Review of UK Climate Change Indicators

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Department for Environment Food and Rural Affairs

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Contents

Review of UK Indicators of Climate Change

Summary

1. The list of 34 Indicators of Climate Change in the UK that were published in 1999 were reviewed at an expert meeting in March 2003, with representatives of the Devolved Administrations. Notes from that meeting are presented. Notes are also given from an expert meeting held in November 2000, when the opinions of 21 respondents to the 1999 consultation were considered.

2. Data were sought to update the series for all 34 Indicators. Data were obtained up to 2002 for 25 Indicators and up to 2001 for as further 6 Indicators. The use of irrigation water for agriculture (Indicator 19) was updated to 2000. Data were unobtainable for 2001 for Indicators 11 and 31, owing to Foot and Mouth Disease restricted access. No updates were possible for potato yields (Indicator 21) or upstream movement of salmon (Indicator 33) and it is suggested that these Indicators be discontinued.

3. The following data series were completely or partially revised owing to improvements in definition or calculation: predominance of westerly weather (NAO, Indicator 4), river flows (Indicator 6), groundwater storage in chalk in southeast Britain (Indicator 8, Holt replaced by Stonor), insect appearance, activity and abundance (Indicators 27 and 28) and small bird population (Indicator 31).

4. The website (http://www.edinburgh.ceh.ac.uk/iccuk.) has been updated with the new data and the website text has been revised as appropriate.

5. The updated data revealed the following key trends:
   - The 10-year period 1993-2002 was the warmest on record in central England, 0.7 °C above the 1961-1990 mean;
   - the average number of hot days (at or over 20 °C) in 1993-2002 in central England was 7.4, over twice the long-term average;
   - in the last four years, the seasonal distribution of precipitation, and the gradient from southeast to northwest Britain, have been close to the long-term average;
   - warm January-March temperatures in recent years have been reflected in lower gas consumption in this winter quarter;
   - recent years have seen large increases in (i) the number of Thames Barrier closures, (ii) cases of Lyme disease, (iii) proportion of potato crop irrigated, and (iv) areas of forage maize, but these are not wholly attributable to climate change. Meanwhile, areas of vines have slightly decreased;
   - yearly changes in the timing of natural events continue to reflect warmer temperatures.

6. Before the current list of Indicators were assessed, consideration was given to Indicators produced in recent years in Wales, Scotland and Ireland, and also by the Environment Agency and the European Environment Agency. The climate change indicators identified in these initiatives include most of those in the UK 1999 list of 34. Many of the regional indicators are not appropriate for the UK, but these studies highlighted the potential value of the following: snow cover, sea temperature, gales and wind speed, fish stocks, and growing season length.

7. A brief report is given of the possible role of the UK Environmental Change Network in providing data for Indicators of Climate Change in the UK.

8. The following recommendations are made for the revision of the indicators.

Temperature

The Central England Temperature data should remain a key indicator. But a new indicator, the length of the thermal growing season, derived from the CET, should be added. This new indicator is presented in full.

Precipitation

The seasonality and SE-NW gradient in precipitation should be retained. But a new indicator measuring the relative intensity of winter and summer precipitation events should be investigated, perhaps covering regional variation. Winter rainfall is increasingly received in intense rainfall events (downpours).

Westerly weather

In addition to the North Atlantic Oscillation, it is worthwhile to follow the lead taken in Wales to identify indicators measuring gale incidence and surface wind speeds.

Hydrology

The existing hydrological indictors (Indicators 5-8) should be retained, but:

(i) data on wet and dry soil conditions should be obtained regionally from the Met Office rather than simply the Wallingford site , and

(ii) low and high river flow indicators should use ‘peaks over threshold’ (which is the approach used by EA, SEPA and in the Flood Estimation Handbook) rather than percentage departures from the average.

Thames Barrier

The barrier is now closed to exclude tidal water from the Thames in times of high river flow. This means that this indicator is of limited value as a measure of sea flood defence, unless it is possible to discern the reasons for each barrier closure.

Atmospheric ozone

It is useful to retain this indicator, although it is affected by many factors. However, it is better related to number of sunshine hours rather than temperature, as in the 1999 report.

Domestic property insurance

New data now make it possible to attribute claims to different events (severe frost, flood, wind storm) and more work needs to be done on standardizing the data relative to the Retail Price Index.

Supply of gas to households

This Indicator should be retained.

Domestic holiday tourism

There have been major methodological problems in obtaining a consistent time series. The series needs to be revisited to be sure that it is homogeneous. A possible replacement series could be sought amongst data on visits to National Parks and visitor attractions.

Scottish skiing industry; Number of outdoor fires

These Indicators should be retained.

Health

The series on lyme disease incidence (Indicator 17) is subject to sudden jumps, reflecting medical staff awareness rather than incidence, but it should be retained, preferably with further work to remove trends that are not climate related.
The seasonal pattern of mortality, which is currently presented for England and Wales, should include Scotland.
An additional indicator should be added on the incidence of food poisoning. There is a clear upward trend and data are available for England , Wales and Scotland.
Use of irrigation water for irrigation, and proportion of potato crop irrigated
These indicators (Indicators 19 and 20) are responsive to summer rainfall and should be retained, although the potato area data are not available every year.
Potato yields (non-irrigated)
Data are no longer readily available to continue this indicator.
Warm weather crops (grapes and forage maize)
These indicators (Indicators 22 and 23) may be showing trends that are unrelated to climate, but they have public resonance and should be retained.
Late summer grass production
This unique long time series from Rothamsted Research should be retained as an indicator (Indicator 24)
Plant and animal phenology (other than insects)
The current indicator is the date of oak leafing in Surrey (Indicator 25). This indicator could be replaced by more secure and comprehensive data series on plant leafing and flowering dates from the UK Phenology Network (UKPN) and other sources. Dates of flowering of snowdrops and daffodil are good candidates (avoiding differences among cultivars). The Welsh series on flowering of ryegrass and clover could be included, and there are good Scottish phenology series. Data on frog spawning dates are available from the ECN and UKPN, are responsive to early spring temperatures and could be added as an additional indicator.
Health of beech trees
This series should be retained (Indicator 26).
Appearance, activity and abundance of insects
These indicators are very responsive to temperature and should be retained (Indicators 27 and 28). However, some of the time series have been replaced, and the abundance of common footman moth appears to be less responsive than other species and should be replaced.
Bird behaviour and populations
The indicators chosen (Indicators 29-31) have high public resonance, are responsive to climate and should be retained: namely, the arrival date of the swallow, egg-laying dates of robins and chaffinches and wren populations.
Freshwater natural events
Data on upstream movement of salmon (Indicator 33) are no longer available and this indicator is discontinued. The duration of ice on Windermere is a surrogate for temperature (Indicator 34). Thus, the current indicator set lacks any measure of freshwater natural events. One candidate would be peak algal bloom dates collected at CEH Windermere. One of these, on *Asterionella*, shows an advance of circa one month over the last 60 years. Prospects for continuance of the series are good and, unlike many series, these data consist of peak dates not first dates.
Marine indicators (see below)

9. A special study was commissioned to examine potential marine indicators, which were represented by two measures of marine plankton in the 1999 indicator set.

Five indicators were selected and are reported in full: (i) sea surface temperature measured in the Irish Sea, (ii) the occurrence of bottom living fish, (iii) barnacle abundance, (iv) plankton abundance (as in the 1999 report), and (v) phytoplankton colour. They all meet most of selection criteria specified in 1999. they include a range of marine habitats (open ocean, inshore waters and the rocky inter-tidal zone) and a range of taxa at different trophic levels (plankton, invertebrates and fish).

10. Candidate headline socio-economic indicators were examined. They included food poisoning, retail sales of air conditioners, foods and drinks, length of growing season and all the socio-economic indicators selected for the 1999 publication. Four were examined in detail: length of growing season, domestic gas supply, Scottish skiing industry, and domestic property insurance. All fulfil the selection criteria of availability, sensitivity, policy relevance, public resonance, future availability and length and homogeneity of time series. The indicator recommended is the value of settled insurance claims for damage attributed to weather perils. Data are available since 1987 and from 1998 the weather perils are separated into effects of severe frost (burst pipes), wind storm and flood. The recommended alternative socio-economic indicator is winter domestic gas consumption.

1. Objectives

Background

The report *Indicators of Climate Change in the UK* summarising 34 indicators of UK climate change impacts, covering climate, socio-economic and environmental factors was published by DETR (Defra) in 1999. The indicators are also available at www.nbu.ac.uk/1ccuk/.

Rationale

Since publication of the DETR (Defra) climate change indicators report in 1999, a number of other sets of climate impact indicators (e.g. those commissioned by the European Environment Agency and others) have been developed. Work was needed to review whether a summary set of indicators at the UK-level was still necessary and, if so, how these indicators could best complement other initiatives.

An update of the current set of UK indicators was also necessary, along with a reappraisal to assess whether :

- the original set of indicators was still appropriate;
- new indicators should be devised;
- indicators should be removed from the set.

Research Specifications

1. Review and update indicators

The project considered relevant climate impacts research undertaken since publication of the 1999 report (including environmental indicators developed by the European Environment Agency, and climate change indicators developed by Scotland, Wales and Ireland, English Nature and the Environment Agency).

The project identified gaps and weaknesses in the existing set of UK climate change indicators, particularly in terms of the quantity and quality of the data available. It also took account of the responses to the publication of the first indicators report. Finally, the work highlighted where methodological problems limited our ability to produce better indicators in future, and recommended future areas for research.

On the basis of this re-appraisal, the current set of indicators was updated and refined, to better represent UK climate impacts.

2. Develop a new socio-economic indicator of climate impacts

The Defra publication *Foundations for our Future* (June 2002) presents a variety of sustainable development indicators. Climate change is considered a cross-cutting theme within the report, and is reflected in two of the indicators :

- Emissions of greenhouse gases (UK emissions indicator); and
- Socio-economic impacts of climate change.

The second of these indicators had not yet been developed and Defra has a commitment to produce an appropriate indicator in time for the first revision of the *Foundations for our Future* report (publication expected June 2003).

This project explicitly identified a headline indicator of the socio-economic impacts of climate change indicator for inclusion in the report. It highlighted the reasons why this particular indicator was chosen above others, according to a defendable methodology.

Milestones

Milestone 1 – An expert meeting was held to review current set of indicators and suggest improvements.

Milestone 2 – Current indicators were dated and a socio-economic indicator was developed.

Milestone 3 – The indicator website was updated, and this final report was prepared with a summary document suitable for publication.

2. Expert Meeting, 27 March 2003

Objectives

A meeting was held on 27 March 2003 at Defra with the following objectives.

- To indentify and consider the lists of climate change indictors produced by the European Environment Agency, the UK Devolved Administrations, the Environment Agency and other relevant sources.
- To consult with representatives of the UK Devolved Administrations, the EA and UKCIP.
- To elicit views on gaps and weaknesses in the 1999 list of UK Indicators of Climate Change, covering climate, the natural environment, socio-economic and marine indicators.
- To consider the headline indictor required for the Defra publication 'Foundations for our Future'

Participants

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Havard Prosser (Welsh Assembly) (havard.prosser@wales.gsi.gov.uk)

Notes from the meeting

Consultation with devolved Administrations
Scotland has not produced a report of climate change indicators. There has only been a report of temperature indices for Scotland, which were being updated by CRU. There was some concern that Scotland was not adequately covered by the indicators.

This could be addressed in part by adding narrative to explain the relevance of each indicator to Scotland. Alistair Montgomery agreed to consult Scottish Agencies to determine if other work had been done.

The Welsh report of 22 climate change indicators was completed in 2001. The main reason for the Welsh report was to communicate to people in Wales, by using Welsh sites and data. There was an intention to select about 15 indicators and examine their robustness. The exercise unearthed some good Welsh data on some aspects, such as health and clover/grass mixtures.

No separate initiative has been taken in Northern Ireland. However, a report has been produced for Ireland.

Consultation with EA and EEA
Some participants were involved in the European Environment Agency initiative to produce a list of European Indicators of Climate Change – contracted to the European Topic Centre for Climate and Air. The EEA has listed 49 candidate indicators, of which 18 have been shortlisted (see Section 5). Fact Sheets will be produced within the next year.

The EA Environment Indicators include some relating to climate change. The indicators are scored against the selection criteria – which could be done for the UK Indicators of Climate Change. The EA will complete an audit of all EA databases by August 2003, in an effort to locate data of value as indicators. Salmon catches on the River Wye (since 1920s) were discontinued because of confounding factors; indicators of fish behaviour were preferred. It was thought that flood risk (indicator 7) should be presented as 'peak over threshold' values, as in the EA indicators, but CEH Wallingford would be the appropriate sources of data. CEH has produced a report on Flood Indicators. The Thames Barrier data should identify the reasons for barrier closure – the barrier is used to create a temporary reservoir as well as avert flood risk. (Contact: Sarah Lavery, EA at the Thames Barrier.)

Marine indicators
The 1999 list was deficient in marine indictors. Several are under consideration by the Maribe Biological Association. For sea surface temperature, it was suggested to use the E1 location, rather than the Meteorological Office data – but there are serious data gaps and is little apparent trend.

Headline socio-economic indicator
UEA has considered each of the main socio-economic indicators in the 1999 report.
The meeting considered indicators that the UK 'can do something about' such as (i) planning application refusals for building on flood plains, (ii) uptake of guidance for 20% increase in flood risk when making coastal defence plans, eg number of schemes taking this into account, and (iii) number of water management plans that take account of climate change. However, all these indicators presented difficulties in obtaining consistent data which could be interpreted with confidence. It was concluded that the insurance claims indicator met most criteria and was most robust, especially if new data sources could been identified

3. Consultation on the 1999 indicators, that took place in 2000

Questionnaires were sent out in 1999 by DETR with copies of the Indictors report. Responses and comments were received from the following.

1. J Lewis (E-mail on coastal conservation)
2. The Royal Academy of Engineering B Connorton, Thames Water.
3. B Farmer, Forest Enterprise.
4. GC Russell, Renfrew Council.
5. W Smith, Department of Health.
6. R Crofts, Scottish Natural Heritage.
7. J Kinniburgh, Environment Agency.
8. T Beebee, University of Sussex.
9. D Coleman, Bexley Council.
10. D Giles, Southern Water.
11. J Good, CEH, Bangor.
12. M Harley, English Nature.
13. R Harrington, Bournemouth and West Hampshire Water.
14. K Hofius, Federal Institute of Hydrology, Koblenz.
15. G Jenkins, Hadley Centre.
16. R Jennings, Chartered Institute of Building Services.
17. A Moss, South Staffordshire Water.
18. E Smith, Angia Water.
19. J Tompkins, National Farmers Union.
21. B Wyatt, CEH, Monks Wood.

A meeting was held at DETR, Ashdown House on Monday 13 November 2000 to consider the comments received. (Participants: Penny Bramwell, DETR, Caroline Fish, DETR, Melvin Cannell (CEH, Edinburgh), Tim Sparks (CEH, Monkswood), Terry Marsh (CEH, Wallingford), Terry Parr (CEH, Merlewood), Jean Palutikof (CRU, UEA), Mike Hulme (TC, UEA) ,Jane Kinniburgh (EA), Geoff Jenkins (Hadley Centre)

This group discussed generic issues and detailed recommendations, and considered the comments received by the above respondents. The following points were agreed at that time.

1. The purpose of the Indicators, and hence the criteria used to decide what to include, remains unchanged. Simple presentation and resonance with the public are still important to DETR. There should continue to be a balance between ‘climate’ and ‘socio-economic and natural response’ indicators.
2. The website should include more links to related sites (DETR, Hadley, Tyndall, UKCIP, ECN etc –check).
3. Climate Indicators (Mike Hulme/Geoff Jenkins)
    - Indicator 1 might be changed to ‘Land and sea temperatures’, presenting the CET (as a present) and a measure of sea surface temperatures (to be decided).
    - Indicator 2 might be changed to ‘Temperature extremes’, presenting heat-waves, frost days and heating day degrees.
    - Indicator 3 might be changed to ‘Precipitation trends’, presenting data on seasonality (as in indicator 2 at present), NW-SE gradient (as in indicator 3iii at present) and winter precip. intensity (downpours).

Future projections might be given for most of the indicators above, based on Hadley Centre model runs and CRU analyses for the UKCIP 2001 scenarios for 26 variables.

4. Hydrology Indicators (Terry Marsh)
    - Indicators 5-8 and 10 should remain unchanged, but maybe linked to Wallingford websites which give regional detail. It is realized that flooding incidence is a serious gap. A separate study is needed to derive meaningful statistics, involving CEH Wallingford and the EA. Terry will write separately to Penny Bramwell.
5. Sea level rise (Tim Sparks)
    - This should be retained.
6. Atmospheric ozone (Melvin Cannell)
    - This might be omitted (not discussed, but subject to valid criticism).
7. Socio-economic Indicators (Jean Palutikof and co-workers)
    - Indicator 12 (insurance claims) might be extended to include claims for flood damage, using Association of British Insurers' statistics.
    - Indicators 13-16 are OK
    - Indicator 17 (lyme disease) should stay (despite criticism) but maybe look at European trends and add a new indicator on the number of notified cases of food poisoning.
    - Indicator 18 (human mortality) stays.
    - Indicator 19 (irrigation water use) stays, but a new indicator might be added on household water use – taking into account the EA indicator and going back before 1992.
    - Indicator 20 (percentage potato area irrigated) - there have been no data since 1995, so this may be dropped.
    - Indictors 21 and 22 stay.
    - Indicator 23 (forage maize) should be dropped.
    - A new indicator should be sought on the sale of air conditioners; maybe there is a trade association.

A new indicator should be sought on sales of beer and soft drinks.

8. Natural environment Indicators (Tim Sparks and Terry Parr)
    - Indicator 24 (summer grass production) should stay.
    - Indicator 25 (oak leafing date) should stay, but add the time of flowering of daffodils.
    - Indicator 26 (tree health) should stay.
    - Indicators 27-31 (insects and birds) should stay.
    - Indicator 32 (marine plankton) should be changed to include the existing copepod abundance data and some measure of phytoplankton.
    - A new indicator might be added on sea fish and mammals, consulting the Marine Conservation Society and CEFAS.
    - A new indicator might be added on frog spawning dates, using ECN data and consulting T Beebee.
    - A new indicator might be added on bat activity, provided by the ECN.
    - A new indicator might be added on vegetation change, provided by the ECN.

Water quality was recognized as a serious gap – in the absence of systematic recording of algal blooms.

4. Update of 1999 Indicator Data

The following data updates have been implemented on the intranet. A full hard-copy listing of the data is given a separate document.

Indicators 1. Air temperature in central England. Completed to 2002. CET data from: www.metoffice.com/research/hadleycentre/CR_data/Daily/HadCET_act.txt

Indicator 2. Seasonality of precipitation. Completed to 2002.
www.metoffice.com/research/hadleycentre/CR_data/Monthly/HadEWP_act.txt
http://www.cru.uea.ac.uk/~mikeh/datasets/uk/engwales.htm
The Hadley Centre's precipitation data series has been calculated by a different method from 1998 onwards, which provides a partial explanation of why the figures do not match the earlier update. However, an additional problem is that the parameters of the calculation previously used are not known. That is, what constituted the 'annual' figure against which the 'winter' value is apportioned. In this update the 'annual' figure is the sum of months beginning August and ending July. In accordance with the original series, the year assigned to the final value is the year relating to the month of January. The revised values for 1996 – 1998 are within about 3% of the figures given in the previous update.

Indicator 3. Precipitation gradient across the UK. Completed to 2002

Indicator 4. Predominance of westerly weather. Completed to 2002 and whole series has been replaced.
http://www.cru.uea.ac.uk/cru/data/nao.htm, data file nao.dat.
http://www.cru.uea.ac.uk/~timo/projpages/nao_update.htm
The NAO index series was modified in November 2000, which provides a possible explanation of why the figures do not match the earlier update. However, an additional problem is that the parameters of the calculation previously used are not known. In this update values represent the mean of the five monthly index values (Nov – Mar). The year assigned to the final value is the year relating to the month of January.

Indicator 5. Dry and wet soil conditions. Completed to 2002 by CEH Wallingford. This indicator should be replaced by preferred datasets from eth Met Office (see Section 8).

Indicator 6. River flows in northwest and southeast Britain. Completed to 2002. by CEH, Wallingford. (See section 8).

Indicator 7. Frequency of low and high river flows in northwest and southeast Britain. Completed to 2002. It is recommended that this indicator be replaced by the 'number of peaks over threshold' for a selection of gauging stations (see Section 8).

Indicator 8. Groundwater storage in chalk in southeast Britain. Completed to 2002. The Holt borehole time series has been replaced by the Stonor borehole time series (see Section 8).

Indicator 9. Sea level rise.
Completed to 2001. There has been a change in web address for the source of the data to http://www.pol.ac.uk/psmsl/psmsl_individual_stations.html .

Indicator 10. Risk of tidal flooding in London. Completed to 2002. See Section 8.

Indicator 11. Atmospheric ozone levels in summer in rural England. Completed to 2002 by CEH Edinburgh. Contact: Mhairi Coyle: mcoy@ceh.ac.uk. Incomplete data were available for Ladybower in 2001 as a consequence of the Foot and Mouth epidemic and an estimate has been used in its place.

Indicator 12. Domestic property insurance claims. Completed to 2002 and data for 1998 and 1999 revised. Data from: The Insurance Statistics Yearbook and Retail Price Index 1996. Abistats@abi.org.uk Association of British Insurers, 51 Gresham St, London EC2V 7HQ. Tel. 020 7600 3333 Fax. 020 7696 8999 info@abi.org.uk
New contact: Diana O'Keefe, diana.o'keefe@abi.org.uk.
The precipitation data are from:
www.metoffice.com/research/hadleycentre/CR_data/Monthly/HadEWP_act.txt
A revision to the data was made in Q2 2000 Bulletin, due to the discovery of previously unreported data from one large company. The 1998 and 1999 data were amended and republished to account for this. The whole series also needs adjustment. The 1999 report Figure caption was wrong – values are for UK not England & Wales as stated.
See previous note relating to revision of precipitation data series. (Variance from previous update of up to 5mm.)

Indicator 13. Supply of gas to households. Completed to 2002 with update of 1998 and 1999 data. Data from: Energy Trends, available from DTI. http://www.dti.gov.uk/energy/inform/energy_stats/gas/4_1gasconsumption-Q.xls
www.dti.gov.uk/epa.htm contact
Mr Clive Sarjantson Clive.Sarjantson@dti.gsi.gov.uk
CET data from: www.metoffice.com/research/ hadleycentre/CR_data/Daily/HadCET_act.txt

Indicator 14. Domestic holiday tourism. Completed to 2002 but figs don't match with previous update. The UK Tourism Survey had a change in methodology in 2000. Data from 1995 to 1999 were reworked to allow comparison with later data. This explains the fact that figures obtained for this update do not match those provided previously. The data given are UK Holiday Tourism Trips (Millions), which as previously include at least one night spent away from home. The 1999 report text refers to 'British' residents (Eng, Scot & Wales) but data are for the UK: the Figure caption has been be amended.
Annual UK Tourist Survey, British Tourist Authority, Thames Tower, Blacks Road, London W6 9EL, Tel: (+44) (0)20 8846 9000, Fax: (+44) (0)20 8563 0302. Data from 2000 onwards on website –
http://www.staruk.org.uk/tourismfacts
Joanne Scott, Information Library, English Tourism Council, Thames Tower, Black's Road, London, W6 9EL , Tel +44 (0) 208 563 3000 , Fax +44 (0) 208 563 3234
Jscott@englishtourism.org.uk
CET data from: www.metoffice.com/research/ hadleycentre/CR_data/Daily/HadCET_act.txt

Indicator 15. Scottish skiing industry. Completed to 2001/2. The data relate to winter seasons – i.e. straddling 2 calendar years, whereas snow days data are for calendar years. Perhaps a better approach might be to calculate snow days per winter season. (Although most snow falls Jan – March, with fewer days in Oct to Dec).
Scottish Ski Centres: Skier Days' report
Market Research & Development Branch, Highlands & Islands Enterprise.

Cowan House, Inverness Retail and Business Park, INVERNESS IV2 7GF Scotland. Tel: 01463 234171 http://www.hie.co.uk
New contact: Andrew Sarjeant - direct tel 01463 244480.
a.sarjeant@hient.co.uk
Snow days data from: Met Office, Glasgow Weather Centre. enquiries@metoffice.com

Indicator 16. Number of outdoor fires. Completed to 2001. Home Office Statistical Bulletin: Fires Statistics UK (discontinued after 1999). New source – Fire Statistics, UK, 2001 (and also for 2000). Office of the Deputy Prime Minister http://www.safety.odpm.gov.uk/fire/rds/index.htm
Georgina Ford, Office of the Deputy Prime Minister, Eland House, Bressenden Place, London SW1E 5DU ,http://www.odpm.gov.uk georgina.ford@odpm.gsi.gov.uk
The Home Office Bulletin has been discontinued. The statistics used are now published in Table 23 in the new report produced by the Office of the Deputy Prime Minister (per Georgina Ford) (available on-line). Data for 2002 not available until late this year.
Precipitation data from:
www.metoffice.com/research/hadleycentre/CR_data/Monthly/HadEWP_act.txt

Indicator 17. Incidence of lyme disease in humans. Completed to 2002. CDSC, Abton House, Wedal Road, Cardiff, CF4 3QX. Dr Robert Smith : robert.smith@cdsc.wales.nhs.uk.
CET data from: www.metoffice.com/research/ hadleycentre/CR_data/Daily/HadCET_act.txt
Slight revisions of 1998 and 1999 numbers of cases. Note that figures for 2000 – 2001 and 2002 (provisional) are around double those of previous years. This is due to increased level of disease awareness and differences in methods of reporting (Dr. Robert Smith, Clinical Scientist, CDSC). The 1999 indicator's report states data are UK, whereas they are actually England & Wales only. This has been amended in any revised publication.

Indicator 18. Seasonal pattern of human mortality. Completed to 2001/2. Data from: Office of National Statistics. Julie.gastrell@ons.gsi.gov.uk. CET data as above. For 1997 – 1999 the underlying data vary from the previous update, which has been revised. There is some suggestion that provisional figures were previously supplied, which would provide an explanation for this. Statistics are from the same source.

Indicator 19. Use of irrigation water for agriculture. Completed to 2000. Digest of Environmental Statistics, DEFRA, (March 2002): http://www.defra.gov.uk/environmental/statistics/des/index.htm
Gillian Welberry, EA Peterborough Office, 01733 464193 email:
gillian.welberry@environment-agency.gov.uk
Precipitation data as above.

Indicator 20. Proportion of potato crop that is irrigated. Data received and percentage for 2001 calculated comparing irrigated ha with total potatoes (ha) from England plus Wales Ag & Hort June Census 1991. DEFRA Survey 2001, undertaken by Cranfield University. Dr. K Weatherhead, Cranfield k.weatherhead@cranfield.ac.uk
Precipitation data as above.

Indicator 21. Potato yields. Data to update the series are unlikely to be available before May 2003, depends if resources are available. sgerrish@potato.org.uk
Steve Gerrish, Information Resources Manager, Oxford Office, British Potato Council
Precipitation data as above.

Indicator 22. Warm-weather crops: grapes. Completed to 2002. Annual Harvest and Production Declarations, Wine Standards Board (statistics supplied to DEFRA Food & Drinks Industry Division for the EC). New contact –John Boodle, Wine Standards Board Tel 0207 236 9512. Email j.boodle@wsb.org.uk
The Indicators report suggests the statistic are for the UK, whereas the data supplied for this and the previous update relate to England & Wales (assuming none in Scotland and NI).

Indicator 23. Warm weather crops: forage maize. Completed to 2002. Agricultural & Horticultural Census : 5 June 2002, United Kingdom Revised Results. Noelle Floyd, Maize Growers Association. Mga1@globalnet.co.uk Values are for England, Wales & N.Ireland only. Enquiries to the Scottish office suggested that maize acreage there is negligible – less than 30ha. However this could be the place to watch.

Indicator 24. Late summer grass production.
The data source is now officially Rothamsted Research and data are obtained from Ian Woiwod. A modified series with minor changes has been provided, complete to 2002.

Indicator 25. Date of leaf emergence on trees in spring
The data source is now the UK Phenology Network. Data continues to be recorded by Mrs Combes and plans for a replacement in the longer term should be considered. Complete to 2002.

Indicator 26. Health of beech trees in Britain. Completed to 2001. Research Information Note, Forestry Commission. Contact: steven.hendry@forestry.gsi.gov.uk

Indicator 27. Dates of insect appearance and activity. Completed to 2002. Modified series have been provided for Common Footman and Orange Tip. The Moth and Aphid data source now officially Rothamsted Research.

Indicator 28. Insect abundance.
Completed to 2002. Modified series have been provided for Common Footman and Common Blue. Moth and Aphid data source now officially Rothamsted Research.

Indicator 29. Arrival date of the swallow.
Completed to 2002.

Indicator 30. Egg-laying dates of birds.
Completed to 2001.

Indicator 31. Small bird population changes.
Completed to 2001, however no data are available for 2001 because of the Foot & Mouth epidemic.

Indicator 32. Marine plankton.
Completed to 2002. New indices have been used for the Gulf Stream Position Index (new address http://www.pml.ac.uk/gulfstream/newpage1.htm) and NAO data used for Indicator 4 have been used for consistency.

Indicator 33. Upstream Movement of Salmon.
This indicator has been discontinued because of difficulties in obtaining data.

Indicator 34. Ice on Lake Windermere. Completed to 2002. Data from CEH, Windermere: contact Dr Glen George.

5. Consideration of Welsh, Scottish and Irish Indicator Initiatives

Welsh Indicators

Buse, A., Sparks, T. H., Palutikof, J., Farrar, J., Edwards-Jines, G., Mitchelson-Jacobs, G., Corson, J., Roy, D. B. and Lister, D. 2001. Review of possible climate change indicators for Wales. Centre for Ecology and Hydrology, Bangor. National Assembly for Wales contract No 232/2000. 63p

Anon. 2001. Climate change indicators for Wales. Review of options for monitoring changes in the Welsh climate. Centre for Ecology and Hydrology, Bangor

This report considered over 60 candidate indicators, using data from (or relevantto) Wales. 22 were then selected as meeting essential criteria of availability of data, demonstrable response to climate, resonance, cost and scientific basis. Here we consider the 22 selected indicators.

A number of the indictors are the same as in the UK 1999 list, but use data from Welsh sites. These variables are:
Air temperature. Rainfall, Outdoor fires, Human mortality, Leafing dates, Timing of peak insect abundance, Insect abundance, Bird migration timing, Egg laying time, Sea level, Upland and lowland river flows, *North Atlantic Oscillation*.

The variables which are not included in the UK list, but need to be considered are:
Snow cover – measured on Snowdon (also in the EEA list)
Westerly winds, and gale index – of special relevance to Wales and western Britain
Sea temperature – an omission in the UK list
Flowering of clover varieties – a special Welsh long-term dataset (IGER)
Ear emergence – also a special Welsh long-term dataset on ryegrass (IGER, since 1930)
Greenness – available fortnightly from NDVI analysis of satellite images at 8 km resolution every 2 weeks since 1982. This variable would be costly to extract, and would encounter problems of cloud cover.
Flowering time of native flora – the UK phenological network may reveal opportunities for the UK (see this report).
Timing of frogspawn – again, the UK phonological network would provide data for the UK.
Gulf Stream index – the position of the Gulf Stream is included in the UK dataset as an independent variable in Indicator 32 (Marine Plankton), but could be listed as an important variable in its own right It is available form eth Plymouth Marine Laboratory website (www.pml.ac.uk/gulfstream/inetdat.htm).

Scotland and Northern Ireland Indicators
Purves, R. S., Harrison, S. J., Tabony, R. C. and Turrell, W. R. 2000. Development of temperature indices for Scotland and Northern Ireland. SNIFFER, Stirling. Report No SR (99) 07F.36p.

Three terrestrial temperature indices were proposed:
Northern Ireland – Armagh.
Scottish Mainland - Braemar, Dumfries, Edinburgh Royal Botanic Gardens, Paisley and Wick.
Scottish Islands – Stornaway, Lerwick.

Three sea surface temperature indices were proposed:
Shelf Edge – west of Shetland, based on two Fisheries Research Services (Aberdeen) sites plus GISST grid squares.
North Sea – south of Shetland, also based on two Fisheries Research Services sites plus GISST grid squares.
West Coast – based on Millport and GISST grid squares.

These temperature indices are being developed by the Climate Research Unit, UEA, under contract to SNIFFER.

No other systematic initiative has been taken in Scotland or Northern Ireland to develop indicators of climate change using Scottish and Northern Irish datasets.

Ireland Indicators
Sweeney, J., Donnelly, A., McElwain, L. and Jones, M. 2000. Climate change indicators for Ireland. Environmental protection Agency, Wexford, Ireland. (john.Sweeney@may.ie), (www.epa.ie).

This report considers a very wide range of potential indicators for Ireland. It does not identify a list of indicators, which meet certain criteria.
The list of potential indicators covers most of those considered in the UK 1999 list. It does not include any socio-economic indicators which were not in the UK list.

However, the following indicators were considered for Ireland, which do not occur in the UK list (although many were considered).
First and last days of frost and frequency of frost days.
Frequency of rain and wet days.
Maximum 1-day precipitation events – (also the subject of study in the UK: Osborn, T. J., Hulme, M., Jones, P. D. and Bassett, T. 2000. Observed trends in the daily intensity of United Kingdom precipitation. Int. J. Climatol. 20, 347-364.)
Bat activity – In the UK data are available from the Bat Conservation Trust. (bats.org.uk and scotbats.org.uk). In December 1995, DETR commissioned a five-year programme of research (1996-2000), the National Bat Monitoring Programme (NBMP), with the overall goal of developing an effective monitoring strategy for resident species of bat in the UK. However, the programme relies on data gathered by volunteers.
Fish stocks - but data availability a problem.
Length of growing season – needs to be considered for the UK
Distribution of plants – similar to the aspirational indicator of the EEA, with difficulty in obtaining robust data.

6. European Environment Agency Indicators of Climate Change

The EEA European Topic Centre for Climate and Air selected 49 indicators of climate change in Europe in 2002 (Marcus Erhard, erhard@pik-potsdam.de; Jelle van Minnen, Jelle.van.Minnen@rivm.nl; Thomas Voigt, Thomas.voigt@uba.de)

The 49 indicators considered are listed below. The indictors selected for development and description on Fact Sheets in 2003 are shown with an asterisk.

*Temperature
*Precipitation
*North Atlantic Oscillation
*Greenhouse Gas Concentrations
    Storms/Storm Events
    Lightening Frequency
    Cool and Shrinking of Strato-, Meso- and Thermosphere
*Snow Cover
*Mountain Glaciers
*Arctic Sea Ice Extent and Duration
    Permafrost/Profiles of Temperature
    Lake and River Ice
    Baltic Sea Ice
    Soil Moisture Availability
*Sea Surface Temperature
    Characteristics of Storm Surges
    Thermohaline Circulation of North Atlantic
*Sea Level Rise
*Net Carbon Uptake (NEP)
    Crop Suitability
    Forest Suitability
    Forest Growth
    Pests and Diseases
    Shift in Tree Line
*Growing Season Length
*Plant Phenology
*Change in Ecosystem Composition/Biodiversity
    Ecosystem Fires
*Marine Ecosystems and Biodiversity (Zooplankton)
*Annual River Discharge
    Discharge form Small Undisturbed Watersheds
    Lake Temperature
    Water Availability
*Frequency of Low and High River Flows
    Temperature of the Intermediate Layer (Baltic Sea)
    Coastal Erosion and Retreat
    Energy Consumption for Space Heating in Winter
    Number of Weather-related Catastrophic Events (Insurance)
    Disruption of Transport
    Tourism/Number of Skiing Tourists in Winter

Sales of Seasonal products
Seasonality of Hay Fever (Pollen and Allergic Disorders)
Vector Distribution
Distribution of Vector-borne Diseases
Catastrophic Weather Events (Floods, storms)
Death Attributable to Heat
Seasonal Peak of Flood and Water Borne Diseases

It will be noted that the indicators that the EEA is taking forward first (asterisked) are dominated by climatic and hydrological variables, for which there are readily available and robust data. The 'climatic' variables that are included in the EEA list, but do not occur in the UK 1999 list are:
Snow cover – which can now be assessed from space. In the UK, there are also records of snow patches at 12 sites at about 1000 m on Ben Wyvis (5 miles north of Inverness) made since 1973 by John Pottie (john@pottie.demon.co.uk). There are also records of the snow line on the Carneddau, Glyderau and Snowdon in Wales, monitored since 1994/5 (see Welsh Indicator study). Long records of heavy snowfalls have been compiled for GB (Wild et al. 2000. An analysis of heavy snowfalls/blizzards/snowstorms greater than 13 cm across Great Britian between 1861 and 1996. Journal of Meteorology 25, 41-49.)
Greenhouse gas concentrations – it was policy to omit this from the UK list.
Mountain glaciers and Arctic ice - not relevant at the UK scale.
Sea surface temperature – an obvious omission in the UK list (see this report).
Growing season length – also an omission from the UK list (see this report).
Annual river discharge – the UK list deals more appropriately with a number of other hydrological variables.

The non-climate variables in the EEA priority list include the following, which are not in the UK list:

Net carbon uptake – this is the net terrestrial carbon sink, due to CO_2 and N fertilization (and other factors) being estimated by a combination of inventory, ecosystem modelling, atmospheric inverse modelling and flux measurement. At present, the methods do not agree. It would be impossible to establish a robust trend in this variable for the UK.
Changes in ecosystem composition/biodiversity – this variable uses assessments of ecosystem biodiversity within national networks. It might be possible to consider this variable in the UK using the ECN data, but it would be difficult to interpret any trends.
Marine ecosystems and biodiversity – an obvious omission in the UK list (see this report).

The non-priority list of EEA indicators (without asterisks) includes many variables for which data are not readily available across Europe. Some of the variables have been included in the UK list (eg the NAO, fires, soil moisture, tourism), others have been considered and rejected because they are difficult to interpret or no data are available (eg disruption of transport, coastal erosion, crop and forest suitability).

7. Role of the Environmental Change Network

Background
The Environmental Change Network (ECN) (http://www.ecn.ac.uk) is the UK's long-term integrated ecosystem research network designed to aid in the detection, interpretation and forecasting of environmental changes resulting from natural and human causes. It is a multi-agency initiative with a network of 54 terrestrial and freshwater sites making regular measurements on the main drivers of change (e.g. climate, atmospheric chemistry, land use) and ecosystem responses (e.g. soil, flora, fauna and water quality). ECN has been collecting data since 1993 and produces data and information relevant to users in education, research and policy. It covers issues such as environmental indicators, the impacts of climate change, biodiversity loss, atmospheric pollution, soil degradation and water quality.

Use of ECN Data in relation to Climate Change Indicators
ECN data are relevant to Defra's requirements for climate change indicators for::

- Disaggregation: to show regional or site level trends for national indicators;
- Interpolation: to fill in gaps between national census years e.g. annual vegetation data to fill gaps between Countryside Surveys every 8-10 years.
- Interpretation: to disentangle multiple causes by comparing the effect of climate to the effects of other confounding factors on the indicators. The range of additional information on physical and chemical variables collected by ECN will facilitate the interpretation of discovered trends. Relationships between trends in different species or groups of species can also be examined, for example trends in invertebrate species compared with trends in insectivore birds.
- Indicator development: to produce new climate change indicators based on ECN data. With 10 years of data available ECN is now becoming an increasingly important source of data for the development of climate impact indicators (e.g. see Section 5).

The main disadvantages of ECN as a source of indicators of climate change in relation to the UK are (i) its lack of long-term historical time-series data for most variables at most sites; (ii) its relatively small number of terrestrial sites and (iii) it cannot provide national statistics because its sites are not chosen randomly, although sites are representative of the main UK environmental gradients in the UK.

Current uses of ECN Data for Illustrating Changes in National Indicators at Local Levels
ECN collects data which are relevant to over one-third of Defra's 34 climate change indicators (Table 1). Although none of these data were used in the first Defra "Climate Indicators" report, they are already being used to show how national indicators vary at different sites across the UK. An example is shown in Figure 1. The ECN www pages (see http://www.ecn.ac.uk/CCI/cci.asp) already show site specific data for the following Defra Climate Change Indicators:

Climate, Hydrology, Sea level and Air Pollution

Number of hot days
Number of cold days
Annual mean temperature
Percentage of precipitation falling in winter
Annual river flows

Insect and Birds

Abundance of common blue butterfly
Abundance of common footman moth
Peak flight times of the orange tip butterfly
Peak flight time of the common footman moth.

Strengths of using ECN data in this way are:

- Graphs updated automatically on www when ECN summary database is updated.
- Data can be inspected and downloaded for further analysis
- Data on possible confounding variables at the same site can be examined
- Direct link to national indicator pages

Future Uses of ECN Data in relation to Climate Change Indicators

ECN is a long-term programme and in future years should be able to provide additional and more robust indicators of climate change. ECN measures over 260 sets of variables. Some of their potential uses as indicators of climate change, particularly in relation to measures of biodiversity and environmental quality, are summarised in Table 2 and described below.

<u>Biological response variables</u>

Changes in species-abundance

ECN can provide estimates or indices of population size for individual species of birds, butterflies, moths, bats and ground beetles at terrestrial sites and measurements of diatoms, phytoplankton, zooplankton and macro-invertebrates to mixed-taxon levels in freshwater communities. Data on both species richness and population size are usually collected:

	Sp. richness	Popn. size
Terrestrial sites		
Butterflies - weekly transect count	✓	✓
Moths - daily catches using the Rothamsted light trap	✓	✓
Ground predators - fortnightly pitfall trapping	✓	✓
Birds - BBS, CBC and Moorland bird census	✓	✓
Bats - transect counts four times a year	✓	✓
Vegetation - quadrat surveys at 3 year intervals, annual subset	✓	✓
Tipulidae larvae - twice yearly core sampling	-	✓
Freshwater sites		
Invertebrates - rivers:twice-yearly, lakes:annually	mixed taxon	✓
Macrophytes - rivers: annually, lakes: 2 years	✓	
Zooplankton - lakes: 4 times a year	✓	✓
Phytoplankton - lakes:4 times a year	mixed taxon	✓
Epilithic diatoms - yearly	✓	-

Populations in these taxa will change in response to annual fluctuations in weather conditions and longer term climate change, although in most cases it will be very difficult to extricate climate related change from the effects of non-climate factors.

Changes in community structure

Changes in animal or plant community structure can often provide robust measures of environmental change. For example, RIVPACS is an excellent example how changes in the community structure of aquatic macro-invertebrates can be used to provide a general indicator of water quality. (However, such modelling techniques are typically calibrated with respect to reference sites which are themselves sensitive to climate change and natural succession over time.) Similar approaches need to be developed in relation to climate so that ECN's data can be used in this way.

Changes in species-phenology
Moths, butterflies and ground predators (beetles) are recorded regularly through the year at ECN sites and shifts in timing of appearance or peak abundance of species can be determined from the data. ECN also records the date of first frog spawning at its sites.

Changes in species-morphology
ECN also makes some very specialised measurements, on some arthropod species, of morphological characteristics which have been shown to be closely related to climate or other types of environmental change. These include colour morphs of the spittle bug (*Philaenus spumarius*), leg colour morphs of the beetle *Pterostichus madidus* and leg lengths of harvestmen (*Mitopus morio*). These are probably currently of academic interest only - there would be credibility problems in the form of the " so what and who cares" reaction in trying to use them as popular indicators of climate change.

Indicators of water quality.

There are currently no indicators reflecting climate change impacts on water quality. This probably reflects the difficulty in separating the impacts of climate change from the many other factors that influence water quality. ECN data may help here.

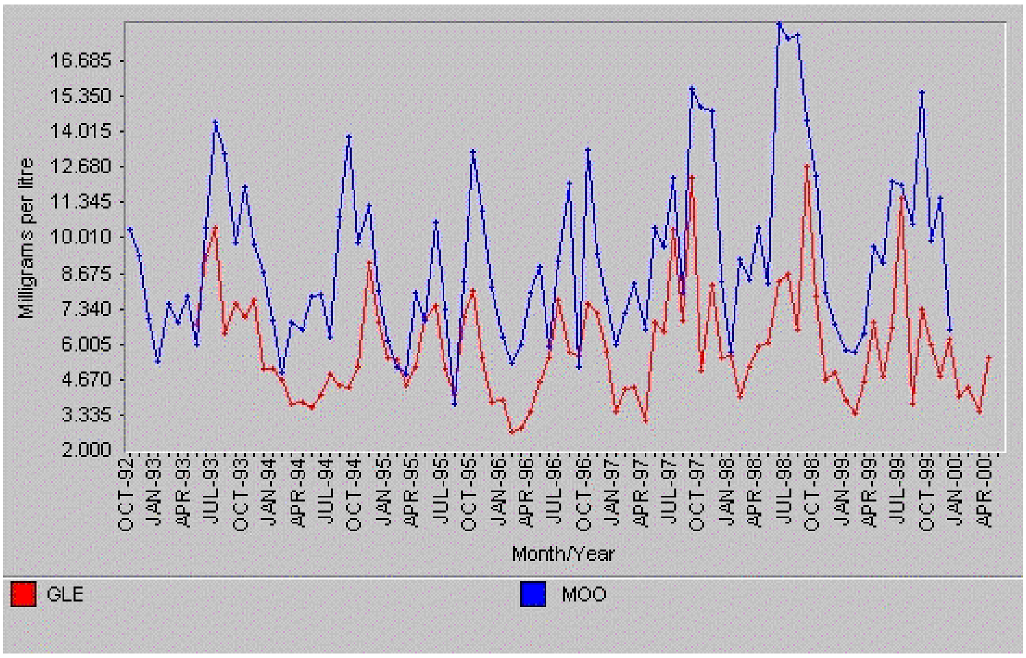


Figure 2. *Changes in dissolved organic carbon (related to water colour and water quality) in upland catchments. Annual variations related to weather conditions. Drying of upland peats may result in higher levels of DOC in river water.*

Many water quality variables measured by ECN at freshwater sites and terrestrial sites are likely to be influenced by climate change. One variable which is likely to change if the climate warms is dissolved organic carbon (DOC) in upland streams (Figure 2). This gives rise to the "water colour" problem which is familiar to the public and has economic implications because of the high costs associated with its treatment in water supplies. DOC shows seasonal and weather related cycles and has peak concentrations in stream-waters coming from peat soils as they wet-up after drying. One scenario is that with climate change we should expect to see increases in DOC as water tables in upland peats tend to get lower over the summer period. We would need to fit models to the data in order to extract long-term climate related trends from short-term seasonal or flow-related effects and interactions with land-use, vegetation, soil type, biological and hydrological processes may also need to be taken into account. In particular, DOC in upland streams is affected by fires (and so is related to indicator 16).

Climate monitoring

Continuous climate monitoring with automatic weather stations is done at ECN's terrestrial sites. Many ECN sites also have long runs of climate data which might be used to illustrate specific aspects of climate change at local levels.

Ongoing Work On Developing Indicators of Climate Change on Biodiversity

ECN is currently developing for Defra (Wildlife and Countryside Division) a climate change indicator for biodiversity in England based on changes in the abundance of climate sensitive species at ECN sites. The feasibility of this approach has been demonstrated through work showing the effects of the 1995 drought (Morecroft et al 2002) and longer-term correlations between summer temperatures and abundance individual species of moths, beetles and butterflies.

This indicator will form part of a formal set of Biodiversity indicators for England to be published in late 2003, as described in "Working With The Grain of Nature: A Biodiversity Strategy For England" (Defra 2002).

References

Sykes J.M. and Lane A.M.J. (1996) (eds.) *The UK Environmental Change Network: Protocols for standard measurements at terrestrial sites.* HMSO, London.

Morecroft, MD., Bealey, CE., Howells, E., Rennie, SC. and Woiwod, I. (2002). Effects of drought on contrasting insect and plant species in the UK in the mid-1990s. *Global Ecology and Biogeography*, **11(1)**, 7-22.

Table 1. *ECN can provide data relevant to nearly one third of the indicators selected for the climate change indicators project.*

CANDIDATE INDICATORS	ECN DATA COVERAGE
A. Climate, Hydrology, Sea Level and Air Pollution	
1. Air Temperatures in Central England	✓
2. Seasonality of Precipitation	✓
3. Precipitation Gradient Across the UK	✓
4. Predominance of Westerly Weather	x
5. Dry and Wet Soil Conditions in Southern England	✓
6. River Flows in NW and SE Britain	✓
7. Frequency of Low and High River Flows in NW and SE Britain	✓
8. Groundwater Storage in the Chalk of SE Britain	x
9. Sea Level Rise	x
10. Risk of Tidal Flooding in London	x
11. Atmospheric Ozone Levels in Summer in Rural England	x
B. Insurance, Energy, Tourism and Fire	
12. Domestic Property Insurance Claims	x
13. Supply of Gas to Households	x
14. Domestic Holiday Tourism	x
15. Scottish Skiing Industry	x
16. Number of Outdoor Fires	x
C. Health	
17. Incidence of Lyme Disease in Humans	x
18. Seasonal Pattern of Human Mortality	x
D. Agriculture and Forestry	
19. Use of Irrigation Water for Agriculture	x
20. Proportion of Potato Crop Area that is Irrigated	x
21. Potato Yields	x
22. Warm-weather Crops: Grapes	x
23. Warm-weather Crops: Forage Maize	x
24. Late summer Grass Production	✓
25. Date of Leaf Emergence on Trees in Britain	✓
26. Health of Beech Trees in Britain	?
E. Insects and Birds	
27. Dates of Insect Appearance and Activity	✓
28. Insect Abundance	✓
29. Arrival Date of Swallow	x
30. Egg-laying Dates of Birds	x
31. Small Bird Population Changes	✓
F. Marine and Freshwaters	
32. Marine Plankton	x
33. Upstream Migration of Salmon	?
34. Appearance of Ice on Lake Windermere	x

Figure 1. Example of ECN data used to disaggregate national indicator to local (site) level .

(http://www.ecn.ac.uk/CCI/cci.asp)

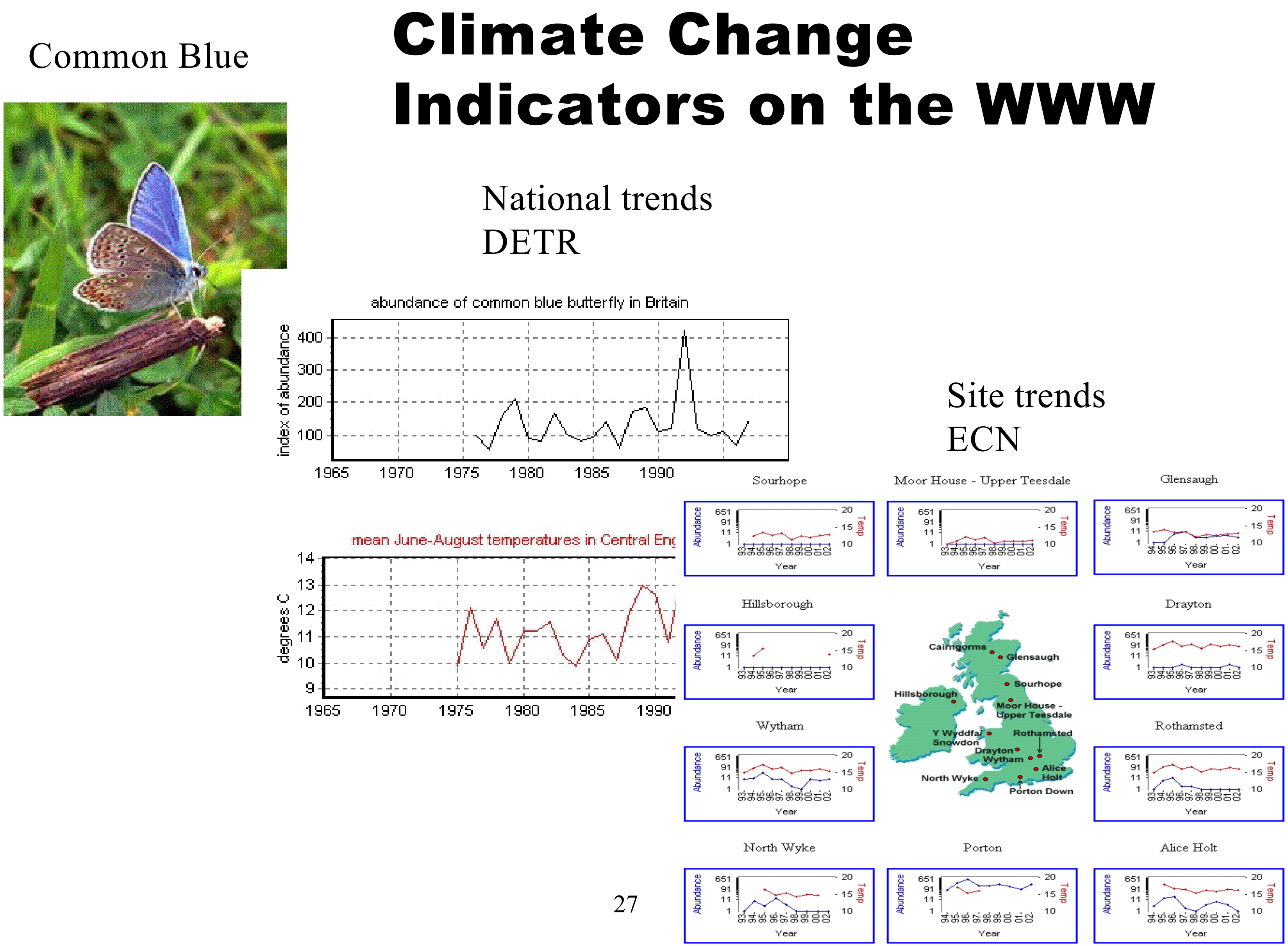


Table 2. Potential "New" ECN Climate Impact Indicators (not Including Moths and Butterflies)
8/11/00
(all indicators can be related to appropriate climate variables at site level)

Indicator	**Description**	**Climate Sensitivity (*** = high)**	**Public Resonance (*** = high)**	**Data availability**	**Implementation status**
Frog spawning date	Indicator of spring warming - may vary regionally.	***	***	8 sites x 10 years	OK
Bat activity	Number of bats recorded on 4 walks - increase likely to be related to increases in population size and increased activity	* (not a particularly robust measure and no great year to year variation recorded so far.) (interactions/ non-linear responses possible)	**	10 sites x 10 years	OK
Ground beetles - phenology	Time of peak abundance	***	*	10 sites x 10 years	Some work to screen species
Ground beetles - population responses	Predatory species may respond positively to increase in food availability.	* (interactions/ non-linear responses possible)	*	10 sites * 10 years	Analysis needed to evaluate indicator.
Vegetation - annual change in key species	Ruderal species and deep rooted species become relatively more abundant after drought.	* (interactions/ non-linera responses possible)	**	10 sites * (max 8-10 years)	Some work to screen species. Dependent on continued DETR funding for annual veg monitoring.
Late summer grass production (c.f. indicator #24)	c.f. indicator #24. ECN can provide data for other sites.	**	*	3 sites * Up to 10 years	OK (but some data to chase)
"Genetic" changes - spittle bug morphs - beetle morphs	Published relationship between morph frequencies and climate.	**	Low unless hyped up.	10 sites x 10 years	Presentation issue.
Coloured water/dissolved organic carbon	Related to either and likely to be afffected by climate change.	** (interactions/ non-linear responses possible)	**	2 sites x 10 years	Presentation issue.
Water quality	Likely to be a complex indicator based on chemical andbiological responses	Unknown may be difficult to disentangle climate effects from confounding factors	***	8 years * 42 river and lake sites (longer data runs from some sites)	Speculative. Trying to interest EA in research project.

8. Current review of strengths and weaknesses of the 1999 indicators

This section presents our current assessment of the strengths and weaknesses of the 1999 indicators, bearing in mind the assessment made in November 2000 (based on the 1999 consultation) and the indicator initiatives by the devolved authorities and the European Environment Agency.

Indicator 1. Air temperature in central England

As stated in the original report, 'CET is perhaps the single most important and representative measure of the surface climate of the UK'. The length of the available series, the efforts which have been devoted to ensuring its homogeneity, and the very many papers which are based on analyses of the series mean that it is a familiar and reliable guide to temperature fluctuations which, at the annual scale at least, are representative of most of the UK.

CET is available as annual, monthly and daily series. It can therefore form the basis for calculation of derived indices which are meaningful indicators. In the original report, daily CET was used to derive the number of hot days and cold days in each year. These, together with annual CET, should continue as indicators.

We recommend the addition of a new indicator derived from daily CET: the length of the thermal growing season. This has relevance to farmers, affecting the timing of operations such as sowing, fertilizer application and harvesting, as well as yields and choice of crop variety. The time series of thermal growing season length, based on CET, appeared in the UKCIP02 climate change scenarios (Hulme et al., 2002). It has been updated to 2002 and supplied to CEH with accompanying text and graphics for inclusion on the web page.

The following change is required to the existing text on the website for Indicator 1:

Change over time

Over the twentieth century the annual-mean Central England Temperature warmed by about 0.67°C (mean linear trend). The warmest years in the entire 340-year record occurred in 1990 and 1999, and five of the ten warmest years occurred in the last decade. This has made the 10-year period 1993-2002 the warmest such period in the record, 0.7°C above the 1961-90 mean.

There has also been an increase in recent years in the number of summers with large numbers of hot days. The summer of 1995 recorded 26 such days - easily the largest number this century - and 1976, 1983 and 1997 also recorded many hot days. The average number of hot days per year over the last decade, 1993 - 2002, has been 7.4 days, more than twice the long-term average. It is noticeable that the period 1962 to 1966 inclusive did not record any hot days in the UK.

The number of cold days shows little long-term trend over the twentieth century. The period from about 1940 to 1970 recorded generally average or above average numbers of cold days, with the record of 57 cold days occurring in the winter of 1962/63. The most recent decade, 1993 - 2002, has recorded on average only about six such days per winter, well below the long-term mean of nearly 11.5 days. The early decades of this century, however, also recorded *relatively few cold days. The winters of 1922/3 and 1924/5 for example, did not record any cold days at all, a situation repeated only twice this century: in 1974/5 and 1997/8.*

In the last four years annual CET has remained well above the 1961-90 average, and indeed only slipped below 10°C in 2001. The year 1999 matched the highest value, which was also recorded in 1990, and 2002 had the fourth highest CET annual temperature in the record. Despite this, the number of hot days has not been exceptionally high in the last four years. The number of cold days has, however, been well below average in every year since 1998 except the 2000/2001 winter.

Anticipating continued global warming, it is expected that the annual-mean Central England Temperature will continue to warm, with higher numbers of hot days and fewer cold days. Such trends, however, will only be manifest when averaged over periods of 10 years or more. Individual years will experience large fluctuations and some, like 1996, will record temperatures below the average. It remains quite possible, for example, that in the next few years we will experience a very cold winter with a large number of cold days.

Reference

Hulme,M., Jenkins,G.J., Lu,X., Turnpenny,J.R., Mitchell,T.D., Jones,R.G., Lowe,J., Murphy,J.M., Hassell,D., Boorman,P., McDonald,R. and Hill,S., 2002: *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.* Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp.

In addition to Central England Temperature, some measure of the length of the growing season is required, because of its relevance to farmers, affecting the timing of fertilizer and cutting operations, yields and potential crop types. The season can be defined by the dates of last and first frosts, which have resonance with gardeners, or by the number of growing day degrees, which is more widely used by farmers (eg. Tsum 500 = 500 day degrees exceeding 5 °C). Both measures are sensitive to the choice of temperature threshold. Frosts are notoriously difficult to define (being subject to local variation, different for exposed and non-exposed surfaces and 'killing' temperatures varying from zero to below –30 C.), although clear trends are evident (Wilby R. L. 2001. Cold comfort Weather 56, 213-215.) The recommended indictor is as follows.

Length of the thermal growing season (J.P.Palutikof)

This is calculated from the daily Central England temperature (CET) record. A graph of the Length of the Thermal Growing Season appears in the UKCIP Climate Change Scenarios (UKCIP, 2002) for the period 1772 to 2001, as Fig. 7. This is calculated relative to a threshold of 5.5°C. More recently, this series was the subject of a letter to *Weather* (Mitchell and Hulme, 2002) where, with a threshold of 5°C, it was proposed as an Indicator.

The thermal growing season length is defined as beginning when the temperature on five consecutive days exceeds some threshold, taken here to be 5°C, and ending when the temperature on five consecutive days is below that threshold. It runs between the first day of the former period, and the day preceding the latter period.

For the Indicators update, recent daily CET data were requested from Phil Jones of the Climatic Research Unit, and supplied to Tim Mitchell of the Tyndall Centre for Climate

Change, so that he could perform the update to 2002. This was done relative to the 5^{o}C threshold. The data have been plotted and a smoothed curve added so that the general trend can be seen. A sample plot is shown below, for the period 1900 – 2002 (over which the climatological indicators are plotted in the original Indicators report).

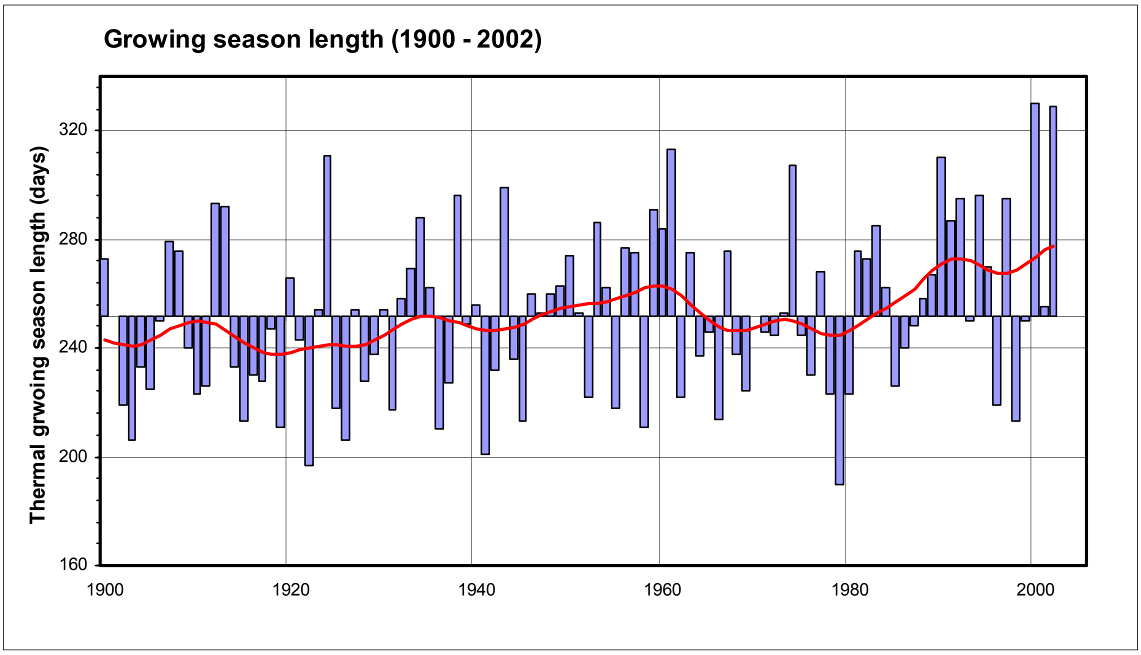


***Figure 1**. The length of the thermal growing season in each year, compared to the mean growing season length 1961-90 (252 days)*

The longest growing season in the 229-year record was 330 days, in 2000. However, the second longest value, and only one day shorter, occurred in 2002 (329 days). According to Mitchell and Hulme (2002), there was an increase in growing season length over the twentieth century of 28 days, which took place mainly in two phases: 1920 – 60, and 1980 – 2000. Whereas the earlier period saw both an earlier onset of spring and a later onset of autumn, all of the recent increase has been due to an earlier onset of spring. This result agrees with the results of other authors, for example Menzel and Fabian (1999).

It is unlikely that this series will prove difficult to update in the future, since daily CET is supplied on a regular basis by the UK Met. Office to the Climatic Research Unit. The programming to derive the index from daily CET is simple and straightforward. This potential indicator has public resonance and is closely related to policy concerns. It therefore makes an ideal candidate as a new indicator.

References

Hulme,M., Jenkins,G.J., Lu,X., Turnpenny,J.R., Mitchell,T.D., Jones,R.G., Lowe,J., Murphy,J.M., Hassell,D., Boorman,P., McDonald,R. and Hill,S., 2002: *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.* Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp.

Menzel, A., and Fabian, P., 1999: Growing season extended in Europe. *Nature*, **397**, 659.

Mitchell, T. D., and Hulme, M., 2002: Length of the growing season. *Weather* **57**, 196-198.

Indicator 2. Seasonality of precipitation

The England and Wales precipitation record is now calculated by the UK Met. Office in a slightly different way from the record which was used in the original Indicators report. However, this was also the case at the time of the last update, and both Mike Hulme and David Lister are assured that the long-term record remains homogeneous. Moreover, the way in which the data are presented in the Indicators report, i.e., winter rainfall as a percentage of annual, should lead to homogeneity despite any changes in the record.

Some measure of the seasonality of precipitation should continue as an indicator, although it is not clear that this is the best one. It is worth exploring whether additional indicators, or a modification of this one, would be worthwhile. This indicator, although looking at winter seasonality, takes no account of the intensity of precipitation. Furthermore, in recent years it has tended towards very average values, with no sign of the wetter winters indicated by the models. We recommend an investigation of some measure of the relative intensity of winter and summer precipitation events, based on daily rainfall, as opposed to the monthly series employed here. Osborn and Hulme (2002) have shown clearly the tendency for winter rainfall intensity to increase, and summer rainfall intensity to decrease, over the period 1961 to 2000, and a similar trend is indicated for the future by climate models. Moreover, since they found regional variations in this overall trend, with winter intensity increasing more markedly in the north-west of the British Isles, and summer intensity decreasing more markedly over SE England, this gives the potential to develop regionally specific indicators relevant to the devolved governments of Scotland and Wales. A careful examination of data availability and cost would be required to underpin any recommendations regarding such an indicator.

The following change is required to the existing text on the website for Indicator 2:

Change over time

The proportion of precipitation over England and Wales falling in winter has remained quite constant during the present century with a 1961-90 average of about 27 per cent. However, two of the three years with the highest proportions of winter precipitation this century occurred in the 1990s - 1990 and 1995 - although there have also been recent years with quite low proportions - 1992 and 1997.

Recent years have seen proportions slightly above - 1996 - and slightly below - 1997 - the long-term mean. The last four years (1999 – 2002) have been close to the long-term average, with no exceptional occurrences. Although climate modelling studies suggest that we might expect to see higher proportions in future, precipitation, including its seasonal distribution, exhibits large natural variations from year-to-year and from decade-to-decade, and clearly identifying such underlying trends may require many more years of data.

Reference
Osborn, T.J. and Hulme, M., 2002: Evidence for trends in heavy rainfall events over the UK. *Philos. Trans. Roy. Soc., Series A*, **360**, 1313-1325.

Indicator 3. Precipitation gradient across the UK

This indicator was successfully updated with no difficulties encountered. Differences in the overlap period are considered to be due to revision of provisional statistics.

Under Indicator 2, we discussed the possibility of introducing an indicator based on daily rainfall intensity, and looking at the contrasts between regions of the UK, broken down by season. Indicator 3 is a good introduction to such a proposed precipitation intensity indicator, since it combines regional with seasonal patterns of precipitation in a single measure based on monthly data. As such it is easy to compute, based on readily-available data at no cost to DEFRA, and likely to be available for the foreseeable future.

The following change is required to the existing text on the website for Indicator 3:

Change over time

The ratio of winter precipitation in Scotland to summer precipitation in SE England has increased in recent decades. Whereas in the first 20 years of record the ratio only exceeded 3.0 on five occasions, in the last 20 years of record ten values were in excess of 3.0. Unusually high ratios occurred in 1921, 1949 and then in a series of years in the 1970s and 1980s. In 1995 the highest ratio, close to 12.0, was recorded, Scotland having a very wet 1994/95 winter and SE England a very dry 1995 summer. This coincided with the highest value of the North Atlantic Oscillation index (see next Indicator) recorded this century.

The last four years have recorded ratios close to the long-term average of 2.9, with the exception of 2000 which recorded a ratio of 5.0 due mainly to above average precipitation in the Scottish winter. Climate modelling studies suggest that global warming might induce precipitation increases in northern UK, especially in winter, and decreases in the south, especially in summer. If so, then we would expect to see higher values of this index in the future. Regional precipitation exhibits large natural variations from year-to-year and from decade-to-decade, however, and identifying such contrasting trends in regional precipitation may require many more years of data.

Indicator 4. Predominance of westerly weather (the North Atlantic Oscillation or NAO)

This indicator is based on the standardized pressure difference between SW Iceland and Gibralter. A small inhomogeneity was recently found in the Gibralter pressure record, and this has led to some changes in the NAO values. Although these are generally less than 0.2, we have replaced the old NAO index, used in the original Indicators report and the first update, with the new version, see:
http://www.cru.uea.ac.uk/~timo/projpages/nao_update.htm

It is noted that records of extreme storms date from 1950, which the Hadley Centre is extending further back. NAO records have been extended back to the 1820s. Reanalysed data from 1948 could be used to provide indices of westerly flow, Additionally, new monthly mean pressure datasets could be used to provide a record form the mid- 19th century.

The North Atlantic Oscillation is a measure of activity over the North Atlantic, and is correlated with UK temperatures, wind speeds and, to a lesser extent, rainfall. As such it is a relevant indicator, which will continue to be available in the future. It perhaps lacks public resonance, and as such it is worthwhile considering the possibilities for replacement. These include:

a. *The gale index*. This was looked at for the Welsh Indicators report. It is readily available (calculated from gridded sea level pressure data), straightforward to compute and will continue to be available in the future. It has two major strengths. First, it is site specific, and therefore regional series could be computed as are seen to be appropriate. Second, it is straightforward to understand, in a way which the NAO is not.
b. *Surface wind speed series*. These have the advantage of being readily understood and offering the potential for development of regional series. However, such indicators are likely to involve data purchase costs, and there is no guarantee that the stations selected for calculation of the indicator will continue to exist in the future.

The following change is required to the existing text on the website for Indicator 4:

Change over time

The period until about 1970 saw a generally decreasing trend in the winter (November to March) North Atlantic Oscillation index, towards more negative values. The winter of 1968/69 yielded the second lowest index value this century, being exceeded only by 1995/96. The period from about 1970 recorded rising index values, with the highest value being recorded in 1994/95.

The change in North Atlantic Oscillation condition between the winters of 1994/95 and 1995/96 was quite remarkable - from the highest twentieth century value to the lowest twentieth century value in successive years. The very low index value in winter 1995/96 was associated with a cold winter in the UK. Since the extraordinary fluctuations of the mid 1990s, five of the last six winters have had positive values of the NAO, with a maximum, but by no means exceptional, deviation of 1.54 in 1999/2000. The exception is 2000/01, which had a slightly negative NAO value.

It is difficult to predict how the North Atlantic Oscillation may change in the future as the world warms. It displays variations on a number of different timescales, most of which may be unrelated to global warming. However, given its importance in determining winter weather over the UK, trends in UK climate cannot fully be understood without reference to the North Atlantic Oscillation.

Indicator 5. Dry and wet soil conditions

The following modification has been made to the text on the website:

Persistently high soil moisture deficits were a feature of 1988-92 and 1995-1997 but the intervening period was wet - notably the winter – and above average rainfall since mid-1997 has counterbalanced the higher evaporative demands which have characterised the recent past. Although maximum soil moisture deficits have been notably high in the 1990s, the length of time over which substantial deficits have obtained has not been unusual. The dry soil conditions over the winter of 1996/97 greatly restricted the period available for groundwater recharge but, thereafter, the recharge season has been of normal length – allowing groundwater levels to recover to within their normal range.

This indicator is unlikely to be sustainable in the absence of targeted funding to support its updating. The preferred datasets are held by the Met Office. Discussions should be initiated with the Met Office to determine how best to derive a regional soil moisture index for future usage. Their MOSES system appears to have considerable potential.

Indicator 6. River flows in northwest and southeast Britain

The following is the main change to the text on the website:

The tendency for mean flows to increase from the early 1970s was not sustained in the mid 1990s but average flows for both 1998 and 1999 were significantly above average and runoff for the decade is almost certainly the highest in the 20th century.'

No clear trend is evident over the 1961-99 period but the cluster of low runoff years in the 10 years to 1997 is notable. Accumulated flows in the two-years 1996-97, and four years, 1989-92, were probably the lowest for 50 years. Very low groundwater levels (and spring outflows) were a major contributory factor to the depressed river flows during these periods. Increased groundwater inflows to rivers in south-eastern Britain is reflected in the modestly above average runoff for 1998 and 1999.

This indicator should be retained. However, revisions to the stage-discharge relations at a number of gauging stations (generally associated with 1998-2001 floods) have resulted in changes in the river flow time series. However, these changes will impact only modestly on the indicator time series.

Indicator 7. Frequency of low and high river flows in northwest and southeast Britain

The main changes to the text on the website is as follows:

In northwest Britain, where the number of low flow days are less variable than in the southeast, periods of low river flow show no clear trend over the 1970-99 period but the century ended with notable few low flow days.

Regarding high flows:
This is consistent with the exceptionally high winter precipitation, especially over the post-1988 period which has featured a cluster of damaging floods in rivers draining the Scottish Highlands.

This indicator tracks the prevalence of high and low flows based on daily flow data for representative gauging stations. The choice was a serviceable compromise given the constraints under which the original selection procedure operated (see below). The low flow element remains valid. But in relation to high flows, what is really required is an indicator that relates more directly to flood magnitude and frequency.

Most analyses of trends in floods rely on the availability of annual (or water-year) maximum flows (AMAX) or peaks over a threshold (POTs) – where a threshold is selected which, on average, will yield 3-6 independent flood events per year. This approach was used in the Flood Studies and the Flood Estimation Handbook projects. But MAFF funding for the extraction and national collation of flood data ceased in the mid-1990s (some extraction continued locally) at which time, nationally available flood time series for most gauging stations in the UK ended in the late 1980s or early 1990s.

The cluster of recent major flood episodes triggered a major £1.5 million programme (EA led) to update AMAX datasets; this is scheduled to end in 2004. In addition, the upgrading of hydrometric data processing capabilities in EA and SEPA should allow POT extraction to proceed more smoothly than hitherto.

It is recommended therefore that the number of peaks over threshold for a selection of gauging stations be used for the headline indicator in the future (by implication, such an indicator would allow any trends in annual maxima to be tracked also). Detailed discussions with EA (SEPA and Rivers Agency also) will be essential prior to finalising the network of gauging stations to use – preliminary discussions have taken place.

Note that the proposed new indicator would be complementary to, rather than an exact replication of, the EAs 'Flood Levels in Rivers' indicator, which is correctly termed an Environmental Indicator. For tracking climate change impacts an indicator based on flows is to be preferred – it is less sensitive to hydraulic changes to the river channel or floodplain.

The new indicator would reflect the recommendations made in the Defra/Environment Agency Flood & Coastal Defence Programme R&D Technical Report FD2311 (published in Feb 2003 – Project Manager, Frank Farquharson, CEH Wallingford).

Index gauging stations could be selected to allow a NW/SE comparison (as in the UK Indicators report). However, to have real utility the headline indicator would need to be supported by a national set of catchments, which provides the capability to examine trends in any region or catchment type (we may, for instance, see differing signals from clay, chalk and urban catchments in the English Lowlands).

The national collation of flood data for the stations selected to derive the new indicator would form part of the routine work programme of the National River Flow Archive – the archive incorporates flow data for England and Wales, Scotland and Northern Ireland, providing a UK-wide capability.

Indicator 8. Groundwater storage in chalk in southeast Britain

Only one minor change has been made on the website:

Very healthy recharge over the following two winters resulted in a substantial recovery in groundwater levels – which stood around average entering the new millennium.

This indicator has the limitation of being relevant to one region of Britain, but it should be retained. However, groundwater levels at the Holt borehole have been severely affected by groundwater pumping since 1999. Consequently, the Stonor borehole has been substituted for the Holt time series since 2000.

Indicator 9. Sea level rise

The series is readily understood and has high public perception. Data continue to be readily available. The following changes have been made to the website:

Specific Indicator
Sea level relative to the land (known as the revised local reference) is recorded at sites all

around the UK as a UK Permanent Service for Mean Sea Level. Sea levels at two sites are chosen as specific indicators: Lowestoft in Suffolk and Newlyn in Cornwall.
*[Source: **http://www.pol.ac.uk/psmsl/psmsl_individual_stations.html**]*

Relevance
Global mean sea level increased by 1.0-2.0 mm per year during the 20th century.

Change over time
Mean annual sea level fluctuates from year to year. Much of this variation is related to the position of the Gulf Stream - high sea levels occur when the Gulf Stream follows a northerly path and the Gulf Stream Position Index is large. Thus, at Lowestoft, over the period 1966-2001, the correlation between the annual mean Gulf Stream Position Index and sea level (the revised local reference level) was very significant (0.46).

A gradual increase in sea level is easily detected in the records around the southern and eastern coasts of England. At Lowestoft, mean sea level increased by 2.01 (± 0.42) mm per year over the period 1960-1996 and at Newlyn by 1.19 (± 0.31) mm per year. These are highly significant upward trends.

Indicator 10. Risk of tidal flooding in London

The following changes have been made on the website:

Thus, changes in rainfall and evaporation which alter the flow of the Thames (particularly during the winter) may also affect the number of closures of the Barrier. Any future changes in the operating rules could also influence closure frequency.

Nonetheless, the tendency over the last 17 years has been for barrier closures to become more frequent. Closures over the 1993-99 period greatly exceed those for the preceding 10 years. The 1990s were characterised by significant year-on-year variability. Nine closures were required in 1993 but none in 1997 when water levels in the Thames were low following prolonged drought – high tides which would normally have triggered a closure required no action. The six closures during 1999 all occurred during December.

Because the Thames River Barrier is now subject to different operating rules, it may be less useful as an indicator. The barrier is now closed to retain water in the Thames River as well as to lessen the risk of flooding. (It was closed on 9 successive tides at the start of 2003.) Thus, the number of closures has increased greatly in recent years. This indicator would only be useful if it were possible to distinguish the number of closures made specifically to lessen flood risk. The EA officer at the barrier would be able to assess what is possible.

Indicator 11. Atmospheric ozone levels in summer in rural England

The relationship with April-September CET previously present in the short 11 year series has changed and is no longer significant unless the data are first detrended (there has been a significant reduction since 1990). It is recommended that April-September CET is replaced with either July CET or July sunshine hours as a related climate variable. For both of these, significant correlations exist (r=0.739 and r=0.617 respectively) in the 16 year series. Variations in summer ozone concentrations are strongly linked to the frequency of anticyclonic weather patterns over the UK. A London Climate Scoping study showed that these patterns are expected to increase, leading to a predisposition to air pollution episodes. There is some evidence that they are occurring earlier as spring temperatures increase.

The following changes have been made to the website:

Specific Indicator

[Source: Centre for Ecology and Hydrology, Bush Estate, Penicuik, Midlothian EH26 0QB]

Sensitivity to climatic and other factors
The selected indicator (1987-2002) is closely correlated with the number of sunshine hours and temperatures in Central England in summer.

Change over time
The indicator values have fluctuated between 2000 and 10000 ppb hours between 1987 and 2002, being greatest in years with warm, sunny summers.

In the long term, there has been a tendency for rural ozone concentrations in the UK to increase by about +0.5 ppb/yr, but there appears to have been a decline since 1990. This is linked with a reduction in the magnitude of peak zone concentrations which occur during the summer, possibly as a result of changing meteorological conditions. Thus, in the period 1972-1985, maximum hourly average concentrations often exceeded 150 ppb and even 250 ppb in the hot summer of 1976. But in 1986-1995, the hourly maximum exceeded 150 ppb only three times at any of the UK monitoring sites. Peak ozone concentrations in the exceptionally hot summer of 1995 were not as high as expected, owing to reductions in emissions of hydrocarbons and nitrogen oxides in some European countries and air circulation patterns which frequently brought relatively clean air into the UK from N. Europe.

Clearly, rural ozone levels could increase if summers became warmer and sunnier and other conditions were favourable.

Indicator 12. Domestic property insurance claims

The insurance indicators were readily updated to 2002 with assistance from the Association of British Insurers. It is now (since 1998) possible to obtain the Weather Peril series broken down into burst pipes, flood and wind storm, and these new series are considered in the section on Headline Indicators.

With respect to the value of settled subsidence claims, there is some indication that the series is becoming less sensitive. This is likely to be because claims are taking longer to settle. Thus the dry years of 1995 and 1996 did not lead to a peak in claims until 1998, since which time there has been a gradual fall off year on year to the end of the record. This tendency could be controlled for by using a running mean as the Indicator. Inspection of the series suggests a five-year mean would be appropriate.

The Weather Perils Indicator is controlled primarily by wind storm. There have been no major wind storm events since 1990, and this is clearly demonstrated in the record. Since 1994 there has been a gradual upward trend in the value of settled claims.

The insurance indicators are standardized by the Retail Price Index to a base year of 1996. This year could usefully be updated if the Indicator is to continue. In addition, we need to explore and possibly enhance the basis of the standardization. Although the RPI takes into account inflation, it does not contain any element to express the growth in national wealth, and hence the fact that we are living in better and more expensive houses. This could usefully be built into the standardization procedure.

Changes to the web page are:

Change over time

Subsidence claims are greatest when it is dry, as in 1976, 1989, 1990, 1995 and 1996. However, claims were surprisingly low in the severe drought year of 1976 relative to later dry years, presumably because of changes in the quality and value of housing. Claims peaked in 1989-90: the equally severe conditions in 1995-6 led to a much more damped response in claims, peaking in 1998 and dying away gradually in the following years. This is presumably due to changes in the way in which insurance companies handle claims, and also because the housing stock is gradually being made subsidence-proof, either through repairs or by improved building standards in new housing.

Damage due to 'major weather perils' shows clearly the influence of the severe gales in 1987 and 1990. There have been no major wind storm events since 1990, and this is clearly demonstrated in the record, which in non-windstorm years is primarily a response to flood claims and burst pipes. Since 1994 there has been a gradual upward trend in the value of settled claims. The occurrence of a spell of freezing conditions has the capacity to push up the level of claims from a background £250 million to, in 1996, over £500 million. This was primarily due to freezing weather in December 1995 in the North-west and Scotland, but is small compared to the £1900 million (at 1996 prices) claimed in response to the 1990 storms.

It is clear that the major climatic determinant of large fluctuations in this series is gale damage. Thus future trends will largely be in response to any changes in the frequency and/or severity of wind storm. Climate models give conflicting evidence with respect to future patterns of storminess over the UK.

Indicator 13. Supply of gas to households

This indicator remains accessible, understandable and, despite the relative stability of recent wintertime CETs, responsive. It should be maintained as an indicator, and is a candidate for the Headline Indicator requested by DEFRA.

Changes to the web page are:

Change over time

Years with cold winters, including 1979, 1985-87, 1996 and to a lesser extent 2001, show relatively high gas consumption in the winter quarter. As expected, in more recent years gas consumption appears to display a greater sensitivity to temperature. Thus, the coldest first quarter in the series was in 1979, when the average temperature was 1.8^{o}C and gas use was

42% of the annual total. In 1996 the winter-quarter temperature was 3.8^{o}C but gas use was 43% of the annual total.

The winter quarter of 1996 was the fifth coldest in the record, and produced the third highest gas use figures. Since then, January – March temperatures have been warmer than average in five of the six years up to 2002, and gas consumption has in consequence been unusually low. The exception, 2001, was relatively cool at 4.3^{o}C, and hence gas consumption rose.

The winter season will always produce the lowest temperatures and the highest use of domestic space heating. With or without the higher temperatures predicted by global warming, the relative seasonal differences in space heating requirements are likely to be maintained at similar levels to those of today. Thus, winter gas use, as a proportion of annual use, will reflect temperature variability as it has done in the past. So long as gas retains its present space-heating role (which depends on energy pricing structures) the sensitivity of the series is not expected to change substantially.

Indicator 14. Domestic holiday tourism

The recent data for domestic tourism are provided below. The updating of this series has posed considerable problems. In addition, we have noticed an error which, according to the graphics on the Indicators web pages, occurred when the 1997 and 1998 values for holiday trips were added to the web page during previous updates.

When the original series was compiled, there was a discontinuity in the series for holiday trips, due to a change in methodology used by those assessing the regional totals. To correct for this discontinuity, it was necessary to add a fixed annual amount (12.5 million) to the England+Wales+Scotland total. The failure to add the 12.5 million during updating for 1997 and 1998 has caused the current web site graphics to be in error for these two years.

In addition, there has been a recent change in methodology used by the United Kingdom Tourism Survey (UKTS), the body which has conducted "the" survey since 1989. The survey forms the basis of the published data relating to the volume of domestic tourism. Fortunately, parallel data sets have been provided which allow the comparison of data produced by the "old" and "new" survey methods. The period of overlap is 1995-99. This allows five years of comparison and thus the production of conversion factors (old to new).

To maintain this Indicator series, the second tier of adjustment is necessary. It is the only way of retaining the holiday series back to 1974. A second level of adjustment (over and above the addition of 12.5 million, post-1988) may be regarded as a little unsafe, given that the whole series is based on consumer surveys. However, the annual ratio of new:old for the overlap period is remarkably constant over the period 1995-99, at around 1.2.

The table below gives the corrected values for the years 1997 and 1998, based on the now superseded methodology (i.e. with 12.5 million added). In addition, the 1999 value, according to the old method, is provided. The values for 2000 and 2001 (based on current methods) are also given. To adjust the pre-2000 values (including the 1997-99 values below) to the current "levels", requires all values to be multiplied by 1.22. Ideally, and given the large changes which have taken place over time, this series needs to be revisited to ensure that it is homogeneous. A possible replacement could be sought amongst data on visits to National

Parks and visitor attractions such as stately homes, which may be expected to be weather dependent.

Year	Trips (millions)	Method
1997	82.5*	Old (corrected to first level)
1998	76.8*	Old (corrected to first level)
1999	86.9*	Old (first level)
2000	104.5	New
2001	100.0	New

* requires multiplication by 1.22 to make compatible with 2000 and 2001 data.

Indicator 15. Scottish skiing industry

The number of ski pass days was obtained up to the season 2001/2, and the accompanying number of snow days at Braemar was obtained from the UK Met. Office. There is a small charge for the snow data. This indicator, and its accompanying climate variable, is of particular interest in that the snow data extend back to 1928, so that recent fluctuations can be inspected within the longer-term context. It also has the advantage of being specific to Scotland, and therefore providing a regional dimension to the indicator set. It should certainly be continued.

Changes to the web page are:

Change over time

There are large year-to-year fluctuations in the number of Scottish ski days, but overall between 1983/4 and the most recent season there is a small downward trend. However, since the poor season of 1997/8, which was accompanied by a low number of snow days, the last four seasons have seen a recovery in ski pass numbers. Notably poor skiing seasons were 1988/9, 1989/90 and 1991/2, none of which had more than 40 days of snow lying at Braemar. However, the winter with the most snow days (1993/4) was not the most successful for the industry, because of the large number of weekend storms. The recent poor season of 1997/8 was accompanied by 43 days of snow, which is the fourth lowest value in the record since 1983/4, when ski pass data began.

The figure includes snow data back to 1928/9 - well before the skiing industry existed in Scotland. It is of interest to see that there is no long-term trend in the snow data, although there is a recent downward trend from 1993/4 to the latest year. In future we would expect that warming will reduce the number of days with snow lying, and hence the viability of the skiing industry. However, this does not necessarily follow immediately: a more active hydrological cycle in the early years of global warming might lead to more snow days, provided that the warming in winter is small enough to keep temperatures below zero.

Indicator 16. Number of outdoor fires

This indicator was successfully updated, with no problems encountered. The 2002 data are not yet available.

This indicator continues to be a reliable, in terms of availability and homogeneity, and responsive indictor. For the complete series, the correlation between the number of outdoor fires and summer England and Wales rainfall amounts is -0.74. This series should certainly be retained as an indicator.

Changes to the web page are:

Change over time

There is a clear upward trend in the annual number of outdoor fires. Superimposed on this, there are fluctuations from year to year, which can be linked to the occurrence of unusually dry or unusually wet summers. Thus, the dry summers of 1989, 1990 and 1995 were marked by very large numbers of outdoor fires, whereas the wet summers of 1985, 1988 and 1992 resulted in relatively few fires over the year as a whole.

Since the 1995 hot dry summer, no extreme summers have been experienced, and rainfall amounts have been unexceptional. In parallel with this, the occurrence of fires has been close to the long-term average. If climate change brings an increased frequency of dry and hot conditions in the summer half-year we would expect the number of fires also to increase. Although people may become more careful with respect to disposal of hazardous materials, this is unlikely to fully offset the trend towards more frequent outdoor fires.

Indicator 17. Incidence of Lyme disease in humans

There have always been problems with this indicator, because it is not mandatory for medical staff to notify Lyme disease. The series is therefore susceptible to sudden jumps and fluctuations as medical staff become more aware of the disease and/or more likely to make a notification. Such a jump occurred between the late 1990s and the 2000s. Thus, although summer CET has remained very close to the series average of 15.8^{o}C in the three years 2000 – 2002, the number of cases of Lyme disease more than doubled between 1999 and 2000 from around 150 to over 300, and since 2000 the annual number of cases has not dropped below 260. This indicator is relatively straightforward to obtain, and has public resonance, and therefore should if possible retained. Some procedure to remove the long-term trend should improve the responsiveness to interannual climate fluctuations, and looking at the graph of the time series an exponential fit is indicated.

Changes to the web page are:

The data series is for England and Wales, not the UK.

Change over time

Cases of Lyme disease diagnosed and reported by UK laboratories have increased tenfold since records began in 1986. Since the late 1990s the number of cases has almost doubled. The period 2000 – 2002 has seen record levels of more 250 cases per year. Overall, there has been a dramatic increase in recent years.

In the future, it is expected that, with warmer year-round temperatures, the UK would see more cases of Lyme disease related to all of the factors described above, including more outdoor recreation, changes in the tick numbers and activity.

Indicator 18. Seasonal pattern of human mortality

The indicator is available up to 2001 from the Office of National Statistics. There are no problems regarding availability, continuity or homogeneity, and the series should be retained as an indicator. There is some suggestion in the time series that it has become more responsive in the last few years, and this tendency needs to be monitored. The series would be much more effective as an indicator if it could be looked at side-by-side with a history of influenza outbreaks, which strongly confounds the relationship with temperature.

This indicator is currently for England and Wales, and could be revised and extended to include the seasonal pattern of mortality in Scotland in addition. Monthly data on mortality in Scotland are given in Appendix I (supplied by Alistair Montgomery, Scottish Executive).

It would be possible to augment the health indicators by adding a series on Food Poisoning notifications. These data are available separately for England and Wales, and for Scotland, giving the potential for regionally-specific indicators. The series shows a strong upward trend over time which is unlikely to be climate related, and would have to be detrended. However, the strong seasonal cycle peaking in summer suggests a weather-related link, and this has been clearly demonstrated, for example, in the report on the impacts of the hot summer of 1995 produced for the Department of the Environment (Bentham, 1997).

No data are available on summer mortality due to thermal stress or respiratoiry admissions.

Changes to the web page are:

Change over time

An inverse relationship between January temperature and the proportion of annual deaths occurring in January is clear at the beginning of the record and through the 1990s, but the relationship is weaker during the 1980s and in the last few years. In 1983 and 1990 the proportion of deaths occurring in January was high although January temperatures were among the highest in the record. One explanation is that, in both these years, there were influenza epidemics. This is known to be an explanation for the unusually high proportion of deaths in January 1997, when there was a severe influenza outbreak. Since 1996, the series has become more variable, with an exceptional high percentage of January deaths in 1997, 1999 and 2000. The 1997 peak can be related to low January temperatures, but the 1999 and 2000 peaks cannot. Low percentage values were recorded in 1998 and 2001. Although January CET in 1998 was well above average, this was not the case in 2001.

The proportion of annual deaths occurring in January would be expected to decline in a warmer climate. Models suggest that, for a 1^oC increase in temperature, about 30 fewer deaths would be expected to occur each day in January and that this would hold true for temperatures up to 3^oC higher than the January norm.

Note that that this does not mean that we shall live longer in a warmer climate, rather that we may be more likely to end our lives in summer than is the case at present.

Reference

Bentham, C.G., 1997: Health. In *Economic Impacts of the Hot Summer and Unusually Warm Year of 1995* (Palutikof, J.P., Subak, S. and Agnew, M.D., eds.) University of East Anglia, Norwich, (for the Dept. of the Environment), 196 pp.

Indicator 19. Use of irrigation water for agriculture

This has been completed without any problems, but only until 2000. It is taken from the *Digest of Environmental Statistics*, and as such is likely to remain readily available in future. We compare it with May – July rainfall, a period which was decided on by trial and error when the original Indicators report was compiled. This needs to be revisited to ensure that the choice of months is optimal. The irrigation series fluctuated widely in the early and mid 1990s and, whereas the wet summer of 1994 was accompanied by a large reduction in irrigation water use, a slightly higher summer rainfall amount in 1999 led to a much smaller reduction in use. However, the series is clearly responsive, and should be retained.

Changes to the web page are:

Change over time

Since 1981, water abstractions have averaged at least 100 million litres per day, even in wet years. In 1989, which was a notably dry year, there was a step-jump in abstraction amounts. Since then, levels have dropped below 250 million litres per day in only one year, 1993. Superimposed on these trends, there is a clear inverse relationship between rainfall and amounts abstracted. Relatively high abstraction levels are found in the earlier years, including the dry year of 1976. However, whereas in 1976, 150 million litres per day represented a substantial increase in water abstractions against average levels, in recent dry growing seasons, such as 1990 and 1996, abstractions have averaged more than 350 million litres per day. The winter and spring preceding the 1996 growing season was exceptionally dry in most areas of England and Wales, unlike the winter 1994-95, when rainfall was above average. This difference probably accounts for the greater amount of irrigation water used in 1996. Since 1996, summer rainfall amounts have been higher, and this is reflected in a reduction in irrigation water use, although abstractions still remain above 250 Ml/day.
The amount of water used to irrigate crops is expected to increase in future, regardless of any trend in climate, due to pressure from retailers to produce crops of high and predictable quality. However, lower rainfall and increased evaporation (in response to higher temperatures) could lead to increased water abstraction, unless voluntary and mandatory measures are taken to conserve water supplies in the face of growing water shortages - perhaps forcing a shift away from spray irrigation towards more efficient trickle irrigation.

Indicator 20. Proportion of potato crop that is irrigated

This indicator is only available in occasional years, being compiled by survey. A survey was made for 2001, and showed that around 60% of the crop is now irrigated, compared to just 46% in the last survey year, 1995. To produce the time series, a linear interpolation between survey years is used. Inspection of the series shows that the rate of increase of this indicator has been approximately constant since the mid 1970s. It might be the case that this indicator should be included with the warm weather crop indicators (area of forage maize and of productive vines) because its episodic nature means that we are unable to show a relationship with interannual weather fluctuations. However, it should certainly be maintained as an indicator.

Changes to the web page are:

Change over time

Large investments were made in irrigation equipment following the drought years of 1975 and 1976. Thus, in 1975 only around 12% of the potato crop was irrigated in a dry year, but by 1978 this figure had risen to 21%. From the mid 1970s onwards, there has been a steady increase in the percentage area of the crop irrigated, reaching 46% in 1995 and in the most recent survey year, 2001, 60%.

It is likely that producers without irrigation, especially in much of the eastern and central lowlands of England, will be influenced by an increased incidence of very high (summer) soil moisture deficits, as predicted in climate change scenarios. The percentage of potatoes irrigated may therefore increase further, although this may be moderated by a range of adaptive measures which will reflect the finite nature of water resources in many growing areas, plus the possibility of voluntary and mandatory restrictions on water use. Adaptive measures could include the use of drought resistant varieties, changes in growing schedules to avoid late summer maturation and moves towards cultivation in wetter areas.

Indicator 21. Potato yields (non irrigated)

It has not proved possible to update this indicator. Although the data exist, staff shortages at the British Potato Council mean that no-one is available at present to extract the information we need. Telephone enquiries suggested that something might be available in late spring, but we are not confident of this. Although this has been a useful indicator, the effort required to update it is probably not justified, and we should be searching for an alternative.

Meanwhile, this indicator has been discontinued.

Indicator 22. Warm-weather crops: grapes

This indicator continue to be straightforward to collect, and has been updated to 2002. When plotted, it shows that the productive area under vines fell slightly and gradually from a maximum of 842 ha in 1998 to 783 ha in 2002. This leaves a question mark over this indicator. If the cultivated area continues to decline, the time series is no longer suitable as an indicator. It should not be immediately discarded, as it has substantial public resonance. The issue can be resolved in the next 2-3 years.

Changes to the web page are: The data series is for England and Wales, not the UK.

Change over time

The area of vines in production has more than doubled over the period of record, from around 350 ha in the late 1980s to around 800 ha in the last five years. The area in production is known since the mid-1980s, although grapes were produced by a few pioneers in the decades after World War II. A notable increase occurred in 1989, reflecting vine-planting three years *previously. Heavy summer rains greatly reduced the 1993 crop and obviously had a discouraging effect in that the productive area fell in 1994. The area under production reached a maximum in 1998 of 842 ha, and has remained relatively stable since then, declining gradually to 783 ha in the latest year of record, 2002. It will be of interest to see whether market forces have placed a cap on the area of productive vines in England and Wales, or whether the upward trend of the early years of the record can be re-established. The potential to produce greater quantities of grapes and a better quality of wine accompanies the prospect of a warmer climate, and so, in the long term, we might expect to see a further increase in production area in the future.*

Indicator 23. Warm weather crops: forage maize

This indicator is straightforward to collect, and no inhomogeneities have emerged in the time series. It has been updated to 2002. A period of stabilization in the late 1990s ended with a sharp increase in area in 2001, and it will be interesting to see if this increase is maintained (a slight decrease in 2002 did not see the area fall below 120,000 ha). This series should be kept as an indicator.

Changes to the web page are:

The data series is for England and Wales, not the UK.

Change over time

Although stable in area throughout the 1980s, the area of forage maize roughly quadrupled through the 1990s. This large expansion is due to a combination of factors, including the introduction of new varieties which are better adapted to UK conditions, perceptions of a warming climate, recent experience of warmer weather and the introduction in 1993 of an arable payment scheme under the Common Agricultural Policy.

The area of maize stabilized in the late 1990s at around 110,000 ha. However, a sudden jump in 2001 took the area to over 120,000 ha and, despite a small reduction in 2002, the area is still above this threshold. In future, the area under production might be expected to increase in a warmer climate, tempered by reduced payments for new producers if the ceiling on area payments is not raised. However, elevated temperatures will favour higher maize yields only so long as there is sufficient soil moisture. A reduction in precipitation of 10% accompanying higher temperatures resulted in lower yields in south and south-east England in simulation experiments. The value of the crop tends to be too low to warrant investment in irrigation. Therefore expansion in production area may be concentrated in the western and northern regions of the UK, which receive higher rainfall but are currently too cool for maize production.

Indicator 24. Late summer grass production

The source of data for this indicator is one of the longest running experiments in the country. The opportunity has been taken to revise the series to incorporate some minor corrections. The source of data is now Ian Woiwod at Rothamsted Research, the new name for IACR.

No changes have been made to the text on the web site

Indicator 25. Date of leaf emergence on trees in spring

This series has high public resonance and has shown marked changes related to temperature. Whilst it is collected by an elderly lady in Surrey, eventual transition to a series from the UK Phenology Network should be straightforward. Data source should now be labelled as UK Phenology Network not ITE.

The following changes have been made on the website:

Sensitivity to climatic and other factors

Records at Ashtead, from 1947 to 2002, suggested that mean temperatures in January-March in Central England could explain over 55% of the variation in the date of first leafing of oak - the warmer the temperature, the earlier leafing occurred.

Change over time

The Central England records show a general trend towards warmer temperatures in early spring and the records at Ashstead show correspondingly earlier dates of oak leafing. The warm springs of 1957, 1972, 1990, 1998 and 2002 were associated with early leafing and the cold springs of 1969, 1979 and 1985 were associated with late leafing. The relationship between leafing dates and early spring temperature suggests that a 1◦C increase in temperature is associated with a 7-day advancement of leafing. The current climate change scenarios suggest that we might see more first leafing dates occurring in the month of March unless chilling and other controls on leafing exert an effect.

Indicator 26. Health of beech trees in Britain

Data continue to be provided by the Forestry Commission. Since beech has been identified as an "at risk" species in a drier climate it would be valuable to continue this indicator.

The following change has been made on the website:

Change over time

High percentages of beech trees were poorly foliated (ie with over 25% crown density reduction) in 1987, 1989-1992, 1995, 1997 and 2000. In all instances, these years followed previous dry summers and many of the symptoms observed indicated drought damage which may have resulted from root death the previous year. In some years, such as 1990 (but not 1991) poor foliation was clearly associated with heavy seed production.

Indicator 27. Dates of insect appearance and activity

Phenology (timing) indicators are easy to understand. The opportunity has been taken to revise the common footman and orange tip series.

The following changes have been made to the website:

(References to ITE and IACR have been changed to CEH and Rothamsted Research respectively.)

Change over time

The relationships with temperature suggest that a 1degree C increase in temperature is associated with a 16-day advancement in the first appearance of peach-potato aphid, a 6-day advance in peak flight time of the orange tip butterfly and an 7-day advancement in the average time of activity of the common footman moth. Thus, in the event of climate warming we would expect all three species to make considerably earlier appearance, particularly the peach-potato aphid.

Indicator 28. Insect abundance

Data for the series continue to be recorded in a robust manner. The opportunity has been taken to revise the common blue and common footman series. Unfortunately the relationship with temperature for common footman is no longer quite significant (p=0.07) and it is recommended that it be replaced with an alternative species. Reference to ITE and IACR should be changed to CEH and Rothamsted Research respectively.

The following changes have been made to the website:

Change over time

The relationships with temperature suggest that 1ºC warming would increase aphid, common blue and common footman populations by factors of 2.5, 1.7 and 1.1, respectively. Clearly, we would expect insects to be more abundant in a warmer climate, especially aphids, except perhaps in years with severe droughts

Indicator 29. Arrival date of the swallow

Swallow arrival has a very long history of recording and is seen as a vital sign of spring. Data continue to be collected at the four observatories that contribute to this record. Recent research has shown the combined value of migration route temperature and UK temperature on arrival time and it might be appropriate to incorporate both in the future if migration route temperatures can be made available more quickly.

No changes have been made to the website.

Indicator 30. Egg-laying dates of birds

Data continue to be provided by the BTO. This is a very long time series and should be retained as a indicator.

The following changes have been made to the website:

Change over time

Robins lay about 20 days earlier than Chaffinches, on average, and the earliest 5% has varied each year between 11 March and 17 April for Robins, compared with between 2 April and 2 May for Chaffinch. Earlier laying occurs in years with warm March temperatures: for

Chaffinch every degree of extra warmth leads to 2.4 days advancement in laying, and for Robin it leads to 3.1 days advancement.

Overall, there has been a tendency for March temperatures to become warmer in recent years and this is reflected in consistently earlier laying by both species. Years with particularly warm March temperatures occurred in 1957, 1959, 1961, 1981, 1990 and 1997-2000, often with correspondingly early laying by both species. Years with cold March temperatures, for example 1955, 1958, 1962 and 1969 were associated with later laying.

Indicator 31. Small bird population changes

Another good long term series provided by the BTO, although data from 2001 are not available because of restrictions during the Foot and Mouth epidemic. The series has been recalculated but the data continue to show a very strong relationship with winter temperature.

No changes have been made to the website.

Indicator 32. Marine plankton

Both series are provided by SAHFOS based on long term systematic recording of plankton. Both continue to show a relationship with their selected environmental variable, although there is some suggestion that *Calanus finmarchicus* has changed its response in recent years and it may be pertinent to reassess this series. The opportunity has been taken to include recalculated NAO and Gulf Stream series.

A new address for the GSPI is necessary - http://www.pml.ac.uk/gulfstream/newpage1.htm

No changes have been made to the website.

Indicator 33. Upstream Movement of Salmon

This indicator has been discontinued, owing to difficulty in obtaining data.

Indicator 34. Ice on Lake Windermere

The indicator has been update.
No changes have been made to the website text.

9. Marine Indicators of Climate Change

Review of marine indicators in 1999 report

In 1999 the DEFRA report on UK Climate Indicators included only two marine indicators (one provided by SAHFOS) and one freshwater indicator. However, UK marine systems are extremely important providing a variety of services and goods to society. These include food production, raw materials of biogenic origin, nutrient cycling, waste treatment, refugia for much biodiversity and opportunities for recreational and cultural activities. It is also clear from the wider scientific literature that global climate change is having a profound effect on UK marine systems. It is therefore appropriate that additional marine indicators be identified and included in the 2003 update report.

The lack of marine indicators in the 1999 report perhaps reflected the interests of the network of original authors, but may also have resulted from the fact that few central databases on marine time series existed and if they did, were held by individual organisations. In 2003 the situation is much improved mainly because appropriate researchers/organisations have been identified and contacted.

Here at the Marine Biological Association and the Sir Alister Hardy Foundation for Ocean Science a wealth of physical and biological time series have been systematically archived and (more recently) analysed with respect to global climate change. In addition funds have been secured to co-ordinate the continued collection and analysis of marine data. Therefore our organisations and associated researchers are well placed to provide information for candidate marine climate indicators.

A number of climate change research projects are being conducted at the MBA and SAHFOS details of which can be accessed through our web sites, www.mba.ac.uk and www.sahfos.org.

Candidate marine indicators

From the possible list of marine indicators that could be included in the 2003 update report the following five indicators (four biological and one physical) were considered most suitable. An account of each indicator is detailed below, following the format of the 1999 report as closely as possible. Sea surface temperature is taken from the Irish Sea; the two plankton indicators reflect change in the North Sea, the remainder change in the Western English Channel.

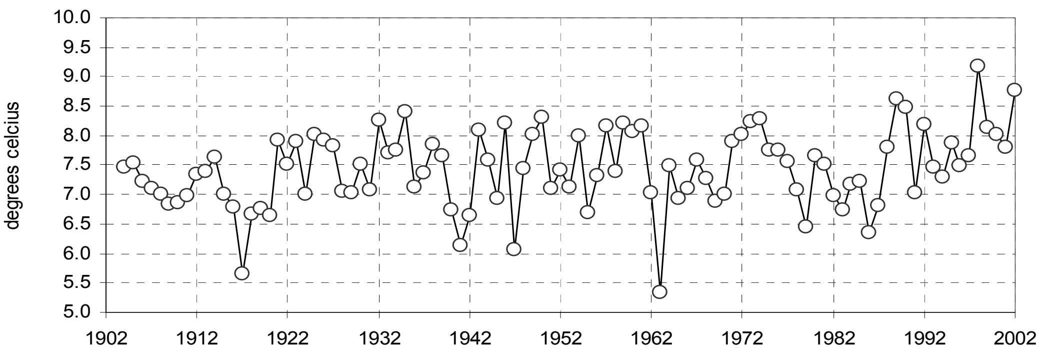
Table 2.1. Candidate Indicators.

Candidate Indicator	**Climate Variable**	**Responsibility**
Physical		
Sea surface temperature in the Irish Sea	N/A	Hardman-Mountford
Biological		
Occurrence of bottom living sea fish	Sea surface temperature	Sims
Barnacle abundance	Sea surface temperature	Leaper
Plankton abundance (retained from 1999)	Strength of westerly circulation in winter	Reid
Phytoplankton colour	Sea surface temperature	Reid

Sea temperature in the Irish Sea

NJ Hardman-Mountford & R Leaper

annual winter (Jan-March) mean sea surface temperature at 54° 05.01'N 04° 46.02'W



Specific indicator
Sea surface temperature is the temperature of the surface 0-100cm of water and is measured from bucket samples using a thermometer. The hydrographic (temperature, salinity) series from Port Erin Marine Laboratory (54° 05.01'N 04° 46.02'W) has been collected on a monthly basis from 1904 to the present and is one of the longest marine time series in British waters.

Relevance
Sea temperature is an obvious indicator of environmental change, particularly global warming and sets the biogeographic limits of marine organisms.

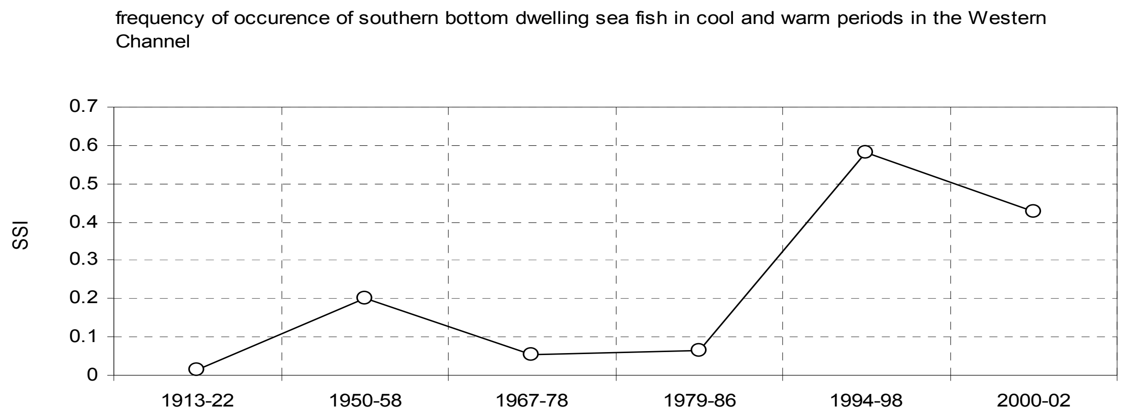
Sensitivity to climatic and other factors
Because of the high specific heat capacity of water and its dynamic nature, sea temperatures tend to integrate the effects of atmospheric heating and cooling, both spatially and temporally. Thus they tend to reflect long-term changes (climate) more than short-term fluctuations (weather). Furthermore, winter sea surface temperatures tend to reflect climatic processes better than summer sea surface temperature, which is more influenced by weather.

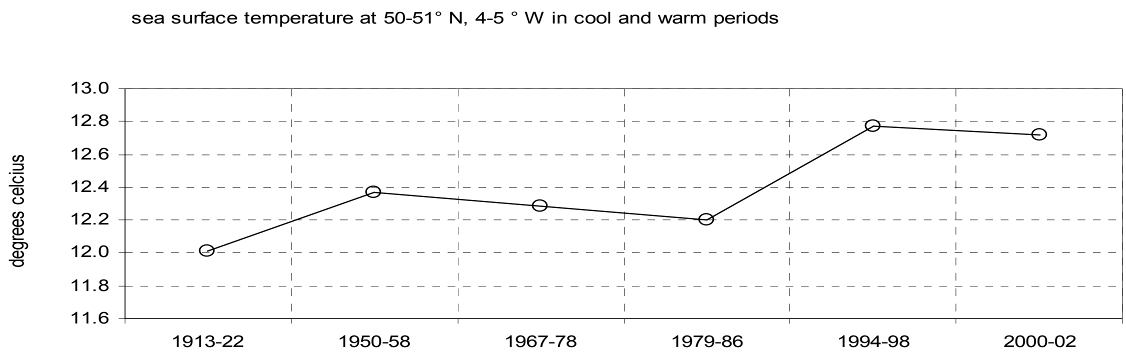
Changes over time
Over the period of the 20th century, Port Erin winter sea temperatures have warmed by about 0.66°C (mean linear trend). The warmest winters occurred in 1998 and 2002 with other warm winters in 1989 and 1990. The coolest winters occurred in 1917 and 1963 with other cool winters in 1941 and 1947. Increases in sea surface temperatures at Port Erin have been particularly marked in the last 20 years.

[Data available at http://www.mba.ac.uk/research/MECN/index.htm on request].

Bottom living sea fish

DW Sims & R Leaper





Specific Indicator

Since 1913 the Marine Biological Association has recorded the occurrence and relative abundance of 94 species of marine bottom dwelling fish intermittently during monthly trawls in the western English Channel (50°-50°16'N, 4°-4°24'W). Seven species of fish with latitudinal distributions south of 50°N were selected from this record: *Mullus surmuletus* (Red mullet), *Pagellus bogaraveo* (Red bream), *Spondyliosoma canthurus* (Black bream), *Cepola macropthalma* (Red band fish), *Callionymus maculates* (Spotted dragonet), *Blennius ocellaris* (Butterfly blenny), and *Syngnathus acus* (Greater pipefish). The mean sum of the frequency of occurrence in the monthly trawls of these species were used to devise the 'southern species index' SSI.

Relevance

Marine fish support global fisheries of high economic value. This means that monitoring the abundance and distribution of species is important, given that any changes will doubtless have economic consequences both regionally and nationally.

Sensitivity to climate and other factors
The majority of marine fish species are ectothermic; hence their body temperature is the same as the surrounding environment. Fish have a specific thermal niche, which is defined as their preferred temperature ± 2°C. Therefore, fish are particularly sensitive to changes in sea temperature and as such, their occurrence, abundance and distribution reflects broader climate-linked temperature fluctuations. Furthermore, fish are at, or close to, the apex of marine food chains and so are likely to integrate a broad range of ecosystem health parameters. Taken together, this presents fish as ideal species to monitor climate and human-induced environmental change.

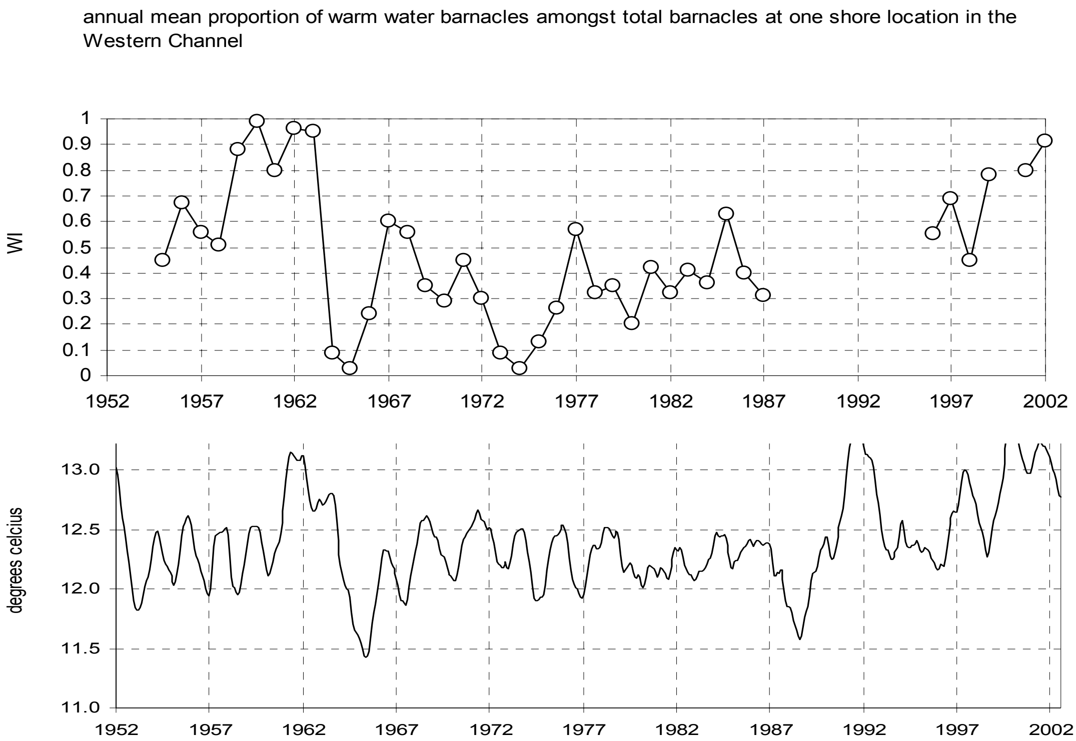
Change over time
The sampling area in the western English Channel encompasses a faunal boundary between northern boreal and southern warmer water species, and at such boundaries responses to climatic variation are often greatest. This region has been subject to major climatic shifts, with mean annual sea surface temperature (SST) fluctuating within a range of 1.8ºC. These trends are consistent with the larger-scale patterns in Northern Hemisphere temperatures over the last century, namely warming in the 1950s and in the 1990s to the present day, following relatively cooler periods between 1900 and the 1920s, and the 1960s to the early 1980s.

In 'warm' years, the selected species were more frequently captured than during 'cold' years. The increase in the southern species index (SSI) was up to an order of magnitude higher in warming periods compared to cooler years. A modelled relationship between the SSI and SST enables predictions to be made concerning the occurrence of southern species with respect to future climate change. For example, given the forecast of an SST in the western English Channel of 13.2°C by 2020 (under the UKCIP Low Emissions Scenario), we predict that the occurrence of any of the selected species in trawls will reach 100%.

[Data available at http://www.mba.ac.uk/marclim/ on request].

Intertidal Barnacles

R Leaper, SJ Hawkins & AJ Southward



Specific Indicator

The acorn barnacles *Chthamalus montagui*, *Chthamalus stellatus* and *Semibalanus balanoides* typically make up the intertidal barnacle zone in the southwest of the UK. Since the 1950's the adult abundance of these three species have been measured in grids (25-100 cm^2 in size) at three different tidal heights at Cellar Beach (50° 31'N 04° 06'W) in Devon. Counts are made every autumn. One specific indicator, the 'warm index' (WI) has been selected from this record and describes changes in the abundance and species composition of the barnacles. It is calculated as the ratio of the mean abundance of the two warm water species to the total mean abundance of all three barnacle species.

Relevance

Acorn barnacles are regarded as the most dominant and characteristic organism of midshore rocky intertidal communities worldwide. Rocky intertidal invertebrates are often sensitive bio-indicators of many types of environmental change and in this respect they are ideal subjects for monitoring in much the same way as terrestrial invertebrates.

Sensitivity to climate and other factors

Since the three dominant species of barnacle on UK shores are at the edge of their biogeographic distribution they are particularly sensitive to changes in climate. Thus they represent ideal species with which to monitor human-induced climate change. Two of the species surveyed are of warm water distribution, (*Chthamalus stellatus* found from Northeast Scotland to West Africa, and *Chthamalus montagui* South and West Britain, the Irish Sea to the Adriatic Sea); while *Semibalanus balanoides* is a boreo-arctic species (found from the Arctic to Northern Spain). Because seawater temperatures often determine range limits, increased water temperature may be a dominant factor effecting alterations in the distribution and abundance of marine species (barnacles included), particularly in the next 50-100 years.

Change over time

The Western English Channel has been subject to major climatic shifts, with mean annual sea surface temperature (SST) fluctuating within a range of 1.8ºC. These trends are consistent with the larger-scale patterns in Northern Hemisphere temperatures over the last century, namely warming in the 1950s and in the 1990s to the present day, following relatively cooler periods between 1900 and the 1920s, and the 1960s to the early 1980s. Warming has been especially rapid in the last 20 years, with increases of up to 0.7 ^{o}C in this period.

During the period 1954-1961, a warm period, the WI was high, between 50-100%. This typically decreased to between 0-60% in the following cool period 1960 to the late 1980's, whilst during the recent warm period (1996-2002), there has been a very clear rise, up to 90%. Statistical analysis shows a strong and significant correlation between changes in SST and the switch in the relative abundance of the lusitanian species *Chthamalus montagui* and *Chthamalus stellatus* and the more boreal species *Semibalanus balanoides,* but with a two year lag ($r = 0.56$). If SST continues to rise in the Western English Channel as predicted, then we predict that the two warm water species will dominate the intertidal zone in southwest of the UK.

[Sea surface temperature data available BADC at http://badc.nerc.ac.uk/home. Barnacle data available at http://www.mba.ac.uk/marclim on request].

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Marine Plankton

PC Reid, M Edwards & TH Sparks

Specific Indicator

Since the 1930s, marine plankton abundance has been measured in the North Atlantic and North Sea by towing a Continuous Plankton Recorders behind commercial shipping on defined routes. Two zooplankton indicators were originally selected from this record:

i. the total annual abundance of copepods (small shrimp-like crustaceans) in the North Sea (51-61ºN, 3ºW-10ºE) and

ii. the abundance of the cold-temperate copepod species, *Calanus finmarchicus* now averaged for the North Sea (51-61ºN, 3ºW-11ºE).

A third zooplankton index is presented here on the basis of new research:

iii. the percent ratio of the cold-temperate *C. finmarchicus* to its warm temperate sister species *Calanus helgolandicus*, both averaged for the whole North Sea (51-61ºN, 3ºW-11ºE).

Relevance

Marine plankton are basic biological productivity units of our oceans and reflect both the health of the seas and the management of this resource by man. Copepods form an important part of the diet of fish and their larvae and these indicators provide therefore, integrated measures of ocean biological production in waters close to the UK. There is increasing evidence that copepod abundance reflects changing patterns of ocean currents and seawater temperatures. In this respect they are ideal subjects for monitoring environmental change.

The first index is largely based on small copepods and the second on the dominant large copepod in the northern North Atlantic that normally accounts for more than 80% of the zooplankton biomass. The third index is presented as a means of reflecting south to north movements of biogeographic zones as a response to global warming. The relative abundance of the two *Calanus* species has been shown to reflect both changing patterns of inflow of oceanic water into the North Sea and a northerly movement, by 10° latitude, of warmer water plankton in the last 40 years.

Sensitivity to climate and other factors

Invertebrates can multiply rapidly. Consequently their populations fluctuate readily in response to changing conditions. Two of the main variables commonly used as indices of environmental change in the North Atlantic region are the Gulf Stream Position index (GSPI) and the North Atlantic Oscillation (NAO) index. The former (available only since 1966) measures the position of the north wall of the Gulf Stream off the eastern coast of North America, such that high values indicate a more northerly path. The latter measures the difference in atmospheric pressure between Iceland and the Azores in the North Atlantic – when it is high there tends to be a strong westerly flow of relatively warm air over the UK.

The total abundance of copepods is positively correlated with the Gulf Stream position in April; that is, there are more small copepods when the Gulf Stream follows a northerly path. A strong 'negative' relationship existed between the abundance of C. *finmarchicus* in the northern North Sea and the NAO in winter (December to March) until 1995, such that strong westerly air flow in winter reduced the numbers of this copepods. This relationship has broken down since then.

Change over time

Total annual abundance of copepods in the North Sea has varied greatly between about 250 and 1250 per $3m^3$ standard sample. Peaks have tended to be associated with a more northerly Gulf Stream position and the timing of the onset of spring stratification (the formation of a warmer surface layer in the sea).

In contrast, over the period 1958-1995, there has been a marked decline in populations of *C. finmarchicus* in the North Sea associated until ~1995 with a trend towards stronger westerly air flows over the Atlantic in winter (higher values of the NAO). The relationship appears to have broken down as a response to a number of factors that include rising temperatures in the North Sea (unsuitable for a boreal species), a northerly biogeographic shift and changes in the deep over-wintering habitat of the species in the Norwegian Sea.

A step-wise change has occurred in the relative abundance of the two *Calanus* species, in other copepods and for other trophic levels after the mid 1980s that is closely correlated with increasing Northern Hemisphere temperatures. This event has signalled a major reorganisation of North Sea ecosystems with an apparent increase in the growing season, increased deposition to the bottom, leading to a richer growth of benthic organisms and changes to the fishery. The extent to which the event is reversible is not clear, nor how North Sea ecosystems will respond to further rises in sea temperature. Also, the long-term response of the Gulf Stream to global warming is very uncertain. As good integrators of weather and hydrography these planktonic indicators are likely to give early warning of future change.

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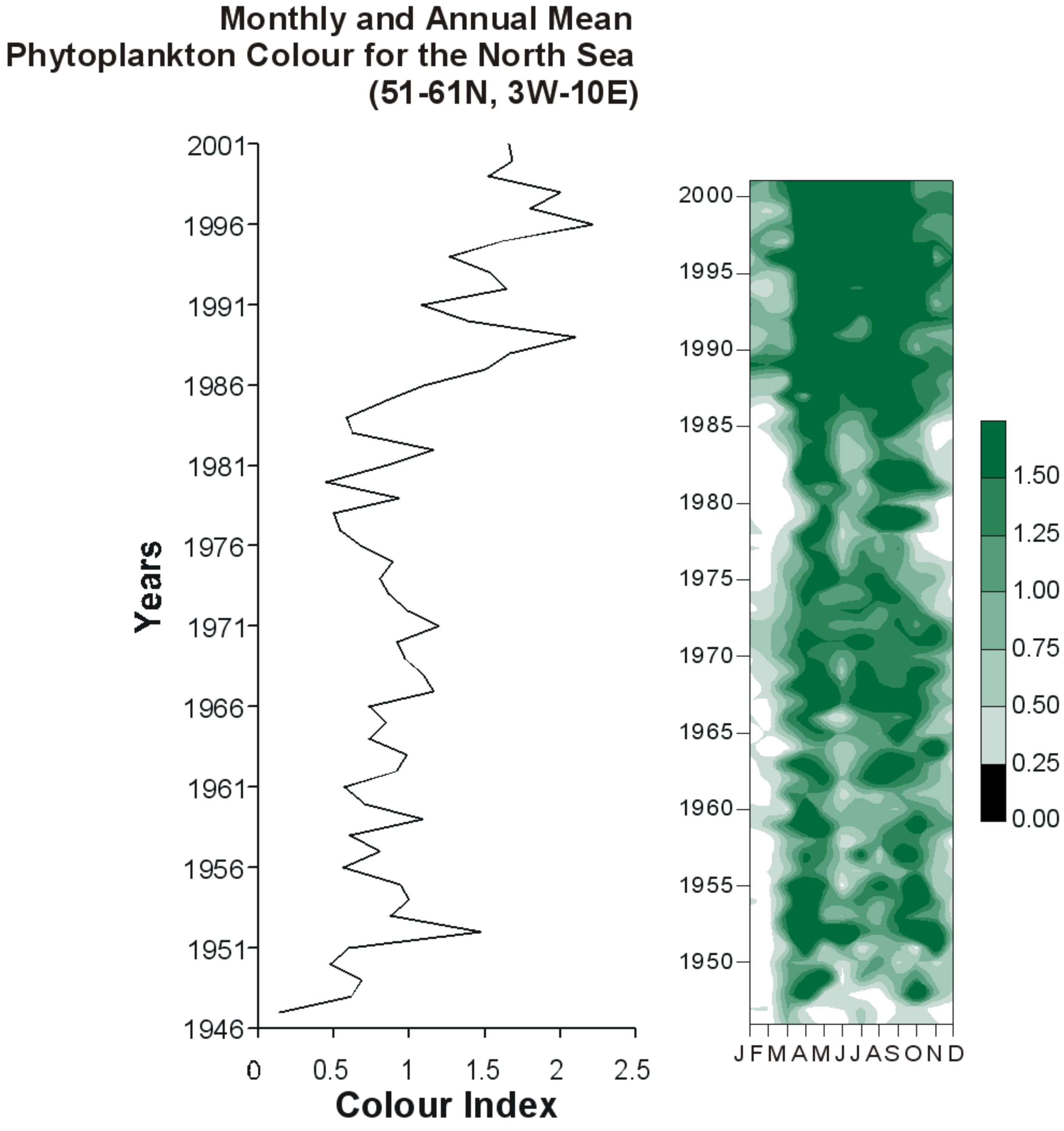
[Data available at: The Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth, PL1 2PB. The plankton data are available from the SAHFOS Data Manager and in part on http://www:sahfos.org. Gulf Stream position data are available from http://www.pml.ac.uk/gulfstream/default.htm and the North Atlantic Oscillation data from http://tao.atmos.washington.edu/data_sets/nao/)

Phytoplankton Colour

PC Reid & M Edwards



Specific Indicator

Continuous Plankton Recorders (CPRs) have been towed behind merchant ships to monitor the plankton on a number of routes across the North Sea each month since January 1946. A four metre band of the filtering silk used in these instruments provides a 'film' of the plankton along a transect of ~450 nautical miles. Phytoplankton Colour is a simple index of chlorophyll (a basic measure of phytoplankton biomass) determined from a visual assessment, into four categories, of the colour of the CPR sampling silk. The methodology used has not changed since January 1946. Annual means of the data are plotted for the North Sea defined by 51°-

61°N, 3°W-10°E based on results from xxx samples. Other data for this index are available on the SAHFOS web site averaged for xxx Standard Areas covering the northern North Atlantic.

Relevance

Phytoplankton are at the base of the food chain in the seas around the UK; variability in their composition and abundance is thus crucial for all other marine life. They are sensitive indicators of environmental change and can be used to help distinguish anthropogenic from natural variability especially with respect to eutrophication and climate change. A number of phytoplankton species cause Harmful Algal Blooms and are toxic; information on natural change from the CPR helps to interpret the mechanisms behind HAB and develop management strategies.

Sensitivity to climate and other factors

The spring bloom heralds the beginning of the growing year; its timing as well as subsequent successional changes in composition and abundance are known to be highly linked to meteorological (e.g. sunshine, wind) and hydrographic (e.g. currents, stability of the water column) variability as well as grazing from the zooplankton. Temperature is a key variable in phytoplankton growth and development as well as strongly influencing their physical environment through for example the development of water column stability. Evidence from the CPR has shown that Phytoplankton Colour is significantly correlated with both sea surface temperature and Northern Hemisphere temperature in both the North Sea and much of the eastern North Atlantic. A weak relationship has also been found between Colour and the North Atlantic Oscillation.

Change over time

Phytoplankton Colour has shown pronounced changes over time with a step-wise increase in the index after about 1987, which reflects a much earlier and longer growing season as well as higher levels of Colour in the summer months of the year. These changes are also reflected in other trophic levels of the plankton in the biomass and diversity of the benthos (animals living in and on the bottom) in fish catches, in returns of salmon to home waters, in nutrient concentrations and in the inflow of oceanic water into the North Sea. The latter has been shown to be highly related to the North Atlantic Oscillation and as the major source of nutrients to the North Sea has an important impact on productivity. The step-wise change in all these variables is also reflected in Northern Hemisphere temperatures, the NAO.

[Data available at: The Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth, PL1 2PB. The North Atlantic Oscillation data are available from http://tao.atmos.washington.edu/data_sets/nao/] plus NHT.

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Strengths and weaknesses of marine indicators and methodological problems and future research

We used a number of criteria to appraise the strengths and weaknesses of the seven candidate indicators detailed in this report, and shown in Tables 3.1 and 3.2, below. These criteria followed those detailed in APPENDIX II ('Indicators Omitted Or Rejected') of the 1999 Report.

Table 3.1. Criteria for selection: Biological indicators.

Criteria for selection	SST	Fish	Barnacles	Plankton	Colour
Are long-term data sets available?	1903-	1913-	1955-	1958-	1948-
Does the historic record show indicators are sensitive to temperature?	n/a	✓	✓	✓	✓
Or, are indicators insensitive to non-climatic factors?	n/a	x	x	✓	✓
Will the indicator produce a long-term trend?	✓	✓	✓	✓	✓
Are data sets readily available?*	✓	✓	✓	✓	✓
Are indicators readily understandable by intelligent laymen?	✓	✓	✓	✓	?

*Please see general discussion below

In general the chosen indicators met most of the criteria for selection. In the case of two biological indicators, namely bottom dwelling fish and barnacles, there are known non-climatic factors that also influence population abundance. With bottom dwelling fish, many species are of commercial importance and therefore fishing effort can have a strong influence on abundance. However, the SSI we use only included species of non-commercial fish. In the case of the barnacles, although there is evidence to suggest that northern (cold water) species and southern (warm water) species compete with each other for habitat space and resources at the local scale, primarily, climate (sea and air temperatures) mediates competition, and over large spatial scales, determines the species respective distributional limits. Laymen should understand nearly all of the indicators.

As with all long time series however, there are some caveats. There are missing data in some time series due mainly to the two world wars (1914-1918 and 1939-1945) and the NERC funding crises in the late 1980's when many monitoring programmes in the UK were stopped. Missing data can reduce the statistical power for trend detection and thus make interpretation of long-term trends difficult. As already discussed, some indicators will be influenced by other factors, such as biological interactions and other anthropogenic activities. However, this will be the case for any biological indicator, not just those from the marine environment, for example, many terrestrial species are greatly affected by land use change and pollution. What is key here is that climate impacts can be demonstrated over and above other impacts.

In general the strength of the new marine indicators (caveats included) are that they include a range of marine habitats; open ocean, inshore waters and the rocky intertidal, and a range of taxa at different trophic levels; plankton, invertebrates and fish. We have also included a physical indicator made up of empirical rather than interpolated or modelled data. In terms of data quality (missing years aside), these series are comprehensive in their coverage over the last 50-100 years. The quality is also very good consisting of largely quantitative data rather than qualitative. Most importantly, the systematic archive and (more recently) analysis of time series with respect to global climate change is now being conducted. However although funds for the next 5 years have been secured to co-ordinate the continued collection and analysis of marine data, longer-term support is needed to continue these valuable time series.

In conclusion the indicators identified in this report are a starting point for a cohesive study of marine climate change in the UK. Further analysis of MBA and SAFHOS data series will provide greater insights in to future climatic change leading to the development of further indicators.

Acknowledgements

This contribution is referenced by the MBA as: C023 1020 D4 021. The contributors are Dr. Rebecca Leaper [1] (Co-ordinator of the contract and correspondent for the report) Dr. Nick Hardman-Mountford [1]Dr. Philip C. Reid [2] Dr. David Sims [1] with acknowledgements to Prof Steve Hawkins [1, 3] (Director, MBA) and Prof Alan Southward [1, 3] (Research Fellow).

1. The Marine Biological Association, The Laboratory, Citadel Hill, Plymouth PL1 2PB.
2. The Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel Hill, Plymouth PL1 2PB.

3. Data on bottom living fish provided by the MarClim project.
4. Data on barnacles, marine plankton, and plankton colour provided by SAHFOS

10. Summary of Recommended Revision of the Indicators

Temperature
The Central England Temperature data should remain a key indicator. But a new indicator, the length of the thermal growing season, derived form the CET, should be added. Section 8 presents this new indicator.
Precipitation
The seasonality and se-NW gradient in precipitation should be retained. But a new indicator measuring the relative intensity of winter and summer precipitation events should be investigated, perhaps covering regional variation. Winter rainfall is increasingly received in downpours.
Westerly weather
In addition to the North Atlantic Oscillation, it is worthwhile to follow the lead taken in the Welsh indicator initiative, to identify indicators measuring gale incidence and surface wind speeds.
Hydrology
The existing hydrological indictors (Indicators 5-8) should be retained, but:

(iii) data on wet and dry soil conditions should be obtained from the Met Office rather than Wallingford, and

(iv) low and high river flow indicators should use ‘peaks over threshold’ rather than percentage departures from the average.

Thames Barrier
The barrier is now closed to retain water in the Thames. This means that this indicator is of limited value as a measure of sea flood defence, unless it is possible to discern the reasons for barrier closure.
Atmospheric ozone
It is probably useful to retain this indicator, although it is affected by many factors. However, it is better related to number of sunshine hours rather than temperature, as in the 1999 report.
Domestic property insurance
New data now make it possible to attribute claims to different events (severe frost, flood, wind storm) and more work needs to be done on standardizing the data to the Retail Price Index.
Supply of gas to households
This Indicator should be retained.
Domestic holiday tourism
There have been major methodological problems in obtaining a consistent time series. The series needs to be revisited to be sure that it is homogeneous. A possible replacement series could be sought amongst data on visits to National Parks and visitor attractions.
Scottish skiing industry; Number of outdoor fires
These Indicators should be retained.
Health
The series on lyme disease incidence (Indicator 17) is subject to sudden jumps, reflecting medical staff awareness rather than incidence, but it should be retained, but with work to remove trends that are not climate related.
The seasonal pattern of mortality is currently for England and Wales and should be extended to include Scotland.
An additional indicator should be added on the incidence of food poisoning. There is a clear upward trend and data are available for England, Wales and Scotland.

Use of irrigation water for irrigation, and proportion of potato crop irrigated
These indicators are clearly responsive to summer rainfall and should be retained, although the potato area data are not available every year.
Potato yields (non-irrigated)
The data are no longer readily available to continue this indicator.
Warm weather crops (grapes and forage maize)
These indicators may be showing trends that are unrelated to climate, but they have public resonance and should be retained.
Late summer grass production
This unique long time series form Rothamsted Research should be retained as an indicator.
Plant and animal phenology (other than insects)
The current indicator is the date of oak leafing in Surrey. This indicator could be replaced by more secure and comprehensive data series on plant leafing and flowering dates from the UK Phenology Network (UKPN) and other sources. Dates of flowering of snowdrops and daffodil are good candidates (with regard to differences among cultivars). The Welsh series on flowering of ryegrass and clover could be included, and there are good Scottish phenology series. Data on frog spawning dates are available from the ECN and UKPN, are responsive to early spring temperatures and could be added as an additional indicator.
Health of beech trees
This series should be retained.
Appearance, activity and abundance of insects
These indicators are very responsive to temperature and should be retained. However, some of the time series have been replaced, and the abundance of common footman moth appears not to be as responsive as other species and should be replaced.
Bird behaviour and populations
The indicators chosen have high public resonance, are responsive to climate and should be retained: they are the arrival date of the swallow, egg-laying dates of robins and chaffinches and wren populations.
Freshwater natural events
Data on upstream movement of salmon are no longer available and this indicator is discontinued. The duration of ice on Windermere is a surrogate for temperature. Thus, the current indicators lack any measure of freshwater natural events. One candidate would be the peak algal bloom dates collected at CEH Windermere. One of these, on *Asterionella*, shows an advance of circa one month over the last 60 years. Prospects for continuance of the series are good and, unlike many series, these data consist of peak dates not first dates.
Marine indicators
(See Section 9)

11. Headline Socio-economic Indicator of Climate Change

UEA was asked to develop a 'headline' socio-economic indicator of climate impacts for inclusion in the DEFRA publication *Foundations for our Future*, which will undergo its first revision for publication in June 2003.

The evaluation has concentrated on the indicators identified in the original report, plus one added in the current update – the length of the thermal growing season. The reason for this is that a rigorous evaluation of available indicators was carried out at the time of the original report. Many potential indicators were identified, explored and eventually discarded because of problems associated with data availability, lack of sensitivity and/or policy and public relevance. Time and financial constraints in the current contract do not permit a complete re-evaluation of the decisions made for the original report, nor do we consider this to be a worthwhile exercise. We have made a brief examination of new candidates for the headline indicator, discussed in Section 11.1.

11.1 Evaluation of potential new indicators

We have considered the possibility of adding an indicator on food poisoning occurrence. This would satisfy criteria related to policy relevance and public resonance. Moreover, the data are readily available. The time series contains three components:

i. an exponentially rising trend over time – by far the dominant influence;
ii. a seasonal cycle, peaking in summer and reaching a minimum in winter; and,
iii. interannual variability linked to temperature fluctuations.

We would only be interested in the third of these. Thus, the series would have to be detrended before it could be used as an indicator, making it difficult to explain to a general audience without being misleading. The long-term rising trend is likely to be due to failures in public and domestic hygiene.

Many potential indicators fail because of commercial sensitivities. This is particularly the case in the retail sector. It is frequently suggested that useful indicators could be derived from sales of goods such as air conditioning units, of foods such as ice cream, and of drinks such as beer. We have investigated these possibilities both for the DEFRA Indicators and for the Welsh Indicators report. It has proved impossible to obtain statistics, whether from individual companies or from trade organizations.

11.2 Evaluation of existing indicators

In Table 11.1, a systematic evaluation of the existing indicator set, including growing season length, is carried out. On the basis of sensitivity, policy relevance and public resonance we can identify four candidates:

i. Length of growing season
ii. Domestic gas supply
iii. The Scottish skiing industry
iv. Domestic property insurance

Each of these has advantages and disadvantages, and we discuss each in turn below.

Table 11.1: Evaluation of potential Headline Indicators

Indicator	Current availability	Sensitivity	Policy relevance	Public resonance	Future availability	Length/homogeneity of current series
Economic/environmental						
Domestic gas supply	Published statistics	High	Low	Moderate	Likely to continue	Good series available to 1972
Domestic property insurance	From the ABI	High, depending on peril	High	High	Likely to continue. ABI may charge; estimate £400 per annum.	Weather perils broken down by storm, flood etc. only available from 1998 Standardization to base year required
Domestic tourism	From the British Tourist Authority	Moderate	Low	Low	Likely to continue	This series has suffered from a number of changes over the years. A homogeneous series can only be guaranteed from 2000
Number of outdoor fires	Published statistics	High	Low	Low	Likely to continue	Good series available to 1984
Scottish skiing industry	By enquiry to Highland and Islands Enterprise	High	Locally high	High	Likely to continue	Good series available to 1983
Health-related						
Lyme disease occurrence	By enquiry to Communicable Disease Surveillance Centre	Low – confounded by notification	Low – only a few hundred cases each year.	High	Likely to continue	Series available to 1986 but not homogeneous
Winter human mortality	From the Office of National Statistics	Moderate – confounded by influenza outbreaks	Moderate	Moderate	Likely to continue	Series available to 1983 unbroken
Agricultural						
Irrigation water use	Published statistics	Moderate – confounded by need to meet supermarket standards	Moderate and growing	Low	Likely to continue	Available to 1971
Proportion of potato crop irrigated	Survey statistics – not available in every year. No survey between 1995 and 2001	Gradual upward trend – better considered as warm-weather crop.	Low	Low	Likely to continue on periodic basis	First available survey year 1963
Non-irrigated potato yields	From the British Potato Council, but no data	High	Low	Low	Very uncertain due to lack of staff	1987 – 1997, and homogeneous within this period

	have become available since 1997					
Area of productive vines	From Wine Standards Board, supplied by DEFRA	Warm weather crop with gradual upward trend	Low	High	Likely to continue	Available to 1985
Area of forage maize	Published statistics	Warm weather crop with gradual upward trend	Low	Moderate	Likely to continue	Available to 1979
Length of growing season	High – based on daily Central England temperature	High	Moderate	High	Very likely to continue	Series available to 1772

11.2.1 Length of growing season

This is a new indicator, calculated from the daily Central England temperature (CET) record. A graph of the Length of the Thermal Growing Season appears in the UKCIP Climate Change Scenarios (UKCIP, 2002) for the period 1772 to 2001, as Fig. 7. This is calculated relative to a threshold of 5.5°C. More recently, this series was the subject of a letter to *Weather* (Mitchell and Hulme, 2002) where, with a threshold of 5°C, it was proposed as an Indicator. Mitchell and Hulme define the thermal growing season length as beginning when the temperature on five consecutive days exceeds a threshold of 5°C, and ending when the temperature on five consecutive days is below that threshold. It runs between the first day of the former period, and the day preceding the latter period.

For the Indicators update, recent daily CET data were requested from Phil Jones of the Climatic Research Unit, and supplied to Tim Mitchell of the Tyndall Centre for Climate Change, so that he could perform the update to 2002. This was done relative to the 5°C threshold. The data have been plotted and a smoothed curve added so that the general trend can be seen. A sample plot is shown below, for the period 1900 – 2002 (over which the climatological indicators are plotted in the original Indicators report).

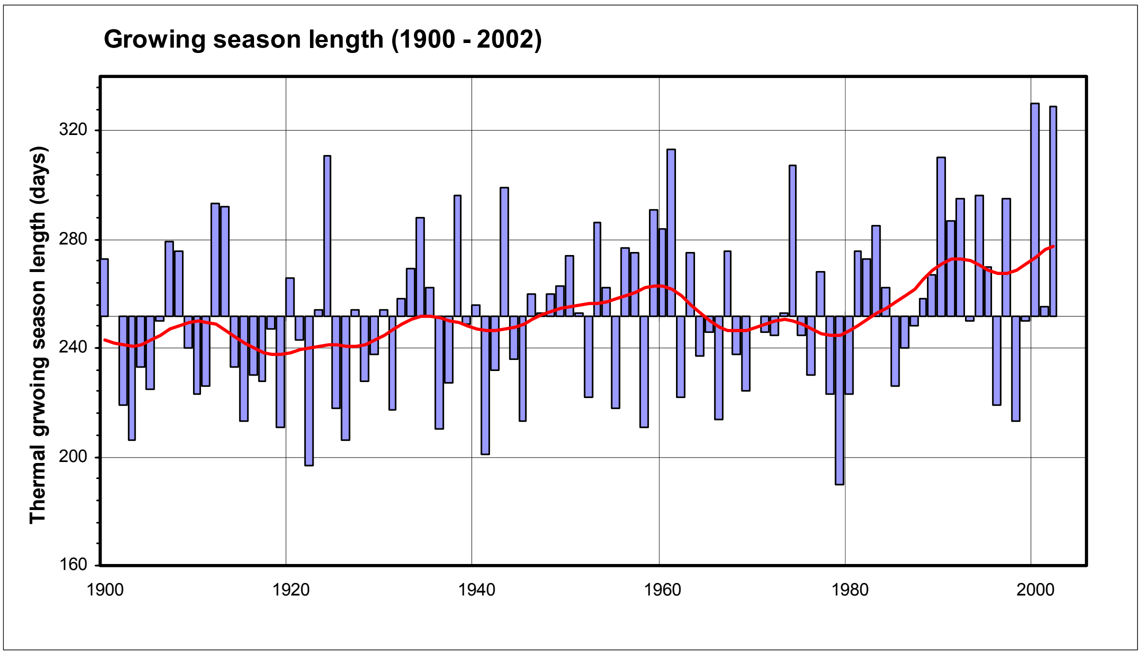

Figure 11.1 Thermal growing season length, calculated from CET

The longest growing season in the 229-year record was 330 days, in 2000. However, the second longest value, and only one day shorter, occurred in 2002 (329 days). According to Mitchell and Hulme (2002), there was an increase in growing season length over the twentieth century of 28 days, which took place mainly in two phases: 1920 – 60, and 1980 – 2000. Whereas the earlier period saw both an earlier onset of spring and a later onset of autumn, all of the recent increase has been due to an earlier onset of spring. This result agrees with the results of other authors, for example Menzel and Fabian (1999).

This indicator has public resonance, since it is of importance not only to farmers planning their sowing and harvesting operations, but also to gardeners. It has policy relevance to DEFRA, because of its relevance to the agricultural and land management community. It is highly sensitive. It is unlikely that this series will prove difficult to update in the future, since daily CET is supplied on a regular basis by the UK Met. Office to the Climatic Research Unit. The programming to derive the index from daily CET is simple and straightforward. Its major disadvantage as a headline indicator is that it is not strictly socio-economic, being derived purely from climatological data. Further, to be a true measure of growing season length, it should take into account moisture availability, and this will become more relevant in future under conditions of climate change.

11.2.2 <u>Winter domestic gas supply</u>

The updated series for winter domestic gas supply is shown in Fig. 11.2. Gas consumption is expressed as the percentage of annual amount which is consumed in the first quarter of the year (January – March). It is shown together with CET for the same months, and the correlation between the two series is -0.7. This is one of the most consistently sensitive series in the Indicator set.

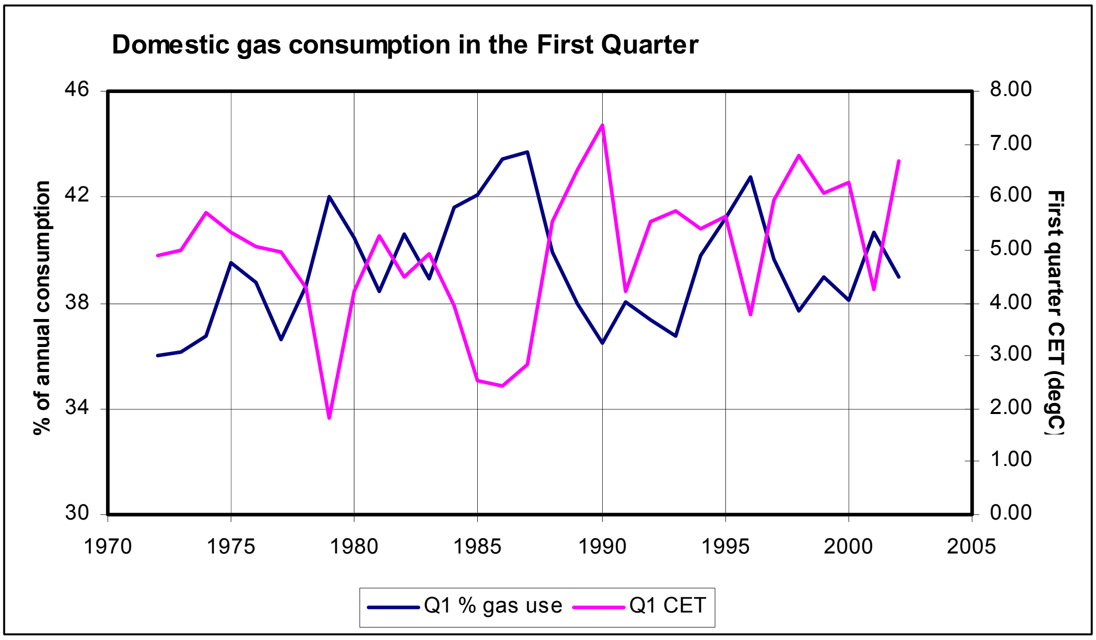

Fig 11.2 Domestic gas consumption and CET for January – March

This would make a good headline indicator. The data are readily available at no cost, extend back to the early 1970s, and are likely to continue to be accessible in the future. The high sensitivity seen throughout the time series should persist for the foreseeable future. The negative attributes relate to lack of policy relevance and public resonance.

11.2.3 Scottish skiing industry

The updated series for ski days (found by summing the number of ski lift and tow passes bought at the five main Scottish skiing centres) is shown in Fig. 11.3. The series is available from 1982 to present, and is shown together with the number of days with snow lying at Braemar, a site in the midst of the skiing region. The two series are clearly related, and the correlation between them is 0.6.

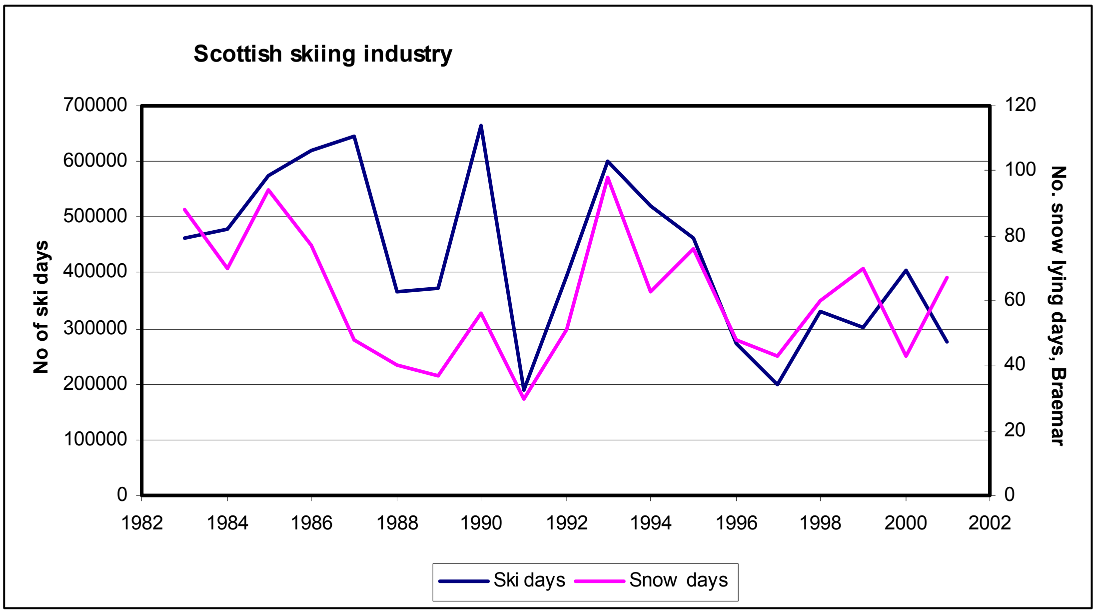

Fig. 11.3 No. of Scottish ski days and days with snow lying at Braemar

This is a sensitive indicator which is likely to continue to be available in future. There is a small cost involved, to purchase the snow data from the UK Met. Office. It has the advantage that the snow data extends back to the early 1920s, and demonstrates clearly the lack of long-term trend, although it is clear (Fig. 11.4) that a short-term downward trend has existed since a high of 98 days in 1993/4. The principal disadvantage is that this indicator is not general to the UK, nor even to the whole of Scotland, but relates to just one region of Scotland. Although the skiing industry is important locally as an employer and income generator, its contribution to the national economy of Scotland is small.

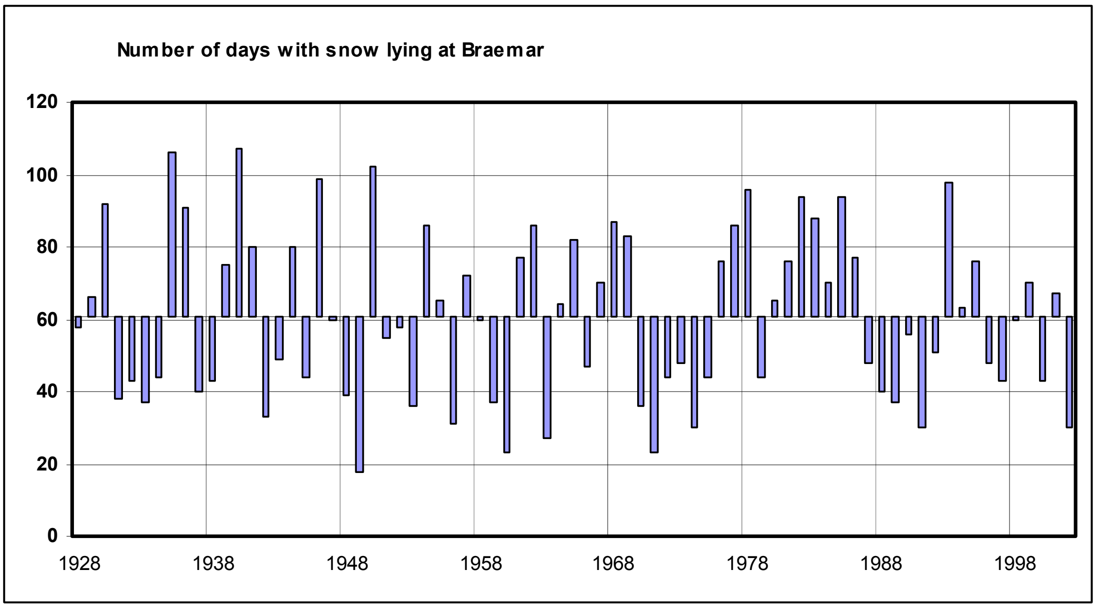

Fig. 11.4 Number of days with snow lying at Braemar, 1928/9 – 2002/3

11.2.4 Settled claims for weather perils

Two indicators related to the insurance industry were used in the original report, and have been updated here (see Section 8). These are the value of settled claims for subsidence damage, and the value of settled claims for weather perils. They are shown in Fig. 11.5. Subsidence is related to drying out and shrinkage of clay soils. It is therefore shown together with England and Wales rainfall for April – September. Weather perils includes wind storm, flood and burst pipes. This latter series is completely dominated by the effects of the 1987 and 1990 wind storms.

With respect to the value of settled subsidence claims, there is some indication that the series is becoming less sensitive. This is likely to be because claims are taking longer to settle (i.e., the series is becoming smoother), and also because improved building and repair standards are making the housing stock less vulnerable to subsidence damage. Thus the dry years of 1995 and 1996 did not lead to a peak in claims until 1998, since which time there has been a gradual fall off year on year to the end of the record.

The Weather Perils Indicator is controlled primarily by wind storm. There have been no major wind storm events since 1990, and this is clearly demonstrated in the record. Since 1994 there has been a gradual upward trend in the value of settled claims.

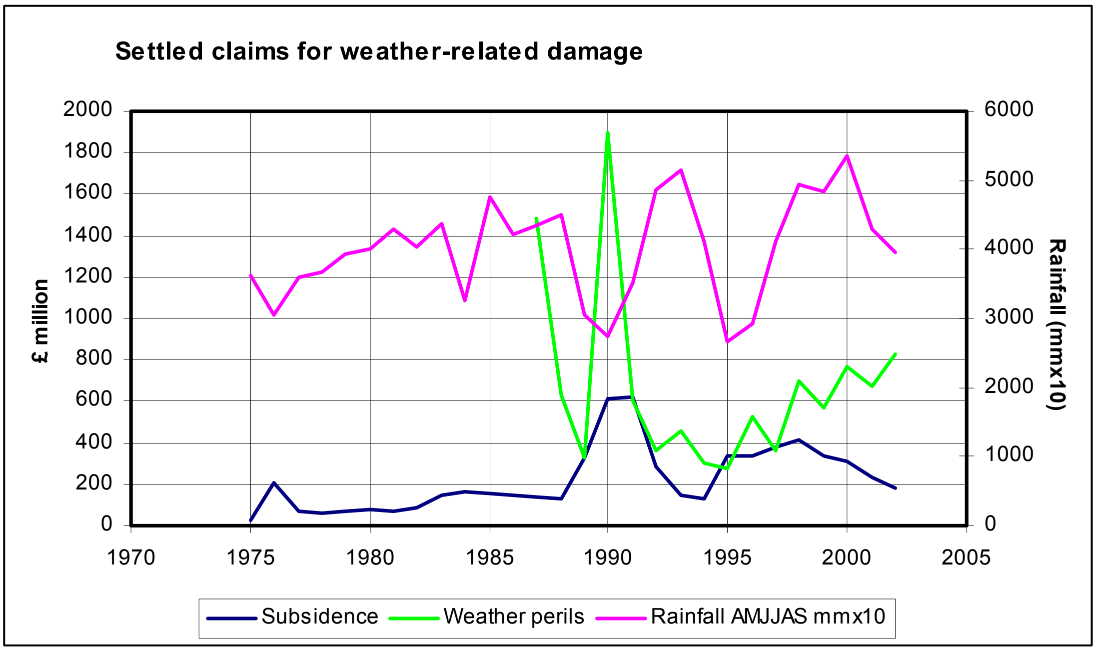

Fig. 11.5 Value of settled claims for weather-related damage (standardized to a common base using the Retail Price Index). Subsidence claims can be compared with April – September England and Wales rainfall

The insurance indicators have public resonance and policy relevance. They are readily available from the Association of British Insurers, although if we require information on a regular annual basis it is possible charge would be made to access the data from the web site. This would also be a more convenient method of regular updating. We estimate this charge to be of the order of £400 per annum. The series have the disadvantage (i) that the subsidence indicator is possibly becoming less sensitive, and is only of relevance to areas where clay dominates the surface geology and (ii) that the weather perils combine losses due to three separate risks: burst pipes, wind storm and flood. However, since 1998 the claims associated with these risks have been available separately, as shown in Fig. 11.6.

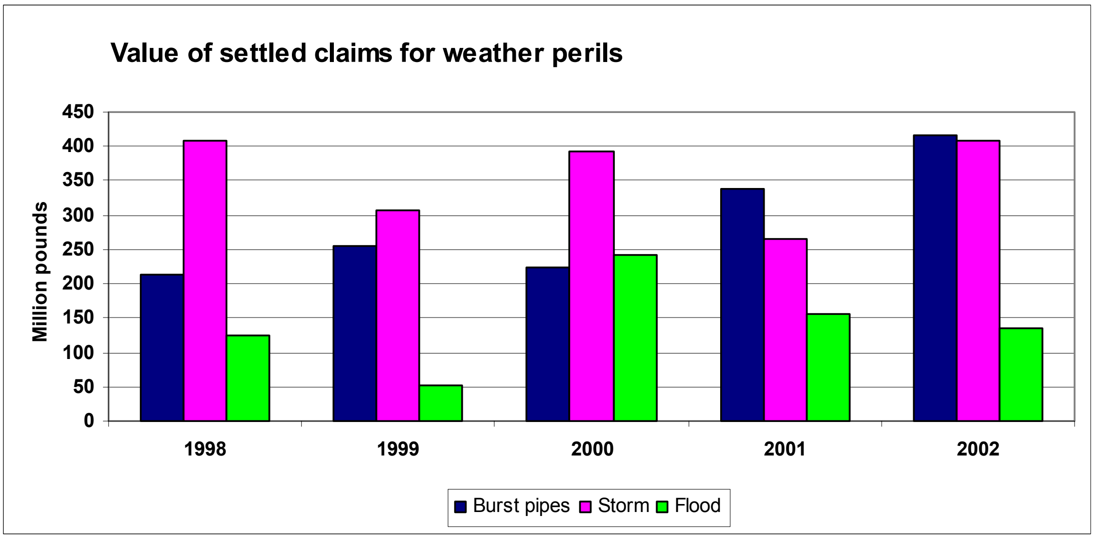

Fig. 11.6 Settled claims for burst pipes, storm and flood

As shown by Fig. 11.6, the greatest weather-peril losses are due to wind storm (1998, 1999, 2000) or burst pipes (2001, 2002). The responsiveness of the series is shown, for example, by the flood claims data. In response to the autumn floods of 2000 which affected both southern England and parts of Yorkshire (Kelman, 2001), settled claims for flood damage more than quadrupled between 1999 and 2000.

11.3 The selection of headline indicator

We have proposed four potential headline indicators for use by DEFRA. These all fulfil the criteria that they are currently straightforward to obtain, and are likely to remain so in the future. The shortest series, Scottish ski days, is 19 years in length. All have been shown to be sensitive to climate fluctuations.

In making a final selection, there remains the issue of policy relevance and resonance with the general public. On this basis, we would choose the value of settled claims for weather perils. Unfortunately, prior to 1998 these are only available as a composite series, making it impossible to disaggregate the separate effects of cold weather (burst pipes), wind storm and flood. Only five years of disaggregated data are currently available, 1998-2002. However, a graph could be prepared showing the combined losses up to 1998, and the disaggregated losses thereafter, along the lines of Fig. 11.7.

Weather perils have no obvious climate variable to accompany them. Text would be required to point out the major perils occurring during each year, and the likely impact on the series.

The short disaggregated series, and the requirement for accompanying text, may make the weather peril indicator less attractive as a headline indicator. In this case, we would select, as the second choice, winter domestic gas consumption. However, the final choice will be made on the basis of policy considerations and accessibility to a non-specialist audience, and should rest with DEFRA.

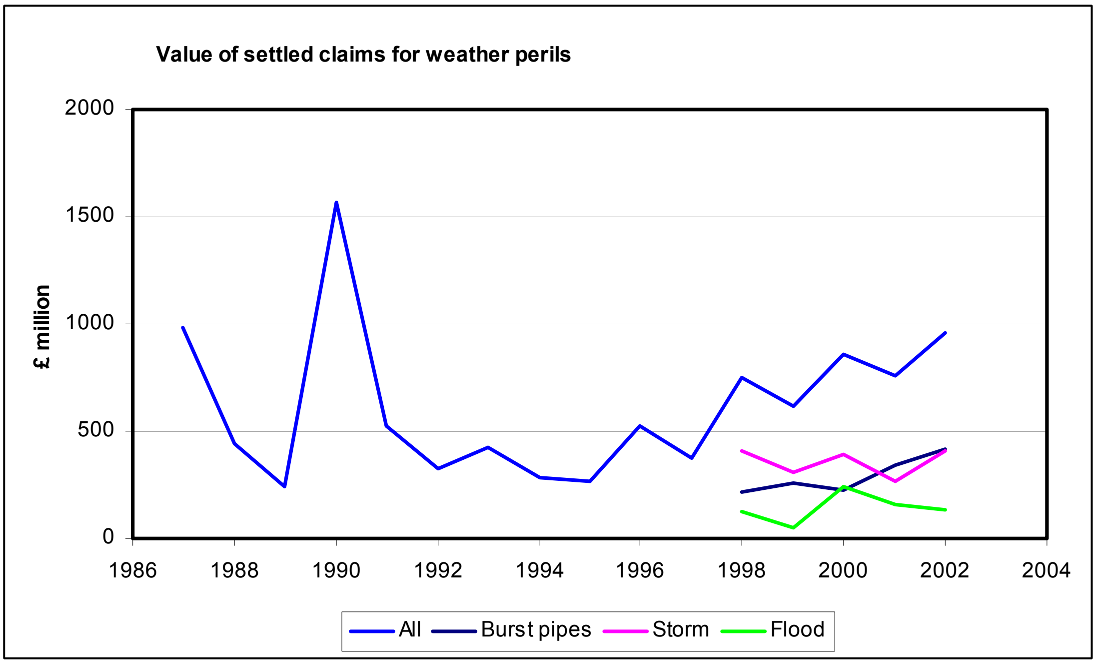

Fig. 11.7 All weather peril data from 1987 to 2002.

References

Hulme,M., Jenkins,G.J., Lu,X., Turnpenny,J.R., Mitchell,T.D., Jones,R.G., Lowe,J., Murphy,J.M., Hassell,D., Boorman,P., McDonald,R. and Hill,S., 2002: *Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report.* Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp.

Kelman, I., 2001: The autumn 2000 floods in Emgland and flood management. *Weather*, **56**, 346-348, 353-360.

Menzel, A., and Fabian, P., 1999: Growing season extended in Europe. *Nature*, **397**, 659.

Mitchell, T. D., and Hulme, M., 2002: Length of the growing season. *Weather* **57**, 196-198.

We also note the following works on discriminating between weather and non-weather related insurance claims:

Pielke, R. A. and Downton, M. W. 2000. Precipitation and damaging floods: trends in the US, 1932-97. Journal of Climate 13, 3625-3637.

Meehl, G. A. et al. 2000. An introduction to trends in extreme weather and climate events: observations, socio-economic impacts, terrestrial ecological impacts and model projections. Bulletin of the American Meteorological Society 81, 413-416.

Sarewiz, D and Pielke R. 2001. Extreme events: a research and policy framework for disasters in context. International Geology Review 43, 406-418.

Appendix I

Monthly deaths in Scotland by month. Data are available since 1986.

Deaths in Scotland by month of registration,both sexes
BOTH SEXES

YEAR	TOTAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
1997	59,494	7,014	5,070	4,505	5,058	4,706	4,655	4,586	4,226
1998	59,164	5,241	4,883	5,607	5,218	4,492	4,730	4,665	4,512
1999	60,281	6,428	5,675	5,588	4,667	4,271	4,735	4,300	4,672
2000	57,799	7,564	4,763	4,842	4,294	4,886	4,484	4,310	4,401
2001	57,382	5,976	4,654	5,163	4,802	4,713	4,243	4,523	4,549

SEP	OCT	NOV	DEC
4,565	5,025	4,495	5,589
4,635	4,731	4,978	5,472
4,360	4,354	5,021	6,210
4,211	4,741	4,708	4,595
4,188	4,926	4,576	5,069