CHAPTER 6

NATURAL ENVIRONMENT DOMAINS

LIKELY IMPACTS AND POSSIBLE ADAPTATION RESPONSES

Introduction

This section considers those domains in the South West which fit broadly under the heading of the natural environment. Such headings are necessarily arbitrary but have proved useful in progressing and reporting on the study. So, the natural environment section explores the following impact domains:

1. Agriculture and Horticulture
2. Biodiversity and Habitats
3. Coastal Issues
4. Forestry
5. Marine Fisheries
6. Rivers and Riverine Flooding
7. Water Resources.

(For details of the methodology adopted for researching and reporting on these domains please see the Appendix.)

This introductory section precedes the detailed consideration of each domain and considers some of the general issues that relate to climate change and its impact on the natural environment. A brief discussion of the baseline in the region is followed by a summary of climate change impacts on the domains and a summary table of recommendations.

Baseline

The 'natural' environment of the South West region is one of its greatest assets, contributing to the attraction of the region for tourists, and accounting for some 13% of business establishments in the region that are involved in one or more of the agricultural, hunting, forestry and fishing sectors.

The far South West with its many small coastal resorts is a tourist magnet, especially in summer, although Newquay is fast becoming a year-round surfing resort. The 'natural' beauty of the Cotswolds in the north of the region also attracts many tourists, and the Forest of Dean in Gloucestershire is well used by tourists, cyclists and walkers. In all parts of the region, however, most tourism is based on the private car, and its widespread use has implications for the further development of the tourist potential of the region without compromising its 'natural' qualities.

The region is blessed with two National Parks, several large AONBs, and long sections of heritage coastline. The upland areas of the National Parks — Exmoor and Dartmoor — have largely been deforested for millennia, but Dartmoor in particular contains pockets of probable former wildwood. There are a disproportionately large number (compared with other regions) of sites managed by The Woodland Trust.

With the exception of the more linear stretches of protected coastline and some river-valley woodlands, many of the protected sites for nature conservation in the region are 'islands' of semi-natural habitat in a sea of agricultural landscape. However, in south Dorset, urban encroachment on areas of semi-natural heathland is perceived as a greater threat than that of agriculture.

The South West has a regional Biodiversity Action Plan (unlike most other regions), but its practitioners in nature conservation are hampered in fully realising the plan by various perceptual, institutional and practical barriers to planning for biodiversity in the wider countryside (Watts, 2001).

The whole question of biodiversity in the region is one that merits further discussion. Biodiversity is usually seen as a quality or attribute that is perceived as being inherently 'good' (i.e. more is better). Some of the region's most prized semi-natural areas are, however, in reality dominated by relatively few vegetation species (heather moorland and *Sphagnum* bogs being two examples) and have relatively low vegetational biodiversity. On the other hand, other areas have much greater vegetational diversity (such as chalk- or limestone grassland) but are far from 'natural'. By that we mean that without continued grazing by livestock and by the (non-native) rabbit, many of these areas would quickly give way to scrub and eventually to woodland, which would in reality be the 'climatic climax' (final growth stage) ecosystem for most of the region.

Summary of Climate Impacts on Domains

Overall

The natural environment is probably the most conspicuous and visible receptor for the impacts of weather. In both public and professional realms it is the natural environment that first comes to mind in considering the impacts of climate change, for example through coastal and river flooding, water supply and demand, natural habitats, and potential changes in agricultural crops. For these, and other, reasons it is the aspect that has received the greatest attention in earlier studies of climate change impacts.

Biodiversity

With regard to bio-diversity in the region it is clear that changes are already taking place. The range and variety of species will not just be affected by how we manage protected and designated areas but how integrated land use and management strategies can be developed. Difficult choices are required from those with management responsibility. We have encountered many conservation specialists who have difficulty in accepting the potential impacts of climate change and seek (Canute like) to hold onto protected species and habitats in the face of significant changes in the weather. Even during the course of the study we have observed a change in this attitude, and a much clearer recognition of the inevitability of climate change and the need for more radical responses.

Agriculture

The effects of climate change on agriculture are now broadly understood. These include an extended growing season, the potential for new crops, an increased requirement for water for summer irrigation, a potential loss of competitive advantage compared with other locations, and reduced die-off of pests and diseases due to warmer winters. Some of these changes are already occurring but within the farming community generally there is not much awareness or concern. At present there are more pressing issues on the agricultural agenda, including BSE, the aftermath of Foot and Mouth disease, the implications of the Curry Report and changes to the Common Agricultural Policy.

Forestry

Existing, established woodland trees generally are likely to survive changes in climate but new planting may require consideration of different species or different nursery regimes.

Coastal Issues

The main impacts on the coast will mainly be to do with coastal erosion and the reduced depth of beaches arising from increased sea levels and storm surges. Difficult decisions are required from those with responsibility for the management of coastal defences. Abandon; manage retreat; or defend robustly are the main options in the vulnerable locations. Again an integrated approach is required.

Marine Fisheries

As with agriculture the marine harvest is already changing but there are again more pressing issues than climate change. Traditional species such as cod are migrating north whilst new, more exotic species are now present in southern waters. The other items on the fisherman's agenda include the recent pronouncements on EU quotas (belatedly designed to control overfishing), and the need to renegotiate the Common Fishing Policy. These have tended to pre-empt consideration of climate change impacts, despite the empirical evidence that change is already happening.

Rivers and Flooding

The main impacts associated with rivers and other watercourses concern flooding in its various forms. The recent experience of riverine flooding is still in the public consciousness and the planning system is now exerting further control on potential development in floodplains. Periods of intense rainfall also lead to problems associated with excessive run-off from the land, and flash flooding in both town and country, largely associated with insufficient capacity in existing drainage. Insurance companies are taking an increased interest in the financial consequences of flooding, and through premium pricing or new policy exclusions are likely to determine policy in this area.

Water Resources

Issues of both supply and demand are affected by increased rainfall in winter but reduced rainfall in summer. As usual storage across the seasons becomes the main problem, particularly when extended periods of summer drought will increase demand for domestic and agricultural irrigation as well as commercial and industrial use. The quality of water is also of concern as river flows reduce and pollutants increase. Nevertheless, the water companies in the region appear to have a clear understanding of the main issues and appropriate adaptation strategies.

Cross-sectoral Issues

The various domains that are grouped together in this part of the report are difficult to separate from each other. Indeed, decisions taken in one sector (e.g. agriculture) may have major repercussions in others (e.g. biodiversity; floods). A pilot project that has focused on the River Parrett in Somerset demonstrates this interconnectedness, and shows how important can be the role for integrated land management. Decisions taken on upland land use in a catchment can have major implications downstream, and this is exemplified particularly during and immediately after prolonged or high-intensity rainfall events. The role that forestry might play in intercepting precipitation and mitigating surface run-off, and the role that a more sensitive agriculture can play in providing refuges and corridors for species, are worth further investigation in the context of the climate scenarios for the South West. *(See further discussion of Cross-sectoral Issues in Chapter 10.)*

Recommendations for Natural Environment Domains

- Encourage the implementation of the South West Biodiversity Action Plan incorporating the findings of the Scoping Study.

- Monitor the quantity, frequency and impacts of run-off from agricultural land and uplands generally.

- Make full use of the principles established in the MONARCH and REGIS studies in their potential application in the South West.

- Avoid preconceived and fixated views on what should be found living in specific locations, and alongside what other species, in the face of natural, uncontrollable changes in climate and habitat.

- Site visits for all relevant sectors to those mainland European locations which currently experience climates similar to those anticipated for different parts of the South West region.

- Make use of historical and archaeological evidence, as well as contemporary evidence, in considering likely impacts of climate change on the natural environment.

- Undertake further research in order to improve the quality of data with regard to extreme events and probability, particularly with regard to coastal storms.

- Quantify need for increased summertime irrigation for South West a**griculture and horticulture.**

- Continual monitoring of climate change impacts to increase awareness in **agricultural** sector.

- Review the potential loss of competitive advantage for South West **agriculture.**

- Develop policy responses to address **biodiversity** issues by considering integrated land-use management (including integrated marine and coastal management).

- Review potential species loss, opportunities for range expansion, and climatic effects on landscapes in assessing impacts on regional **biodiversity.**

- Encourage further research into, and monitoring of, the erosion of **coasts** and beaches.

- Rationalise the current split in responsibilities for **flood and coastal defence** and work towards more integrated management.

- Assess the risk of remobilisation of toxic substances in **riverine/estuarine** sediments.

- Renegotiate Common **Fisheries** Policy in the light of species loss and relocation.

- Monitor the impacts of changing water quality/quantity in **rivers** on habitat and biodiversity.

- Create a searchable database of hydrological data on water quality/quantity data in **rivers** in the SW Region to be available to stakeholders including general public.

- Increase control on future development within **flood risk** areas, including increased status for the Environment Agency in the review of planning applications.

- Manage abstraction licences for **water supply** faced with increased demand for irrigation and industrial usage.

- Review impact of longer droughts and modelled 4% rise in household water demand by 2021 on regional **water supply**.

- Review capacity of **sewerage and drainage infrastructure** in the prospect of flash floods, flooding of sewer networks, and rising sea levels.

- Manage increased turbidity, nitrates concentration and *cryptosporidium* content in **groundwater** during wetter winters.

AGRICULTURE AND HORTICULTURE DOMAIN

Scope

Agriculture, horticulture and related issues of commercial food production and distribution, including management of agricultural land, and potential diversification of land use.

See Also

Biodiversity, forestry

Background

The South West has a land area of 23,829 km^{2}, more than two thirds (70%) of which supports agricultural production, either solely or as part of a multi-functional land useto agriculture. This proportion is comparable to the level of agricultural land use across the UK, though the region has a higher proportion of semi-natural grazing land (moorland, heath) than in other regions of southern Britain. The land-based industries play a major role in maintaining and preserving the region's distinctive and varied countryside and landscape. Because of its present climate horticulture forms an important part of the agricultural economy. Glasshouse production tries to capitalise on this climatic comparative advantage.

The region has the second largest agricultural workforce and proportion of agricultural employment in the country, and the third highest share of agricultural output in regional GDP. Agriculture thus directly sustains 3.7% of the regional workforce, generating 2.2% of regional GDP.

Despite the relatively non-agricultural nature of regional employment, there are localities within the region with comparatively significant proportions of agricultural employment. The highest proportion at county level is in Cornwall at 7.3% of the workforce although much higher concentrations exist at district level.

> **"Farmers are already changing their buying patterns and adapting their practices"**
>
> Agricultural Co-operative, Cornwall

The South West has a particularly large concentration of businesses in the agriculture, hunting, forestry and fishing sector, accounting for almost 13% of all business establishments in the region. Agriculture in the South West is thus less profitable and more labour intensive than that in other significantly rural region. Remote rural parts of the South West have experienced slower economic growth than more accessible areas. These areas have the lowest wages and experience significant levels of seasonal unemployment, partly due to the importance of agriculture in their economy.

Key Issues

- Elevated carbon dioxide levels could enhance growth of some crops.
- Longer growing period offers potential for increased productivity, but increased summer drought may offset this through reduced growth of crops and forages.
- Potential for novel crops such as sunflower, grapevine and bio-fuels including vegetable oils.
- Potential increase in pests and diseases, including species new to the region.
- Increased need for irrigation. This could be offset by on-farm storage of excess winter precipitation, but this will require financial outlay and man-hours in terms of reservoir construction.
- Potential for loss of competitive advantage for South West agriculture to other regions of the UK.
- Challenges and opportunities for inland fish farming. (Increased temperatures, reduced oxygen levels, new species).
- Increased heat stress for poultry and livestock, and also for employees.
- Intense rainfall may increase direct and indirect damage to crops and soils.
- Reduction in water quality due to leaching of nutrients, fertilisers, pesticides etc.
- Areas of agricultural land vulnerable to flooding from sea level rise – e.g. Somerset Levels, low-lying river valleys and coastal areas.
- Damage due to run-off – soil erosion, blockage of drains, damage to rural road network/field access. Impact on fish spawning streams (silting of gravel beds).

> **"There is a feeling that *'it* (climate change) *might not happen'* which discourages action"**
>
> Source unknown

Specific Climate Issues for the South West

- Flooding risks for the Somerset Levels and other low-lying and coastal areas.

- The risk of the South West losing the competitive advantage currently held, particularly in the extreme South West.
- Loss of prime land on the Isles of Scilly due to sea inundation and sand drift, as well as coastal erosion.

Risks that have been identified:

- Changing windows of opportunity available for land work, which will have effects on soil condition, compaction and run-off.
- Availability of water at crucial points in crop development.
- Damage to standing crops by heavy precipitation, high winds, flash floods etc.
- Increase in pest and disease damage due to low winter die-off, increased winter humidity and introduction of alien pest species through changing climate and the growth of novel crops.
- Worker health and safety issues.
- Sunburn and heat stress in livestock.
- Increased depth of roots due to dry conditions put the nutrients out of reach for some crops.
- Increased growth of weeds while the land is too wet to deal with them.
- Flash flooding increases the risk of slurry pollution events.
- Effects of poor land management due to unpredictable weather will have effects beyond the reach of the farm itself.
- Some crops currently grown on light soils (e.g. potatoes) may become inappropriate due to unpredictable weather events such as intense storms.
- As climate changes throughout Europe the SW's climatic comparative advantage may be lessen especially for glasshouse production.

> **"If there are not sufficient water reserve in the South West, there will be no way for farmers or growers to adapt"**
>
> Various, regional

Opportunities that have been identified:

- Increased geographical range and productivity of some crops such as maize.
- Potential for new crops such as grapevines, sunflowers and other oilseed crops.
- Potential for renewable energy generation.
- Potential for diversification – e.g. tourism potential.
- Less potential for snow damage to polythene tunnels.
- Reduced heating costs for glasshouse crops.
- Increased demand for salad crops during warm weather.

The Way Forward

Key drivers have been identified as primarily the Common Agricultural Policy (CAP) and other funding mechanisms. "Policy drives agriculture" is a common statement, and one that will need to be considered carefully before any change can be encouraged or expected.

Mention was made of the importance of the SWRDA, Government Office, and for Cornwall Objective One and even the Eden Project as key drivers for the sector. The importance of DEFRA as a policy driver was emphasised.

> **"Consideration needs to be given to the growth of water retaining crops on the Somerset Levels, but to bring this forward requires further incentives – a policy change."**
>
> Agricultural Development Officer, Somerset

It was stated that Building Regulations would be the proper format to shape future decisions on ensuring buildings are appropriate for future climatic conditions, and that water supply, one of the most important factors to affect agriculture, is very much in the hands of the supply companies.

It was stated that apathy on the part of the industry was one of the biggest barriers to change in the region. This was linked to the lack of capital and ready finance, without which the industry was unlikely to be prepared to take risks on an uncertain topic.

Farm income was recognised as a major barrier, as change requires time and money to implement. Without financial resources, labour is at a premium, which limits the time and motivation for increasing knowledge levels needed for change.

There is limited information available regarding soil management issues as they relate to climate change. Land capability will need to be better matched to soil type and capability so that appropriate land use under changing climatic conditions can be identified.

It is possible that there is a knowledge barrier, e.g. on alternative enterprises and the development of vertically integrated systems. This contrasts with the situation in New Zealand where farmers have gone from primarily sheep farming to not just growing grapes but producing high quality table wines within a few years.

There was a general consensus that the message of adaptation was reaching the farm level, and that in fact adaptation had already occurred. Reports from Cornwall, Devon and Somerset were that drilling times have already changed in many areas, but that there may not be a recognised link between changing practices and climate change.

While some knowledge is reaching the layman, there is a feeling that while academics are studying the weather and global warming, the debate still continues and there are no certainties on which to act conclusively.

There is an understanding within the industry generally that continual monitoring of the situation as it pertains to agriculture will be necessary for action to be proactive rather than reactive, although it was felt that this message was not coming down clearly from any trade organisation.

"Much depends on public and private sector clients' attitudes towards short-term changes in the nature of their ornamental (and edible) plant stocks and cultivation practices. Unenlightened attitudes are all too commonplace."

Garden Design & Maintenance company, Devon

While some reported that there was ample knowledge available, it was widely stated that there was a dependence on IT related access to information, which limited those who were likely to make use of it. Information needs to be made more accessible to the non-IT community.

There is a degree of "not wanting to know" the information that may be available, but where people are interested, the material is not relevant or focussed enough to be useful to them.

Recommendations for action

It was suggested that site visits to European locations experiencing comparable climates to those expected for the South West would be extremely useful to help the industry to adapt if the probability was suitably high to warrant the time and expense. Such visits would need external funding.

For the knowledge to reach throughout the industry there needs to be a continual "drip feed" of information through the trade journals and farming media. This is not yet happening in the South West.

More emphasis is needed to encourage the uptake of renewable energy options such as bio-fuel production, and the anaerobic digestion of slurry.

Relevant localised information is essential for the industry to move forward. This must be combined with top-level support in the form of both Policy and Funding.

An authoritative, localised study identifying key issues and recommendations is required, supported by appropriate Government intervention.

Challenges and Opportunities of Key Climate Impacts on Agriculture Domain

Climate Impacts		Challenges + Opportunities
Increased Summer Temperature	C	Reduced heating costs for glasshouse crops.
	C	Reduced Oxygen levels in fish lagoons.
	C	Increased risk of machinery operator accidents due to heat stress.
	C	Conditions for supply staff and glasshouse/ poly-tunnel workers may become unfavourable and may require new working practices.
	O	Increased costs associated with glasshouse horticulture and associated industries as cooling methods increasingly needed.
	O	Potential to farm more “exotic” fish species.
	O	Potential for innovative crops and products for changing markets.
Reduced Summer Rainfall	C	Potential inability of water system to cope with increased demands under reduced supply conditions without stringent conservation measures and improved storage, as well as changed on-farm practices/cropping regimes.
	C	Variability in water supply may increase stress to susceptible horticultural and arable crops.
	C	Potential for increased risk of fires on heathland and moorland grazing areas
	C	Also, potential for reduced forage for summer grazing, especially on soils of low soil available water capacity.
	O	Opportunities to increase use of new drought tolerant varieties.
Increased Winter Temperature	C	Reduced over-winter die-off of pests and diseases, encouragement for the spread of fungal diseases.
	O	Early growth will necessitate an earlier start to lawn management etc. providing increased business opportunities to management companies.
	C O	Later animal housing and reduced feed inputs represent a benefit to farmers but a loss to their suppliers.
	O	Soil temperatures in spring rise more rapidly resulting in earlier season growth of crops and forages.
Increased Winter Rainfall	C	Extra man-hours involved in remedial work (e.g. to flattened horticultural crops and plastic covers) will increase costs.
	C	Disruption of pesticide and fertilizer applications, due to waterlogged ground, leaching effects etc.
	C	Localised flooding will delay soil cultivation.
	C	Problems with slurry storage likely, especially in sudden rain events.
	C	Sowing regimes may be affected by soil moisture and workability, e.g. spring rather than autumn sowing may become more appropriate.
	C	Soil erosion problems likely to worsen.
Increased Sea Level and Tides	C	Some low-lying areas could be given over to sea defence, salt marsh and inundation.
	C	Some loss of coastal lowland growing areas likely.
Longer Growing Seasons	C	Earlier plant growth may require earlier attention regarding pollination and pest control.
	O	Potentially less need for glasshouses
Reduced Frosts	O	Potential for an increased growing season could mean increased sales for suppliers, e.g. of machinery, silage wrap, pesticides etc. (Although this would mean increased costs for farmers).
	O	Less frost damage should allow increased productivity.
	O	Potential for new crops presently precluded by frost risk.

Climate Impacts		Challenges + Opportunities
Flooding Increased	C	Implementation of River Parrett Catchment project to assist with flood control and water handling, resulting in loss of land.
	C	Distribution of supplies and produce may be affected adversely by localised flood events.
	O	Introduction of short rotation energy crops to assist with flood control.
	C	Increased threats to livestock grazing river floodplains
Potentially Increased Winds and Storms	C	Damage to buildings, polytunnels and glasshouses.
	C	Damage to standing crops and nursery stock.
	O	Potential for increased demand in windbreak plants for domestic and on-farm use. This would require careful selection, development and propagation of suitable species.

BIO-DIVERSITY, HABITAT, CONSERVATION AND LANDSCAPES DOMAIN

Scope

Protection, management and conservation of the natural terrestrial environment (flora, fauna) including habitats, landscapes, trees and community forests.

See also

Tourism and Leisure; Rivers; Forestry; Agriculture; Marine Fisheries; Coastal

Background

The South West region contains two National Parks (Dartmoor, Exmoor) and significant Areas of Outstanding Natural Beauty. It has a remarkable diversity of habitats, and contains a large number of plant, mammal, bird, amphibian and reptile species, including some national rarities (e.g., Cornish Heath, *Erica vagans*), species confined to the South West (such as the Dorset Heath, *Erica ciliaris*), and those mainly distributed in the South West (e.g. Bristle Agrostis, *Agrostis curtisii* [syn. *A. setacea*]; Britain's rarest reptile, the smooth snake *Coronella austriaca*).

The South West region's long peninsula creates a strong oceanic climate. Nevertheless, the climatic contrasts between the north east of the region and the far South West (e.g. Isles of Scilly) are in many cases greater than the climate changes shown for any part of the region between the 1961-90 baseline and the 2050's climate scenarios. This means that at first sight there might seem to be no particular difficulty in species adapting to the climate changes implied by the UKCIP02 scenarios. However, this ignores the effect of habitat fragmentation by the largely agricultural and urban landscape through which native plant and animal species might need to migrate as the climate changes. It also discounts immigration or spread of alien (non-native) species into the peninsula from abroad.

The effect of the warm Atlantic Ocean allows some southern and sub-tropical species to survive in the Isles of Scilly and in the coastal zone of the far South West. These species are likely to be favoured in the warmer climate scenarios. The principal native deciduous tree species that inhabit the area are towards the northern part of their geographical range within Europe, and so might cope with a warming climate without major difficulty. Those species whose distributions are principally to the north of the region and for which the South West is their southern or western outpost might be more severely affected regionally by climate change. This may be compounded by changes in agricultural practice driven by either economic, land-use policy or further climate-change considerations.

Heathland (wet and dry) communities in the South West range from the wet heath/bog complexes of mid-Cornwall, north to the Culm, then eastwards through the *Erica tetralix*, *Ulex gallii*, *E. ciliaris* boundary, across into the *U. minor–E. ciliaris* dry Dorset heaths. This cline is a unique feature of the region: is it feasible to conserve it long-term?

Source unknown

Key Issues

- In a warmer overall climate, species at the southern edge of their biogeographical range are probably most at risk of loss from the region.
- Warmer winters will adversely affect those species suited to a harsher winter climate.
- Reserves set aside for particular groups of species are fixed in space, but the species currently found there may not thrive under new climatic conditions, resulting in overall species loss and local extinction.
- Some regional Species Recovery programmes may be put at risk if the more extreme climate scenarios become reality.
- Biodiversity is strongly influenced by land use, and so policy responses should be developed in terms of integrated land-use management (including integrated marine and coastal zone management: see other domains).
- Agricultural changes resulting from adaptation response to anticipated climate change could have a profound effect (positive or negative) on biodiversity.
- The sector is well informed and believes in climate change scenarios, but is hampered by site-based legislation relating to a fixed interest at each site, and is guided by a National Vegetation Classification (the NVC, which lists groups of species that share similar ecological requirements), which is based on data from the 1970's and might not include potential species assemblages in a changed climate.
- The sector should apply similar criteria to coastal areas of nature conservation importance in respect of protection against sea level rise, as it calls upon others to apply to areas for development or agriculture (viz. avoid calls for unsustainable coastal protection)

Better use could be made of palaeoecological data to inform statutory agencies as to the changing species assemblages that have occurred in the region during the Holocene, and that might provide analogues for times of warmer climate.

Species loss

Of prime concern is that some species with northern distributions may be lost from the South West in a warmer climate. For example the MONARCH study simulates loss of the large heath butterfly from southern Britain (including the South West) in the UKCIP98 scenario for the 2050's (Berry *et al.*, 2001). It also implied potential loss of other species from southern Britain in a warmer climate. But the maps of simulated distributions for 1961-90 may give a false impression, and it must be remembered that the MONARCH study, while useful, was not based on the current UKCIP02 scenarios.

Several plant species feature in the South West in the simulated maps for 1961-90, while the simulated distribution maps for the 2020s and the 2050s show subsequent losses, but in reality several of these species are already absent from the South West. *Salix herbacea*, *Carex bigelowii*, *Geranium sylvaticum*, *Blysmus rufus* and *Linnaea borealis* were not recorded from the South West in the BSBI Atlas (Perring and Walters, 1976) — in fact the last-named is already absent south of the Yorkshire Dales — thereby exaggerating the "loss" of such species in the simulated distribution maps. The issue of potential loss of species must not be denied, but concern must be based on real present distributions. Interestingly, the MONARCH study showed benefits in the South West for the red squirrel (*Sciurus vulgaris*) — a BAP-priority species — under all scenarios, with expansion in its 2050's distribution across the region: "this [simulated] retreat in the north and concomitant expansion in the south is a most unusual [simulated] response that has not been seen with any other species" (Berry *et al*., 2001, p. 65). It also runs counter to the experience of a decline of the red squirrel's former southern distribution over the past 100 years during a period of overall climate warming (clearly, other factors may have been at work over the past 100 years).

A gradual loss of clubmoss species in the South West has been taking place over the last century (partly owing to habitat change), such that Alpine clubmoss was recorded on Exmoor and Dartmoor before 1930 but not subsequently (Perring and Walters, 1976). Climate change may result in extinction of remaining clubmoss species whose main distribution is more northerly in Britain but that presently have southern outposts on moorland of the South West region, for example *Huperzia selago* and *Lycopodium clavatum*.

Opportunities for range expansion

The warmer climate may provide opportunities for range expansion in the South West for a number of mobile species (especially birds and invertebrates) that presently may be towards the northern outpost of their range. There is already some evidence that this can occur if there is a sequence of warmer summers and/or milder winters, for which the Dartford warbler is a particular example.

> **In a climate of drier summers, arable cultivation on chalk downland may decline where there is no potential for crop irrigation, and this would provide a significant opportunity to expand the area of calcareous grasslands in the South West.**
>
> Source unknown

Climatic effects on landscapes

It is expected that as climate changes, so agriculture itself will change, with potential far-reaching consequences for landscapes. For example, the position of the moorland edge in the South West has varied over centuries according to a combination of economic pressures, agricultural demands (such as during the Napoleonic Wars) and climate change (such as during the Medieval Warm Period). It is the effect on agriculture of climate change that may have the greatest consequences for the character of landscapes in the region.

> **"… populations on the edge of their range are responsive to limatic changes which may render redundant resources which have been devoted to them. The rapid rise and fall of butterfly populations illustrates this clearly. Our efforts could be better spent on more tractable problems than trying to create the micro-climate of Spain on English grasslands"**
>
> (see http://www.eco-action.org/dt/hambler.html)

Risks that have been identified include:

- Nature Reserves established with particular rare species may lose that species if vulnerable to climate change or to consequences of climate change (e.g. fire incidence; drought incidence).
- Possible long-term changes in composition of plant communities and corresponding shift in fauna. Examples include heathland on Exmoor.
- Potential for species extinction as a result either of direct climate change effects, or of severe local weather events, and also failure to migrate between habitats to top-up reduced populations.

Opportunities that have been identified include:

- Reorganization of agriculture can and will provide opportunities for nature conservation objectives to be realized, provided climate change effects are taken into account.
- Local invertebrate rarities (including several southern grasshopper species, and the bee wolf — a solitary wasp and former Red Databook species) and some bird species (e.g. Dartford warbler onto Exmoor) could be favoured by warmer temperatures.
- Dorset heathland could be safeguarded by removing forestry from former heathland and so expanding the heathland habitat to act as buffer against increased fire risk. (Pers. Comm., English Nature).

Effects of climate changes on agriculture may impact also on biodiversity and on the practice of and opportunities for nature conservation, with such concepts as set-aside, stewardship, and successor schemes, etc., as intimated in the Curry Report, likely to have implications for biodiversity and nature conservation. However, there is the danger of possible over-emphasis amongst nature conservation organizations on loss of conspicuous species (e.g. colourful butterflies; conspicuous flowering plants) and under-emphasis on other types of less conspicuous or less-studied organisms whose distribution may be more severely affected either by climate change and/or by agricultural change.

The Way Forward

Mussner and Plachter (2002, p. 3) argue that a major reason nature conservation often fails is that there is no standard methodology. In fact, palaeoecological data (studies of ancient plant remains) suggest that while plant community formation is likely to be influenced by climate it is not determined by it. Consequently it is possible that if too rigid a protocol is used when dealing with community responses to climate change, effective conservation will not occur.

Watts (2001) investigated planning for biodiversity in the wider countryside and identified a number of competing issues. He argues that the traditional approach to nature conservation in England has been to protect a series of small, isolated sites, but that recent research has demonstrated this to be inadequate, suggesting a need to direct energies more towards conservation in the surrounding wider countryside. He points out that there are considerable difficulties associated with achieving biodiversity objectives in the wider countryside, as there is a heavy reliance on non-statutory planning mechanisms. His work contained case studies on particular habitats in the South West, including the Culm grassland in Devon, but the general principles have wider application in the South West region.

Perception of Adaptation Issues

Although climate change is widely perceived as an issue within the sector, the adaptation responses are less clearly developed at present, especially as nature reserves are fixed in space but mobile organisms are not. The MONARCH study suggested that climate change should be incorporated within Biodiversity Action Plans (BAPs). This may be an appropriate mechanism, but other opportunities, identified by Watts (2001) through case studies from the South West, might also be taken.

Examples of Good Practice:

- **Managed retreat of parts of southern coast, and of 'unmanaged' or 'natural' retreat at Porlock. (Recognising that sea-level rise will happen, and it is not always sustainable to defend the coast).**
- **The only mainland site of the ladybird spider (previously thought extinct in Britain but re-discovered in Dorset in 1980) has been extended, and studies conducted in terms of suitability of introduction to nearby sites based on continental parallels.**

One of the outcomes of the Wales UKCIP Climate Change Scoping Study was identification of the need to create corridors between habitats so as to ensure dispersal of organisms as the climate changes. Although there has been debate over the effectiveness of corridors in the dispersal of some wildlife, and whilst claims of the relevance of island biogeography to nature reserve design have been questioned (Hambler and Speight, 1995), this is not the general perception within the statutory and voluntary conservation agencies of the South West. Practitioners here believe both in applications of island biogeographical theory to nature conservation and of the desire for corridors between habitats. Indeed within the region, there is persuasive evidence that corridors such as rail routes have permitted the dispersal of alien species such as the Oxford ragwort (*Senecio squalidus*) and the butterfly bush (*Buddleja davidii*) throughout the rail-served parts of the South West, such that these species are now widespread and well established (Tikka *et al*., 2001).

The particular physical characteristics of the region suggest that creation of corridors between reserves may be an appropriate adaptive response to concerns over the biogeographical effects of climate change, although this would still result in (and could indeed, facilitate) loss of northward migrating species from the region and the possible spread of alien 'nuisance' species.

Knowledge and Information Base

Parts of the sector are very well informed on climate change issues and many practitioners and supporters find the climate change scenarios credible. The Woodland Trust has sought to involve the public in monitoring of key phenological indicators (see www.phenology.org.uk). However, Wildlife Trusts are concerned that a significant proportion of potential supporters are sceptical of the role of human influence in climate change, and are not sufficiently persuaded by present campaigning literature that focuses on the topic. This may affect the capability of wildlife trusts to generate sufficient budget to deal with climate change issues.

Research Needs

There is a need for further research on effects of climate change on species and habitats in the region. Although part of this work will involve contemporary monitoring, and may also involve computer modelling, it is suggested that research should also incorporate analysis of long-term biological records (where available) and of other palaeoecological data. Dartmoor, Exmoor and the Somerset Levels in particular have long palaeoecological records, and other locations within the region have sediments amenable to comparable detailed study.

Recommendations for action

For those parts of the region (e.g. Exmoor) where long-term (>1000 years) continuous palaeoecological records can be generated, there could be an investigation into landscape changes and species responses to previous episodes of climate change (e.g. before and during the Early Medieval Warm Period), to act as an approximation for vegetation response to anticipated climate changes. While useful, it is recognised that the use of such data would need to be combined with other methods of study.

The MONARCH study suggested that a more forward-looking, flexible and dynamic approach to nature conservation is required to accommodate climate change, involving habitat management and landscape-scale responses.

Challenges and Opportunities of Key Climate Impacts on Biodiversity Domain

Climate Impacts		Challenges + Opportunities
Summer Temperature Increased	C	Increased incidence of fire, especially to Dartmoor, Exmoor and to Dorset heath and other heath areas.
	C	Increased risk to species that suffer in times of drought.
	C	Risk of expansion of naturalized aliens, such as *Fuschia* in Cornwall.
	C	Possibility that species at southerly limit of their range may be competitively excluded.
	O	Species ranges likely to be affected, with increased numbers of those presently at the northern limit of their range.
	O	Rare *Lepidoptera* at northern limits of ranges may be favoured.
	O	South West has *c*. 50% of UK resource of calcareous grasslands; these areas could be expanded if arable agriculture declines on chalk downland.
Summer Rainfall Reduced	C	Drying up of streams — both over hard-rock geology and groundwater fed, such as chalkland streams — and consequent loss of species. Possible threat to water vole in Wiltshire chalkland streams.
	C	Reptiles (e.g. smooth snake) and birds, e.g. nightjar, Dartford warbler, woodlark potentially adversely affected in Dorset heathland (SPA) by increased incidence of deliberate/accidental fires in dry summers.
	C	Wet heaths may suffer, as may blanket bogs and other wetlands.
	O	Change in agricultural practice may provide opportunities for achieving biodiversity targets, especially if more land is set aside from agriculture.
	O	Removal of commercial forestry from heathland areas would create larger areas of heath and might act as a buffer against forest fire incidence.
Winter Temperature Increased	C	Species with their southern breeding limit in South West may become excluded (e.g. red grouse believed recently extinct on Exmoor, and not suitable for reintroduction under anticipated climate scenarios; golden plover now transitory and no longer breeding in South West).
	C	Plant species that need sustained cold period of winter dormancy may be adversely affected.
	O	Some species may be favoured by milder winters (e.g. Dartford warbler)
	O	Need for monitoring of species changes could lead to increased job opportunities.
Wintertime Rainfall Increased	C	Changing distribution of seasonal precipitation may affect agricultural crop regimes (Spring-, not Autumn-sown), and so affect wildlife in winter.
	O	Delivery of Biodiversity Action Plans through changes in agricultural regime; may also provide opportunities for reappraising biodiversity targets.
Sea Levels and Tides Increased	C	Potential loss of coastal and estuarine habitats and increased erosion of cliffs with loss of characteristic species.
	O	Opportunity for integrated land management in the South West estuaries and in Somerset Levels (and inland) to manage effects of increased winter precipitation and of high tides; managed retreat may include encouragement of saltmarsh creek systems to absorb tidal energy.
Longer Growing Season and Reduced Frosts	C	Species that require sub-zero period to break seed dormancy or encourage growth could be adversely affected. (Crowberry, *Empetrum nirgum*, requires cold winters for successful growth).
	O	Opportunities for species with pronounced southern distributions to become more widespread (but possibly at expense of other species).

Climate Impacts		Challenges + Opportunities
Flooding Increased	C	Flood risk to river bank-dwelling species.
	O	Integrated land management to regulate flooding would have a positive impact on biodiversity.
Potentially Increased Winds and Storms	C	Potential threat to Chesil Beach and its saline lagoon (danger of breach and consequent loss of international SPA/RAMSAR site; also a candidate Special Area of Conservation)
	C	Windthrow of forest and other trees.
	O	Field-layer species favoured in areas of wind-thrown forest. Opportunities for butterflies in resulting forest mosaic.
	O	Opportunity for sustainable management on coast of Somerset Levels, which would encourage biodiversity.

COASTAL DOMAIN

Scope

Key activities occurring within 1km of the land/sea interface including issues of coastal erosion, management and defence.

See Also

Tourism and Leisure, Rivers, Fisheries, Bio-diversity and Transport.

Background

The coastal zone of the South West region is fundamental to its economy and its inhabitants' quality of life. Of all the UK's regions, it is the South West that is the most influenced by the sea. The importance of the coastline to the region's economy is emphasized by the publication of "South West Coast: A Prospectus for the Future" produced by the South West Coastal Issues Group in 2002 with the support of several key regional stakeholders.

The South West of England's 1,020 km of coast extends from the Bristol Channel to Land's End and along the English Channel coast to Christchurch, and includes the Isles of Scilly and the Isle of Lundy. Parts of the region therefore have a truly maritime nature with the longest seaboard and the highest ratio of coastline to land area of any region in the UK.

Many of the principal urban areas of the region, which include Bristol, Plymouth, Exeter, Torbay and Bournemouth/Poole, are situated on or very near to the coast. Bristol/Severnside is one of the UK's largest commercial ports; Plymouth is the UK's largest naval base; and Bournemouth's tourist trade is second only to London in terms of hotel accommodation.

The national and international significance of the region's coast is shown by its range and number of environmental designations:

- A UNESCO World Biosphere site (Braunton Burrows in North Devon), the only natural UNESCO World Heritage Site in mainland UK (the Dorset and East Devon Coast), and a potential further World Heritage Site near the Cornish coast (the historical tin and copper mining area surrounding Redruth/Camborne).
- The UK's highest number of coastal and marine Special Areas of Conservation (49) and Special Protection Areas (59) which form part of Europe's Natura 2000 network.
- England's only Marine Nature Reserve (the Island of Lundy) and all but two of the UK's Voluntary Marine Nature Reserves.
- One third of its area (and a high proportion of the coast) designated as Areas of Outstanding Natural Beauty (AONBs), one of the nation's National Parks (Exmoor) bordering the Bristol Channel coast, and 60% of the country's Heritage Coast.

In addition, the South West has:

- Nearly half (187) of the UK's top beaches (as listed in the Marine Conservation Society's Good Beach Guide) whose quality consistently exceed the national average.
- Over 400 kilometres of the coast owned by the National Trust, including 40% of the total length of the Cornish seaboard.
- The South West Coast Path which is the longest National Trail in the UK, and a huge range of coastal leisure and watersports activities available.

Key issues

- Rising sea levels and potential increased storminess will increase rates of coastal erosion. Protecting coastal assets (or relocating them) may be costly if the effects of climate change are sudden rather than gradual.
- Increased wave heights and potential storminess may lead to damage to coastal amenities including piers, promenades, beach cafes etc. Flooding caused by storm surges and sea level rise may damage coastal rail lines and roads. The unpredictable coastal dynamics may lead to erosion of some beaches. These problems are likely to be particularly acute in the region due to the fact that the landmass is subsiding.
- Natural assets in the coastal zone may be lost, such as wetlands, mudflats, saltmarshes, beaches and sand dunes. The flora and fauna associated with these will also be affected.
- Existing areas of saline intrusion may become more extensive, though more as an indirect result of changing water balance than as a direct consequence of sea level rise, except on the most low lying coasts.
- Retreating from coastal areas may not be viable in many areas of the SW such as the Isles of Scilly and protecting the area at risk may be uneconomical in many places. The resulting costs of maintaining and building new coastal defenses are likely to be significant.

Specific Climate Issues for the SW

Of major significance to the South West are the potential impacts of climate change on its functions, all of which depend upon its physical characteristics, appealing landscape, cultural heritage, natural resources, and rich marine and terrestrial biodiversity. Climate changes such as rising sea levels, increased wind speeds and storms and resultant storm surges will significantly effect the coastal zone. In addition, changes in seasonal temperatures and rainfall patterns will also have less direct but equally important impacts.

Risks that have been identified:

Rising sea levels and possible increased storminess are likely to increase rates of coastal erosion. Natural assets in the coastal zone may be lost and areas of saline intrusion will increase, particularly in low lying coastal areas. Many beaches too may be 'squeezed' by rising sea levels, which could threaten their viability – particularly those which are only exposed at low tide. Managers of areas vulnerable to sea level rise will face stark choices on how to manage those sites in future.

Opportunities that have been identified:

Increases in tourism may bring a boost to the economy in the coastal zone. There may be increased opportunities for developing outdoor recreation and watersports. There may be further opportunities for offshore wind power development. In addition, there maybe opportunities for new crops and a longer growing season may lead to improvements in agriculture in some coastal areas.

Specific locations vulnerable to climate change include:

- Somerset Levels – The use of LIDAR is needed to determine absolute level and thus flooding risk
- Steep-sided Cornish Valleys – e.g. Polperro and Pentewan. River and flood defence is needed to improve defence against flash floods.
- Isles of Scilly – The islands are particularly vulnerable to sea level rise and storm damage leading to impacts on whole community and its economy.
- Natural coastal assets – e.g. Loe Pool, the largest freshwater lake in Cornwall may be flooded by saltwater.
- Dorset coast – coastal erosion of cliffs is damaging infrastructure and creating dangerous landslides onto beaches.
- Quays and harbours – e.g. Devoran Quay and Mullion harbour on the Lizard peninsula. Rising sea levels and increased storminess could threaten quays and harbours.

coastal and marine resources. The coastal zone provides important economic, transport, residential and recreational

- Estuaries – e.g. Helford, Camel, Gannel catchment. Estuaries may be silted up due to changes in water flow. Businesses may be effected by decrease in boat traffic due to storm events.
- Beaches – Beaches in the region may be eroded and surf breaks may be altered by shifts in sediment e.g. Fistral Beach. Opportunities may be available due to increased tourism.

The Way Forward

- There is a continuing need to incorporate accurate measurements of land level subsidence into sea level rise calculations.
- With increased risks of storms, tidal surges and flooding frequency, there is concern about rising costs of insurance and compensation. This has the potential to impact on development within the coastal zone, and so is likely to engender concern and thus both change and research.
- Inland flooding can exacerbate coastal flooding, especially where there is a high spring tide or surges.
- There is a need to establish ownership of coastal defences and the land they are on in some circumstances.
- There is a need to further establish the value of land/environment in relation to the cost of defending it.
- There is a need to establish a system of publicly accepted justification for which areas of land should be sacrificed and which defended.
- There is a growth in Integrated Coastal Zone Management (SMPs, LEAPs etc), but such plans are not statutory and could be more effective if they were.
- Need for an integrated governance for decision making. Integrated Coastal Zone Management (ICZM). SMP's, LEAPS's e.g. Porlock beach/marsh.

Knowledge and information base

The value of the coastal zone to the South West's inhabitants, and the enormous pressure on it, provide strong incentives for a greater scientific understanding which can ensure efficient and sustainable management. Research undertaken within the coastal zone to assess the impact of climate change is vital. However, it is essential that links are made between the physical impacts of climate change and the effects these have on the local economy. For example damage to the coastal railway at Dawlish (the only Rail link into the SW from the North and East) would have considerable impacts on the economy of the region. In addition coastal managers need to take into account future changes in sea levels and increases in storminess when planning coastal defence. Some areas may have to be sacrificed to rising sea levels and this will provide some difficult choices for the future.

Recommendations

- Utilise opportunities for artificial reefs for surfing and diving as well as for recreational fisheries for exotic southern species (e.g. tuna) brought about by climate change.
- Invest in research into offshore renewable energy sources - wind, wave energy and reassess the environmental and economic effects of the Severn Barrage.
- Carry out more accurate measurements of land level subsidence to improve the models for rise in sea level.
- Encourage further research into the erosion of coasts and beaches; a careful balance will be needed between protecting certain assets and retreating from others where costs of sustaining coastal defences or replenishing beaches becomes uneconomic.
- Rationalise the current split in responsibilities for flood and coastal defence and work towards more integrated management.
- Monitoring of coastal erosion and research into coastal defence needed as well as research into the movement of sand and shingle to ensure the maintenance of beaches.
- Assess the risk of remobilisation of toxic substances (e.g. heavy metals) in riverine/estuarine sediments.

Challenges and Opportunities of Key Climate Impacts of Coastal Domain

Climate Impacts		Challenges + Opportunities
Summer Temperature Increased	C	Increased tourism (if brought about by this aspect of climate change) may lead to environmental damage within the coastal zone (e.g. litter and surface erosion to coastal footpaths, damage to flora and fauna, etc).
	O	Increased tourism in the coastal zone and islands may lead to a boost in the economy and an increase in watersports, environmental tourism and outdoor activities.
Winter Temperature Increased	C	Negative impact on flower farmers on Isles of Scilly as their competitive advantage due to early flowering is lost to other areas.
	O	Potentially more tourism on short winter breaks.
Summer Rainfall Reduced	C	Water supply problems particularly on Isles of Scilly.
	C	Negative effects on flora and fauna in coastal zone due to droughts and possible increased erosion of coastal paths.
	O	Increased tourism as above.
Winter Rainfall Increased	C	Flooding in coastal zone areas leading to damage to natural assets and infrastructure e.g. subsidence leading to disruption to transport services.
	C	Increased run-off and leaching from agricultural land potentially damaging to flora and fauna in coastal zones of land and sea.
	C	Remobilisation of metalliferous mine wastes affecting bathing water quality and inshore fisheries
Sea Level and Tides Increased	C	Erosion of cliffs and beaches damaging natural assets as well as infrastructure and archaeological heritage.
	C	Loss of beaches and coastal footpaths in the South West could damage local economy. Cliff side hotels are also particularly vulnerable.
	C	Damage to coastal defences including extensive protection to farmland.
	C	Damage to quays and harbours
	C	Flooding of Somerset levels and Isles of Scilly damaging infrastructure and natural assets.
	C	Increased water in harbours and estuaries may lead to increased sediment and need for dredging.
	C	Damage to transport routes due to coastal erosion (e.g. at Slapton Ley)
	C/O	Changes in tides, sediment and sea levels may affect surfing breaks, creating new ones or making existing ones less practical or worthwhile to use.
	O	Erosion of cliffs may expose previously unseen archaeological remains.
	O	Creation of new habitats by inundation of sea water.
Larger Growing Seasons + Reduced Frosts	C	Negative impacts on agriculture in coastal zone e.g. damage to horticulture
Flooding Increased	C	Increased risk of flooding to coastal towns e.g. Pentewan, Helston. Salt water flooding of natural assets (e.g. Loe Pool). Loss of saline lagoon habitats and associated flora/fauna due to saltwater inundation.
Potentially Increased Winds and Storms	C	Storm surges leading to flooding of coastal areas may damage harbours, quays, marine businesses and natural assets. Publicity of areas damaged by storms can lead to a negative image and detrimental effects on tourism.
	C	Many coastal hotels and businesses get a lot of trade from boats (e.g. Helford estuary) which severely declines during storms and strong winds.

Climate Impacts		Challenges + Opportunities
Potentially Increased Winds and Storms	C	Small businesses which are numerous in the coastal zone could be badly effected as they will not include extreme events in business planning
	C	Damage to infrastructure in coastal areas e.g. homes, cafes, shops, hotels, road (e.g. Slapton Ley) and rail networks (e.g. Dawlish).
	C	Increased erosion of natural assets e.g. beaches and cliffs.
	C	Storm events on the Isles of Scilly damage the whole economy.
	O	Potential to develop “storm-watching” tourist trade.
	O	Increased wind speeds can be beneficial for wind farms and may lead to further opportunities for development of on and offshore wind farms.

FORESTRY DOMAIN

Scope

The forestry sector including areas of managed woodland both for timber production and for amenity forest.

See also

Agriculture; Biodiversity

Background

Forestry within the region varies from Forestry Commission plantations of softwoods (e.g. Sitka Spruce – *Picea sitchensis*) to areas of managed broadleaved (hardwood) trees, principally of native species, such as oak (both *Quercus robur* and *Q. petraea*) but also of species possibly introduced to parts of the region (such as beech, the extent of whose natural, native distribution in the South West is disputed). Forestry occupies upland areas (as discrete 'blocks', such as in parts of Dartmoor, Exmoor and the Mendips), lowland, and includes some large areas of variable topography (such as the Forest of Dean).

Depending upon the criteria chosen (e.g., whether commercial forest products are produced), forestry might not easily be separable from areas of amenity woodland, or woodland reserves. Within the South West, for example, are areas of (largely, broadleaved) woodland owned or managed by the National Trust and especially by the Woodland Trust, which has a greater density of its sites in this than in any other UK region. For the purposes of this review, the focus has been on the commercial forest sector, but the scope includes also amenity forest.

Forestry is an economic activity that operates over relatively long timescales (in relation to other economic activities). It can take several decades or even hundreds of years for a tree to reach maturity, but the timber (or other) harvest is usually taken before full maturity and certainly before senescence. Return periods of 20 to 50 years for weather events therefore routinely have to be factored into site assessments (e.g. through calculating exposure values; assessing drought susceptibility, flood risk), and plantations must be capable of withstanding severe storm events.

Broadleaved trees are more susceptible to damage from major storms if these occur when the trees are in full leaf. For evergreen conifers (i.e., all plantation conifers in Britain, with the exception of larch), windthrow can be a major problem, and so any increase in the incidence of very severe storms may be problematic.

However, forestry is used to experiences with extreme weather events (for softwood crops grown for minimum of 20- to 40-years in marginal environments) and is used to assessing risks, and so is one of the sectors potentially well informed on the possible effects of climate change. Up until recently, however, the issue was not perceived as a major problem. Other issues have been higher up the forestry agenda, but within the next five years it is anticipated that the regional conservancies will be responding to the climate change agenda, prompted by work done by Forest Research.

Key Issues

- Until recently the sector has been slow to appreciate the gravity of the issue of climate change and respond accordingly.
- Forestry practice is set in the context of (inter-)national Forestry and Woodlands Strategy, in compliance with the Helsinki Accord, but this has no explicit reference to climate change.
- Likely to be a major shift in perception and in adaptation response within the next five years.
- A key driver for change may be the recent publication *Climate Change: Impacts on UK Forests* (Broadmeadow, 2002).
- Established forests are reasonably robust, and resilient to climate change.
- Establishment of new plantations of trees could be affected by soil moisture deficits.
- There is possible greater susceptibility to damage by green spruce aphid under all the climate scenarios suggested.
- There may possibly be greater susceptibility to *Phytopthera*.
- There are possible problems of imported diseases in a new climate regime.
- A major barrier to perception is conflicting reports in some of the broadcast media, which leads practitioners to believe there is no consensus on the direction and magnitude of climate change.
- Floodplain forestry may be a suitable adaptation response for continually flooded agricultural land. However, conifers could cause acidification of water bodies which would have negative water quality impacts.
- A possible barrier to adaptation response is in defining what constitutes a 'native' broadleaved species in a warmer climate scenario.

Potential risks

Awareness of climate change in this sector is slightly higher than in the late 1990s, and is probably higher than in many other sectors investigated in this study. Nevertheless, across the forestry sector as a whole, climate change is not yet taken seriously. (Pers. Comm. Anon.)

Although established forest trees are resilient to climate change (Broadmeadow, 2002), establishment of new forestry (or new planting within felled forest) is more susceptible. Under the more extreme temperature scenarios from UKCIP02, some native species may be put beyond their natural range in the UK. This may include beech in the southeast of England, although within the South West its native status is in dispute and the temperature effect may be less marked. So far as other native species are concerned, these are towards the north or north-west of their European geographical range (e.g. oak) and so are not threatened immediately in the climate change scenarios.

A major barrier to a shared perception of concern is the conflicting reports in some of the broadcast media, which leads practitioners to believe there is no consensus on the direction and magnitude of climate change. It is hoped that the recent Forestry Research publication (by Broadmeadow, 2002) will help to counter this, along with the release of the UKCIP02 data.

The major barrier to change in practice is the 40-50 year lead-time. Of the challenges presented above, wind damage is seen as a potential problem in amenity forests if severe storm incidence were to increase.

Positive Benefits

A potentially positive response from the climate change scenarios is an increased rate of forest growth. However, the causes of increased growth rate are difficult to disentangle, and may be due more to silvicultural practice rather than climate change, but a CO_2 fertilization effect is also possible. Unfortunately, faster growing trees may in some circumstances prove more susceptible to windthrow (damage to forests caused by strong winds involving roots being pulled from the ground and the whole tree being toppled).

"[Grey] squirrels are more of a threat to lowland forests [in the South West] than climate change ever will be."

District Forester

The Way Forward

The effect of climate change on forestry is summed up very well in a new publication entitled Climate Change: Impacts on UK forests, edited by Mark Broadmeadow. Forestry Commission Bulletin 125, Edinburgh. This has been published this year (2002) in association with the Institute of Chartered Foresters.

There is clearly a need to take predicted climate change into account in making long-term decisions about species choice and management systems. Advice before planting is available from the Forestry Commission, but local site assessors are best placed to evaluate individual sites. Overall, the pace of climate change can be accommodated satisfactorily with most species currently planted in the South West (except beech). Conifers have a 50-year rotation time, so no problem is envisaged for these, especially Douglas Fir (e.g. in Forest of Dean), although Sitka Spruce is slightly more of a concern.

There is a possibility that beech will not be living in a suitable climate when mature in 80-100 years (although it should still have climate space in the South West; see Broadmeadow, 2002). The precautionary principle suggests a policy that includes diversification of species and age structure, so as to spread risks. There is great potential for floodplain forestry in low-lying flat areas of the South West (eg in parts of Somerset), and there may be potential for urban forestry in the major conurbations, although space (and land prices) may be at a premium. On floodplains it is possible to plant willows as a robust land use, resistant to flooding; whilst in the upper parts of a catchment, forestry can be used to intercept precipitation, increase evapo-transpiration and reduce run-off, although this may have the effect of reducing river flows and availability of water resources for other purposes. Forestry can therefore be seen as a major tool for use as part of integrated land management schemes (see for example the River Parrett catchment).

In international discussions that have followed the Kyoto Protocol, carbon offset, by planting trees, is seen by some as a major mitigation policy. Some see the planting of forests as a method of sequestration of CO_2, but in reality this is neither a long-term mitigation solution, nor a long-term adaptation response, as CO_2 is only locked up for as long as the resulting wood is unburnt or undecayed.

Research Needs

Although climate change modeling in the UK is well funded, the implications of climate change for forestry and woodland ecosystems in the South West are largely unresearched. The impacts on woodland species and ecosystems in particular are uncertain, and remain to be researched in detail.

Recommendations

- Educate practitioners in the forestry sector, by reference to Broadmeadow (2002).
- Research the implications of climate change for forestry and woodland ecosystems in the South West.
- Research the impacts on woodland species and ecosystems in particular.

Challenges and Opportunities of Key Climate Impacts in Forestry Domain

Climate Impacts		Challenges + Opportunities
Summer Temperature Increased	C	Possible increase of fire incidence, or more intense fires, in coniferous plantations.
	C	More visitors to forests, so potentially greater fire setting and fire risk.
	C	Increased risk of pathogen attack.
	C	Extension of range of insect vectors of pathogens.
	O	Some insect pests may themselves suffer.
	O	Growth rate high on floodplains.
	O	Greater volume production.
Winter Temperature Increased	C	*Hylobius* and *Hylastes* beetle numbers may increase (affect new trees at ground level).
	C	Green Spruce Aphid may overwinter in greater numbers.
	C	Greater Grey Squirrel numbers and consequent damage.
	O	Less damage from winter cold.
Summer Rainfall	C	Decreased growth rate in areas susceptible to summer droughts.
Decreased	C	Drought crack damage to conifers.
	C	Soil moisture deficits leading to plant stress and abnormal root growth.
	O	Opportunity to introduce more drought-tolerant species
		NB Increased CO_2 levels will increase growth while causing stomatal closure and thus reducing water loss.
Winter Rainfall Increased	O	Decreased soil quality from increased wintertime precipitation
Sea Levels and Tides Increased	C	Only a problem where forests are planted in coastal locations; not significant in South West, except in instances of new floodplain forestry.
	O	Floodplain forestry (willows) could be an adaptation response for agricultural land that is continually flooded and so becomes uneconomic to farm.
Longer Growing Season and Reduced Frosts	C	Risk of unexpected Autumn frosts becoming more damaging as a result of later hardening and predicted diurnal temperature ranges in the south, due to plant conditioning to the “new” normal conditions. This is also a consequence of increased CO_2 levels.
	C	Norway Spruce may cease to be a productive species (not a feature of timber production in South West; grown for Christmas trees).
	O	Increased growth rate (also as a consequence of increased $C0_2$.)
Flooding Increased	C	Root damage. Makes trees then more susceptible to summer drought.
	C	Alternating flooding and drought places stress on trees, possible making them more susceptible to *Phytopthera* infections
	O	Flood plain forestry could be an adaptation response for agricultural land that is continually flooded and so becomes uneconomic.
Winds and Storms Potentially Increased	C	Need to minimise risks, as gusts of more than 40 m per sec result in widespread damage. Amenity forests susceptible.
	O	Potential impact not thought to be that great in commercial forests, as forestry is already conducted in a windy climate. Continuation of best practice thought to be sufficient.

MARINE FISHERIES DOMAIN

Scope

Coastal commercial fisheries and associated activities. Some consideration of inland fisheries included for completeness of cover.

See Also

Rivers, Tourism and Leisure, and Coastal.

Background

The South West region's coastal waters mark a boundary between warm southern and cool northern areas. This creates an abundance of different species in one of the richest marine and coastal habitats in the world. Therefore, marine fisheries are particularly vulnerable to climate change and may face significant challenges to this important part of the local economy.

Although the fishing industry is in relative economic decline, 42% of England's fishing operations are in the South West. The main fishing ports are Newlyn, Brixham and Plymouth. In 1997 the region’s ports landed fish from UK vessels to the value of £62.8 million and accounted for more than half by quantity and value of all fish landings in England (with Newlyn in the lead). Fishing dominates the identity of many of the small coastal settlements, playing a vital role in the region’s history and image. For every person employed in fishing there are another 3.5 jobs in distribution and processing.

The South West has a mixed fishing fleet with no one species dominating landings. In general they are low volume high value species which are popular outside the UK, for example; species such as megrim, hake, sole and monk. The region also has the highest concentration of landings of pelagic species such as mackerel, pilchards and sprats.

Shellfish landings are also substantial, of which crabs and lobsters are important. Half of all shellfish waters in England and Wales are in the South West (9 out of 18). The EC Shellfish Waters Directive controls their quality and in 1998 the South West had 100% compliance. In the last survey in 1995 all but one estuary in the region was classified as good, a high level of quality only equaled by the Southern Region.

South Devon is one of the major centres for crab, in particular Brown Crab, in the UK. 100% of the crab caught goes for live export, except during September, October and November when around a third is sent to be processed in factories around the region. The crab must be transported live which restricts the market, as they must be relatively close to home if the crab is to survive the journey.

Approximately 90% of the fish landed in the region are exported to other parts of the country and direct to the continent. The market in the South West is mainly for fresh fish, very little frozen fish, and limited value-added industry.

Fish from Newlyn are transported by lorry to other parts of the UK, or in most cases are taken via Plymouth or Poole to the continent. Brittany Ferries are reluctant to take fish lorries from Plymouth especially during the summer months (as the smell would not be pleasant for passengers), therefore it means a long journey by road from Newlyn to Poole. The South West is highly dependent on its road and ferry links but these are presently inadequate for the rapid transportation of a perishable product, which is vitally important to the region’s economy.

Key issues

- Rising global temperatures are likely to reduce the overall productivity of the oceans, affecting species across the entire marine food chain, from plankton, to many fish species and seabirds. Such changes would exacerbate current pressures on fish stocks, and would have serious consequences for fisheries in the region, which are important to the local economy.
- There is recent evidence to demonstrate that fish species are changing in local waters. Fish are unable to control their body heat internally, but do so by swimming to waters that suit their temperature optimum. Fish are particularly sensitive to small changes in temperature, causing changes in distribution at the extremities of their ranges.

> **“Recently spotted off the South West coast are the Knobbed Triton (the largest marine snail), Sea Slug, Long Snouted Sea-horse, Trigger Fish, Garfish and the Sunfish.**
> **New records of fish caught in the last 10 years include Pandora, Couche’s Sea Bream, Spanish Mackerel, Long-fin Tunny, Basking Shark, Hammerhead shark and Thresher Shark. None of these species is commercial.”**
>
> Tony Stebbing
> University of Plymouth

- New research shows increasing numbers of new southern fish species appearing in Cornish waters over the period 1960-2001 (Stebbing *et. al*. J. Mar. Biol. Ass.UK 2002)
- With the warming of the North Atlantic, there will be significant losses of indigenous South West species to the north (e.g. sea trout or cod may be lost altogether from these waters.)
- Research has shown that recruitment is inversely related to temperature for a number of cod populations, particularly those at the southern extremity of their range. (e.g. CEFAS has shown significant losses of fertility in cod as the southern North Sea has warmed.)

Specific Climate Issues

Significant impacts can be expected on fisheries. Rising global temperatures are likely to reduce the overall productivity of the oceans, affecting species across the entire marine food chain. Such changes would exacerbate current pressures on fish stocks, and would have serious negative consequences for fisheries in the South West, which are important to the local economy.

Areas particularly vulnerable are those in which a high proportion of the community is involved in the fishing industry. These naturally tend to be coastal areas, and as such are also vulnerable to increases in sea level and potential storm events.

Risks that have been identified include:

- Changes in fish stocks and populations could have significant impacts on local fisheries. Fish production will suffer if wetlands and other habitats that serve as nurseries are lost with sea level rise.
- Stocks of more northerly species such as cod, sprat and plaice may decrease.
- Increasing sea levels and storm events could damage harbours and quays.
- Estuaries may become silted up leading to permanent dredging to ensure access.
- Increasing pollutants from concentrated river flow during droughts and from leaching of agricultural land during high rainfall may lead to poorer inshore water quality.
- The remobilisation of metalliferous mine and industrial wastes due to storms and increased winter rainfall may pollute inshore waters and have potential impacts on fisheries (larvae), and shellfish stocks.
- Climate change impacts are likely to exacerbate existing stresses on fish stocks - notably overfishing and pollution.

There is however, potential for development of recreational fisheries for exotic southern species (tuna, shark) which would allow diversification and boost the tourism industry.

There may be new warmer water species for aquaculture (clams, goose barnacles, seaweeds etc).

Artificial reefs for surfing and diving may be developed, and diving in particular could benefit from the appearance of "rarities" with no commercial value.

Changes in fisheries policy will have dramatic impacts on the local fishing industry, although it cannot be absolutely predicted how these will take effect under changing climatic conditions.

Any strengthening or weakening of the Gulf Stream as a consequence of climate change will affect the degree of warming of waters around the region, although it is noteworthy that the UKCIP02 scenarios do not show any evidence for cooling.

> **"UKCIP forecasts suggested that with warming, species will shift their distributions pole-ward at rates of 50-80 km per decade. While this is a crude estimate, it proves right for the observed northward advance of 60 km per decade of the Sailfin Dory over the period 1960 to 1995."**
>
> Tony Stebbing, University of Plymouth

The Way Forward

- As one fishery disappears due to loss of the species from the region's waters, fishermen are likely to move on to other species.
- A new vision is needed for fisheries management involving stakeholders and government agencies.
- There is increasing need to renegotiate Common Fisheries Policy in light of climate impacts.
- There has been little work to date on the effects of climate change on commercial fish species, but the upcoming regional-led MarClim study will be of great benefit in this area of research.
- A major barrier to be addressed is that according to stakeholders in the region, fishermen are unlikely to plan long term for changes in fish species and will adapt on a 'day-to-day' basis. In other words, the industry is likely to be reactive rather than proactive without significant external inputs.
- While it is likely that fishermen will adapt to changes in fish species around the region's coast, reductions in the overall productivity of the oceans will exacerbate current pressures on fish stocks and thus the industry as a whole.

Recommendations

- Encourage the development of artificial reefs to capitalize on the appearance of exotic species for diving and recreational fisheries. This will result in immediate benefits to the industry regardless of the pace of climate change as it is known that exotic species are already appearing regularly in South West waters.
- Thermal boundaries for fish species are known and therefore research should be enhanced into shifting geographic ranges, which are presently less well understood.
- Continuous monitoring of key determinants of environmental quality is essential to monitor change in the region and encourage proactive industry responses.

- Existing databases (e.g. ERICA, operated out of the Cornwall Wildlife Trust) providing long-term data should be maintained, developed and utilised.
- At the present time very little is known about the changes in fisheries in the region due to climate change. Further research is required to provide a baseline of stocks and species presently found in the region. In addition, continuous monitoring and the upkeep of databases is required to identify changes in fish species and stocks as well as to monitor temperature changes in the marine environment.

Challenges + Opportunities of Key Climate Impacts to Marine Fisheries Domain

Climate Impact		Challenges + Opportunities
Summer Temperature Increased	C	Changes in fish stocks in response to warming of inshore waters may result in the loss of certain commercial fisheries and the development of others.
	C	An extended tourist season due to warm weather may lead to fish being exported to the continent via Poole rather than Plymouth more frequently as the ferry companies will not transport fish lorries from Plymouth during summer months, when the tourist trade takes priority.
	C	Trout farming is known to be highly sensitive to changes in water temperature and quality. Changes in air temperature and in the nature and frequency of rainfall events could have a significant impact on aquaculture.
	C	Increased water temperatures may also reduce microbial quality, leading to a deterioration of shellfish growing areas in the region.
	O	If sea temperatures increase, there may be scope for aquaculture of new species, which may offer opportunities for the industry to diversify and reduce pressure on existing stocks.
	O	Increase in southern species of fish and unusual sightings e.g. sunfish, sharks etc. may be beneficial for tourism.
Winter Temperature Increased	C	May extend the breeding seasons of specific species, again leading to changes in the fisheries present in inshore waters.
	C	As for increased summertime temperature.
	O	May also enhance existing fisheries by extending breeding seasons.
Summer Rainfall Reduced	C	Aquaculture in the UK is largely tied to the farming of salmonids (e.g. rainbow trout, Atlantic salmon), mussels and oysters. Salmonids are particularly susceptible to changes in water quality and climatic conditions. Temperature influences growth and, among salmon, the timing of sexual maturity.
	C	Low rainfall will lead to low river flow and hence a concentration of the pollutants within rivers. This could lead to follow-on effects to marine life when pollutants are carried out to sea.
Winter Rainfall Increased	C	Potential detrimental impact of repeated CSO discharges into vulnerable coastal waters, particularly in areas with bivalve shellfish.
	C	Potential for increased leaching of nitrate based agrochemicals into vulnerable inshore waters, which combined with elevated wintertime temperatures, may increase the susceptibility of these areas to planktonic blooms. Vulnerable species are bivalve molluscs, particularly scallops and oysters. Closure of scallop fishery would have ongoing impacts on other inshore fisheries with the displacement of effort.
	O	Inshore shellfish stocks may increase if fishing effort is reduced which may enable more proactive management.
	C	Soil runoff from areas adjacent to subtidal and intertidal areas could lead to silting up, species being smothered, increased water turbidity and shore erosion.
Sea Level and Tides Increased	C	The increase in seawater in estuaries could change the dynamics of the salt/freshwater interface and hence impact on the flora and fauna within.
	C	May lead to silting up of estuaries causing access problems and need for dredging.
	C	May lead to erosion of harbours and ports affecting fishing fleet.

Climate Impact		Challenges + Opportunities
Potentially Increased Winds and Storms	C	Storm damage to harbours, quays and ports may effect fishing fleet.
	C	Marine life of both subtidal and intertidal areas could suffer from an increase in sediment movement.
	C	Reduced days at sea for both fishing vessels and fisheries patrol vessel
	O	Reduced fishing effort may enhance fishing stocks currently under pressure

RIVERS, FLUVIAL FLOODING AND DRAINAGE DOMAIN

Scope

Impacts of climate change on river and catchment processes involving the transfer and storage of water and sediment in water courses.

Primary effects on water quantity in water courses including flooding, low flows, surface drainage; and urban drainage. (see also Water Resources Domain)

Physical flood and low flow impacts on water courses in different scales of catchments and physiographic settings.

Human activities exposed to increased flood risk.

(Some reference is also made to effects on water quality and biodiversity in water courses although this is mainly addressed in the Water Resources Domain)

See Also

Water Resources, Coastal, Transport, Biodiversity.

Background

The hydrological character of selected catchments in the South West can be summarised as follows:

River	Basin area (km^2)	Q_{MED}	Q_{MAX}	Q_{95}
Exe (at Thorver-ton; 1956-2002)	600	175	493 (Dec 1960)	1.96
Lower Severn (at Haw Bridge; 1975-2002)	9884	493	872 (Dec 2000)	20.51
Frome (at Frenchay; Bristol; 1961-1988)	149	29	70 (July 1968)	0.170
Tone (at Bishops Hull; 1961-1993)	204	67	113 (Sept 1968)	0.708

Q_{MED} - median annual maximum flood (FEH; shorter dataset than Q_{max})

Q_{MAX} - maximum flood

Q_{95} - flow exceeded 95% of time

Dates indicate length of gauged record for maximum flood

Figure 6.1

Hydrological Character of River Catchments in SW

Source: *Flood Estimation Handbook* (CEH, 1999)

When considering physiographic characteristics, catchments in the South West region occur at a range of scales, with a diversity of geological and physiographic settings (see following table).

Location	Hydrological regime	Specific examples
lower Severn estuary with its gathering grounds in mid-Wales and the Midlands	attenuated patterns of flood storage; high tidal range (Severn bore)	areas of flood risk e.g. Tewkesbury and Alney Island, Gloucester
low-lying areas of the Somerset Levels	extensive areas of floodplain 2 m below high tide level of the Severn estuary	e.g. River Parrett and Tone catchments
chalk landscapes of Wiltshire and Dorset	broad flat bottomed valleys with meandering rivers	e.g. River Avon and Wylye
small, steep sided catchments, draining upland moors rising to 600m with bedrock at or near the surface	flashy runoff response to intense rainfall	e.g. River Lyn at Lynmouth; River Pol at Polperro
wide valley floors with Quaternary deposits	drainage into former workings for aggregate extraction	Cotswold Water Park

Figure 6.2

Physiographic character of River Catchments in SW

It should be noted that the South West region which is the focus of this study does not coincide with Environment Agency's catchment-based regions. The study area therefore encompasses parts of the Environment Agency's South West Region and part of the Midlands and Thames Regions.

Water quantity and quality in water courses

The following baseline information is taken from the Environment South West RDA Observatory Web site.

In terms of water quantity, river flows can be measured against their long-term average to identify yearly trends. A low point in river flows in 1996 corresponds with low annual rainfall. Since then, flow rates have recovered and most of the monitored rivers currently have flow rates greater than their long-term average.

Water abstraction has already had an unacceptable environmental impact by reducing river flows (e.g. on the Rivers Wylye, Avon at Malmesbury, Piddle, Allen, Tavy and Taw). Low flows on the Wylye, Malmesbury Avon and Piddle are caused by groundwater abstraction by Wessex Water. A statement of intent to restore acceptable flows on these stretches of river by March 2003 has been agreed by the Environment Agency, Ofwat, English Nature and Wessex Water.

Other low flow problems of major public concern are on the River Bourne, Nine Mile River and the River Nadder. These are being addressed by the Environment Agency's National Environment Programme and in Environment Agency (2001) Regional *Water Resources for the Future* strategy.

In terms of water quality, river flows in the South West region are generally good, which is important for water supply, wildlife, visual amenity and recreation. In a recent survey (2001), the South West had the highest proportion of 'very good' quality rivers and the lowest proportion of 'bad' quality rivers in England.

Almost all of the region's rivers are of very good or good chemical and biological quality (82 % in 2001 and 87 % in 2000, respectively). River water quality has improved significantly since 1990 and compares favourably with the average (69%) for England and Wales. Significant improvements include parts of the River Wylye (Wiltshire), River Axe (Somerset), and River Tavy (Devon). Cornwall has the highest proportion of chemically good or very good quality river stretches in the region, based on the Environment Agency's *General Quality Assessment* (GQA) scheme that measures the chemical and biological quality of rivers. There are, however, some reaches that are mining-affected and of poor quality.

A key water quality issue is eutrophication caused by an excessive build-up of nutrients (mainly phosphorus and nitrogen derived from human activities) and affected by water quantity/dilution as well as quality. Eutrophication in rivers and shallow lakes tends to be evident through algal blooms and alterations to aquatic life through reduction in oxygen levels. Cotswold Water Park has problems with blue green algae in some of its shallower lakes. Pilot *Eutrophication Control Action Plans* (ECAPs) have been set up on Slapton Ley and the Hampshire Avon (Environment Agency, 1998c).

The lower sections of the River Creedy and Exe, Bristol Avon, Hampshire Avon, Taw Estuary, River Cober/Loe Pool and the Truro/Tresillian Estuary are affected by large sewage works and are designated as sensitive areas (eutrophic) under the Urban Waste Water Treatment Directive that limits the levels of nutrient discharge.

Salmon are present in rivers throughout Devon and Cornwall, and in the chalk streams of Dorset and Wiltshire. Their numbers are not significant in Somerset and Gloucestershire as the catchment geology and generally lower gradient of the rivers is not ideally suited to salmon.

Coarse fish populations are significant in rivers to the east of the Region (e.g. the Dorset Stour, Hampshire Avon and Bristol Avon). Many natural and artificial stillwaters and canals provide important fisheries.

Flooding

Flooding incidence can be considered in terms of causal and intensifying factors at basin, network or channel levels. Flooding can be broadly conceptualised in three categories: (a) flooding associated with river and stream channels including the ‘main river’ channels monitored by the Environment Agency; (b) local flooding due to saturation and sheet run-off from rural slopes; and (c) flooding of storm sewers as a result of urban or rural run-off (with significant responsibilities for sewer planning and maintenance held by water companies). Principal concerns expressed in the South West involve the first category. However, on a more local scale the other types of flooding are potentially very significant to property and transport infra-structure (especially the road network). Sustainable Urban Drainage Systems (SUDS), piloted by the Environment Agency, form a useful and expanding means of addressing urban drainage flooding as well as improving water quality and amenity. Greater planning consideration in the urban environment is being directed to increasing land permeability so ensuring that infiltration is optimised (cf. surface runoff).

Historically major floods have been caused by both longer duration rainfall events in larger catchments (e.g. River Exe, Dec 1960; River Avon, Bath and Bristol, July 1968) and intense convective storms in smaller catchments (e.g. August 1952 flood, River Lyn, Lynmouth; see Newson, 1975). The latter event was one of the most extreme floods in a small UK catchment and has been important in establishing UK flood envelope curves.

In the South West region, riverine and coastal floodplains account for between 5 and 10% of the land (see 1999 Indicative floodplain map of England and Wales, IoH, Wallingford and Environment Agency). The Environment Agency Web site supplies mapping of areas at flood risk to 1 in 100 year, or largest recorded, for fluvial events and 1 in 200 year, or largest recorded, for tidal floodplain, but these figures are based on historical data rather than predicted climatic conditions.

Where there are floodplain defences, these frequently require costly and ongoing maintenance. There are 450 km of estuary and sea defences in the region and on 4,000 km of 'Main River', there are 2,800 km of fluvial main river defences. In 1999/2000, over £20 million was spent on flood defences in the South West. Cities (e.g. Exeter, Bath and Gloucester) and towns (e.g. Brunton) have locations alongside rivers with some properties currently vulnerable to flooding (see *Exeter Flood Plan; Brunton Flood Plan*). Some areas, e.g. the lower River Severn at Gloucester, are undefended from major floods while being a focus for urban regeneration efforts.

Work with local communities and indigenous industries to develop new economic opportunities, methods, equipment etc to help them cope with changing circumstances, including the adverse effects of climate change.

Environment Agency's Water Management Strategy Action Plan for the Parrett catchment . 2002

There are conflicting imperatives. The South West faced its worst flooding for 53 years during the winter of 2000/2001 (*Environment South West, 2002*). Since 1996, the numbers of planning applications for residential developments on floodplains in the region has been increasing (*Environment Agency 2000b/c*). Climate change predictions indicate that for some areas in the South West, the flows/levels that presently define a 1 in 100 year flood may occur 1 in 10 years.

Climate change research studies suggest that a 20% increase in river flow would mean that the flows/levels that presently define a 'once in 100 year' flood would occur around 'once in 40 years'.

Key Issues

- Potential climate change impacts on water courses in the region are very varied in both the nature and scale of their impacts and in the range of stakeholders affected.

Water quantity and quality in water courses

- Water temperatures in water courses in the region will rise in response to increasing air temperatures, but also as a consequence of changes in other meteorological parameters such as cloudiness and relative humidity.
- Changing river discharges, especially more extreme low flows in summer months, will encourage higher stream and river temperatures. In some watercourses, future rises in mean and maximum water temperatures might be expected to be the same as those in air temperature. In contrast, in others the increase in water temperature will be significantly less than that experienced in air temperature. Larger rivers at downstream locations are likely to see greater changes than some headwater streams.
- Given the uncertainty surrounding the predictions of many climatic variables, not least precipitation, and the complexities of downscaling to small catchment areas, assessments of the major components of catchment hydrology (including water transfer and storage) in a warmer world have a number of uncertainties. In water courses, it is probably the quantity rather than the quality elements of the hydrological cycle for which the impact of future global warming can be predicted more readily, and with greater certainty.
- As the quality of water is strongly influenced by the quantity, predictions of future water quality are less certain. This is because uncertainties in predicting impacts on the processes affecting water chemistry, sediment transport, etc. are superimposed on the uncertainties in predicting flow volumes. Even quality parameters that are relatively simple to predict, such as water temperature, cannot be predicted with complete confidence in the future. This is because information on future values of key controls, such as solar radiation inputs is insecure, and knowledge of likely future changes in channel morphology and riparian vegetation is incomplete.
- Rather more subtle and complex changes in water chemistry may be associated with changing climatic patterns. These include the impact of higher winter soil temperatures and greater winter precipitation, as well as higher summer temperatures and lower summer rainfalls. Cycling and storage of chemicals in catchment ecosystems could be influenced by changing hydrometeorological conditions, as well as more directly by planting of different crops in response to climate change.
- Initial research has suggested that for the Severn catchment (partly in the study area) increases in peak flow of around 20% for a given return period could be experienced within 50 years. In PPG 25, these are recognised as preliminary findings with further work required. The national guidance indicates that these predictions give added incentive to maintain current defences, where they are justified, and to adopt robust and sustainable solutions

where defences are replaced. (*National Planning Guidance - PPG 25 Development and Flood Risk*).

- Such considerations also add importance to the need to evaluate the potential impact of extreme events even where it may not be economic to contemplate high levels of protection. (*National Planning Guidance - PPG 25 Development and Flood Risk*).

The key is to be upbeat and indicate varying degrees of confidence. We need to start planning for 50 years plus, but there are major problems in getting people to think this distance ahead.

Somerset Moors and Levels Partnership

- River managers in the region need up-to-date and systematic assessment of the potential impacts of high and low climate change scenarios on the quantity and quality of flow regime to develop management strategies in a climate change context. This information includes: changes to the quantity and quality of average flow patterns and low flow conditions; and the nature and scale of changes in flood magnitude, frequency, seasonality and duration across a range of physiographic settings.

- The impact of increased flooding on other catchment processes including soil erosion, sediment mobilisation and yield and land slipping also requires investigation. Changes in river flow regimes may lead to changes in river morphology with both deposition and erosion being potentially affected. Changes to sediment supply and patterns of river sedimentation are potentially exacerbated by land use practices.

- Land use changes may also make soils more susceptible to erosion, and increased winter precipitation and storminess could also encourage the mobilisation of more sediment into rivers. Some soils that may be mobilised have the potential to be contaminated by metals from mine wastes (particularly in Cornwall and West Devon). Actual soil erosion has increased in recent years to about 6% of arable land, with half of all land in the South West at risk (*Environment South West; RDA Observatory Web site*).

- Secondary impacts include changing patterns of biodiversity in water courses/water bodies and the changing suitability of these habitats for specific species (cf. those environments currently experienced). For example, inland transgression of salt marshes may occur in former floodplain areas with increased sea levels. The relationship between sea level rise, deposition in estuaries and ecological impacts may also be complex.

- Land use and climate change have the potential to be either antagonistic or synergetic in their impact on water courses. Land use practices that exacerbate the impact of climate changes need to be identified and managed to reduce impacts. This involves practices that reduce vegetative cover during periods with predicted greater frequency of intense storms or increase the proportion of permeable surfaces through sub-urban development.

- Flood risk managers' activities within the context of the South West region have to evaluate: (a) the potential human and economic impact of increased extreme events even though it may not be financially feasible to consider higher levels of protection; (b) the relative merits of structural measures to mitigate against increased flooding in comparison to measures that involve adjusting of human activities.

- Mechanisms need to ensure more timely links between research into climate change impacts on rivers and the development of informed policy for river and flood risk management.

The options appraisal should encourage the construction of flood defences that can be easily modified, through incremental changes, in response to growing confidence about the impacts of climate change, thereby maximising the efficiency of future investment decisions.

Environment Agency, Lower Severn Area

- There are important opportunities to capitalise on recent public experience of flood risk and so improve public understanding in the region of changing patterns of flood risk in a climate change context.

- The potential impact of changing flood patterns on existing exposed human activities and vulnerable floodplain groups in the region needs to be established for different climate change scenarios. This is particularly critical given the potential for withdrawal of insurance cover or increase in insurance costs in the Severn area after the insurance guarantee expires at the end of 2002. The impact of possible changes in the frequency and intensity of extreme floods on the insurance industry is being appraised nationally.

- The appropriateness of existing engineering structures and design standards relative to predicted changes in flood magnitude and frequency needs to be reappraised.
- A methodology is required for the evaluation and implementation of floodplain areas with the potential for managed retreat (within the options of hold, retreat or advance defences). Shoreline Management Plans provide a vehicle for this type of assessment in estuarine environments.
- Transport infrastructure will be exposed to an increased risk of flooding and associated problems from excess precipitation and damage, as well as increased storminess.
- Unsustainable floodplain development needs to be prevented in areas of increased flood risk. The planning system must be reviewed and adjusted to ensure this control. Environment Agency evidence as to the flood risk of the site needs more weight in the planning process.
- If the substantial extra housing in the region (see State of Environment Report) is to be implemented then the hydrological impacts need evaluation in the context of changing rainfall intensities. Urban developments tend to increase flood peaks and decrease the lag time of peaks. This provides a challenge to ensure sustainable urban drainage systems (SUDS) in a climate change context. SUDS options need to be evaluated and designed carefully on a case-by-case basis and may not be suitable in every situation.
- Selected floodplain activities may require relocation from floodplains with debated degrees of compulsion. New sustainable land uses on floodplains may need to be established.
- Lower flows mean lower levels of dilution of contaminants and resulting lower water quality. Consent conditions for both water abstraction by Water PLCs and pollution inputs by riparian users to water courses, both regulated by the Environment Agency, could be applied more tightly.

Flooding

- Specific floodplain locations within the region (e.g. River Exe, lower River Severn) are potentially vulnerable to increased riverine flooding. *(See also Coastal Impact Domains.)* Future inundation by extreme floods may well include locations beyond current flood experience, and therefore outside current Environment Agency floodplain mapping.
- Changes to storm surge patterns may also have impacts to riverine environments and flood risk through tidal lock in estuarine areas with a high inter-tidal range.
- Levels of flood protection offered by existing flood defences will reduce.
- Organisations tend to base decisions on past data rather than future-based predictions.
- There is a risk that insurance companies could withdraw from insurance of properties on floodplains that demonstrate increasing flood risk, which, combined with problems in dealing with uncertainty may mean no or slow action among some stakeholders.
- The opportunity exists to shift in particular circumstances from structural engineering measures to more sustainable measures including behavioural approaches such as effective flood warning systems.
- There is scope for the Environment Agency's public awareness campaigns to be refocused from highlighting risk towards taking risk reduction measures.
- There are opportunities for agencies involved in emergency flood risk planning to work together in preparatory, emergency and review stages (and so improve efficiency of operation).
- Integrated management of floodplains can work to reduce flood risk and enhance biodiversity.
- Potential for climate change can be used to aid the business case for investment in infrastructure (e.g. transport). It may not be economic to upgrade protection for a site that floods once every few years. If future flooding is likely to occur more often, it may cost less in the long run if some investment is made now.
- Increased application of Sustainable Urban Drainage Systems (SUDS) and permeable ground surfaces should be considered in urban environments as a means of counteracting potential under-capacity in storm-sewer systems resulting from higher rainfall intensities / frequencies.
- Responsible authorities, land-owners and regulators should work in an integrated fashion to ensure that inappropriate land-use management does not exacerbate the potential for increased rapid overland flow and surface flooding.

The Way Forward

Flooding in the South West needs to be addressed on an integrated catchment-wide basis and in a sustainable manner (Environment South West, 2001). There are tensions between engineering solutions that work to 'control nature' by maintaining and increasing defences and adaptation agendas.

There is a need to adopt 'robust and sustainable solutions' in situations that allow this. Environmentally sustainable solutions involve increasing storage capacity by restoring floodplain, modifying catchment runoff or causing increased conveyance by deepening and widening the channel.

There are strong organisational steers (e.g. within Environment Agency regionally and insurance industry) and media pressure to get local, regional and national government and environmental regulators to respond to evidence of increased flood risk associated with climate change. In planning for flood risk in specific areas (e.g. on Somerset levels and lower Severn), there is strong evidence for local public ownership of flood problems borne of recent experience of extreme floods in the last 5 years.

National guidance PPG 25 has a section on climate change and sets development and flood risk at least partly in this context. National government policy on river management for flooding needs to be implemented to meet the needs of changing flood risk at catchment scale within the region.

Local Authorities need to prevent further exposed development on floodplains unless it can be demonstrated that property is not affected by increasing levels of flood risk and the problem of increased flood risk is not exported upstream or downstream.

Integrated planning and flood defence strategies need to be considered at a catchment scale as outlined in English Nature Position Statements and developed by the Environment Agency, English Nature, Local Planning Authorities and Drainage Boards.

Catchment Flood Management Plans (CFMPs; an initiative developed by DEFRA and Environment Agency) are being developed to provide a strategic vehicle for considering holistic approaches to flood management at a catchment scale. Best practice is for these to consider climate change impacts as part of their broader remit. In addition, there are Shoreline Management Plans (SMPs), which are multi-organisation, high level strategic plans (comparable to CFMPs) that encompass estuarine areas. These plans have potentially overlapping regions. For the lower Severn, the SMP extends upstream to Hawbridge, the CFMP extends downstream to Gloucester and there are also CFMPs for tributaries that extend to the estuary.

It is important to establish ways in which potential impacts of changing flow regime, water quality (including temperature) and sedimentation patterns can be capitalised on or managed in terms of biodiversity and specific species habitats.

The government and the devolved administrations have already started to respond to the threat of climate change by building adaptation into many of their policies. Examples include revising the approach to development on floodplains, improving flood warnings and increasing public awareness of flood risk and further research into the potential impact of extreme flood events.

Continuing dialogue on effective adaptation strategies should be encouraged - among Environment Agency (at regional and national level), Local Authorities, business, insurance industry, probably through a number of facilitator routes including the SWRDA, GOSW and professional bodies. Good practice needs sharing nationally.

Barriers to change

There are a number of barriers to organisational and individual change in flood risk planning including:

- The cost of increasing the design limits of existing structures or adding to new engineering measures for flood risk management. For example, in the Severn estuary, most structures are currently 1 in 100 year but some are around 1 in 10. The latter are defences where capital improvement by the Environment Agency cannot currently be justified.
- The sheer number of organisations involved in flood risk management including Flood Defence Committees, the Environment Agency, Local Authorities and Drainage Boards. This issue is currently under governmental review.
- Catchment boundaries in the region (the most appropriate unit for managing land and water) do not necessarily coincide with government regional and sub-regional; boundaries when approaching flood issues at a catchment level (e.g. Severn estuary).
- The propensity for organisations to consider shorter timescales in planning for climate change e.g. 10 year rather than 50 year over which more significant hydro-meteorological changes are likely to take place.
- The difficulties in organisations dealing with uncertainty and probability in assessing the impact and issues associated with flooding in different climate change scenarios.

This being said, the majority of river managers in the South West are well aware of the potential impacts of climate change on the river environment. For some managers, climate change means primarily engineering solutions, building larger structures to higher design limits, rather than adapting human usage of areas with increased flood risk.

Perception of changing flood risk within a climate change context is of variable strength within Local Authorities. Sustainability agendas are frequently higher profile. Some policy statements on flood defence make no reference to a climate change context and changing flood frequency.

There is improved awareness by the general public about flood risk issues in a climate change context. However, the link to improved adaptation to flood risk needs to be strengthened in public awareness campaigns.

Knowledge and Information base

There is probably enough basic information for rivers in the region to attempt modelling of how future climate change will impact on river flows, groundwater levels and other quantitative aspects of the hydrological cycle. There is much less detailed baseline information on the quality of rivers in the South West on which to base future predictions.

Accessible future-based information on flood and low-flow impacts is required at a regional level.

Example of Good Practice

Community based residents groups (eg Alney Island Gloucester) are acting to raise awareness of adaptation needs. This is important in raising awareness of practical steps to reduce flood damage and taking ownership of the problem.

There is considerable scope for basic research into how aspects of water quality will change with global warming and for assessing the ecological impacts of those changes in rivers and other freshwater ecosystems.

There are no South West region-specific policy documents relating flood defence and climate change. There are, however, a number of government policy documents in this area and evidence that the sector is accessing and using the 2002 scenarios published by UKCIP, within a regional context. Sources used in considering adaptation possibilities include the general media, UKCIP, DTLR, DEFRA. Specialists are using Hadley Centre and IPCC technical reports, conferences held by UKCIP, ICE and BHS and papers to Local Flood Defence Committees.

Environment Agency flood awareness promotions, recent flood experience and media coverage of recent extreme flood events within the region and UK mean that the lay public has had more exposure to information about flood risk than e.g. five years ago. The Environment Agency will be producing indicative flood risk outlines for the 1:1000 year floods and plans to put these on the Web by September 2003. Further investigation is required to see if this information retains high profile or is converted into action to reduce losses.

Other stakeholders involved in flood hazard management are variably informed about climate change impacts. Wide ranging education and training need targeting at specific areas of the sector e.g. some county councils.

There is a need for higher resolution data relating changing meteorological inputs to a catchment’s hydrological response. The implications for water quantity and quality in water courses can then be evaluated along with appropriate adaptation needs and strategies at a regional level

There is a need to work towards improved flood risk identification in a climate change context. Strategic planners for flood risk require more detailed specialist information. The UKCIP 2002 report covers the changing frequency of the extreme daily rainfall event. Transport managers, for example, need information about change in frequency of extreme 5, 7 or 10-day events above a specific threshold and implications of prolonged rainfall on flood risk.

Recommendations

- The impact of changing water quality/ water quantity (flood and low flows) on habitat and biodiversity should be systematically monitored in a climate change context e.g. impact of changing temperature profiles on fish resources.
- A searchable database of hydrological data on water quality/quantity data for the region should be made available to stakeholders including the general public. Ideally this should draw on historic data, numerical modelling and future predictions, possibly in a GIS-based system. The information presented should be Web-based and have a ‘Science and Society’ flavour with interpretative tools. There is nothing currently with this interactive flavour available although the Web-based SW Regional Observatory has general environmental information and synthesis.
- Regularly updated statistical analysis of rainfall and river flow data using both historical and ongoing hydrological data should be undertaken, building on data and methodologies in the FEH Handbook (CEH, 1999).

Examples of Good Practice

Somerset Levels and Moors (Parrett) is one of five pilot study areas being carried out nationally to develop methodologies for the production of Catchment *Flood Management Plans*. The Somerset Levels and Moors Partnership has involved stakeholders in appraising the impact of high and low emission scenarios for the 2050s on activities within the catchment.

- Experimental catchments should be set up within the South West to monitor the impacts of climate change on catchments with different physiographic and land use contexts. The monitoring resources of the academic community, the Environment Agency and regional Government need to be focused to maximise potential for useful scientific data to inform catchment management.

- The experience of recent extreme floods needs to be capitalised on in improving organisational and individual practice in adaptation for flood risk. This work is already in progress within the Environment Agency.

- Floodplain mapping for flood risk should consider potential maximum probable flood scenarios in a climate change context. Status, resolution and limitations of the mapping on the Environment Agency Web site should be explicitly stated. This work is already in progress within the Environment Agency.

- There needs to be strong control on future development within flood risk areas under potential climate change scenarios. The status of the Environment Agency in the review of planning applications for flood risk should be reviewed nationally. The implementation/success of current planning regulations for vulnerable land uses (e.g. caravan parks) in flood risk areas within the region should be reviewed and evaluated.

- Models of good practice in planning for floods at a catchment scale (through Catchment Flood Management Plans) should be implemented as soon as possible in other catchments with land uses at risk from flooding.

Challenges and Opportunities of Key Climate Impacts on Rivers, Flooding, and Drainage

Climate Impact		Challenges + Opportunities
Summer Temperature Increased	C	Increased soil moisture deficits lead to shrinking of peat soils in the Somerset Levels, lower surface levels and make flood waters harder to evacuate.
	C	Issues of health, contamination and spread of disease may occur on floodplains that have recently suffered flooding.
	C	Water temperatures in water courses rise in response to increasing air temperatures (also cloudiness and humidity).
	C	Changing river discharges, especially more extreme low flows in the summer months, will encourage higher stream and water temperatures.
	C	Changing thermal regimes of rivers are likely to have diverse ecological implications as water temperature has a strong impact on virtually every facet of the freshwater fauna and flora.
	C	Changes in water temperature may deplete dissolved oxygen levels and reduce the assimilative capacity of watercourses. It will alter chemical processes, e.g. rates of denitrification, in streams and rivers.
	C	Increased evaporation from surfaces of shallow lakes (e.g. Cotswold Water Park) will occur. Where high levels of nutrients are present, this may encourage increased incidence of blue/green algae.
	C	Changes in water temperature may make river water a less efficient coolant in industrial processes.
	C	As river temperatures warm, game fish may become stressed and summer growth could be reduced compared to present conditions. Rising winter water temperatures may also have an impact on game fish spawning and subsequent egg and alevin development.
	O	Longer working periods will exist for the maintenance of design standards of operational flood defence works (funding dependent).
Summer Rainfall Reduced	C	Lower summer flows in rivers will lead to higher concentrations of dissolved constituents in water courses and reduced capacity to dilute effluent discharges.
	C	Reduced water resources will exist for abstraction from water courses and for the natural environment (although still risk of summer storms)
Winter Temperature Increased	C	More rapid snowmelt can lead to potential increase in flood risk
	O	Slight benefits are involved in flood defence maintenance – increased germination of grass seed sown out of season following earthworks.
Increased Winter Rainfall	C	More robust designs will be required for rainwater disposal systems above and below ground.
	C	Decreased erosive resistance of flood embankments and soils with low vegetation cover to intense rainfall events will have implications for sedimentation of watercourses.
	O	More water will be available in rivers but needs capturing and storing with incentives from water companies.
	O	Farming practices can adapt to ensure winter ground cover so that sediment is not flushed rapidly into water courses in intense winter rainfall.

Climate Impact		Challenges + Opportunities
Increased Sea Level and Tides	C	Impacts on the magnitude, frequency, timing and duration of tidal lock on estuaries will have implications for the evacuation of increased fluvial flooding from upstream areas.
	C	Tidal limits will migrate inland and affect boundary conditions leading to problems associated with river hydraulics
	C	Estuarine sediments could remobilise and some, in Cornwall and Devon, may be highly contaminated due to mining related sedimentation.
Longer Growing Seasons and Reduced Frosts	C	Changes in farming practice (e.g. choice of crops) could affect flood risks due to increased runoff and erosion.
	O	More maintenance work on flood defence structures could be achieved on-site during winter.
Flooding Increased	C	Improvements will be required to existing drainage systems and re-assessment of present criteria for new drainage systems in case higher specifications are required (especially urban).
	C	Reduced effectiveness of existing defences may lead to the need for additional works to maintain existing defence standards.
	C	Channel widening and dredging may only partly match predicted increases in flood magnitude and required channel capacity to evacuate flows downstream.
	C	Increased flooding may enhance potential for increased scour around in-channel structures (e.g. bridge piers) with subsequent increased maintenance requirements.
	O	There is opportunity for introducing sustainable urban drainage systems in new developments, e.g. use of porous materials to allow more percolation of winter rainfall.
	O	There are commercial opportunities for enterprising businesses working in flood proofing, flood protection technologies or engineering structures for flood defence.
	O	Advice to developments and planners on flood risk has significant regard for climate change effects.
	O	Flooded aggregate-extraction pits provide opportunities for integration in flood storage schemes in Catchment Flood Management Plans. Appropriate water management and extensions to capacity may be necessary.
	O	Potential to encourage new approaches of adaptation e.g. possible removal of properties most at risk from flooding, re-creation of floodplains, greater use of washland schemes; control over detrimental land management practices etc.
	O	Potential for climate change to be used to aid the business case for investment in the infrastructure.
	O	Greater public awareness of danger of flooding will occur through experience with greater consequent support for the Environment Agency's work.
	O	Management of floodplains in a climate change context can help meet biodiversity targets (e.g. through floodplain retirement strategies).
	O	There is opportunity to integrate estuarine and coastal defence strategies for effective management of flood risk.
Potentially Increased Winds and Storms	C	Increased storminess contributes to increased risk of flooding and exacerbates impacts. This requires allowance in design of flood defences.

WATER RESOURCES

Scope

The availability of and demand placed on water as a resource for industrial, domestic and general supply, for maintenance of aquatic environments, for generation of renewable energy (hydropower) and for safe and sustainable disposal of sewage effluents and by-products.

This section deals with both the quality and quantity aspects of water resources though some aspects of water quality are also referred to in the section on Rivers, Flooding and Drainage domain.

(Some reference is also made to effects of flooding on foul-sewer systems, though flooding as an issue is addressed principally through the Rivers, Fluvial Flooding and Drainage Domain)

See Also

Rivers, Fluvial Flooding and Drainage; Coastal; Natural Environment

Background

Water resources are managed principally through the suppliers and distributors (the Sewage and Water Companies (part of Severn Trent, part of Thames Water, Wessex Water, South West Water); the water-only companies: (Bournemouth and West Hampshire, Bristol Water, Cholderton and District) and the two regulatory bodies (the Environment Agency and OFFWAT). Sectors, companies and organisations with particular interests in water as a resource include *inter alia* those involved in hydropower, food and drinks manufacture, brewing, chemical industries, mineral extraction, and paper production.

In terms of hydrology and water resources the South West region can be divided into three areas roughly paralleling the South West Region's three principal water company areas (Severn Trent: Gloucestershire; Wessex Water: Bristol and Avon area, Wiltshire, Dorset and Somerset; and SW Water: Devon and Cornwall).

These areas are characterised by significantly different topography, geology and catchment sizes which influence variably all water resourcing aspects outlined within the scope. Water supply in the Gloucestershire area of Severn Trent is dominantly through river abstraction and ground water. In the Wessex area groundwater forms 80% of the supply, with 20% derived from surface sources (reservoirs and river abstraction), whilst in the South West Water area, 90% of the supply is from surface sources and 10% from groundwater.

The South West Water area is served by a network of 17 smaller and older upland reservoirs utilised now to provide the main winter water to local demand centres. Since the 1970s, three additional strategic reservoirs have been constructed to supply water throughout the peninsular; these act as contingency resources used when local supply is required to maintain river flows. The eastern area (Somerset, Wiltshire, Dorset and Avon area) is served by 12 impounding reservoirs and abstracted water from five main rivers.

Key Issues

- Maintenance of critical river flows during dry conditions.
- Management of abstraction licences with potential increases in irrigation and industrial demands.
- Impact of longer and increased frequency of droughts on water supply;
- Modelled 4% rise in household water demand by 2021 factoring in climate change.
- Increased turbidity in groundwater water during wetter winters.
- Increase flushing of nitrates into the groundwater during wetter winters.
- Potential increase in *Cryptosporidium* content of groundwater during wetter winters, with consequent human health impacts.
- Uncertainty in replenishment rate of aquifers.
- Potential salinity increases in borehole and river-mouth abstraction points as a consequence of rising sea-levels and/or storm surges.
- Potential flooding of sewer networks.
- Potential need for re-engineering of sewer outfalls as a consequence of rising sea-levels.
- Difficulties in winter land-access for disposal of sewage sludges on agricultural terrain.

The Current Situation

The limited number and specialised nature of the principal 'players' in controlling aspects of water resources has ensured that the potential impacts of climate change have been considered in depth. Sophisticated analytical tools and diverse strategies have been adopted by the water companies and regulators.

Numerous reports have been produced both by the Environment Agency and by the water companies, often in collaboration, such as in the joint UK Water Industry Research Group / Environment Agency report by Arnell *et al.* (1997). This nationally based study provided water companies with a method to include climate change impacts in the third asset management plan (AMP3) discussions with the Environment Agency at OFWAT (Lonsdale, 2000).

Additional studies on water resources and demand prediction are underway and will inform AMP4 negotiations. In terms of climate change, the 2020's UKCIP scenarios are seen as the most relevant as the 2050s and 2080s scenarios lie significantly beyond the water industry's thirty year planning horizon.

South Western part of South West	North and East part of South West
Significant areas of high elevation	More subdued elevation
Heavily dissected, steep sided valleys	Broader, shallower angle valleys
Rapid run-off, flashy response rivers	Generally less prone to flash floods
Largely impermeable bedrock	Permeable bedrock areas
Principally surface water resources	Significant groundwater resources

Demand Issues

Demand changes in the water industry are thought to be the most significant area of sensitivity to climate change (EA, 1999: 41). The social trend towards lower household size is thought likely to lead to a significant increase in domestic water demand. Increasing living standards also create greater *per capita* water use. In one of the few studies of demand Herrington (1996) applied a micro-component approach to assess the impacts of climate change on domestic use and forecasted a 3-6% increase in demand by 2021, with a suggestion of a marked increase in peak demand.

With 6000 new homes built per year, the South West Water company area is the second fastest growing water company area (after Anglian Region) in the UK.

In the South West Water Region the industrial demand for water is, however, below the national average but tourism is a significant factor in terms of water demand. In the Wessex Water region the Dorset Coast area (e.g. around Poole) places an additional tourism demand slightly above the national average for the sector, whereas the peninsular South West exhibits a highly pronounced (30%) summer population bulge increasing the resident population of 1.5 million by 0.5 million in each week of summer (more than 8 million visitors per year). The potential impacts of this increase fall largely on the infrastructure in terms of meeting peak demand, although current predictions do not place the impacts beyond that already accommodated by planned infra-structural improvements. There is, nevertheless, a need for an updated study in terms of the new UKCIP02 climate scenarios.

Extension to the tourist season as a result of milder and drier spring and autumn seasons and the increased popularity and marketing of 'short breaks' may also place additional demand on the water supply. It is anticipated that this extension will not influence supply adversely as it falls in season where river abstraction is possible and unused river flows would otherwise return water to sea.

In the South West Water area with no new schemes considered, demand predictions suggest that water will 'run out' in 2011; with climate change modelled, water runs out in 2006-7, i.e. the effect of climate change is to pressurise the planning strategy by up to five years. Additional pump storage, leak-reduction and conservation strategies are in place to address this as part of the ongoing strategy.

The Swindon area forms one of the most rapid growth centres in the South West and water resources may become an issue in the longer term. Discussions over the need for a new reservoir in the Thames catchment have been ongoing for some years whilst the possibility has been raised of using a restored Stroudwater canal and the Costwold Canals to transfer water from the River Severn into the Thames basin, utilising freshwater that would otherwise have been 'lost' to the sea.

Water conservation presents a significant problem in estimating what impact individual users have in terms of water saving. The impact of domestic water saving schemes (hippos etc.) is uncertain as there is limited knowledge of the number of schemes used whilst double-flushing is thought to be an issue. There is also some concern that successful home-based water saving may result in insufficient dilution of solid wastes in the foul-sewer.

Principal Water Resource Issues

In no priority order, the three principal issues associated with water resources are (i) water supply and management; (ii) water quality; (iii) sewage transfer, treatment and disposal. (iv) maintenance of flow levels in rivers and water levels in aquifers.

(i) Water Supply and Management

Leakage

Historically, one of the main issues associated with water supply and management has been the issue of leakage. The major water companies in the South West have invested significantly in minimisation of leakage over the last decade. This is reflected in a major reduction in the forecast and actual demand for water since the late 1990s

Water companies report that by 2003 leakage will be reduced to or below the economic threshold where cost benefit analysis determines that further leakage minimisation is not cost-effective. Wessex Water report that leakage reduction has turned a late 1990s deficit into a surplus that, without consideration of the effects of climate change, is predicted to last beyond 2030.

If future climate change were to have significant impacts on water resources then the water companies and regulators would need to re-evaluate the threshold of this economic limit. Scope remains for further adjustment as leakage in some areas is predicted to shift from 27% to 15% by 2005.

Precipitation Information

Water companies and the Environment Agency have invested significantly both in terms of their own and contracted research in assessing the potential impacts of climate change on water resources. The main enviro-climatic parameters that are of concern are potential summer rainfall reduction, winter rainfall and evapotranspiration (as determined particularly by ambient summer temperatures).

Most UKCIP98 (the first generation) climate change scenarios (Hulme and Jenkins, 1998) for the 2050s showed an increase in annual average rainfall with, in terms of precipitation, increasingly wetter winters apparently offsetting drier summers. However, the latest UKCIP02 scenarios informing this study suggest that the effective shift is towards an annual *reduction* in precipitation (by up to 10%).

In the RegIS study of water resource issues in East Anglia and the North West, modelling has been undertaken to assess the vulnerability of groundwater recharge to 1998 predictions (Holman *et al*., 2001). However, despite the increased precipitation overall in these models, the consequences of concurrent "more clement" conditions were thought to lead to an increase in the length of the growing season such that the duration of the winter recharge period is reduced.

In addition, soils take longer to absorb water in the autumn and begin to dry out sooner in the spring. These factors are important in governing whether or not increased annual precipitation would necessarily lead to an increase in groundwater recharge and total annual river flow.

By inference, the latest scenarios (UKCIP02: Hulme et al., 2002) with an annual *reduction* in precipitation, indicate that such groundwater recharge and annual river flow will tend more to deficit than the earlier work suggested. Detailed work is needed in the South West, where intra-regional water resources are strongly dependent on a single water source type.

Results for the Wessex area in which the modelled duration of the 1976 drought was extended suggest that climate change would reduce the water yield from 426 Ml/d (million litres per day) to 403Ml/d (i.e. a reduction of 5.4%) by 2020.

One issue in the water resource industry is the process whereby precipitation data are converted into hydrological data pertaining to river flows and aquifer / reservoir replenishment potential. Again using the 2020's UKCIP98 scenarios (Arnell *et al.* (1997)), both Wessex Water and SW Water have fed these results into hydro(geological) models to facilitate long term supply estimation.

Complex catchment-response models have been used by other companies (e.g. Severn Trent) but these require more work and are less readily transferred from catchment to catchment. Potentially more work on rainfall-runoff models may be useful in the region.

Water Storage

The most critical of the hydrodynamic climate variables is viewed as summer temperature and precipitation. In the South West where tourism significantly swells the population (in parts of Devon and Cornwall the population can increase by 33% in summer) and 'short-break' stays may increase in response to more clement weather, especially early and late season, availability (water yield) and demand drivers work together to stress the supply system. Balancing these opposing drivers is at the route of resource strategies for the water companies. Climate change is recognised as a factor that may be significant perhaps within the planning horizon rather than immediately.

A significant control on the vulnerability of water stores to the potential impacts of climate change is the responsiveness (or recharge rate) of the reservoir / aquifer. In the South West smaller stores generally behave as one-season critical (i.e. they fill in just one season) and are potentially less sensitive to climate change than the (usually larger) reservoirs that take two or more seasons to fill. Indeed in many cases, the small reservoirs may fill during a single storm, and certainly early on under current winter precipitation conditions. However, these smaller reservoirs tend to reach their lower volume limits earlier in the dry season and prescribed minimum levels must be maintained to ensure river flow continues.

The larger reservoirs and aquifers provide sufficient 'usable' storage to sustain excess demand over summer recharge lows. However, in terms of efficiency of use and distribution, being gravity rather than pump-driven supplies (pumping costs - energy consumption - for some reservoirs approach £3k-£4k per day) the smaller reservoirs close to the demand centres are the most economic. Water security issues - guaranteeing a supply - means that the alternative larger pumped stores are necessary to supplement or replace the local supply as the small reservoirs are drawn down to their prescribed minimum levels. Additionally, some areas are only supplied by the local 'small' reservoir without access to a wider distribution network and so reserves must be maintained for these.

Most of the water company research has been based on the UKCIP98 climate scenarios where the winter precipitation increases exceed the summer decline, creating an annual increase in precipitation total. However, the UKCIP02 scenarios predict an overall reduction in annual precipitation totals, suggesting further work is needed to assess water resource issues.

The potential impacts from the former scenario are complex and depend on the critical factors governing reservoir/aquifer recharge. Currently most small surface stores fill during the annual cycle, often in localised stores and the wetter winters predicted will not supplement the supply. In contrast, some larger groundwater reserves (although reasonably responsive to precipitation) and the larger surface reservoirs currently do not fill on an annual cycle and so wetter winters may benefit these.

In broad terms, the principally groundwater-supplied Wessex Area may 'benefit' from such recharge especially in Wiltshire and Dorset, although in terms of the annual supply cycle, Somerset - being dominantly surface water supplied (e.g. Clatworthy reservoir) - may be less 'climate change proof'. In Devon and Cornwall with 90% surface water supply, 75% of surface storage is in three strategic reservoirs (Wimbleball – 21,320 Ml; Colliford - 28,540 Ml; Roadford – 34,500 Ml) with the remaining 25% of surface water in 17 smaller reservoirs. Wetter winters will again advantage supply in the larger stores, whilst the smaller reservoirs will be more susceptible to demand pressures, not having the benefit of enhanced winter top-ups.

Using the UKCIP98 scenarios aquifer recharge is shown (Arnell *et al*., 1997) to be highly dependent on the particular climate model and the geology of the aquifer. Thus groundwater recharge in Permian sandstones (e.g. the East Devon aquifer) may increase by as much as 14% by the 2020's, whilst recharge of chalk aquifers as in Dorset and Wiltshire may decline by up to 6% (see EA, 1999: 40).

In the Wessex area, dominated by groundwater supply (the Wiltshire and central western Dorset aquifers supply most of the area – c. 80% of the demand), most surface and especially aquifer stores are large, tending to be two-season critical (although the surface reservoirs are mix of large and small stores). Currently the Wessex area is therefore more vulnerable to droughts of two years duration.

The smaller stores with small catchments frequently experience no summer inflow in the present climate regime. Drier summers will therefore have no additional impact in terms of water harvesting, although increased evaporation under warmer conditions may have additional small effects. The reservoir supply (12 surface stores) in the Wessex area are mostly based in the catchments draining higher rainfall semi-uplands of Somerset.

In Hampshire winter flow 'excess' in the River Avon has been utilised to top up the Blashford Lakes (formerly gravel pits). Pipe links have been established which permit transfer of groundwater to the Somerset reservoirs in dry summers.

Given the importance of the groundwater resource, Aquifer Storage and Recovery (ASR) trials have been adopted in Dorset. ASR treats surplus surface water to drinking water standards when supplies are plentiful (principally winter) and returns this to the aquifer for use in peak demand periods. In full operation an ASR scheme is predicted to supply in excess of 20 Ml per day (enough to supply towns the size of Weymouth). Schemes such as these may prove increasingly important where abstraction excess and drier summers lead to late season low flows. Historically this has been a sensitive issue, for example in the rivers Avon (at Malmesbury), Wylye (south Wiltshire) and Piddle (Dorset).

Abstraction and Pump Storage

In the South Western part of the region, the impermeability of the regional geology and the steep and heavily dissected nature of much of the terrain ensures that there is minimal or no steady base flow and a need for significant surface storage. The lack of steady base flow also necessitates the reservoirs use as river-regulation points. This creates an additional demand on water availability as reserves are required to maintain river flows. Reservoirs therefore release water to maintain flow, and additional abstraction points are located near the mouth of major rivers (e.g. Wimbleball reservoir releases water to the R. Exe, which is abstracted to supply Exeter; Colliford reservoir releases to the R. Fowey; and Roadford reservoir to the R. Tamar which is pumped to N. Devon).

Abstraction points are sited as close to tidal limit as possible, to maximise the effective catchment. The Environment Agency monitors environmental and flow conditions to ensure that appropriate flow levels are maintained. Management of these abstraction licences is an important process, particularly if demand patterns or summer water availability patterns change. This tends to be a summer issue although some areas (e.g. Cornwall which currently receives most of its winter water via river intakes) could become vulnerable if multi-season droughts became more frequent.

In addition to downstream abstraction strategies, water supply is also managed through pump storage schemes that significantly enhance the water harvesting potential of a catchment. Here, where the reservoir occupies one limb of a catchment, abstraction pumps are sited downstream of additional tributaries to utilise water from parallel, un-dammed catchments. During periods of high flow, water is pumped from rivers to top up the local reservoir. This thereby maximises the effective catchment without having reservoirs in all tributaries. This is done as long as flow permits (i.e. minimum discharge) and top up is needed. For example, a tenfold increase in Wimbleball reservoir's effective catchment is achieved through an abstraction license permitting pumping between 1st Nov and end March. This permits the water to be drawn down from the reservoir at a greater rate, more secure in the knowledge that a winter replenishment is readily achievable. In effect this turns a multi-season reservoir into a single-season reservoir.

Offsetting Costs

Operation of these schemes is expensive, however, and the energy used in the Wimbleball pumping scheme costs £3k-£4k per day. Increased useage of these schemes will therefore impact on energy consumption and ultimately water pricing. To some extent this may be offset by local hydropower schemes: a good example is provided by the R. Tavey which at one time was generating England's cheapest electricity whilst supplying power for several hundred houses. As this shows, where water availability permits, water companies have the opportunity to mitigate against climate change.

Roadford and Burrator reservoirs generate energy continuously on river-compensation flow via supply release. If at certain times of year the supply control curves permit, release can be made specifically for power generation. This is particularly appropriate in reservoirs constructed relatively recently as each reservoir has a 50 years planned lifetime. New reservoirs therefore have over-capacity in their early life and can release water to generate power without prejudicing water supply. Such generation also favours the water companies in terms of the climate change levy.

Sea Level Rise

Rising sea level is a potential issue in a component of the integrated water resources strategy. Two potential operations are at risk. First, the abstraction of the low-flow compensation water at the mouth of major rivers (e.g. the River Exe). Abstraction generally occurs as low down the system as possible, i.e. close to the tidal limits of a particular channel.

Sea level rise solely or in combination tidal surges may lead to a greater incidence or further penetration of up-river saline penetration on the high tide. This could result in periodic shut-down of the major abstraction pumps. As several abstraction points are relatively close to current maximum saline incursion limits, this is viewed as a long-term threat. Nevertheless water companies may need to consider the potential for such intrusions when undertaking AMP 4 review.

A more significant threat is the potential for saline intrusion of key aquifers. The most significant of these is the East Devon aquifer (supplying 10% of SW Water's supply). Two locations may be at significant risk. First, the Otterton boreholes related to the River Otter. Two production bore holes supply water with 11 observation boreholes surrounding these used to measure water conductivity and water. This monitoring is in place so that warnings can be issued, enabling automatic abstraction cut backs.

Secondly, additional problems may occur in the Permian sandstone aquifer at Dawlish (which is a first resort local source with good quality and cheap water), which is environmentally acceptable - the Otterton water would otherwise flow out of cliffs.

Sedimentation

Climate change and changing agricultural practice may have a direct influence on land-erosion and subsequent re-sedimentation within reservoirs. Potentially this could impact on long-term resource planning by reducing the available storage volume of sensitive reservoirs.

(ii)Water Quality

Chemical

Whilst maintenance of water supply is perhaps the most readily appreciated issue in terms of potential vulnerability to climate change, the maintenance of water quality may in fact pose a more substantial problem. The principal modes of vulnerability are associated with an increase in leached agrochemicals, surface sediment and contaminant run-off and a potential increase in water-borne pathogens.

Nitrates and phosphates are the principal agrochemical inputs which are monitored in relation to drinking water standards and the concentration of nitrates in particular has been shown to have a strong seasonality, with significantly elevated levels occurring in winter months.

It appears that higher groundwater levels result in higher concentrations, with soil nitrates being captured from by rising groundwater to flushed through following intense rainfall. However, there remains significant uncertainty in many instances as to the relative importance of:
(i) inputs increasing as a result of flushing/leaching of agrochemicals following higher precipitation; and
(ii) relative concentrations decreasing as a result of increased discharge (see EA 1999: 41).

Nitrate levels are considered more of an issue in the groundwater dominated Wessex Water area than in the peninsular South West that also has a less significant proportion of land use associated with arable agriculture. Wetter winters, as predicted in the UKCIP02 scenarios are thought likely, by Wessex Water, to lead to an increase in nitrates during winter months.

Biological

In the SW Water area a potentially greater concern is the increase in water-borne pathogens, in particular *Cryptosporidia*. The oocysts of the *Cryptosporidia* which can cause severe gastro-intestinal disruption are too small to be filtered from the water at a rate sufficient to meet water demand. They are also not easily detected by direct monitoring. However, the close association between *Cryptosporidium* occurrence and suspended sediment concentration allows the Drinking Water Inspectorate (DWI) to require automatic shut-down mechanisms at abstraction points that are triggered when water turbidity exceeds a prescribed value.

Increased rapid run-off as a result of potential storminess increases and wetter winters may result in increased incidences of *Cryptosporidium* contamination. It is thought probable that more clean-up plants will be required to counteract the potential increase in *Cryptosporidium* events.

A notable *Cryptosporidium* event occurred in the South Hams area of Devon in 1995, following heavy rainfall after a prolonged dry period.

Algal blooms and eutrophication (excessive nutrient enrichment) also have the potential to increase in response to the warmer and drier conditions predicted by UKCIP02 scenarios.

The latter is a particular problem to conservation and biodiversity, but also impacts on water quality. In addition to nutrient status, the decreasing solubility of gases in warmer waters, with consequent reduction in the dissolved oxygen holding capacity is a major factor controlling eutrophication. Algal blooms however are more serious in terms of water supply and can lead to harmful toxicity levels within standing water masses such as lakes, canals and reservoirs.

Elevated temperatures occurring when water levels are low can lead to a lack of oxygenation and turn-over in the water column. Shallow water is particularly sensitive in this respect and depleted reservoirs may be more vulnerable. It is possible that some reservoirs may need minimum water levels to be revised. The Roadford, Clatworthy and Upper Tamar reservoirs have all experienced bloom and eutrophication impacts and more work may be needed to investigate the potential elsewhere.

Agricultural catchments are particularly vulnerable to eutrophication and algal blooms as increased nitrate and phosphate levels enhance the conditions for their occurrence. The increase in temperatures is likely to see an increase in early and late season phytoplankton growth as the favourable temperature range is 10^{o}C to 20^{o}C with a decline in growth rate occurring only after 25 ^{o}C (Arnell *et al*., 1994).

Organic Material

Other water quality issues (EA, 1999) linked to climate change relate to:
(i) treated sewage effluent
(ii) changes to soil matrix; and
(iii) agricultural waste products and manures.

Agricultural activity in the South West forms significant sources of pollutants. However, in many areas sewage treatment works form the primary source of pollutants in rivers (EA, 1999) and the treated effluent contributes much of the biochemical oxygen demand (BOD) and ammonia load which reduce dissolved oxygen concentrations. Higher water temperatures lead to increased rates of biological activity with a tendency to reduce in-stream oxygen levels, although the potential enhancement of aquatic plant growth and photosynthesis could offset this. Temperature-driven reduction of in-stream oxygen levels could be compounded by a decrease in water levels.

Given that sewage treatment works are more efficient at higher temperatures it is uncertain whether climate change will have positive, negative or neutral effect on this aspect of water quality. Nevertheless, at certain times of the year if river flows are greatly reduced sewage treatment plants will have a negative effect on water quality due to the lack of dilution. This will be compounded by the fact that population increase is significant in dry periods due to tourists and therefore sewage treatment works are treating higher flows of concentrated sewage.

Drying, however, has a pronounced effect on soils particularly where clay-rich. Shrinkage and cracking during desiccation is followed by swelling after rain. The cracks and fissures remain sometime after the onset of rain. Nutrients and other active chemical agents which would otherwise by adsorbed by the clay particles or taken up by plants, are more readily transported to the groundwater and water courses.

In the water companies a major concern principal relating to climate change is the potential for increased winter precipitation to magnify the run-off related risk of point-source agricultural pollution.

(iii) Sewage Treatment and Disposal

The impacts of climate change on sewage treatment work capacity and size of sewers are regarded by water companies as being probably of greater significance than direct water resource issues. The network of foul sewers is largely 19th or early 20th century and its capacity and state of repair are such that significant investment is required. The impression given by the water companies in the South West Area suggests that this issue may not have received as much attention as in the Lower Severn area in the north of the Region.

The main issues are seen as:

(i) over-flow of the foul sewer into settlement areas
(ii) overwhelming of sewage treatment works by river flooding, direct run-off or interception of urban storm run-off by foul sewers
(iii) overwhelming of storm sewers by surface runoff intensities greater than design capacities;

(iv) over-performance of treatment plants setting the norm against which water quality targets are set and therefore potentially requiring investment in plants that are not ‘over-performing’.

Domestic and settlement-area contamination frequently occurs following flooding. Whilst consented sewer outfalls (CSOs) permit sewage overflow into rivers during floods, the issue of backing-up still occurs when water levels are high. Individual properties can be protected against sewer back-flooding by the introduction of one-way valves. New-build and re-plumbing schemes may be advised to incorporate such valving where properties are low-lying. However, localised flooding is increasingly caused by run-off excess which is inherently less predictable; the identification of properties at risk is not straightforward. Siting of new CSOs is probably best considered down-stream of settlements to minimise potential contamination.

Overwhelming of sewage treatment works by river flooding, direct run-off or interception of storm run-off by urban foul sewers is an area of concern particularly in relation both to increased winter precipitation and the potential increased storminess. Whilst many sewage treatments plants are over-sized to accommodate for growth and safety margins there is still potential for plants to be overwhelmed as a result of increased run-off likely though climate change. In the AMP4 price review, water companies may push for climate change to feature in the costing of over-sizing of sewage treatment plants.

Over performance of sewage treatment plants is commonplace, though varies depending on water company strategies and in some instances the outflow may have a positive influence on the water quality downstream. As climate change may be a driver to generally lower water quality (increased nitrate fluxes, temperature increases, eutrophication etc.) there is a potential concern that over-performance may be required or may need enhancement.

Regulators such as the Environment Agency may need to tighten consent in order to follow protocols such as the Habitats Directive which requires ‘no deterioration’ in the quality of water courses. In contrast to this, where ‘over-performance’ is not occurring, summer low-flows may impede future consents to discharge from sewage treatment plants. Whilst low flows will impact on treated sewage discharge in all catchments, smaller, lower category plants, usually in smaller catchments are most likely to fall into this category and the peninsular South West (Devon and Cornwall) is most likely to be at risk here.

Sewage sludge remaining after the fluid element has been discharged is posing an increasing problem. Disposal at sea is no longer permitted and the British retail organisations (especially the supermarkets) are concerned about disposal on agricultural land. Frequently the supermarkets insist that their suppliers’ land does not receive sewage sludge dressings, and in all instances where sludges are disposed on land the supermarkets require prior treatment. Where land is available, wet ground conditions prevent the disposal of the sludges as access is not possible. Climate change is thought likely to exacerbate this difficult issue, with additional threats posed by rapid nitrate wash-through following winter dressing.

iv) Maintenance of flow levels in rivers and water levels in aquifers

Low flows in rivers have been discussed in the above section in relation to water quality and supply and in the Rivers, Flooding and Drainage Domain. Additionally, it is important to stress the significance of the Environment Agency's Catchment Management Plans (CMPs) and abstraction management strategies that have responded to the potential for climate change. The latter are particularly important in relation to consents for agricultural and industrial abstraction that may have particular impact on headwater drainage systems and local aquifers.

Perceptions and levels of understanding

Climate change is an issue owned convincingly by the water companies and the Environment Agency. Studies have been undertaken to assess water resource predictions etc. using the UKCIP98 scenarios.

Public awareness of the water resource issue is increasing through the educational role of the Environment Agency and the water companies. The level and consequences of this knowledge (e.g. use of grey water, hippos etc.) is, however, uncertain and partial. More effort is needed in terms of education and this is reflected strongly in the findings of the Cheltenham Climate Change Forum (2001), both in terms of water resources and more generally.

The Way Forward

In general terms there appears to be a good degree of cooperation between the water industry and its environmental regulator (the Environment Agency). OFWAT reports that it is following the climate debate with interest and takes advice from the Environment Agency on all matters connected to climate change. It is clear that water companies and regulators need a common base – to agree climate change is an issue and then engage in an in-depth three-way debate. There is some disquiet surrounding the opposing demands requiring the water companies to assume responsibility for water conservation whilst encouraging householders to move to water metering (e.g. 34% of SW customers are on meters). In effect, companies are asking for water -conservation with a reduction in their income as the consequence.

In terms of water supply, a trend towards hotter, drier summers is the most significant climate prediction. The UKCIP98 scenarios did not reveal any major, unconsidered issues associated with water supply. The research and development agendas of the water companies have responded well to these predictions, but continued work is required to assess the UKCIP02 scenarios.

A critical issue may be the difference in predicted annual rainfall trends, and its significance for recharge vs. draw-down as discussed above. However, it does seems probable that only the longer droughts will be of particular significance, with the impact of predicted rainfall variability - in particular seasonal shifts - being of lesser importance. These longer droughts, which were not predicted in the UKCIP98 scenarios, would challenge the 2-season reservoirs and the pump-storage schemes that have converted larger 2-season stores into operational 1-season reserves.

Recommendations

The climate change issues have clearly been taken seriously in the water resources sector. Indeed, whilst there are clear areas of potential disagreement between the water companies and their regulator (the Environment Agency), the public-private partnership that these organizations have developed should be viewed as an example of good practice in the climate change debate. It is clear that much of the research informing climate change science is derived from the research teams established by the Agency and by the water companies, both separately and in partnership.

Greater effort is needed to enhance the public (i.e. the domestic consumer's) knowledge of the potential impact of climate change and their individual abilities both to adapt to and mitigate against climate change.

Climate Change as an economic and environmental driver needs to be factored into policy more strategically by OFWAT than is currently the case.

Challenges and Opportunities of Key Climate Impacts for Water Resources Domain

Climate Impact		Challenges + Opportunities
Summer Temperature Increased	C	Increased evaporative losses from surface water stores.
	C	Increased risk of water demand rises leading to reservoir draw down.
	C	Increased risk of algal blooms and eutrophication in reservoirs containing reduced water levels and low inflows.
Summer Rainfall Reduced	C	Increased risk of water demand rises leading to reservoir draw down.
	C	Increased risk of algal blooms and eutrophication in reservoirs containing reduced water levels and low inflows.
Winter Rainfall Increased	C	Increased run-off may lead to over-stressing and backing up of sewer network.
	C	Problems with transfer of sewage sludges to agricultural land though difficulty in spreading and land access.
	C	Increased potential for nitrate flushing into water stores and courses.
	C	Increased potential for soil erosion and sedimentation.
	O	Greater potential for increasing water releases for hydropower.
	O	Greater potential for one-season recharge of larger reservoirs and aquifers.
Sea Level and Tides Increased	C	Potential for saline incursions into water abstraction plants near river mouth (e.g. Exeter).
	C	Potential for saline incursions into groundwater abstraction boreholes (e.g. Dawlish).
Longer Growing Seasons and Reduced Frosts	C	Potential for an increased growing season could lead to more intensive land use and greater incidence of winter ploughing, with associated sediment erosion into reservoirs and storm sewers.
Flooding Increased	C	Potential over-loading of sewage treatment plants.
	C	Floods can lead to over-stressing and backing up of sewer network.
	C	Distribution may be affected adversely by localised flood events.
Potentially Increased Winds and Storms	C	Increased potential for soil erosion leading to elevated turbidity and cryptosoridium contamination of drinking water.