IMPACTS OF CLIMATE CHANGE ON INTERTIDAL SPECIES

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Executive Summary

There is strong evidence that recent rapid climate change has resulted in changes in the abundance and distribution of southern, warm-water species that reach their northerly limit on rocky shores in the UK. Significant extensions in range have occurred since the mid 1980s with further species range extensions observed over the shorter time period of the MarClim project (2001-2005). Between 2002 and 2004 a number of these species increased their range around N. Scotland (moving clockwise around the coast and into the colder North Sea) and also eastwards along the English Channel. These range extensions were not trimmed back by the recent cold winter of 2005/06 (the coldest since 1995/96 for England and Wales, and since 2000/01 for Scotland and Northern Ireland). Decreases in the abundance of northern, cold-water species that reach their southern limit in northern Europe have been observed; however, there is less evidence on rocky shores of northern cold-water species retreating northwards.

These observed shifts in distribution match those predicted by climate change models based on increases in Sea Surface Temperature (SST). However, there are also other climate-related factors which may be important such as new habitat being made available for rocky shore species along the south coast of the UK as a result of the proliferation of sea defences in response to rising sea levels and stormier seas. This facilitates the spread of species eastwards along the coast in response to warmer temperatures by the breakwaters acting as ‘stepping stones’ to reach rocky shores further east. More research is needed into this combination of factors and on the precise way species are affected by temperature (e.g. are adults or juveniles more sensitive? Is air temperature as important as SST?)

Level of Confidence

Overall, we have a medium level of confidence that climate is affecting the distribution of species

This is based on the fact that there is a large amount of good quality data from time series from a wide spatial extent and covering long time periods (see supporting evidence). Also, the modelling so far undertaken has accurately represented past and present observed distributions using changes in climate variables. However, we can only increase our confidence if future monitoring is carried out to validate model forecasts and if surveys are undertaken to increase the amount of baseline data for areas such as the east coasts of Scotland and England. Also, rates of change are increasing so the

observations need to be more frequent to take this into account, and reversals may occur in the future due to cold winters. Further investigation is also required into the mechanisms influencing species distribution and abundance and influence of factors other than temperature, such as artificial structures.

Key sources of Information

The source for this information is the Marine Biodiversity and Climate Change Project (MarClim) which ran between 2001 and 2005 and is now being continued under the umbrella of the MECN (MECN 2006). All reports and papers, including those containing details of the MarClim model outputs, are available at http://www.mba.ac.uk/marclim/marclim.php?sec=pub (MarClim undated a).

Information on the recent cold winter was provided by the Met Office and a summary can be found at http://www.metoffice.com/corporate/pressoffice/2006/pr20060303b.html (Met Office 2006).

Supporting Evidence

A number of species living on the coastline of the United Kingdom are either warm-water species with their northern limits in the UK or cold-water species with their southern limit in the UK and Northern Europe. These species can, therefore, be used as indicators of climate change by studying their distribution and abundance in response to changes in temperature. Rocky shore species are particularly useful as climate indicators as rocky shores are readily accessible, most species are sedentary or sessile (i.e. do not or cannot move around) and they can be easily sampled in a non-destructive way. There are also numerous long-term datasets available (see table 1), particularly those collected by the Marine Biological Association from the late 1940s onwards. With this in mind the Marine Biodiversity and Climate Change project (MarClim) was instigated in 2001 to undertake broad-scale resurveys around the whole of the UK to compare distributions with those previously recorded. Surveys were continued until the end of the project in 2005 and funding is being sought to continue surveys of climate indicator species in key areas. The final project report (from which most of the information below is taken) was published in 2005 (Mieszkowska *et al.,* 2005).

Geographic distribution	**Original collector**	**Data archived**	**Data Range**
UK, France & Portugal	A.J. Southward D.J. Crisp S.J. Hawkins	(1) Quantitative barnacles, limpets & trochids; semi-quantitative broadscale surveys	1950-1987 1947-1967 1980-2006
UK, N. France	Rocky Shore Surveillance Group (J.R. Lewis et al)	(2) Trochids	1964-1987
Southern England	R. Herbert		1987-2006
Shetland	Shetland Oil Terminal Advisory Group	(3) Quantitative barnacles & trochids; semi-quantitative broadscale surveys	1978-2005
UK, Ireland & France	MarClim Project	(4) Broadscale and transects	2001-2005
		(5) Quantitative barnacles, limpets & trochids; semi-quantitative broadscale surveys	

Table 1. Rocky Shore datasets utilised by the MarClim project (Source: MECN workshop report (Burrows *et al.,* 2006)).

The data shown in table 1 was used to a) develop and test hypotheses on the impact of climatic change on marine biodiversity in Britain and Ireland, and b) forecast future marine community changes on the basis of the Met Office's Hadley Centre climate change models and the United Kingdom Climate Impacts Partnership's climate change scenarios (the broad range of species known or thought likely to be temperature sensitive were covered).

Specifically, the MarClim project investigated the following predictions on the current and future responses of intertidal rocky shore fauna and flora to changes in environmental temperature regimes in Britain:

(1) Northern species will retreat northwards and their abundance will decline; such changes are likely be driven by a reduction in reproductive output and/or decreased juvenile or adult survival during hotter summer periods.

(2) Southern species will expand their range northwards and their abundance will increase. The mechanisms underlying these responses are likely to be an increase in reproductive output and/or juvenile survival during warmer summer periods and milder winters. The extent to which range extensions can occur will also be dependent on length of larval life stages and presence of rocky shores or artificial substrate beyond existing range edges enabling hydrographic barriers to be breached via 'stepping stones'.

(3) Biological interactions including competition, facilitation and predation will modulate the responses of southern and northern species with implications for community structure and ecosystem functioning. For example in barnacles, the northern species (*Semibalanus balanoides*) is competitively superior and the southern species are released from competition by recruitment failure associated with warm springs.

(4) Changes will be greater than in the last warm period in the 1950s prior to the cold winter of 1962/63.

The period for which ecological information exists spans the relatively warm 1950s, the severe winter of 1962/63 and a cool period from the 1970s to the mid 1980s. Experiments investigating the effects of warming on species reproduction and recruitment of the lusitanian topshells *Osilinus (Monodonta) lineatus* and *Gibbula umbilicalis* have been undertaken to investigate the mechanisms influencing these species increase in range and abundance (Mieszkowska *et al.,* 2006). In parallel, models were constructed on interactions between northern and southern indicator species, focussing on barnacles and validated by comparisons with long-term time series. Models were also constructed to predict past and current distributions of indicator species and validated against MarClim archived and contemporary data.

The main findings of the project were:

- Range extensions have occurred at the northern limits of the geographical distributions of typically southern, warm water species *Osilinus lineatus* (toothed topshell), *Gibbula umbilicalis* (flat topshell), *Chthamalus montagui* (Montagu's stellate barnacle), *Chthamalus stellatus* (Poli's stellate barnacle) and *Balanus perforatus* (acorn barnacle) since the mid-1980s in Wales, Northern Ireland and Scotland, including greater penetration around the north of Scotland into the colder North Sea

- Eastward range extensions of the southern species *Osilinus lineatus* (toothed topshell), *Gibbula umbilicalis* (flat topshell), *Patella ulyssiponensis* (china limpet), *Patella depressa* (black-footed limpet), *Melarhaphe neritoides* (small periwinkle), *Actinia fragacea* (strawberry anemone) and *Balanus perforatus* (acorn barnacle) have also occurred since the mid-1980s into the colder eastern English Channel beyond previous biogeographic boundaries.

- The northern species *Alaria esculenta* (dabberlocks) and *Tectura testudinalis* (common tortoiseshell limpet) have shown small retractions in their southern distributional limits and declines in abundance at populations close to these range edges, but the rate of recession is not as fast as the rate of advancement in southern species.

- Synchronous increases in abundance have been recorded in populations of southern topshells throughout Britain and northern France since the mid-1980s. These increases are an order of magnitude greater than the inter-annual variation detected, increasing the confidence that these are observations of decadal-scale change rather than the result of anomalous years, providing support to the theory that these increases in abundance are climate-related. These are driven by better and more consistent recruitment.

- Annual reproductive cycles of the southern/lusitanian trochids are commencing earlier in response to milder winters and warmer springs, coupled with increased survival of newly settled recruits exposed to milder, shorter winters on the shore.

- The annual reproductive cycles of the southern/lusitanian limpet *Patella depressa* are starting earlier and lasting longer in south-west Britain. In contrast, less than 20% of the population of the northern/boreal limpet, *Patella vulgata*, reached gonad development stages at which spawning can occur on some shores in south-west Britain in 2004/2005.

- Fluctuations of the northern barnacle *Semibalanus balanoides* and the southern *Chthamalus spp*. have been related to climate change using historical data collected by Southward and advanced statistical methods. These show that there is a direct negative effect of warm springs on survival of *Semibalanus balanoides* which, via release from competition, has an indirect positive effect on *Chthamalus*. These data have been used

for hindcast and forecast modelling using UKCIP climate scenarios. In particular these models have been able to incorporate characteristics such as species mortality, larval supply and competitive interactions to create more biologically realistic predictions of species responses to climate change.

- Models using the extensive broadscale resurvey data have been created for all MarClim indicator species to predict changes in their abundance and distribution in response to wave action and sea surface temperature regimes forecast by UKCIP (MarClim undated b).

Surveys of the distribution of a number of species were carried out after the recent cold winter of 2005/06 (the coldest since 1995/96 for England and Wales, since 2000/01 for Scotland and Northern Ireland) as part of a NERC urgency grant. It was found that the range extensions previously observed were not trimmed back by this event, with the possible exception of reduced abundance of *Anemonia viridis*.

It is important to note that many of the exact mechanisms by which species respond to climate are still under investigation (Mieszkowska *et al.,* 2006) although an initial assessment by the MarClim project is that (Mieszkowska *et al.,* 2005):

- It is likely that the northward range extensions observed in North Wales and those along the north coast of Scotland down into the North Sea have occurred in response to climatic warming increasing reproductive effort and juvenile survival success allowing these species to establish on suitable habitats.

- The increased abundance of some southern species, such as trochids, limpets and barnacles, is likely to have been the result of the earlier commencement (and in some cases prolongment) of annual reproductive cycles in response to warmer springs, coupled with increased survival of newly settled recruits exposed to milder, shorter winters on the shore. These species may also be out-competing northern equivalents as climatic conditions become more suitable for their survival and less suitable for species with cold water affinities.

There are also other factors identified by MarClim which may also have an influence on species range extensions:

- It is likely that range extensions along the eastern English Channel have occurred due to a combination of the proliferation of artificial sea defences along this coast, providing suitable habitat where none was previously present, and greater recruitment success of southern species in response to climatic warming. Hydrographic barriers at Portland Bill, the Isle of Wight and Selsey Bill seem to have been breached.

This is potentially an important additional factor contributing to the spread of certain species and will require further investigation.

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