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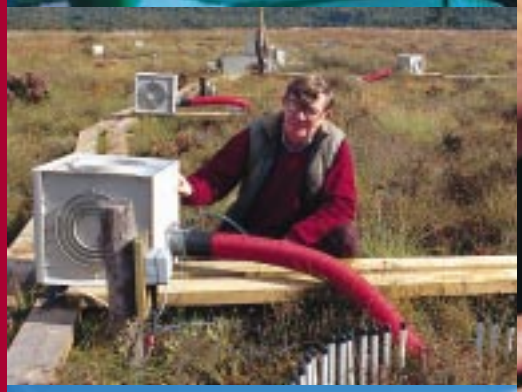
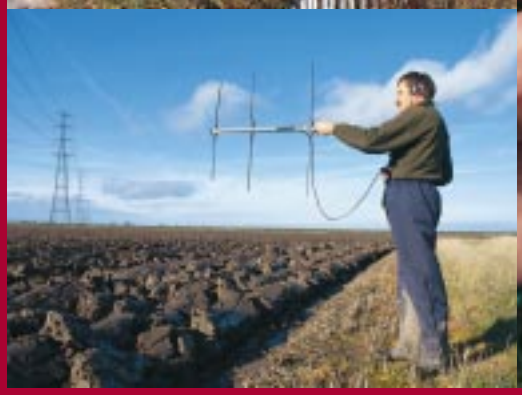
The MarClim Project

Key messages for decision makers and policy advisors, and recommendation for future administrative arrangements and management measures

English Nature Research Reports





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The MarClim Project

Key messages for decision makers and policy advisors, and recommendations for future administrative arrangements and management measures

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Cover note

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MarClim is one of a number of studies conducted under the umbrella of the UK Climate Impacts Programme (UKCIP). Based at the University of Oxford, UKCIP was set up by the Government in 1997 and is funded by Defra to help organisations assess how they might be affected by climate change so they can prepare for its impacts. For more information, see www.ukcip.org.uk or email enquiries@ukcip.org.uk.

The four-year MarClim consortium programme (2001 – 2005) was funded by the following organisations whose support is gratefully acknowledged:

ENGLISH NATURE

ENVIRONMENT AGENCY

SCOTTISH NATURAL HERITAGE

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COUNTRYSIDE COUNCIL FOR WALES

DEFRA
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UNIVERSITY OF PLYMOUTH

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THE CROWN ESTATE

JOINT NATURE CONSERVATION COMMITTEE

Marine Institute
Foras na Mara

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Executive summary

MarClim was a four year consortium project to assess and predict the influence of climatic change. This was achieved by using intertidal rocky shore biota and assessing the resultant implications for the conservation, management and protection of the marine environment in Britain and Ireland. The consortium project was led by the Marine Biological Association in partnership with Plymouth Marine Laboratory, Scottish Association for Marine Science, University of Plymouth and University College Cork, but funded by a much wider consortium of organisations under the umbrella of the UK Climate Impacts Programme (UKCIP). UKCIP itself is part of a wider programme of research into climate change being undertaken by the Department for Environment, Food & Rural Affairs (Defra).

The ethos of MarClim is that in the marine environment, as on land, climate change may influence patterns of biodiversity. Climate shifts, including temperature changes, more frequent storms and other extreme events, as well as variation in intensity and temporal variance of upwelling events, are likely to exert strong impacts at different levels of biological organisation, from genes to ecosystems. How rapid changes in climatic conditions will affect the marine environment is of major concern to a wide range of stakeholders and interested parties including scientists, commercial enterprises, policy makers and the general public, but until now little attention has been focused on the possible effects for marine biodiversity.

Britain and Ireland however, possess extensive data sets for marine species, which when analysed and made widely accessible, will increase our understanding of the impact of climate change on marine biodiversity. The MarClim programme was accordingly directed at making the best possible use of these datasets in order to understand the climatically driven changes that are occurring, and that will occur in the future. With such knowledge it is possible to provide advice to policy makers on the implications that this will have on the way that we currently conserve, manage and protect marine biodiversity, and how such matters may affect society and commercial interests.

The programme reported in winter 2005. MarClim has already generated increased awareness of marine climate change issues that has stimulated the production of climate change scenarios for the marine environment, as well as the creation of the Marine Climate Change Impact Partnership (MCCIP), which was officially launched by Elliot Morley in early 2005. A summary of the key messages is given below with more detail being provided in the main body of this report.

- **British & Irish leadership in assessing the impacts of climate change.** The MarClim database provides a globally unique cover of more than 50 temperature-sensitive seashore species over six decades, across the geographical scale of Britain and Ireland. Used alongside other sources of information this provides Britain and Ireland with a unique opportunity to become world leaders in the understanding of climate change induced trends and impacts on marine ecosystems.

- **The impacts of climate change are real, measurable and growing in extent**. MarClim demonstrates that climate-induced changes are occurring throughout marine ecosystems and that it is a general effect not limited to smaller forms of marine life, such as plankton.

- **Provision of a robust baseline of information**. Whilst there are many other species whose distributions are temperature related, other than data for plankton, none have anywhere near the extensive and robust baseline of MarClim from which to determine future climate change trends and impacts. Results from MarClim, and other work on offshore benthic community datasets, suggest that changes to invertebrate and fish species distributions are also occurring in both coastal and offshore environments, and that these may affect offshore biodiversity as well as species of economic importance for the UK. A priority for future study should therefore be to extend the approach of MarClim into offshore waters, and predict the consequences of climate change for key habitats and species of economic and nature conservation importance.

- **The value and necessity of long-term data sets**. MarClim has demonstrated the fundamental value of long-term data sets in understanding changes in marine ecosystems and the critical importance of a long-term commitment to continued data-collection for analysing climate induced changes in species biogeography.

- **The benefits of a consortium approach with a broad geographic coverage.** The broad geographic coverage enabled by the MarClim consortium, in bringing together relevant agencies and research institutes in the United Kingdom and the Republic of Ireland, has enabled north-south and east-west trends to be validated in a way that a narrower national territorial approach could not have achieved.

- **Developing indicators for marine and coastal biodiversity**. MarClim species should be included as part of the key indicator set for marine and coastal biodiversity: they are easy and cost effective to measure, are very responsive indicators of climate change signals, and are supported by extensive baseline information geographically dispersed across the islands of Great Britain and Ireland.

- **Factoring in marine climate change into day-to-day business**. The predicted scale and nature of marine climate change impacts needs to be built into how we manage human activities, establish conservation sites, monitor, assess and report on the status of habitats, species and ecosystems, as well as the structuring of underlying legislation and policies.

- **A national priority for an integrated marine climate impacts monitoring programme**. The underlying monitoring work, which provides information used to understand and predict impacts of climate change, needs to be properly resourced and structured as a core element of a fully integrated programme. Given the importance of tracking climate change impacts and the geographical association between United Kingdom and the Republic of Ireland and the Gulf Stream, developing and funding such an initiative should be seen as a national priority.

- **Developing streamlined reporting to Government**. The unique value of MarClim data can be increased further by drawing it together with the results of other relevant marine climate change impact projects and programmes (such as SAHFOS for plankton) to provide a streamlined, coordinated and effective reporting framework to deliver key messages *quickly* to Government on a regular and possibly annual basis – the concept of 'Annual Report Cards'

Contents

Although there can be no certainty regarding the precise nature and rate of changes to the marine environment due to alterations in climate, in the absence of policies and measures to prepare for and accommodate the changes, even the more moderate of the predicted scenarios would have major social impacts.

BOELENS, and others 2005. Climate Change: Implications for Ireland's Marine Environment and Resources. Marine Institute. *Marine Foresight Series* No. 2

1 Introduction

1.1 The marine biodiversity and climate change project (MarClim) was devised in the autumn of 2000 and implemented by April 2001, at a time when there was a growing concern over the possible impacts of climate change. The work had a simple, straightforward focus:

- to rescue, assemble and collate historical data on the intertidal environment collected in the 1950's, 1960's and 1970's.

- to use this data (ie intertidal species distributions) to better understand climatically driven changes that are now occurring, and that may occur in the future.

1.2 The islands of Great Britain and Ireland are located in the transition zone between northern "boreal" waters and southern "lusitanian" waters. Native intertidal species biogeography reflects this in an overlap of northern (boreal) species being present at the southern limit of their range and southern (lusitanian) species being present at the northern extent of their range.

1.3 MarClim and other similar projects are of national and international importance in identifying easy to monitor species which could form a 'real time' marine climate change impacts reporting system, capable of annual updates.

1.4 The purpose of this report is to:

- explain the contribution that the **MarClim Project** makes to our understanding of climate change impacts, to the development of marine environmental policies, to our approach to long-term data sets, and to working in partnership on climate change adaptation strategies for the marine environment.

- provide advice to policy advisors and decision makers on the implications that climatically driven change may have for the way we currently conserve, manage and protect marine biodiversity, and how these issues may affect society and commercial interests.

1.5 A more detailed overview of the MarClim Project and its objectives are provided in Section 3, Annex 1, 2 and 3, and can be found in the final technical report, available on the internet at www.mba.ac.uk/marclim.

2 MarClim and climate change

2.1 Since the inception of MarClim in 2000, concern about climate change impacts has increased significantly, as a greater body of evidence has emerged on the likely scale and timing of impacts. Analysis now shows, for example, that:

- The 10 warmest years on record have all been since 1990. Over the last century average global temperatures have risen by 0.6 degrees Celsius: the most drastic temperature rise for over 1,000 years in the northern hemisphere.
- Extreme events are becoming more frequent. Glaciers are melting. Sea ice and snow cover is declining. Animals and plants are responding to an earlier spring. Sea levels are rising and are forecast to rise another 88cm by 2100 threatening 100 million people globally who currently live below this level.
- The number of people affected by floods worldwide has already risen from 7 million in the 1960s to 150 million today.
- In Europe alone, the severe floods in 2002 had an estimated cost of $16 billion.
- The summer of 2004 saw violent weather extremes in parts of the UK.

As our understanding increases and impacts resulting from climate change start to become apparent, the issue has been raised up the political agenda.

2.2 Concerns over climate change have now reached the highest levels of Government. In late 2004 and early Spring 2005 Prime Minister Tony Blair focused on climate change as the world's greatest environmental challenge that will now dominate the future, no matter what else may befall:

> *"What is now plain is that the emission of greenhouse gases, associated with industrialisation and strong economic growth from a world population that has increased sixfold in 200 years, is causing global warming at a rate that began as significant, has become alarming and is simply unsustainable in the long-term. And by long-term I do not mean centuries ahead. I mean within the lifetime of my children certainly; and possibly within my own. And by unsustainable, I do not mean a phenomenon causing problems of adjustment. I mean a challenge so far-reaching in its impact and irreversible in its destructive power, that it alters radically human existence."*
>
> Tony Blair, London, 14 September 2004.

2.3 During 2005 and 2006 the interest in climate change will increase still further as it becomes a key priority for European and world economic powers under the UK chairmanship of EU25 in the European Union and the G8 group of Nations.

2.4 Concern has also spread throughout the population, so that a recent opinion survey by Greenpeace showed that 78% of people are worried about the consequences of climate change. Accurate and timely information is essential to underpin future strategies for dealing with current and future climate risks.

3 Background, relevance and rationale of the MarClim project

3.1 The UK, along with many countries around the world, has commitments to implement legislation and deliver various agreements, many of which are likely to be affected by the consequences of climate change in the marine environment. These commitments generally focus on the need to take management measures that relate to meeting environmental quality targets or delivery of area-based initiatives to protect habitats and species. There are also broader issues involved in delivering sustainable development, which also require knowledge of the impact of climate change in order to determine appropriate adaptation or mitigation strategies.

3.2 During the MarClim project these aspects were considered in detail through two policy advisor workshops convened by UKCIP in 2001 and 2004. The key marine issues identified, where climate change would most likely have an impact, are set out in the table below.

Management measures and reporting requirements	Broader issues
• Birds Directive • Water Framework Directive • Environmental Impacts Assessment Directive • Sites of Special Scientific Interest • Marine Nature Reserves • Habitats Directive • National Biodiversity Strategies • OSPAR • ICES • Common Fisheries Policy • Sustainable Development Strategies • Marine Stewardship Reports • Strategic Environmental Assessment Directive • Environmental Liability Directives • European Marine Strategy • EU ICZM guidance • Ramsar Convention • Convention on Biological Diversity	• Species vulnerability to climate change • Climate change impacts on offshore fisheries and quotas • Climate change impacts on inshore aquaculture • Species distributions, range shifts and impacts on fixed boundaries of designated sites • Changes to components of the Gulf Stream circulation • Climate change adaptation (eg managed realignment) and coastal wetlands • Distinguishing climate change impacts from fishing impacts • Climate change impacts on pollutants, and knock-on effects on marine biota • Spread of alien species as opposed to changes in species ranges • Impacts on marine species as sustainability indicators • Development of data systems (eg Marine Recorder) to note species absence as well as presence

3.3 In 2000, when MarClim was developed, there was no strategic approach to assessing the impact of climate change on the marine environment. There was also no strategic marine project under the aegis of the UK Climate Impacts Programme (UKCIP) to deliver scientifically credible marine information in a timely manner to policy advisors and decisions makers.

3.4 What was evident in the analysis made in 2000, which led to the development of the rationale for MarClim, was that it was timely to bring together a number of issues into a single project:

- All authorities responsible for advising on and/or implementing environmental agreements that related to management measures in the marine environment would need to understand the likely impacts of climate change on their areas of interests.

- There was a wider interest in the impact of climate change beyond the science and environmental sector given the growing level of public concern.

- There is a need for Government Departments to take account of actual and potential climate change risks when conducting their business, particularly when making decisions with long-term consequences or in areas that are sensitive to current climate variability.

- Significant long-term data sets existed for the marine environment, held by individual scientists, or their families where scientists had deceased, that covered Britain and Ireland.

- These data sets were on temperature sensitive species from the seashore that could form the basis of a family of easy to measure indicator species to estimate future climate change impacts, and which had yet to be subject to comprehensive analysis.

- The data sets were sufficiently long term to cover previous periods of warming and cooling of the seas around the islands of Great Britain and Ireland making them especially relevant to understanding climate relationships.

- The data sets included pairs of southern and northern species, enhancing their potential value, given that Britain and Ireland are located at the junction in distribution between warm water and cold water species.

- The species for which there were data sets have life histories that involve planktonic dispersal, so they broadly reflected conditions in offshore waters, allowing correlation to relevant fish and plankton studies (eg SAHFOS).

- UKCIP02 climate change scenarios for the 2020s, 2050s and 2080s provided limited information on the seas, having been predominantly geared towards addressing future impacts on land and, would potentially benefit from future development in consultation with marine stakeholders.

- There was enthusiasm within scientific, conservation and policy circles, and UKCIP, to devise an appropriate project to address the marine environment, as a step towards an eventual fully integrated approach.

3.5 There was an obvious common need, given the policy context and wide range of organisations and individuals to be involved, to undertake this analysis just once in

order to make best use of resources, time and knowledge. There was also the sensitive issue that relatives still holding the valuable raw data of deceased scientists should only be approached once. This accordingly formed the framework within which MarClim was developed, bringing in scientific, conservation, climate and policy experts and data from England, Scotland, Wales, Northern Ireland, Ireland, Isle of Man, and the Channel Islands.

3.6 The original objectives for MarClim are set out in Annex 1, with a summary of the key achievements in Annex 2.

4 Key messages arising from the MarClim work

4.1 General issues

4.1.1 MarClim has been successful in meeting its objectives (see Annex 2 for a summary of achievements), but it has also exceeded them in a number of ways, principally in relation to the more extensive than initially anticipated database, but also in terms of the impact that the project itself has had on the broader scientific, conservation, climate and policy communities. This has resulted in:

- the funding of other related marine climate change impact work since the inception of MarClim,
- recognition of the significant value of truly long-term data sets, the need to preserve them and to provide open access to them,
- the value and role of the 'Advisory Group' user forum concept employed by MarClim for wider climate change discussions (Figure 1).

4.1.2 At a more specific level, the value of the MarClim work, and the key messages that arise, can be grouped under three themes:

- Issues arising directly from the data and analysis undertaken during the project.
- Issues arising from how MarClim undertook its work.
- Strategic issues that arose as a result of undertaking the MarClim project.

4.1.3 The key messages from each of these areas are examined in more detail below.

4.2 Issues arising directly from the data and analysis undertaken during the project

4.2.1 Environmental policy and management measures

4.2.1.1 The seas around the islands of Great Britain and Ireland are at a junction between the distribution of warm water species in the south and cold water species from the north,

with distinct cut-off points in species distribution being well documented. The results from MarClim show that climate change is really happening in a significant way. These changes are now having a profound impact on seashore indicator species, with those favouring warm water having southern distributions reaching up to 150 km further north than 20 years ago, with a slightly less pronounced but nevertheless parallel retraction of cold water species away from southern latitudes. MarClim has thus confirmed that climate change impacts are not just restricted to changing distributions in warm and cold water plankton species, as previously documented, but are evident in the distribution of larger species of animals and seaweeds on the sea shore.

4.2.1.2 MarClim has also confirmed that the changes in seashore indicator species are beyond previous scales of variation seen during the last 60 years when our seas went through a short warming phase, and are therefore now taking us into uncharted territory. The species studied during MarClim are a small subset of many more species known to be temperature sensitive (Annex 3), but as the latter have not been studied in detail, it can only be postulated that more gross scale changes are now occurring to our marine ecosystems.

4.2.1.3 **The key issues that arise from this are that:**

- **the impacts of climate change in marine environments are real, include effects on larger species and not just plankton, and are detectable over large scales (100s of km);**

- **the results of monitoring and surveillance programmes should now begin factoring into assessment and reporting procedures the likely background variability resulting from climate change (eg in the future 'absence' as well as 'presence' of species will be important record as distributions change);**

- **the action directed at establishing individual marine and coastal protected areas must recognise the need to work with dynamic boundaries, as a consequence of marine climate change impacts, as well as the natural dynamics of the environment;**

- **the actions directed at meeting requirements to establish networks of marine and coastal protected areas should build in sufficient replication of sites and geographical coverage to ensure that the sum total effect has resilience in the face of marine climate change impacts; and**

- **a flexible approach should be taken to the incorporation of recovery and conservation areas into broader marine management mechanisms, such as spatial planning, to avoid 'over planning'. Care should be taken to avoid decisions that make it more difficult to cope with future climate. Such broad management mechanisms should focus more on minimising combined and cumulative impacts, working within precautionary tolerances of ecosystems, and seeking 'win-win' opportunities, rather than extending to assigning widespread exclusive fixed 'rights' to areas of seabed to particular sectors and interests.**

4.2.2 The value of long-term data sets and supporting funding arrangements

4.2.2.1 Amongst the central objectives of MarClim was to identify and secure access to historical data sets held by retired scientists, or the heirs of deceased researchers that would otherwise have been lost, as well as revisiting sites to document biological changes since they were last visited in the 1970s, 1980s and 1990s.

4.2.2.2 MarClim has been very successful in achieving these aims, resulting in a data system with 11,000 quantitative sampling records from over 500 spatially referenced historical sites covering Britain and Ireland. Given the geographical location of the islands of Great Britain and Ireland at the end of the Gulf Stream, this work has preserved for the region, and made accessible to all via the Internet, an unparalleled data collection of regional and global significance. No other countries outside Britain and Ireland are currently known to have the ability provided via MarClim, in association with parallel studies on plankton, to efficiently and quickly track and then predict the future impacts of climate change on marine ecosystems against a solid baseline of data stretching back many decades.

4.2.2.3 **The key issues that arise as a result of this work are:**

- **the national and international value of long-term targeted datasets in unravelling the effect that climate variability is now having on marine ecosystems cannot be overstated;**

- **the need to maintain long-term data sets to track broad-scale variability and trends as we enter an unprecedented period of climate change, both in terms of the scale and speed of the changes now being seen;**

- **the need to provide long-term stable funding, as part of an integrated approach to investigating and monitoring the impact of climate change, in order to switch studies such as MarClim, onto a secure footing.**

4.2.3 Working with gaps in knowledge

4.2.3.1 MarClim has been successful in achieving its aims, in large part due to the foresight of the previous generation of marine scientists who chose to study easily monitored seashore species that are known to be temperature responsive. Whilst we now have an unparalleled data system from some seashore species, its value has been weakened by the lack of continuity of sampling, especially in the 1980s and 1990s, when government funding was withdrawn. As we enter a period of rapid climate change continuity will be essential for unravelling further climate change impacts as they occur.

4.2.3.2 In addition, many other species which have not been studied are also known to have relationships to the temperature of the surrounding seawater/air. Even if studies on a suite of such species, perhaps focussing on those linked to economic or social values were initiated now, our confidence in the type of response that may be recorded would be severely hampered by a lack of the solid, geographically extensive, baseline information we already have for MarClim.

4.2.3.3 **Key issues that arise from the work of MarClim are:**

- **how fortunate we are to have MarClim data,**
- **the importance for long-term continuity of such studies in order to gain the greatest benefit and understanding of the impacts of climate change in the future;**
- **the national and international value and robust nature of the MarClim data that are not replicated for other species with the exception of plankton;**
- **there is a broader suite of marine species whose distributions are also temperature related, but about which a lack of information makes it difficult to make any robust predictions;**
- **there is a need to develop and refine our knowledge of marine climate change impacts, using data from studies such as MarClim and SAHFOS as the core from which to expand over time, while acknowledging the limitations to such processes due to a lack of baselines for other areas.**
- **that this project can also serve as a useful example for the development of similar projects in other ecosystems, nationally and internationally.**

4.3 Issues arising from how MarClim undertook its work

4.3.1 Data archiving and stewardship processes

4.3.2.1 One of the key roles of MarClim, once it had located and retrieved historical data sets, was to ensure that they were entered onto a state of the art database that conformed to national data standards. This was necessary in order to assure quality and achieve conformity of the information underlying the analysis work. Through this process it was possible to unlock far greater values in the information than would otherwise have been achieved, as well as making such information widely available.

4.3.1.2 **Key message from this work is:**

- **There is a need for effective data archiving and stewardship at the time data are collected. This is to ensure that nationally important information avoids being lost over time, and is retained in a format that is openly accessible to maximise understanding and value for money**

4.3.2 Geographical spread and cross-sectoral nature of MarClim

4.3.2.1 Two key characteristics have greatly contributed to the success of MarClim. The first is the geographical spread of MarClim. The project covered the islands of Britain and Ireland, including the Isle of Man and the Channel Islands. This was essential in enabling the project to gain the understanding it has of the scope and nature of climate change impacts and trends. Such studies conducted at, say, the scale of the English

coast alone would not have been able to reach the same conclusions, as important changes in distributions of species would have occurred beyond the limits of the work, with local anomalies in how climate impacts on species, masking the broader trends.

4.3.2.2 The second invaluable characteristic relates to the cross-cutting nature of the MarClim project, building and strengthening links between the policy, science, conservation and climate change communities. This enabled effective networking and strong linkages to be made during the MarClim work across all areas, and enhanced the value and ownership of the end products and conclusions.

4.3.3.2 **Key message are that:**

- **future studies and fora on the impact of climate change on marine ecosystems should cover the broadest geographical spread feasible and should place a strong emphasis on bringing together all relevant disciplines to share and consolidate thinking on these issues.**

- **future studies also should incorporate data with the longest temporal range possible.**

- **a multi-partner interdisciplinary approach is essential to evaluating the cross-sectoral impacts of climate change, and future efforts to develop effective climate adaptation strategies will require the engagement of a broad range of stakeholders.**

4.3.3 The value of the MarClim Advisory Group mechanism

4.3.3.1 Strongly related to the previous point, is the value of the Advisory Group developed for the MarClim project. Prior to the formation of MarClim, no national forum existed through which to discuss marine climate change trends and issues, let alone detailed discussions on the implication of long-term data sets. Since its inception, the Advisory Group has enabled the project to undertake its work in an open and interactive manner with funders and other interested parties. It has also proved itself to have far wider value in relation to cross-agency thinking and planning, eg discussing marine climate issues and developing, for example, national views on the need, shape and nature of marine climate change scenarios, that are now under development through UKCIP.

4.3.3.2 **Key messages are that:**

- **the role MarClim's Advisory Group provided should be continued after the end of the project and developed into a national Marine Climate Change Impact Partnership focussed on developing adaptive capacity to climate risks in the marine environment. In so doing, the cross cutting nature of membership should be expanded and the geographical coverage maintained;**

- **work on marine climate change scenarios, stimulated by MarClim, should continue and be supported by the national partnership forum**.

4.4 Strategic issues that arose during the MarClim project

4.4.1 Streamlining and integration of reporting mechanisms

4.4.1.1 One of the issues that the MarClim work highlighted during the four year project was the important need to develop better and quicker mechanisms to communicate information held in the scientific community to policy advisors and decision makers. There also emerged a growing need to develop an overview of the results from the MarClim project and other similar projects investigating marine climate change impacts. This is particularly the case given the high political importance attached to this issue in light of the effects it will have on society and the economy, as well as the environment. This principle is conceptualised in Figure 2.

4.4.1.2 **The key issue this raises is that:**

- **mechanisms should be developed to provide a regular coordinated update on marine climate impacts informed by relevant projects and programmes, in order to minimise the lag time between knowledge and data being acquired and the implications being passed through to policy advisors and decision makers**.

4.4.2 Development of an integrated marine climate change impacts and trends monitoring programme

4.4.2.1 The MarClim project was devised as a strategic project to begin to address the impact of climate change on larger marine organisms on the seashore. It was timely and has contributed specifically to that topic but also more widely (as reported elsewhere in this report). Given the knowledge we now have about the significance of climate change there is a need to build on the successes of the various projects and programmes that have provided, or continue to provide, information on marine climate change impacts. The value of the species involved in MarClim, underpinned now by a large and robust data system, should be capitalised upon in future marine climate change impact work.

4.4.2.2 **The key messages from this are that:**

- **there is a need to develop an integrated marine climate change impacts monitoring programme, through which good coordination of effort and value for money can be achieved, ensuring that full benefits can be obtained from the long-term data sets and any shorter term scientific studies that are undertaken;**

- **MarClim species could play an important role as part of the suite of indicators used to track sustainable development and evaluate the direct impacts of both natural processes and human-induced pressures, with the obvious application for assessing the impact of climate change**.

5 Next steps

5.1 Much has been achieved by the MarClim Project (2000-2005):

- to rescue, assemble and collate historical data on the intertidal environment collected in the 1950's, 1960's and 1970's.
- to use this data (ie intertidal species distributions) to better understand climatically driven changes and trends.

But more still needs to be done to secure the data collected, to subject it to additional analysis and to make it more widely available to the scientific community for added value analysis.

5.2 In 2005, several of the main issues identified in this report will already be being tackled by Government Departments, Agencies, and supporting projects and programmes:

- **A Marine Climate Change Impacts Partnership (MCCIP)** was launched in March 2005. This builds on the successes of the MarClim Advisory Group, bringing together the family of projects and programmes and cross-sectoral interests over a wide geographical scale, into a coordinated and responsive framework. Early tasks the partnership will examine are:
  - streamlining the reporting mechanisms to ensure that key messages on marine climate change impacts from science and monitoring are transmitted quickly and efficiently through to policy advisors and decision makers;
  - contributing to a more integrated approach to monitoring, reporting and managing marine-related climate risks and vulnerabilities.
- **A Marine Data Partnership** was launched in March 2005. This will handle issues concerning data standards, stewardship and ensuring better access to important data, including that obtained through publicly-funded research.
- A new **State of the Art Coupled Regional Climate Model** is being developed at the Hadley Centre, and the Shelf Seas component of this model will provide high resolution three-dimensional scenarios of future change in sea temperature, salinity, currents and sea surface height. While the use of climate change scenarios to inform land based decision-making is well established, marine policy advisors and decision makers are less familiar with this type of information. The MCCIP will offer a national coordinating framework well suited to:
  - providing feedback on the most appropriate processed data products and outputs,
  - publicising scenarios to ensure widest possible uptake in the marine community,

- demonstrating sufficient demand from the broader marine community in order to strengthen the case for funding further developments (eg wave modelling),
- informing future modelling work and scenario generation to inform decision-making in the face of climate risks in the marine environment.

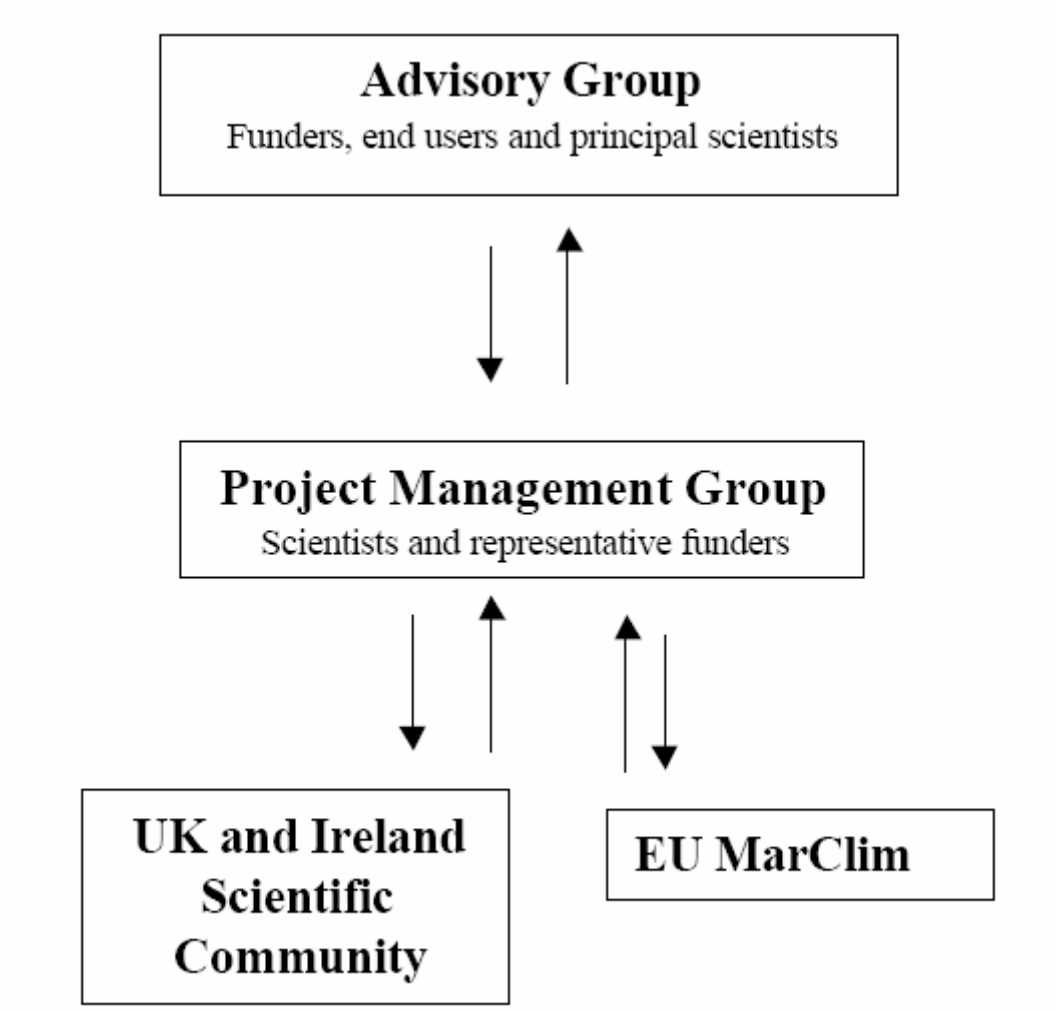

Figure 1. The management structure of the MarClim project, showing the relationship between the Advisory Group and other management processes.

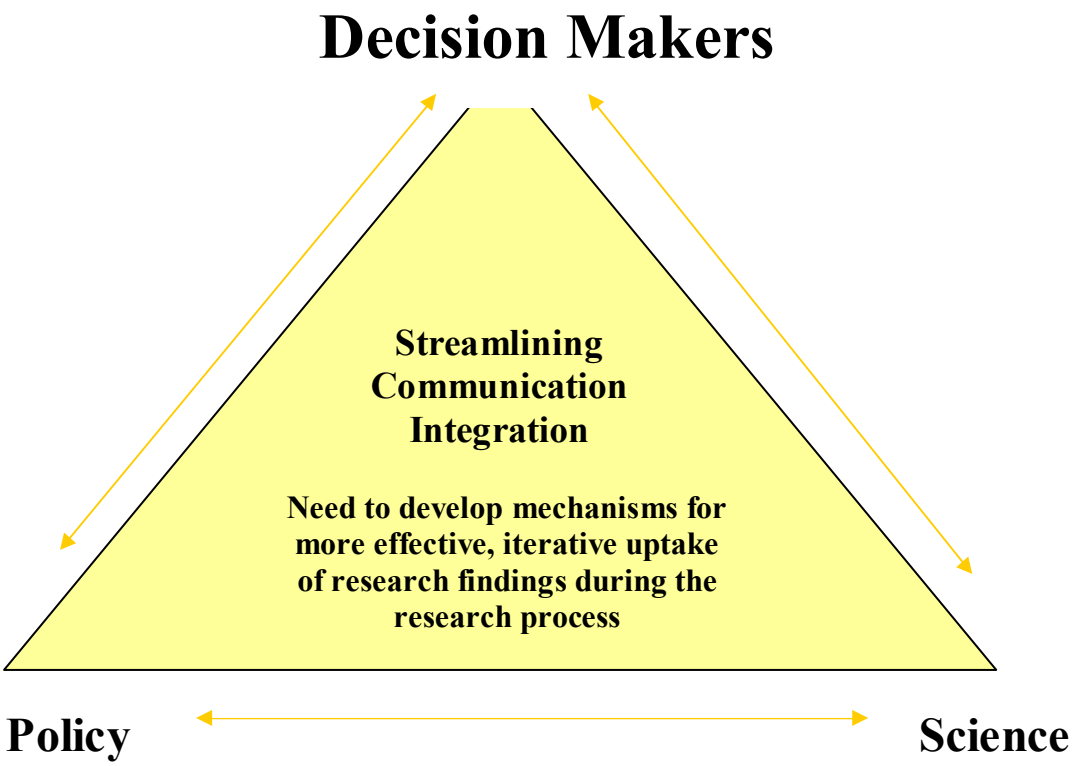

Figure 2. Visualisation of the coherence required between decision makers, policy advisors and scientists that the MarClim project addressed through the implementation of the Advisory Group mechanism

Annex 1 General overview of MarClim and project objectives

Assessing and predicting the influence of climatic change using intertidal rocky shore biota and its implications for the conservation, management and protection of the marine environment in Britain and Ireland

A consortium project led by the Marine Biological Association in partnership with Plymouth Marine Laboratory, Scottish Association for Marine Science, University of Plymouth and University College Cork

S.J. Hawkins, A.J. Southward, M.A. Kendall, M.T. Burrows, R.C. Thompson & R. O'Riordan

Governments and transnational bodies are becoming increasingly concerned about global climate change and its implications, but to date little attention has been focused on the possible effects on marine biodiversity. Britain and Ireland possess extensive data sets for some marine species, which, if analysed and made widely accessible, would increase our understanding of the impact of climate change on marine biodiversity.

This major four-year multi-partner British and Irish project will establish a single focus to start to improve the understanding of these relationships. In so doing it is creating a forum for marine scientists, marine conservationists and climatic change experts to consider such issues, under the auspices of the UK Climate Impacts Programme. The project is focussing on a robust set of temperature-sensitive, readily observed, intertidal climate indicator species for which long-term data sets and monitoring sites are available. This work will demonstrate the changes that have occurred during the last 50 years and results will be used to develop and test hypotheses on changes now occurring. This is in order to forecast 'with maximum confidence' future changes, based on definitive climate models, covering a wider spectrum of temperature sensitive species. The project will also establish a low-cost network to provide subsequent annual updates to track how climate influences the marine biodiversity of the islands of Britain and Ireland. This network, together with the baseline information provided by this project, will be a key tool to help track the effects on biodiversity that will arise as climate changes.

Current scenarios suggest that warming of sea and air temperature will continue in the short term (2020s), but in the longer term there are fears that the North-Atlantic thermohaline circulation may weaken leading to regional cooling in north-western Europe. In addition to broader-scale climatic change there is considerable shorter-term fluctuation possibly related to solar flux as indicated by sun spots and the North Atlantic Oscillation. The results of this work, and particularly the forecasting elements, will be used to help inform policies concerning the marine environment and will also provide contextual information to assist in reporting on the success, or otherwise, of marine aspects of Sustainable Development Strategies, Biodiversity Action Plans, European initiatives including the Habitats, Birds and Water Framework Directives, OSPAR and ICES and management and monitoring of marine activities and resources, including fisheries.

The **MarClim project objectives** were to:

- Use data on intertidal indicator species from the last 50-100 years to develop and test hypotheses on the impact of climatic change on marine biodiversity in Britain and Ireland.

- Forecast future marine community changes on the basis of the Met Office's Hadley Centre climate change models and the UKCIP's climate change scenarios. The broad range of species known or thought likely to be temperature sensitive will be covered.

- Establish a low-cost, fit-for-purpose, network to provide subsequent regular updates and track how climate influences the marine biodiversity of Britain and Ireland.

- Assess and report on the likely consequences of the predicted changes in response to climate for society, for commercial and non-commercial users of the marine environment and the policies and frameworks that conserve, manage and protect marine biodiversity. It will assess whether any more serious impacts can be ameliorated or mitigated.

- Provide general contextual time series data to support reporting on the success or otherwise of marine aspects of Biodiversity Action Plans, European initiatives including the Habitats, Birds and Water Framework Directives, and management and monitoring of marine activities and resources, including fisheries and SACs

- Evaluate whether the climate indicator species used in this work have a wider contribution to make as part of the sustainability indicators that are needed to underpin the UK sustainable development strategy.

- Disseminate the results widely, and accordingly elucidate the known impact climate has had on marine biodiversity over the last 100 years, and may have in the future.

- Provide a basis for the development of a proposal for European Commission funding to establish a pan-European network with related aims.

Annex 2 Key achievements of MarClim

- Identified and secured access to historical data sets held by retired scientists or the heirs of deceased researchers that would otherwise have been lost and entered this data into electronic formats.
- Set up standards for structuring these separately held/collated datasets into a user-friendly project database, with update mechanisms where relevant for the future.
- Synchronised data access and IPR policy with that of the National Biodiversity Network (NBN), (MarClim UK only).
- Contextual information >500 spatially referenced historical sites with a broad spatial and temporal coverage.
- Quantitative (time series) and semi-quantitative (SACFOR) data available for a suite of intertidal species.
- 2,500 SACFOR sampling records entered into database format transferred to Marine Recorder (accessible to the wider community in 2005 through JNCC & NBN).
- 11,000 quantitative sampling records also entered into database format.
- Fit for purpose, rapid sampling protocols developed using both in situ surveys and digital photography and refined to allow data to be analysed using modern statistical analysis.
- The distribution of key intertidal species around the islands of Great Britain and Ireland have been accurately determined.
- The spread of some invasive species has been evaluated and the current status of a Biodiversity Action Plan species assessed.
- Maps produced of the current distribution of key intertidal climate indicator species for the islands of Great Britain and Ireland.
- Noted range expansions of southern species near their northern limit of distribution (120km in the case of Balanus perforatus, c.150km in the case of Bifurcaria bifurcate.
- Extensive geo-referenced baseline data established for 2000's, (when climate change has been especially rapid).
- Quantitative (time series) and semi-quantitative (SACFOR) data available through Marine Recorder, UK wide or for smaller coastal sectors eg close to SAC's.
- UK-wide basis for continuation of climate change monitoring and/or surveillance.

- Extracted temporal and spatial trends in six target (potential indicator) species populations and related these trends to physical (climatic) drivers.
- Untangled small scale natural variation from broadscale (climate driven) effects.
- Generated testable hypotheses that provide evidence for cause-effect relationships, informing modelling and hence prediction & forecast.
- Disseminated findings in international peer-reviewed scientific journals, various semi-popular articles, conferences and stakeholder presentations.
- A baseline against which to monitor future change against.
- Simple inexpensive indicators of climate induced change.
- Contextual information for areas with conservation designations (SACs, SPAs, SSSIs, MNRs)
- Identified areas of the coast of Great Britain and Ireland in which target warm water species are increasing in abundance and expanding their range.
- Developed criteria to select potential sites from existing datasets held under MarClim and refined sampling protocols.
- Conducted pilot trials of the network protocols at a subset of sites around the UK.
- Conducted a statistical sensitivity analysis, examining different sampling strategies and scientific questions informing a range of management objectives.

Annex 3 MarClim publications & presentations

Publications:

ALLEN, B.M., and others (in submission, Biology & Environment). *The status of the invasive barnacle* Elminius modestus *(Darwin) in Ireland*.

BURROWS, M.T., MOORE, J., & JAMES, B. 2002. Spatial synchrony of population changes in rocky shore communities in Shetland: implications for monitoring. *Marine Ecology Progress Series* (In Press).

DAVENPORT, J, & DAVENPORT, J.L. 2005. Effects of shore height, wave exposure and geographical distance on thermal niche width of intertidal fauna. *Marine Ecology Progress Series*, 292, 41-50

DAVENPORT,. J., and others. 2005). Doses of darkness control latitudinal differences in breeding date in the barnacle *Semibalanus balanoides*. *Journal of the Marine Biological Association of the United Kingdom*, 85, 59-63.

HAWKINS, S.J., SOUTHWARD, A. J., & GENNER, M. J. 2002. Detection of Environmental Change – Evidence from the Western English Channel. *Science of the Total Environment* (In Press).

KENDALL, M.A., HAWKINS, S J., BURROWS, M.T., & SOUTHWARD, A.J. 2002. Predicting the effects of marine climate change on the invertebrate prey of the birds of rocky shores. *Ibis Special Edition* (Submitted).

LAWSON, J., DAVENPORT, J., & WHITAKER, A. 2004. Barnacle distribution in Lough Hyne Marine Nature Reserve: a new baseline and an account of invasion by the introduced Australasian species *Elminius modestus* Darwin. *Estuarine, Coastal and Shelf Science*, 60, 729-735.

LEAPER, R. and others, (in prep). *Changes in the distributions of interidal organisms in the Bristish Isles after 45-years*.

Power, A.M., and others, (in press). Patterns of adult abundance in *Chthamalus stellatus* (Poli) (Crustacea: Cirripedia) and *C. montagui* Southward are not determined by settlement or early recruitment. *Journal of Experimental Marine Biology and Ecology*.

POWER, A.M., and others, (in prep.). *Ratio of barnacle species abundance varies at small and large spatial scales*.

SIMKANIN, C.M., (in press). The invasive seaweed *Sargassum muticum* (Yendo) Fensholt found in Lough Hyne Marine Nature Reserve, Co. Cork. *Irish Naturalists Journal*.

SIMKANIN, C. and other. 2003. Monitoring intertidal community change in a warming world. *The Irish Scientist (year book).*

SIMKANIN, C., and others, (in submission, Journal of the Marine Biological Association of the United Kingdom). *Using Historical Data to Detect Temporal Changes in the Abundances of Intertidal species on Irish shores*.

SIMS, D.W., GENNER, M. J., SOUTHWARD, A. J., & HAWKINS, S.J. 2001. Timing of squid migration reflects North Atlantic climate variability. *Proceedings of the Royal Society B*, 268, 2607-2611.

SNH. 2002. *Impacts of climate change on seabed wildlife in Scotland*. Leaflet. (Based on K. HISCOCK, A.J. SOUTHWARD, I. TITTLEY, A. JORY, & S. HAWKINS. 2001. The impact of climate change on subtidal and intertidal benthic species in Scotland. *Scottish Natural Heritage Research Survey and Monitoring Report*, No. 182).

Papers in preparation

LEAPER, R., BURROWS, M.T., & SOUTHWARD, A.J. (In preparation). Spatial synchrony of population changes in intertidal barnacles over a 40-year period in the western English Channel. *Journal of Animal Ecology*.

LEAPER, R., BURROWS, M.T., HAWKINS, S.J., & SOUTHWARD, A.J. (In preparation). Does climate change drive spatial and temporal fluctuations of intertidal barnacle populations in the western English Channel? *Journal of Animal Ecology*.

MIESZKOWSKA, N., BOALCH, G., & HAWKINS, S.J. (In preparation). The geographic range of a brown alga *(Bifurcaria bifurcata* Ross)- revisited. *Botanica Marina*.

MIESZKOWSKA, N., KENDALL, M.A., LEWIS, J.R., HAWKINS, S.J., LEAPER, R., & SOUTHWARD, A.J. Long-term change in the distribution and relative abundance of intertidal organisms in the English Channel: the effect of 40 years of climate fluctuation. *Journal of the Marine Biological Association of the UK*.

POWER, A.M., and others. (In preparation). Spatial variation in abundance of *Chthamalus stellatus* and *C. montagui* during early benthic life in SW Ireland. *Journal of Experimental Marine Biology and Ecology*.

POLOCZANSKA, E.S., BURROWS, M.T., & HAWKINS, S.J. (In preparation). Climate change and competitive interactions in intertidal barnacle populations: models built on 40 years of evidence. *Journal of Animal Ecology*.

HAWKINS, S.J., and others. (In preparation). *Long-term change in the distribution and relative abundance of a northern and southern species of limpet in Britain: the effect of 30 years of climate fluctuation.*

LEAPER, R., and others. (In preparation). Long-term change in the distribution and relative abundance of intertidal organisms in the UK: the effect of 40 years of climate fluctuation.

LEAPER, R., and others. (In preparation). Long-term change in the distribution and relative abundance of intertidal organisms in the English Channel: the effect of 40 years of climate fluctuation. *Journal of the Marine Biological Association of the UK*.

MIESZKOWSKA, N., KENDALL, M.A., & HAWKINS, S.J. (In preparation). *Latitudinal variation in the reproductive cycle of* Osilinus lineatus.

MOORE, P., THOMPSON, R.C., & HAWKINS, S.J. (In preparation). *Climate change and species interactions: the role of* Fucus *patches in influencing the distribution of a northern and southern species of limpet.*

POLOCZANSKA, E.S., BURROWS, M.T., & HAWKINS, S.J. (In preparation). *Space-limited recruitment in intertidal barnacle populations: gregariousness or a constant settlement rate per unit area*?

SIMKANIN, C.S., MCGRATH, D., MYERS, A.A., DAVENPORT, J., & POWER, A.M. (In preparation). Long-term change in the distribution and relative abundance of intertidal organisms around the Irish coast: the effect of 40 years of climate fluctuation. *Journal of the Marine Biological Association of the UK.*

Recent posters on modelling work

Michael T. Burrows, Elvira S. Poloczanska, Nova Mieszkowska, Rebecca L. Leaper, Anne-Marie Power, Christina Simkanin, Stephen J. Hawkins. Coastal warming: data-based modelling of species distributions in response to climate change. Climate Change and Aquatic Systems: Past, Present & Future. 21-23 July 2004 Plymouth, UK.

Michael T. Burrows, Elvira S. Poloczanska, Nova Mieszkowska, Rebecca L. Leaper, Anne-Marie Power, Christina Simkanin, Stephen J. Hawkins. Coastal warming: data-based modelling of species distributions in response to climate change. Advances in Marine Ecosystem Modelling Research. An international symposium hosted by Plymouth Marine Laboratory 27 - 29 June 2005.

(MarClim Ireland has produced several additional posters which are outlined under 'dissemination' in 1st and 2nd Annual Reports).

Masters thesis

Christina Simkanin B.Sc.
'Monitoring Intertidal Community Change in a Warming World' June 2004.
at the Department of Life Sciences Galway-Mayo Institute of Technology, Galway, Ireland.
Supervisors: Dr David McGrath (GMIT) & Prof. Alan Myers (NUIC)

Annex 4 Provisional list of species with climatically restricted distributions or abundance in the UK

These taxa may change in distribution and/or abundance as a result of climate change (summarised from Hiscock, K., Southward, A., Tittley, I., Jory, A. & Hawkins, S. 2001. The impacts of climate change on subtidal and intertidal benthic species in Scotland, Scottish Natural Heritage Research, Survey and Monitoring Report No 182).

Species	Common name	Current distribution other comments	North or South
Porifera			
Axinella dissimilis	sponge	Recorded in the British Isles as far north as Mull, Northern Ireland and Anglesey.	S
Ciocalypta penicillus	sponge	Recorded in the British Isles as far north as Northern Ireland and Anglesey.	S
Hemimycale columella	sponge	Recorded off west Scotland and Shetland in Scotland.	S
Phorbas fictitius	sponge	Records from west Scotland, Orkney and Shetland in Scotland.	S
Haliclona angulata	sponge	Only recorded from SW Britain in the British Isles.	S
Haliclona cinerea	sponge	Recorded from west Scotland and Orkney in Scotland.	S
Haliclona fistulosa	sponge	Recorded from west Scotland and Orkney in Scotland.	S
Haliclona simulans	sponge	A southern species with a few records from west Scotland and Orkney.	S
Cnidaria			
Thuiaria thuja	bottle-brush hydroid	A northern species recorded south to off Northumberland in the British Isles Records from the Firth of Forth, Orkney, Shetland and Lewis in Scotland.	N
Gymnangium montagui	hydroid	A southern species extending as far north as Northern Ireland and Anglesey in the British Isles.	S
Alcyonium glomeratum	red sea fingers	A southern species with scattered records from the west coast of Scotland.	S
Swiftia pallida	northern sea-fan	Only recorded in west Scotland and St Kilda in the British Isles.	N
Eunicella verrucosa	sea-fan	A southern species recorded as far north as NW Ireland and SW Wales in the British Isles.	S
Funiculina quadrangularis	tall sea pen	Recorded on the north and west coasts of Ireland and Scotland. Also occurs in the Mediterranean.	S
Anemonia viridis	snakelocks anemone	Widely recorded on the west coast of Britain and Orkney but not recorded in Shetland during extensive surveys.	S

Species	Common name	Current distribution other comments	North or South
Bolocera tuediae	anemone	The only records in Britain are off the south-east coast of Scotland and north east cost of England and south west coasts of Scotland.	N
Aulactinia (=*Bunodactis*) *verrucosa*	gem anemone	A southern species recorded at a few locations in south west Scotland and Shetland.	S
Actinia fragacea	strawberry anemone	A southern species, present in the channel as far east as Brighton	S
Aiptasia mutabilis	anemone	A southern species recorded as far north as Anglesey in the British Isles.	S
Phellia gausapata	anemone	A northern species recorded in west Scotland, Shetland and Northern Ireland in the British Isles.	N
Amphianthus dohrnii	sea fan anemone	Recorded in west Scotland and a few locations in SW Britain.	S
Corynactis viridis	anemone	A southern species. Recorded on open wave exposed coasts in western Scotland, Orkney and Shetland in Scotland.	S
Annelida			
Sabellaria alveolata	honeycomb worm	A southern species. The only Scottish records are from the Solway Firth and off Lewis.	S
Crustacea			
Chthamalus montagui	barnacle	Southern species commonly recorded off the north and west coasts of Scotland, present in Orkney and Shetland. Also rare at a few places on the east coast.	S
Chthamalus stellatus	star barnacle	A southern species recorded off west Scotland, Shetland and Orkney in Scotland.	S
Semibalanus balanoides	barnacle	A northern species reaching it's southern limit in southwest Britain	N
Balanus perforatus	a barnacle	Only recorded in south west Britain as far north as south Wales in the British Isles.	S
Hippolyte huntii	a shrimp	A southern species which has been recorded off west and south east Ireland and south west England in the British Isles but is rare. Recorded in Scotland also recorded at Strome Narrows.	S
Palinurus elephas	crawfish	Previously widely distributed in south west Britain in the British Isles but has declined in the past 20 years. Recorded on the west coast of Scotland, Orkney and Shetland. Also a few records from the east coast of Scotland.	S

Species	Common name	Current distribution other comments	North or South
Lithodes maia	northern stone crab	A northern species recorded in west Scotland and Shetland in the British Isles.	N
Polybius henslowi	Henslow's swimming crab	Southern species recorded throughout Britain except in Shetland.	S
Ebalia tumefacta	Bryer's nut crab	A southern species recorded at a few locations in south west Scotland in Scotland.	S
Maja squinado	common spider crab	A southern species that only extends as far north as the Isle of Man and NW Ireland in the British Isles.	S
Clibanarius erythropus	crab	Southern species. Northern limit Channel Islands	S
Corystes cassivelaunus	crab	A southern species recorded on SW coast of Scotland and in Orkney in Scotland.	S
Liocarcinus arcuatus	arch-fronted swimming crab	A southern species recorded at a few locations in the south west in Scotland.	S
Liocarcinus corrugatus	wrinkled swimming crab	A southern species recorded from west Scotland and Lewis in Scotland. Also common in Orkney.	S
Goneplax rhomboides	angular crab	A southern species recorded from a few locations on the west coast of Scotland.	S
Pilumnus hirtellus	bristly crab	A southern species recorded on the west coast of Scotland and in Orkney.	S
Xantho incisus	Montagu's crab	A southern species recorded on the south west coast of Scotland.	S
Xantho pilipes	crab	A southern species recorded on the west coast of Scotland and in Shetland	S
Mollusca			
Tonicella marmorea	chiton	Northern species recorded as far south as Northumberland and North Wales.	N
Tricolia pullus	pheasant shell	A southern species of snail recorded off the west coast of Scotland but not in Orkney or Shetland.	S
Margarites helicinus	pearly top shell	A northern species recorded in both west and east Scotland, Shetland and Orkney.	N
Gibbula pennanti	topshell	Southern species found as far north as Channel Islands	S
Gibbula umbilicalis	flat top shell	A southern species commonly recorded on the west coast of Britain and present in Orkney. Also occurs on the east coast of Scotland but not in Shetland.	S
Osilinus lineatus	toothed topshell	A southern species which reaches its northern limits in Northern Ireland and Anglesey in the British Isles.	S

Species	Common name	Current distribution other comments	North or South
Tectura testudinalis	tortoiseshell limpet	A northern species commonly recorded throughout Scotland but reaching its southern limit in the Irish Sea in the British Isles.	N
Patella depressa	black-footed limpet	A southern species which reaches its northern limits at Anglesey in the British Isles.	S
Patella vulgata	limpet	A northern species reaches its southern limit in Portugal	N
Patella ulyssiponensis	limpet	Commonly recorded on the west coast of Britain and present in Orkney. Also occurs on east coast of Scotland and Shetland	S
Bittium reticulatum	needle whelk	Recorded off west Scotland and Orkney in Scotland.	S
Cerithiopsis tubercularis	gastropod	Occasionally recorded off west Scotland.	S
Melaraphe neritoides	small periwinkle	A southern species that occurs on wave exposed rocky coasts. Commonly recorded throughout Britain.	S
Onoba aculeus	gastropod	A northern species recorded off east and west Scotland, Orkney and Shetland	N
Calyptraea chinensis	chinaman's hat	Rarely recorded in SW Scotland and west Ireland.	S
Crepidula fornicata	slipper limpet	An introduced species recorded as far north as the Wash and SW Wales in the British Isles.	S
Clathrus clathrus	gastropod	Records from Mull and Moray Firth.	S
Ocenebra erinacea	oyster drill	Recorded off east Scotland, Shetland and the Firth of Forth	S
Colus islandicus	a gastropod	A northern species with a few British records from north Scotland, Shetland and Northern Ireland.	N
Acteon tornatilis	gastropod	Occasionally recorded all around Scottish mainland.	S
Akera bullata	sea slug	Northern species recorded off west Scotland, Shetland, Orkney and Moray Firth.	N
Pleurobranchus membranaceus	sea slug	Recorded off west Scotland, Orkney and Shetland.	S
Tritonia nilsodheri	sea slug	This species has a south-western distribution in the British Isles and is recorded as far north as NW Ireland.	S
Onchidella celtica	pulmonate	Southern species found in Cornwall, S along Atlantic coast of Europe.	S

Species	Common name	Current distribution other comments	North or South
Atrina fragilis	fan mussel	Present in south west England and western Scotland in the British Isles. Recorded off the west of Scotland (especially around Mull), Shetland, Orkney and the Moray Firth. Rarely encountered.	S
Haliotis tuberculata	abalone	Southern species found as far north as Channel Islands	S
Limaria hians	file shell	A northern species recorded often in large numbers in west Scotland But also recorded on the south coast of England in the British Isles.	N
Ostrea edulis	native oyster	Recorded from Norway to the Mediterranean and the Black Sea. Widely distributed around the British Isles.	S
Crassostrea virginica	american oyster	An introduced species not recorded in Scotland.	S
Anomia ephippium	common saddle oyster	Commonly recorded from north and west Scotland, Shetland and Orkney. Also occurs in the Firth of Forth. Included here because it is an important componant of biotopes in Scotland.	N
Thyasira gouldi	northern hatchett shell	Northern species recorded from upper Loch Etive, Loch Eil and Loch Sunart. The status at the latter two sites is currently unknown. These are the most southerly European populations of this species.	N
Cerastoderma glaucum	lagoon cockle	Rarely recorded on both coasts of Scotland and Orkney.	S
Solen marginatus	grooved razor shell	A southern species recorded as far north as Anglesey.	S
Gari depressa	large sunset shell	A southern species, just extending north into west Scotland in the British Isles.	S
Bryozoa			
Pentapora foliacea	ross	A southern species abundant in southwest Britain and recorded off west Scotland including at St Kilda.	S
Echinodermata			
Leptometra celtica	crinoid	Only recorded on the west coast of Scotland in Britain.	N
Asterina gibbosa	cushion star	Recorded off west Scotland and Orkney in Scotland.	S
Paracentrotus lividus	sea urchin	A southern species which is abundant in parts of south-west Ireland but has only sporadic recorded occurrences in south west England and at a few locations on the west coast of Scotland.	S

Species	Common name	Current distribution other comments	North or South
Leptasterias muelleri	star fish	A northern species recorded widely around the British Isles except on the south coast.	N
Strongylocentrotus droebachiensis	sea urchin	A northern species confined to the east coast of the British Isles. Probably occurs on all North Sea coasts of Britain.	N
Holothuria forskali	sea cucumber	A southern species that is abundant in parts of south west England. Recorded off west Ireland and a few locations off west Scotland around Rum.	S
Cucumaria frondosa	black sea cucumber	A northern species widely recorded in Shetland, also occurs in Orkney in the British Isles.	N
Tunicata			
Phallusia mammillata	sea squirt	A southern species recorded as far north as Anglesey in the British Isles.	S
Styela gelatinosa	sea squirt	Only British population is in Loch Goil (Clyde Sea). Also occurs in Scandinavia and Iceland.	N
Pisces			
Centrolabrus exoletus	rock cook	Most abundant in southern Britain but recorded off west Scotland and in Orkney.	S
Crenilabrus melops	corkwing wrasse	Most abundant in southern Britain but recorded off west Scotland and Orkney.	S
Ctenolabrus rupestris	goldsinny wrasse	Recorded off west Scotland, Shetland and Orkney but not in large numbers compared with densities in similar habitas in Norway.	S
Labrus mixtus	cuckoo wrasse	Widely recorded off north and west Scotland, Orkney and Shetland but uncommon. Also occurs in the Firth of Forth.	S
Lumpenus lumpretaeformis	snake blenny	Northern species recorded off west Scotland, Shetland, Orkney only in the British Isles.	N
Thorogobius ephippiatus	leopard-spotted goby	Recorded off west Scotland, Orkney and in the Firth of Forth.	S
Algae			
Scinaia furcellata	red alga	Present from the Mediterranean and Morocco to southern Norway. Southern species recorded as far north as Anglesey and SW Ireland. In the British Isles. Also a single Scottish record from Barra.	S
Scinaia trigona (= S. turgida)	red alga	Present from the Mediterranean and Portugal to the British Isles. Recorded in west Scotland and Shetland	S

Species	Common name	Current distribution other comments	North or South
Asparagopsis armata (*Falkenbergia* phase)	red alga	The tetrasporophyte (*Falkenbergia*) phase of *Asparagopsis armata*) occurs as far north as Shetland but is not recorded from the east of Scotland. Not recorded from Northern Ireland. (The gametophyte phase is recorded from a few locations in south-west England and from southern Ireland in the British Isles).	S
Bonnemaisonia hamifera	red alga	The tetrasporophyte phase (*Trailliella)* is widely distributed from Mauritania to northern Norway but the gametophyte (*Bonnemaisonia*) phase is only found between Spain and south-west England.	S
Naccaria wiggii	red alga	Present from the Mediteranean and Spain to southern Britain as far north as the Isle of Man. There is a single Scottish record from NW Scotland that requires checking.	S
Jania rubens	red alga	Southern species occuring as far north as Norway. In British Isles recorded northwards to west Inverness and Aberdeen. Very rare in Northern Ireland.	S
Lithothamnion corallioides	maerl	Present from the Canary Isles to Norway. Recorded off west Scotland and Shetland but records need checking and many are dubious. A southern species.	S
Lithothamnion glaciale	maerl	Present from northern British Isles to Arctic Russia. A northern species commonly recorded in west Scotland, Shetland, Orkney and the Firth of Forth. Common in Northern Ireland. Recorded reliably south to Lundy and to Flamborough on the east coast of England.	N
Mesophyllum lichenoides	calcified red alga	Present from Mauritania north to the British Isles. Recorded from west Scotland and Orkney (Shetland records require confirmation).	S
Phymatolithon calcareum	maerl	Recorded off NW Scotland and Orkney. The major maerl bed biotope in Scotland.	S
Calliblepharis ciliata	red alga	Present from Mauritania and the Mediterranean to the British Isles. Recorded off west Scotland and in Orkney.	N
Chondracanthus (=Gigartina) acicularis	red alga	Present from Cameroon to the British Isles. Southern species recorded as far north as Anglesey (record needs checking) and Galway Bay	S

Species	Common name	Current distribution other comments	North or South
Callophyllis cristata	red alga	Northern species recorded on west coast of Scotland, Shetland and Orkney. Also occurs on east coast and in Northumberland. This is its southern limit and does not occur in Northern Ireland.	N
Kallymenia reniformis	red alga	Present from Morocco to the British Isles including Shetland. Recorded off west Scotland, Orkney and Shetland	S
Stenogramme interrupta	red alga	Southern species recorded from Morocco to Cornwall & Devon. In Northern Ireland, rare in littoral, not uncommon in sublittoral. Absent from Scotland.	S
Rhodymenia delicatula	red alga	Present from Morocco to the British Isles. Recorded off west Scotland, Orkney and Shetland	S
Rhodymenia holmesii	red alga	Present from Morocco to the British Isles. Recorded north to Anglesey and with some records for Jura and Islay. Very rare in northern Ireland.	S
Rhodymenia pseudopalmata	red alga	Present from Morocco and the Azores to the British Isles. Recorded off the west coast of Scotland and Orkney and in north-east England. Not recorded from Shetland.	S
Halurus equisetifolius	red alga	Present from the Mediterranean and southern Spain to Norway and the Faroes. Recorded in SW Scotland and Orkney.	S
Sphondylothamnion multifidum	red alga	Present from the Canary Island to British Isles. Distribution in Scotland restricted to a few locations on the west coast.	S
Drachiella heterocarpa (=*Myriogramme heterocarpum*)	red alga	Present from northern Spain to the British Isles. Southern species with a few records from the Outer Hebrides and outer Solway Firth in Scotland.	S
Drachiella spectabilis	red alga	Present in northern France and the British Isles. The only Scottish records are from Islay and St Kilda.	S
Odonthalia dentata	red alga	Present from the British Isles to Spitzbergen. Recorded throughout Scotland and as far south as the Isle of Man on the west coast of Britain and Flamborough on the east coast.	N
Stilophora tenella (= S. hizoids)	brown alga	Present from France to Scotland. Recorded from west Scotland, Orkney and Shetland	S

Species	Common name	Current distribution other comments	North or South
Sphacelaria arctica	brown alga	Northern species only recorded in Shetland in the UK. Also occurs in Denmark, Baltic, Norway & Greenland.	N
Sphacelaria mirabilis	brown alga	Northern species recorded in north Wales, Cheshire, around Scotland to north-east England at Berwick-upon-Tweed.	N
Sphacelaria plumosa	brown alga	Northern species recorded reliably in west Wales, Cheshire, around Scotland to north-east England at Flamborough Head. Rare in Northern Ireland.	N
Halopteris filicina	brown alga	Present from the Azores and Portugal to Scotland. Recorded from western Scotland. (Shetland record requires confirmation)	S
Dictyopteris membranacea	brown alga	Present from the Azores and Portugal to the British Isles. A southern species present in large amounts only in the extreme south-west of Britain with a few records from west Scotland.	S
Taonia atomaria	brown alga	Present from the Azores and Portugal/southern Spain to south-west Britain to the Isle of Man and Ireland.	S
Carpomitra costata	brown alga	Southern species recorded in Channel Islands and southern UK as far north as the Isle of Man and Donnegal. Rare in Ireland and only a few records from the Outer Hebrides.	S
Chorda tomentosa	brown alga	Northern species recorded from west Scotland, Firth of Forth and Northern Ireland.	N
Laminaria ochroleuca	kelp	Southern species currently recorded as far north as Lundy.	S
Bifurcaria bifurcata	brown alga	Southern species recorded from southern Spain to England and Wales. Records from NW Ireland require checking.	S
Cystoseira baccata	brown alga	Present from southern Spain and Portugal to south-west Britain and western Ireland.	S
Cystoseira foeniculaceus	brown alga	A southern species only recorded in the SW of England.	S
Cystoseira tamariscifolia	brown alga	Recorded as far north as the mid outer hebrides, SW Uist. Also recorded in Arisaig, south of Mallaig.	S
Ascophyllum nodosum ecad *mackaii*	knotted wrack	Only recorded from Scotland in the UK and in a few locations in Ireland. Temperature may be important in distribution.	N

Species	Common name	Current distribution other comments	North or South
Fucus distichus distichus	brown alga	Northern species recorded from Scotland to the Arctic. Not recorded in Northern Ireland.	N
Fucus evansecens	brown alga	Present from Shetland and the Danish Baltic to the arctic. The only British records are from Shetland	N
Codium adhaerens	green alga	Present Portugal to the British Isles. Scottish records limited to Argyll and Mull.	S
Codium tomentosum	green alga	Present from the Mediterranean and Azores to northern Scotland. Also recorded in the Netherlands. Recorded in west Scotland and Orkney	S

ENGLISH NATURE

Research information note

English Nature Research Reports, No. 671

The MarClim Project
Key messages for decision makers and policy advisors, and recommendations for future administrative arrangements and management measures

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Introduction

In the last 60 years climate change has altered the distribution and abundance of many seashore species. The MarClim project was a four year multi-partner project created to investigate the effects of climatic warming on marine biodiversity. This was achieved by using intertidal rocky shore biota and assessing the resultant implications for the conservation, management and protection of the marine environment in Britain and Ireland. The consortium project was led by the Marine Biological Association in partnership with Plymouth Marine Laboratory, Scottish Association for Marine Science, University of Plymouth and University College Cork, but funded by a much wider consortium of organisations under the umbrella of the UK Climate Impacts Programme (UKCIP). UKCIP itself is part of a wider programme of research into climate change being undertaken by the Department for Environment, Food & Rural Affairs (Defra). This report examines the policy implications of the projects scientific findings.

What was done

The ethos of MarClim is that in the marine environment, as on land, climate change may influence patterns of biodiversity. Climate shifts, including temperature changes, more frequent storms and other extreme events, as well as variation in intensity and temporal variance of upwelling events, are likely to exert strong impacts at different levels of biological organisation, from genes to ecosystems. How rapid changes in climatic conditions will affect the marine environment is of major concern to a wide range of stakeholders and interested parties including scientists, commercial enterprises, policy makers and the general public, but until now little attention has been focused on the possible effects for marine biodiversity.

continued >>>

The project aimed to use intertidal species, whose abundances had been shown to fluctuate with climatic change, as indicator species of likely responses of species not only on rocky shores, but also those found offshore. The project used historical time series data, from in some cases the 1950s onwards, and contemporary data collected as part of the MarClim project (2001 - 2005) to provide evidence of changes in the abundance, range and population structure of intertidal species and relate these changes to recent climatic warming.

Results and conclusions

The MarClim project provides strong evidence that recent rapid climatic change has resulted in changes in the abundance, population structure and biogeograpic ranges of a number of intertidal indicator species, mirroring changes offshore. MarClim has already generated increased awareness of marine climate change issues. Key policy messages from the MarClim work fall under the following headings:

- The role British & Ireland can play in assessing the impacts of climate change.
- The fact that the impacts of climate change on marine ecosystems are real, measurable and growing in extent
- The provision through MarClim data of a robust baseline of information.
- The value and necessity of long-term data sets.
- The benefits of a consortium approach with a broad geographic coverage.
- The role climate indicators should play in the broader development of indicators for marine and coastal biodiversity.
- The need to act now to factor marine climate change impacts into day-to-day business.
- The national priority for developing an integrated marine climate impacts monitoring programme.
- The need to develop rapid and streamlined reporting to Government on marine climate change impacts.

English Nature's viewpoint

The MarClim work exceeded its original objectives and continues to play a pivotal role in stimulating the development of new approaches to studying and understanding the impacts of climate change in the marine environment. The project leaves a lasting legacy as a number of the policy implications set out above and in the report are already being implemented, such as the production of climate change scenarios for the marine environment, the Marine Climate Change Impacts Partnership officially launched by Elliot Morley in early 2005, and the development of the Annual Report card approach for thematic reporting through to Government.

Selected references

For all products from the MarClim project, including this Research Information Note and the pdf version of the English Nature Research Report please see http://www.mba.ac.uk/marclim/

Further information

English Nature Research Reports and their *Research Information Notes* are available to download from our website: www.english-nature.org.uk

For a printed copy of the full report, or for information on other publications on this subject, please contact the Enquiry Service on 01733 455100/101/102 or e-mail enquiries@english-nature.org.uk

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Top left: Using a home-made moth trap.
Peter Wakely/English Nature 17,396
Middle left: Co_2 experiment at Roudsea Wood and Mosses NNR, Lancashire.
Peter Wakely/English Nature 21,792
Bottom left: Radio tracking a hare on Pawlett Hams, Somerset.
Paul Glendell/English Nature 23,020
Main: Identifying moths caught in a moth trap at Ham Wall NNR, Somerset.
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