* 'H'	1	1	1	1	1	1	1	1	1	1
Prunus avium 'B'		1	1	1	1					1
Robinia pseudoaccacia		1	1	1	1	1	1	1	1	1
Sorbus aucuparia	1	1	1	1	1	1	1	1	1	
**Tilia cordata*	2	1	1	1	1	1	1	1	1	1
Salix aurita		1	1	2	1	1	1	2	1	1
**Salix aucutifolia*	1	1	1	1	1	1	1	1	1	1
Salix smithiana	1	1	1	1	1	1	1	1	1	
Salix viminalis	2	1	1	1	1	1	2	2	2	2
**Corylus avellana*	3	3	3	3	3	3	3	3	3	3
**Forsythia suspensa* Fortunei'	3	3	3	3	3	3	3	3	3	3
**Syringa chinensis* 'Red Rothomagensis'	3	3	3	3	3	3	3	3	3	3

A number of changes have taken place since the network was established. For example, Altamont Garden (Carlow) has been replaced by Enniscoe House (Mayo); Errislannan Manor has withdrawn from the network as has Mount Stewart and Baronscourt, all citing cutbacks in staffing due to the economic downturn. However, as with any network, it is constantly evolving as some sites withdraw while others are joining.

Table 2.3. List of sites in the native species network 2009. Note that number 11 has since withdrawn.

Site		Latitude	Longitude	Altitude	Start of recording
1	Farnham Estate, Co. Cavan	53° 59'	07° 21'W	54 m	2011/12
2	Lodge Park Walled Garden, Co. Kildare	53° 18'	06° 36'W	62 m	2011/12
3	Airfield Trust, Co. Dublin	53° 17'	06° 13'W	62 m	2011/12
4	Killruddery House, Co. Wicklow	53° 08'	06° 40'W	18 m	2011/12
5	Emo Court, Co. Laois	53° 60'	07° 12'W	63 m	2011/12
6	Irish National Stud Co Ltd, Co. Kildare	53° 09'	06° 54'W	51 m	2011/12
7	Kildalton Horticultural College, Co. Kilkenny	52° 20'	07° 19'W	76 m	2011/12
8	Mount Congreve, Co. Waterford	52° 14'	07° 14'W	41 m	2011/12
9	Mount Juliet, Co. Kilkenny	52° 47'	06° 13'W	65 m	2011/12
10	Blarney Castle, Co. Cork	51° 55'	08° 34'W	106 m	2011/12
11	Errislannan Manor Gardens, Co. Galway	53° 29'	10° 10'W	30 m	2011/12

In addition to the IPGs, a series of 'native species' gardens was established and details of their location are presented in Table 2.3 and Fig. 2.2. These sites were established to monitor phenology of native tree species. It was necessary to source native stock which proved more challenging than first anticipated, but was resolved through cooperation with the John F. Kennedy Arboretum, Teagasc, the Irish Birch Improvement Programme and others.

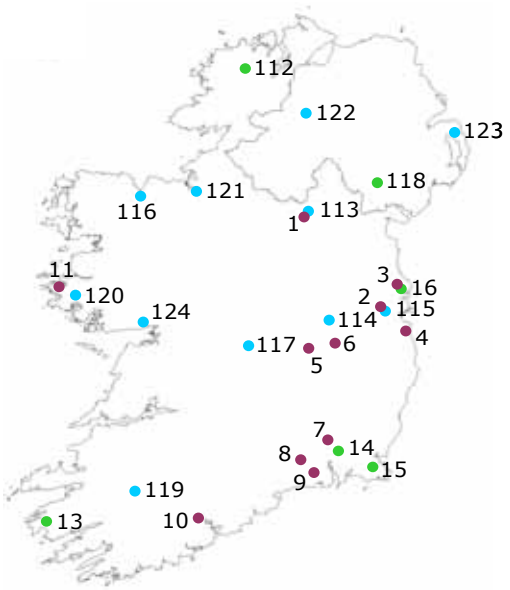


Figure 2.2. Illustrative map showing location of all phenology gardens, International Phenological Gardens pre-2009 (green) and post-2009 (blue) in addition to the native species gardens (red). See tables for explanation of numbers. Note that number 11 withdrew from the network in 2011.

These gardens were provided with cloned native species of birch (*Betula pubescens*), donated by Dr Elaine O'Connor from the Irish Birch Improvement Programme. Hazel Proctor grafted ash (*Fraxinus excelsior*) scions from a mature specimen in John F. Kennedy Arboretum with rootstock donated by Dr Gerry Douglas, Teagasc. In future it is anticipated that more species will be added to the collection and in this regard John F. Kennedy Arboretum, Birr Castle and Blarney Castle have been identified as suitable sites for sourcing species, such as spindle (*Euonymus europaeus*), hazel (*Corylus avellana*) and blackthorn (*Prunus spinosa*), to propagate for the native network.

2.2 Species and Phases under Observation

The species in the IPG sites are listed in Tables 1.1 and 2.2 and are a subset of the IPG recommended species list. Since not all species would thrive in the Irish climate, some were disregarded. The species in the native sites are listed above. Phenological observations should be made on each tree from bud burst to leaf fall over the growing season. The IPG network has set out a list of specific phases which should be monitored where appropriate across the species involved in the entire network. The major phases are:

- Beginning of leaf unfolding;
- May shoot;
- Beginning of flowering;

- General flowering;
- St John's sprout;
- First ripe fruits;
- Autumn colouring;
- Leaf fall.

The following descriptions are adapted from the IPG manual first published in the 1960s:

Beginning of leaf unfolding: This phase occurs when the first regular surfaces of leaves become visible in several places (about three to four) on the observed plant. This is when the first leaf of a plant has pushed out of the bud up to its leaf stalk (petiole).

Mayshoot: This is the first spring sprout of the conifers (firs, pines). The buds are open and the protective sheath – involucre – comes off the bud edges. The involucre either sticks to the buds or falls off. The needles have not yet expanded at this point.

Beginning of flowering: This is when the first regular flowers have opened in several (about three to four) places on the observed plant. Anemophilous plants are those which are pollinated by wind catching and scattering their pollen, for example in birch. If there is strong wind, the first scattering of pollen can easily be recognised in all anemophilous plants. If calm conditions prevail, the observer should shake the branches in order to establish if first flowering has occurred.

General flowering: This occurs when more than half of the blossoms of the observed plant are open.

St John's sprout: The first sprouts of oaks and mountain ashes are regularly followed by a second sprout, the 'St John's sprout'. Buds that are already developed for the next year are caused to sprout prematurely by weather conditions. These second sprouts can be recognised by their 'fresh' colour. The state of the first leaf unfolding is repeated: the first leaves of the sprout have their typical forms but not yet the final size of the fully developed leaves.

First ripe fruits: This phase is observed when the first fruits have ripened in several places (about three or four) on the observed plant. Succulent fruits of ash (*Sorbus* sp.) or currant (*Ribes* sp.) have ripened fully on three to four places in each inflorescence or when capsular fruits burst out of the hulls in species such as birch (*Betula* sp.).

Autumn colouring: More than half of the leaves (>50%) of the observed plant have changed their colour, including those leaves which have fallen in large quantities.

The IPG advises that autumn colouration be distinguished from the withering of leaves and their discolouration due to drought during the summer months. This so-called drought-discolouration of leaves which may have occurred by July in dry years and in dry places must be observed separately.

Leaf fall: This is recorded when more than half of the leaves (>50%) of the observed plant have fallen.

2.3 Observers Manual

In order to ensure consistency of the data being recorded it was useful to produce an *Observers Manual* – a handbook to provide guidelines on how to make observations – for distribution within the network. In addition, information is also provided on phenology in general, various networks and references and useful links. This manual, together with outdoor information boards (Fig. 2.3) and leaflets for each participating garden, was produced in association with the Heritage Council.

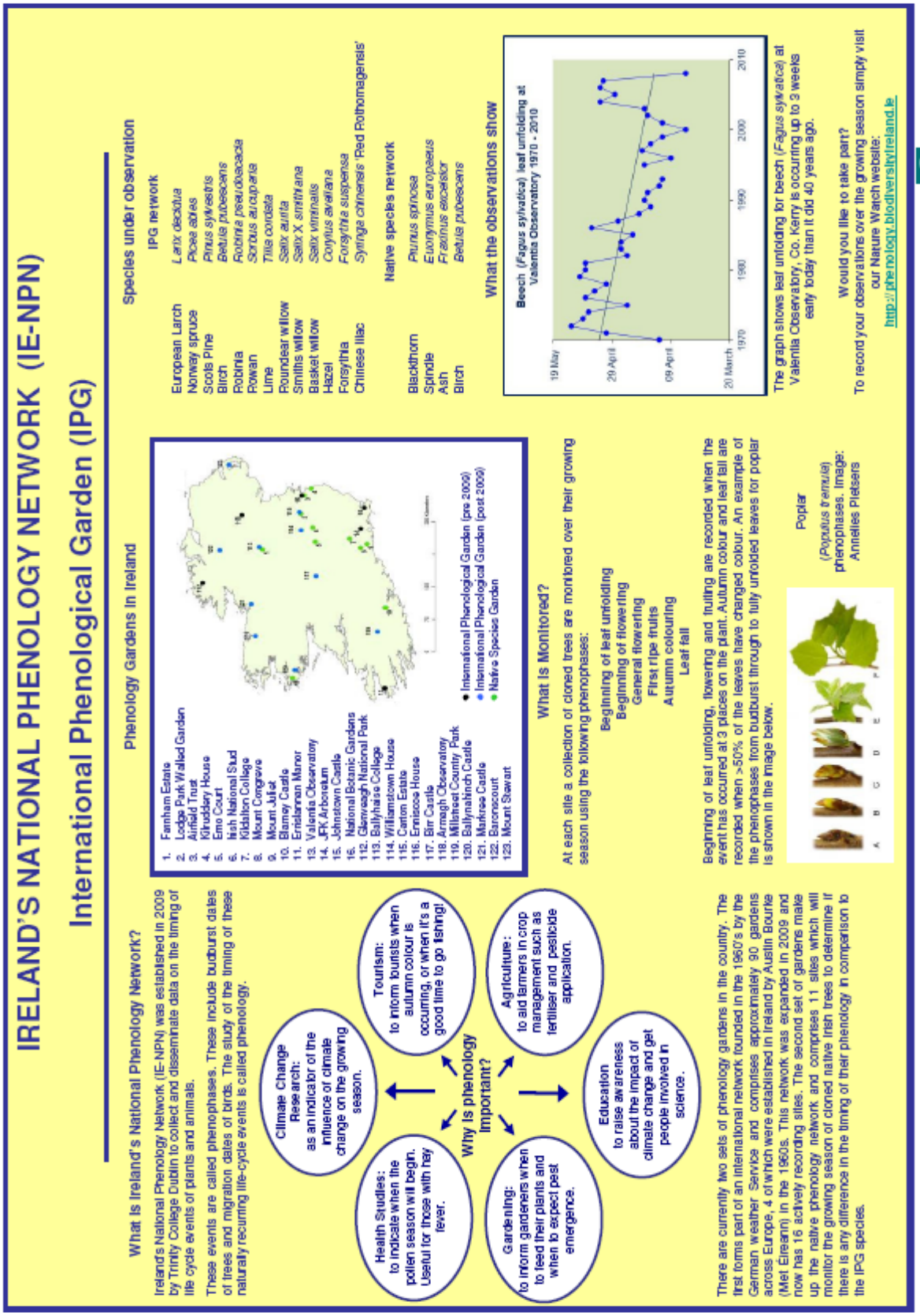


Figure 2.3. Examples of the outdoor information boards located at each of the phenology gardens.

3 Public Participation

In recent years more and more agencies are turning to the general public and schools to become involved in monitoring the natural environment. This type of activity achieves two important goals: its raises participants' awareness of environmental issues and at the same time teaches them the value of scientific monitoring. In doing so, it also facilitates exposure to science to a section of society that may otherwise not be in a position to be involved in such work. In addition, it provides scientists with a valuable dataset from a wider geographical area than they would be able to cover themselves.

'Citizen-science' projects involve volunteers with an interest in the environment but who may not necessarily have any training in science, and usually include tasks such as recording observations or taking measurements. They aim to promote public engagement with research and are seen as a fun way for the general public to learn the scientific method, explore the outdoors and help scientists monitor the environment. Citizen-science projects have evolved over the years to include standard measuring methods, and the use of internet and mobile communciations technology has greatly facilitated its advance in recent times.

Citizen-science networks are used extensively in phenology research and provide a valuable means of determining how climate warming is affecting plants and animals around the globe. Other areas of research where citizen scientists are involved include bird-monitoring, whale- and shark-recording, unusual weather event-reporting and butterfly-monitoring.

3.1 Formation of a Citizen Science Project – *Nature Watch*

In order to widen the range of species and phases being recorded in the IPGs and the native species networks it was decided to establish the *Nature Watch* website (http://phenology.biodiversityireland.ie/) (Fig. 3.1), where members of the general public are invited to submit phenological records. For monitoring purposes, a limited number of easily identifiable plants, birds and insects and associated phenophases (Table 3.1) were selected. The *Nature Watch* website was launched in spring 2010 and is run by the phenology group in TCD in collaboration with the NBDC. To date, a wide variety of observers have registered, ranging from Donegal to Cork and we anticipate more and more citizen scientists getting involved in future.

A Facebook group (Irish Phenological Network) and Twitter (@Nature_Watch) account also are active.

Figure 3.1. Screen-shot of *Nature Watch* website.

Table 3.1 List of species and phenophases currently available for observation and recording on *Nature Watch*.

	Species	Phenophases
Plants	Elder	Beginning of leaf unfolding
	Downy birch	Beginning of flowering
	Common hazel	First ripe fruit
	Common hawthorn	Autumn colour
	European ash	Leaf fall
	Bluebell	
	Coltsfoot	
	Wood anemone	
	Daisy	
Birds	Barn swallow	First sighting
	Northern wheatear	
	Common cuckoo	
	Common house martin	
	Willow warbler	
Insects	Clouded yellow	First sighting
	Cinnabar moth	
	Common green grasshopper	
	Common darter	
	Buff-Tailed bumble-bee	

3.2 Collaboration with the National Biodiversity Data Centre

The existence of *Nature Watch* would not be possible without the collaboration of the NBDC which hosts the site and manages the data records. The NBDC was involved in setting up at least two other citizen-science networks prior to *Nature Watch* and so its experience and expertise was invaluable. Its ongoing projects include 'bioblitz', a co-ordinated intensive biological survey, in which a network of scientists and volunteers record all living species within a designated area on a particular day in Ireland. The aim of a bioblitz is to get the public interested in biodiversity while at the same time recording valuable data. Another NBDC project is the Irish Butterfly Monitoring Scheme, which involves collecting data on butterflies from specific locations throughout the country on a weekly basis from April to September.

3.3 Greenwave and Biology.ie

Two other public networks focus on phenology recording: Greenwave and Biology.ie, which are aimed at primary and secondary schools respectively. Greenwave is an initiative of the Discover Science and Engineering Programme at Forfás that began in 2006; this facilitates primary schools across Ireland observing and recording the arrival of the signs of spring. Students observe, and record on the project website (www.greenwave.ie), details of weather and common species. This allows participants to build a picture of how species in their locality react to longer days and warmer temperatures, and to consider whether the green wave of spring moves from south to north across Ireland or inland from the coast to the centre of the country. During 2011 the project expanded on a pilot basis to 17 European countries as part of the Fibonacci project http://www.greenwave-europe.eu/ (Fig. 3.2).

The project commences in February and finishes in June, with all data gathered being displayed on interactive maps and charts on the website. Greenwave provides opportunities for teachers and pupils to develop an awareness of common species in their locality and their responses to changes in climate. The project model is a practical way to support the teaching of Primary Science (as part of the Social, Environmental

Figure 3.2. Screenshot from Greenwave.ie website.

and Scientific Education curriculum) and provides opportunities to develop skills in observing, classifying, recognising patterns, recording and communicating. Discover Primary Science and Maths (DPSM) schools can also earn credit towards their Award of Science and Maths Excellence by taking part in Greenwave. The data gathered is also a good basis for the application of Maths skills in a real-life context.

Biology.ie was founded in August 2005 as an interactive tool for the collection of *Nature's Calendar* or phenology observations. It grew from a simple Flash-based map (which is still in use) to using Google maps to locate data from the public**.** *Nature's Calendar* includes a Spring Watch and Autumn Watch each year and now has its own domain (www.naturescalendarireland.com). The primary aim of Biology.ie is to increase biodiversity awareness by allowing users keep an online map and nature notes. Regular use allows a user to build up an informative wildlife map of their areas of interest.

4 How the Information is Used

What happens to the data once it is recorded and verified? From a scientific point of view, the data are used to identify trends over time and to determine if rising temperature, due to climate warming, is having a detectable influence on the timing of, for example, leafing in trees, migration in birds and the appearance of insects. The historic phenological data can also be used to make projections of when we might expect leafing times to occur in future as temperature continues to rise. On the other hand, from a public point of view, the data can help raise awareness of environmental issues and promote involvement in scientific research.

4.1 Climate Change Research (Animals, Insects, Projections)

To date, phenological data has proven to be useful in demonstrating the impact of rising temperature on a range of species. Here are a few examples from Ireland. Figure 4.1 shows the day of the year when leaf unfolding occurred for two *Fagus sylvatica* (beech) cultivars from 1970 to 2008 at Valentia Observatory, in Kerry. A lot of year-to-year variation can be seen in the data but the overall trend was that leaf unfolding occurs nearly three weeks earlier in 2008 than in the 1970s. A similar trend has occurred for other trees at different locations in Ireland and has, at least in part, been attributed to rising spring temperature.

Figure 4.2. Day of the year when leaf unfolding occurred for two Fagus sylvatica (beech).

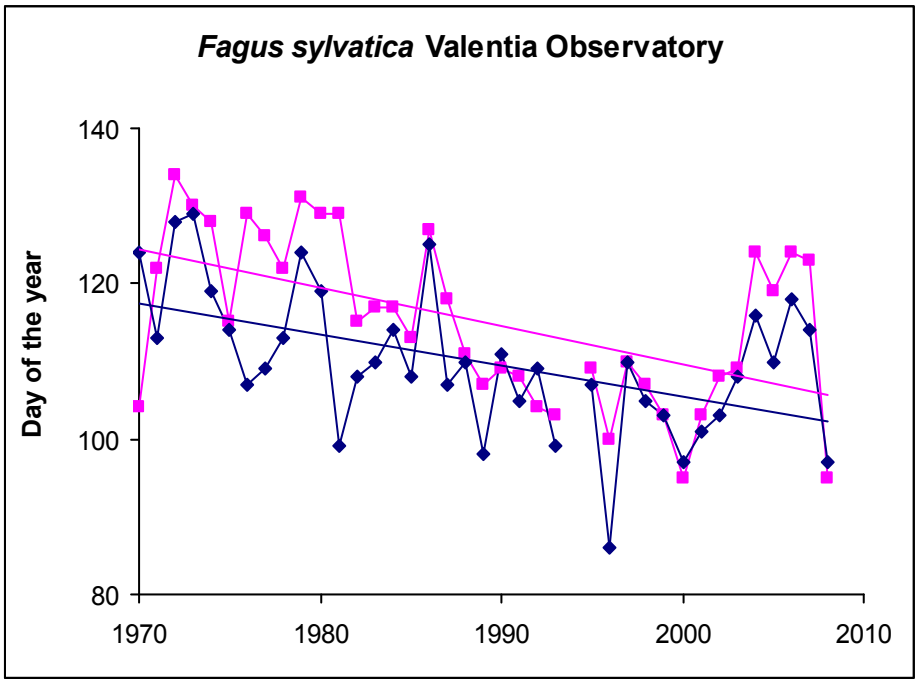


Figure 4.1. Timing of leaf unfolding, 1970–2009 for two cultivars of *Fagus sylvatica* (beech) growing at Valentia Observatory, Co. Kerry.

4.2 Bird Phenology

Data from a range of spring migrant birds were analysed to determine if they are arriving to Ireland earlier over a 30-year period. All the birds studied were arriving from sub-Saharan Africa and only 2 out of the 11 birds examined showed a tendency to arrive later. This meant that the majority of the birds were arriving earlier at the end of the time series than at the beginning. This trend has, at least in part, been attributed to rising spring temperature. Table 4.1 shows the list of birds examined and whether they were occurring earlier or later over the 1969–1999 time period.

Table 4.1. Common spring migrant birds arriving to the east coast of Ireland, 1969–1999.

Species	Trend
Common cuckoo	Later
Common swift	Earlier
Sand martin	Earlier
Barn swallow	Earlier
Common house martin	Earlier
Whinchat	Earlier
Northern wheatear	Earlier
Common grasshopper warbler	Earlier
Sedge warbler	Later
Common whitethroat	Earlier
Willow warbler	Earlier

4.3 Insect Phenology

Another important group are also showing a response to spring temperature – the insects. Analysis of a suite of moth species has shown that appearance dates and flight periods are correlated with spring temperature. When spring temperature is high, appearance dates are earlier and flight periods are longer. For example, Fig. 4.3 depicts the appearance time and flight period for the flame carpet moth from 1995–2009. This shows that appearance times are getting earlier while the length of flight period is extending.

4.4 What does the Future hold and what are the Consequences of an Earlier Spring?

Sophisticated computer models can be used to make projections into the future for bud burst; what becomes clear is that the trend for bud burst to become earlier in spring will continue at least until the end of the current century driven by an increase in spring temperatures. There are advantages and disadvantages related to earlier leaf unfolding.The potential consequences of this are: (i) an increase in timber production as the leaves will be on the tree for longer and photosynthesising for a longer period, thus producing more biomass; (ii) the removal of more carbon dioxide from the atmosphere – again due to the leaves emerging earlier and therefore

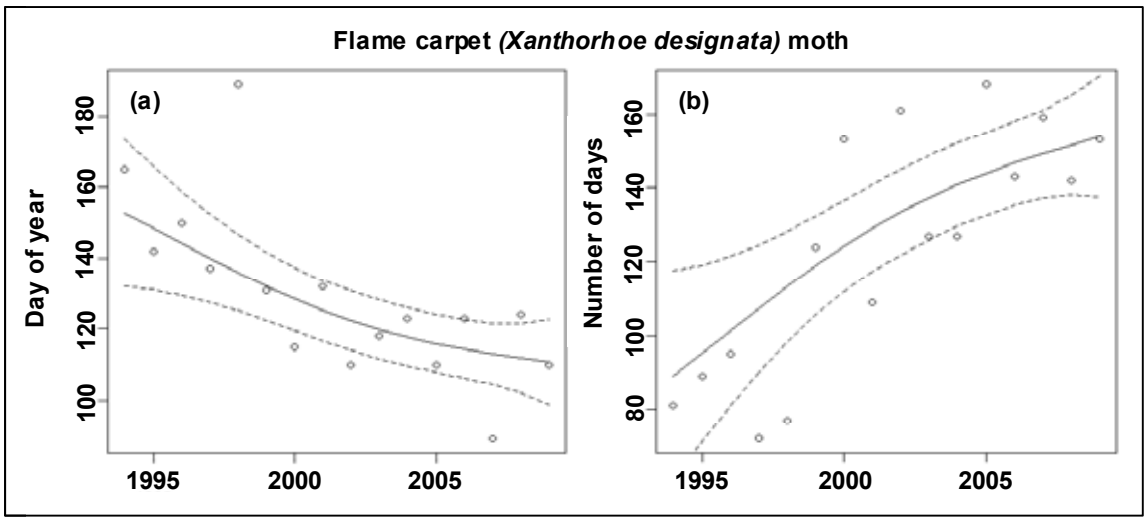


Figure 4.3. *Xanthorhoe designate* (flame carpet moth): (a) appearance time and (b) flight period, Raphoe, Co. Donegal, 1995–2009. Dashed line represents the 95% confidence interval.

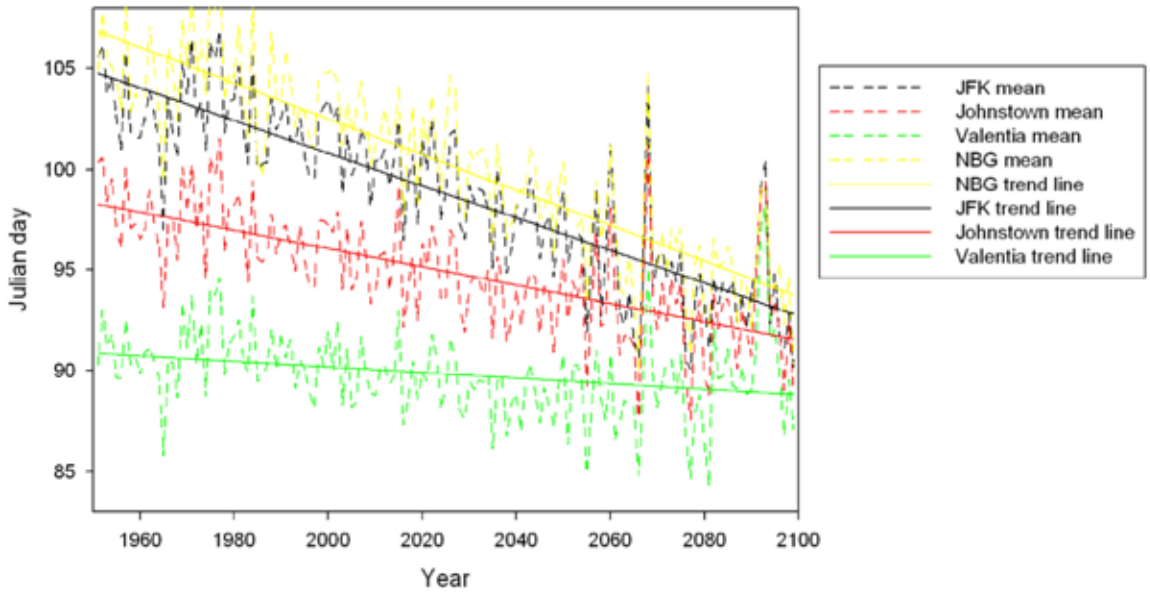


Figure 4.4. Phenological model output for the timing of birch tree leafing at four stations (JFK – John F. Kennedy Arboretum, Co. Wexford, Johnstown – Johnstown Castle, Co. Wexford, Valentia – Valentia Observatory, Co. Kerry and NBG – National Botanic Garden, Glasnevin) in Ireland, 1950–2100.

living longer; and (iii) an earlier start to the pollen season. On the other hand, some negative consequences may arise such as (i) many temperate trees require cold winter temperatures for bud burst to occur but if winter temperatures rise this 'chilling' may not be fulfilled and (ii) young leaves emerging earlier are susceptible to late frost damage and this could cause economic losses for some species of fruit trees.

No computer models as yet are available to project what might happen to birds and insects in future, but based on past data we can expect the earlier arrival and appearance dates in spring to continue at least into the near future.

Up to now, the focus has been on examining the response to rising temperature of individual groups of plants, animals and insects. However, it is now necessary to concentrate efforts on examining ecosystems as a whole. Plants and animals continuously interact and are dependent on one another for survival. For example, caterpillars feed on newly emerging leaves and birds then feed on the caterpillars. Therefore, in order for an ecosystem to survive, the timing of these interdependent phenophases must remain synchronised. However, recent studies (Donnelly, 2011) have shown that leaf emergence of oak and caterpillar emergence are both responding to rising spring temperature at the same rate and therefore remaining in sync. The migrant bird that feeds on the caterpillar is also arriving earlier but its arrival time is not quite as early as it should be to benefit from the peak in abundance of its caterpillar food source. This causes a reduction in the number of migrant bird chicks that the food source can sustain – and a consequent decrease in population size. This can mean an increase in resident bird population size (that were there to profit from the peak timing of the caterpillar food source). As a result, this mismatch in phenology between a predator and its food source because of differing abilities to respond to rising temperature can have implications for the ecosystem as a whole. In addition, there is every reason to believe that these mismatches in interdependent phenophases (such as the plankton–fish–bird chain) will become more evident in future, with resulting changes in biodiversity, as temperature continues to rise.

4.5 Remote Sensing

Earth observation satellites can be used to measure change across whole ecosystems. These are used across the globe to determine phenological timing in vegetated areas in conjunction with ground-based observations. While ground-based measures are point based, space-borne sensors can monitor the phenological development of terrestrial vegetation over large areas. The sensors measure daily reflectance from the Earth's surface in the red and near infrared

wavelengths of the electromagnetic spectrum, which can then be used to derive measures of vegetation growth. One such vegetation measure known as the Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) has been derived from observations made by the European Space Agency (ESA) satellite sensor Envisat *MERIS*. The FAPAR is an estimate of the photosynthetic activity of terrestrial vegetation and a key indicator of the health and vigour of plant growth.

Vegetation phenological timing can be determined from multiannual time-series of the FAPAR. This is achieved by estimating the point in time when there is a change in the annual photosynthetic cycle, for example an increase in photosynthesis after winter dormancy, known as start of spring (SOS) or growing season. Efforts to align the SOS with equivalent ground-based measures, such as the beginning of leaf unfolding, as observed at IPG sites, are the subject of continuing research. This growing body of research, in applying earth-observation satellite measurements to monitoring phenology, is known as Land Surface Phenology (LSP) monitoring. Although fundamentally different in terms of the form of the measurement, both the ground-based phenological observations and LSP measures offer an integrative approach to phenological monitoring, at a variety of spatial scales.

Across the island of Ireland, the SOS has been estimated from a time series of *MERIS* FAPAR data, from 2003 to 2009, at a spatial resolution of 1.2 km. Considerable spatial and temporal variability was observed in the SOS across the island over the course of the seven-year period (Figs 4.5 and 4.6). Spatial SOS variability has been driven largely by Ireland's fragmented land cover of agricultural, semi-natural and natural vegetation types which demonstrate different seasonality characteristics. For example, the first occurrence of the SOS was observed over the rich pasturelands of the Golden Vale in the south of the country while the latest SOS was in upland areas such as Connemara in the west where peat bog and sparse vegetation are found. Elevation differences play an important role in determining such spatial patterns. For example, leafing and flowering is slower to occur in upland areas where it is cooler compared to milder conditions in low-lying surrounds. Interannual variability in the SOS was influenced by changes in air temperature. However, the type and extent of vegetation management by farmers was linked to the nature of the air temperature-SOS relationship. This was particularly evident in eastern and south-eastern areas, where arable cropping is commonplace. Here, cooler winters delay the SOS while warmer springs hasten the onset of the SOS, probably due to the sowing of winter crops. However, where there is mixed agriculture interspersed with areas of natural and semi-natural vegetation, the opposite trend was observed, i.e. warmer winters delayed the SOS while cooler springs advanced it.

While this research has shown the potential of space-borne measures of vegetation growth to track variation in the SOS on a national scale, there are many other useful satellite-derived phenological measures, such as the timing of maximum growth and the length of the growing season. Findings from this work can be used by natural resource management agencies, e.g. Teagasc, to help guide policy formation in the area of agricultural monitoring and carbon accounting.

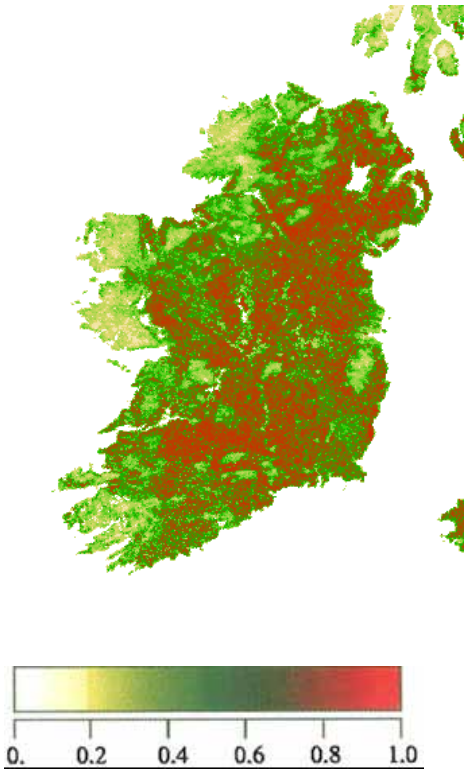


Figure 4.5. Average FAPAR during the period 1–10 May 2008. The beige and yellow areas represent low areas of FAPAR, whilst the green and red areas represent areas of high Fraction of Absorbed Photosynthetically Active Radiation (FAPAR).

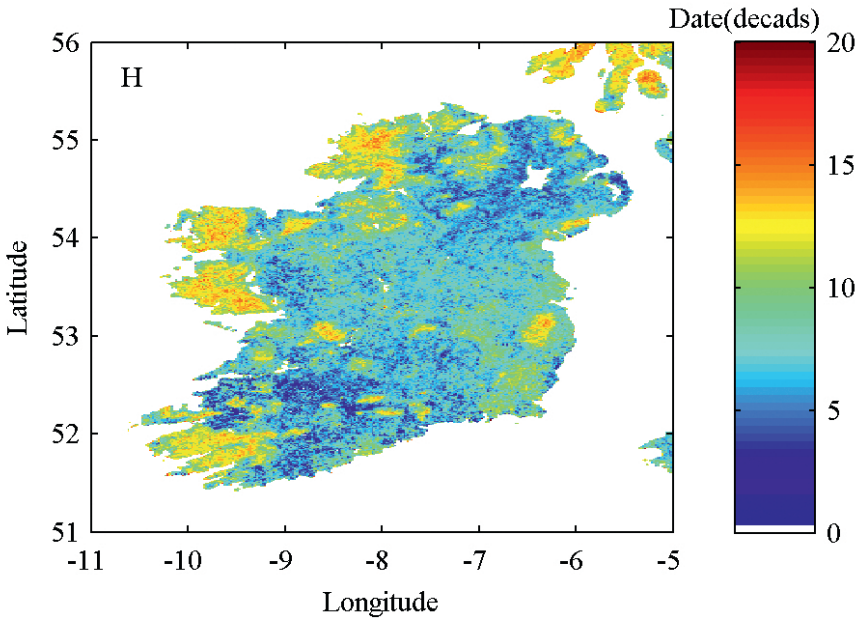


Figure 4.6. Start of Season estimated from a time-series of Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) data for 2008. Date 0 represents 1 January and each decade represents a 10-day period after that. Blue areas represent the earliest start of spring (SOS). (5 on the scale is 50 days or mid February, 10 is 100 days or mid April, 15 is 150 days or end of May)

4.6 Public Awareness of Science

Observing and recording scientific information through phenology can help raise public awareness of science, especially if what they are monitoring affects their lives directly. For instance, by recording the timing of the pollen season over several years it has become evident that the flowering of some species is beginning earlier now than previously. This has implications for asthma and hay-fever sufferers as the exposure time to pollen that causes allergic rhinitis and related asthma has increased. An earlier start to the pollen season may also result in a longer period of exposure to pollen.

The strength of long-term series of phenological observations in raising awareness of climate warming issues became evident when the IPCC in the latest *Fourth Assessment Report on Impacts, Adaptation and Vulnerability* (2007) included a study of more than 100,000 phenophases, from 20 European countries over a 30-year period to convince policy-makers that rising temperatures were having a detectable impact on the environment.

Furthermore, observing phenology can play a role in education programmes, especially for science. The use of phenology as a classroom tool is becoming more and more widespread with the introduction of websites such as the aforementioned Greenwave and Biology. ie both of which may aid teachers and educators in communicating scientific concepts.

5 Conclusion

Phenology activity in Ireland has clearly expanded in recent years, particularly since the completion of the large-scale project funded by the EPA which initiated the co-ordination of phenological observations, research and collaboration. This project facilitated the establishment of IE-NPN, whose role was to co-ordinate all phenological activity in the country, communicate the need for systematic environmental monitoring, forge collaborations with national and international bodies with an interest in phenology and raise awareness among the general public and scientists of the value of phenological data in demonstrating a detectable impact of climate change on our environment. In order to achieve these goals, the network of designated phenological recording sites was expanded, public participation was encouraged and promoted and new collaborations with, for example, the NBDC, were forged. In addition, the research findings from birds, insects and plants were communicated to both the scientific community through regular attendance at conferences and publications in scientific journals and to the general public through media interviews and publications in popular magazines.

6 Recommendations

In order to build on the network and collaborations already forged through the recently established IE-NPN it will be necessary to continue to seek participation from a range of stakeholders, including researchers, administrators and the general public. It is anticipated in the coming years to extend the current network of gardens and to encourage further participation.

6.1 Extend the Network

An extension of the network can be achieved in two ways – by (i) increasing the range of species being monitored at the current locations and/or (ii) extending the number of sites across the country. The former could include not only an increase in the number and type of trees being monitored but could incorporate monitoring of a range of herbaceous plants, birds, insects and other wildlife. At present the network relies on volunteers to collect data but it would be useful in future to be able to establish a network of professionals as the range and number of sites increase.

6.2 Encourage Participation

It is important to promote participation from both citizen scientists and professionals to volunteer their time to monitor the environment in order to keep the network alive and operational. Novel ways of keeping volunteers interested and engaged in IE-NPN will need to be examined on a regular basis. In addition, research outcomes ought to be communicated regularly to potential funding bodies, the media and the scientific community in order to demonstrate the level of activity and the need for such a network.

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Acronyms and Annotations

ESA	European Space Agency
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
IE-NPN	Ireland's National Phenology Network
IPG	International Phenological Gardens
IPCC	Intergovernmental Panel on Climate Change
LSP	Land Surface Phenology
NBDC	National Biodiversity Data Centre
SOS	Start of spring

Appendix: Useful Websites

Biology.ie (www.biology.ie)

Climate Change Impacts on Phenology: implications for terrestrial ecosystems (www.tcd.ie/botany/phenology)

COST Action 725 (http://topshare.wur.nl/cost725/)

Greenwave (www.greenwave.ie)

International Phenological Gardens network (http://www.agrar.hu-berlin.de/struktur/institute/nptw/agrarmet/phaenologie/ipg)

National Phenology Network in the United States – USA-NPN (http://www.usanpn.org/)

National Phenology Network in Sweden SWE-NPN (http://www.swe-npn.se/)

Nature's Calendar – UK (http://www.naturescalendar.org.uk/)

Nature's Calendar – the Netherlands (http://www.natuurkalender.nl/)

Nature Watch (http://phenology.biodiversityireland.ie/)

Pan-European Phenological Database (http://www.zamg.ac.at/pep725)

Project Budburst (http://neoninc.org/budburst/)

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil, Pobal agus Rialtais Áitiúil.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail;
- scardadh dramhuisce.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

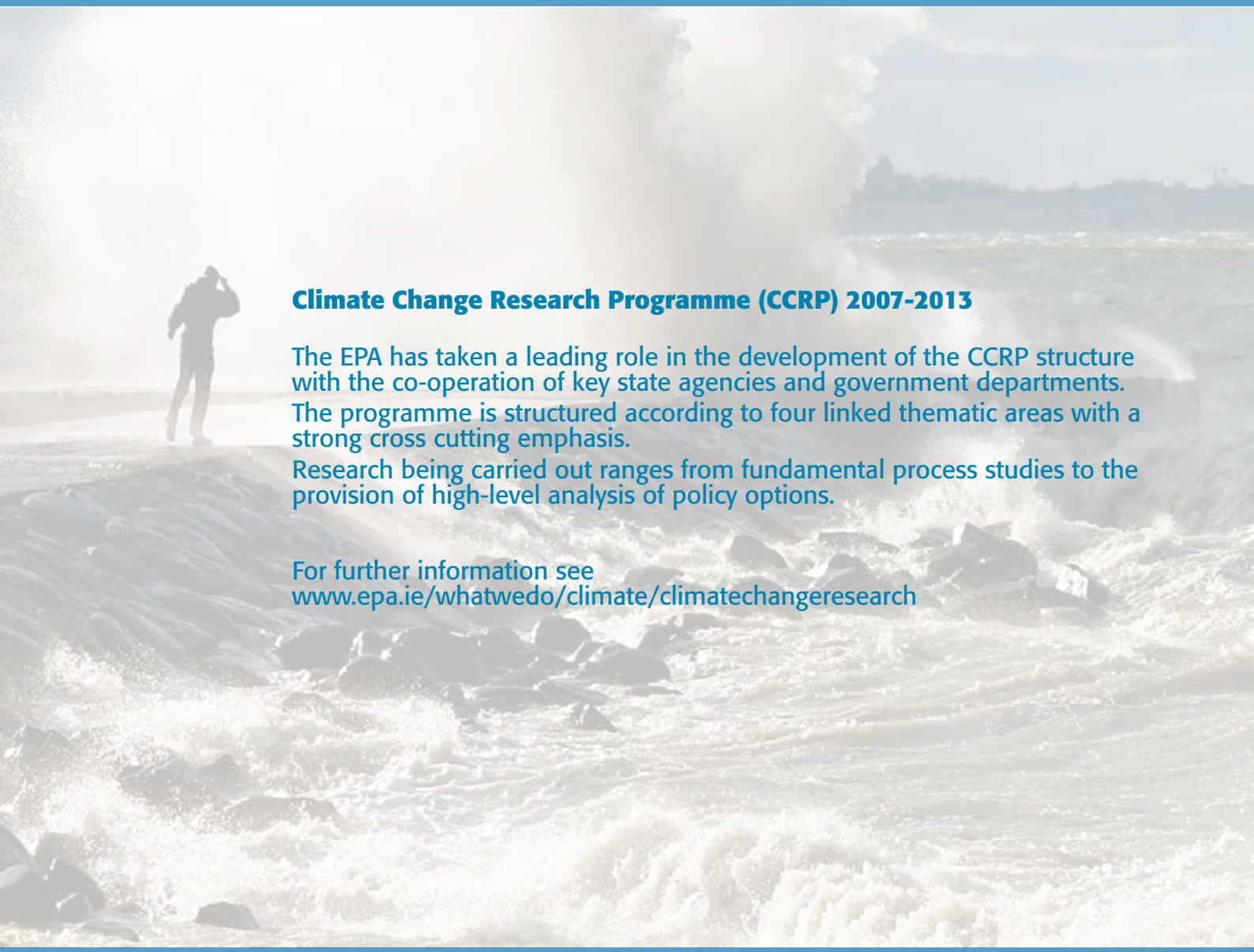
STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.



Climate Change Research Programme (CCRP) 2007-2013

The EPA has taken a leading role in the development of the CCRP structure with the co-operation of key state agencies and government departments.

The programme is structured according to four linked thematic areas with a strong cross cutting emphasis.

Research being carried out ranges from fundamental process studies to the provision of high-level analysis of policy options.

For further information see
www.epa.ie/whatwedo/climate/climatechangeresearch

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

ENVIRONMENTAL PROTECTION AGENCY
PO Box 3000, Johnstown Castle Estate, Co. Wexford, Ireland
t 053 916 0600 f 053 916 0699
LoCall 1890 33 55 99
e info@epa.ie w http://www.epa.ie

SSTI
Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government