MCCIP Marine Climate Change Impacts Partnership

Topic

Intertidal species

Author(s)

Nova Mieszkowska[1], Postdoctoral Researcher, Pippa Moore[1], Postdoctoral Researcher, Steve Hawkins[1], Director, Mike Burrows[2], Senior Scientist

Organisation(s) represented

[1]Marine Biological Association of the UK
The Laboratory
Citadel Hill
Plymouth

[2]Scottish Association of Marine Science
Dunstaffnage Marine Laboratory
Oban
Argyle

Executive summary

There is strong evidence from the MarClim project that recent rapid climate change has resulted in significant increases in abundance and extensions in the northern limits of southern, warm-water species that reach their northern biogeographical limits on rocky shores in the UK since the mid-1980s. Between 2001 and 2005 a number of these species increased their range around N. Scotland and along the English Channel. These range extensions were not trimmed back by the recent cold winter of 2005/2006 (the coldest since 1995/1996 for England and Wales, since 2000/2001 for Scotland and Northern Ireland). Decreases in the abundance of northern, cold-water species have been observed, however, there is less evidence on rocky shores of northern cold-water species retreating northwards.

These observed shifts reflect predictions by climate models based on increased sea surface temperatures, and are occurring faster than most recorded changes in the terrestrial environment, but they are highly species-specific. This is likely to have consequences for biodiversity as the rate and extent of changes will not be synchronous, and biological interactions will be affected. Sea-level rise and storms may have an important indirect impact as sea defences create artificial habitats in areas between natural rocky shores, acting as "stepping stones" by allowing intertidal species to extend their range.

Key points:

- The warmwater macroalga (seaweed) *Bifurcaria bifurcata* has established a new range boundary at Portland Headland in the last 5 years, 150km east of previous records.

- Some warm water invertebrates and algae show continued increases in abundance and have extended their ranges around northern Scotland and along the English channel over the last 20 years.
- Coldwater species have shown a continued decrease in abundance throughout the period 2001-2007. (e.g. *Semibalanus balanoides,* the acorn barnacle, and *Alaria esculenta*, dabberlocks algae).
- Rates of change are mostly faster than in terrestrial systems and highly species-specific.

Full review

The main findings of the Marine Biodiversity & Climate Change Project (Mieszkowska *et al.* 2005) were:

Scotland

- Range extensions have occurred at the northern geographical limits for typically southern, warm water species including *Gibbula umbilicalis* (flat topshell) and *Chthamalus montagui* (Montagu's stellate barnacle) between the 1980s and the 2000s.

- Abundances of warm-water species including *Gibbula umbilicalis, Chthamalus montagui, Chthamalus stellatus* have increased annually between 2002-2006.

- Abundances of northern cold-water species including *Mytilus edulis* (blue mussel), *Nucella lapillus* (dogwhelk), *Semibalanus balanoides* (acorn barnacle), *Fucus vesiculosus* (bladder wrack)*, Halidrys siliquosa* (sea oak), *Ascophylum nodosum* (knotted wrack) and *Pelvetia canaliculata* (channelled wrack) have continued to decrease between 2002-2006.

- Surveys conducted in 2006 after the cold winter of 2005/2006 showed that the general trend of increases in abundance of warm-water species and decreases of cold-water species continued despite this event. The population structures of the warm-water indicator species *Gibbula umbilicalis*, however, had altered at sites close to the northern range limit, with a sudden reduction in the oldest and youngest age classes compared to 2002-2005 surveys.

Wales, Northern Ireland & Isle of Man

- Northern range limits of the southern warm-water species *Osilinus lineatus* (toothed topshell) have re-extended to those prior to the extreme cold winter of 1962-63, which caused massive southern retreats of the ranges to the south of Wales. These extensions have only occurred since the 1990s.

- The northern limit of the southern *Balanus perforatus* (volcano barnacle) has extended further northwards beyond its biogeographic limits in Wales. *Chthamalus stellatus* has been found for the first time on the Isle of Man.

- The northern cold-water species *Tectura testudinalis* (tortoiseshell limpet) has disappeared from the Isle of Man since the 1980s and is now only found in Scotland.

- Abundances of near-limit populations of southern warm-water species including *Osilinus lineatus, Gibbula umbilicalis, Patella depressa* (black-footed limpet) and other warm-water species including *Chthamalus montagui, Chthamalus stellatus* have also increased.

England

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

- Isolated individuals of the southern warm-water species *Bifurcaria bifurcata* (brown alga) were found at Portland Bill in 2002. This species has not been recorded east of Devon in the English Channel since the end of the warm period at the start of the 1900s. *Bifurcaria bifurcata* has become abundant in this location during the last 5 years, and in 2007 it forms a band on open rock in the lowshore region, and confirming a range extension of over 150km since previous records in the 1930s, 1950s and 1990s. Plants were fertile, indicating that the population has the ability to self-recruit in current environmental conditions.

- The northern cold-water species *Alaria esculenta* (dabberlocks) has shown small retractions in the southern distributional limit and declines in abundance at populations close to the range edge, but the rate of recession is not as fast as the rate of advancement in southern species.

- The 2006 cold winter did not cause a decline in the abundance of warm-water species or trim back any range limits, nor was a strong affect on population structures of the southern trochid *Gibbula umbilicalis* observed in the English Channel.

Large-scale trends

- Synchronous increases in abundance have been recorded in populations of the southern trochids *Osilinus lineatus* and *Gibbula umbilicalis* throughout Britain and northern France since the mid-1980s. These increases are an order of magnitude greater than the inter-annual variation detected and demonstrate clear decadal-scale change. The results provide strong support that these increases in abundance are climate-related (Mieszkowska *et al.* 2007) and are likely to be driven by more frequent, stronger recruitment.

- Annual reproductive cycles of the southern warm-water trochids *Osilinus lineatus* and *Gibbula umbilicalis* are commencing up to 3 months earlier in response to milder winters and warmer springs in the 2000s, coupled with increased survival of newly settled recruits exposed to milder, shorter winters on the shore.

- The annual reproductive cycles of the southern warm-water 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.

- Surveys of the distribution of a number of species were carried out after the recent cold winter of 2005/2006 (the coldest since 1995/1996 for England and Wales, since 2000/2001 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*.

Future predictions

Ecological 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** (www.mba.ac.uk/marclim).

There are also other factors identified by the MarClim team 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.

A full list of publications and other outputs from MarClim can be found at http://www.mba.ac.uk/marclim/.

Confidence assessments

'What is already happening' - Medium

Overall, we have 'moderate confidence' that climate is already affecting distributions of species

This is based on the existence of a large archive of high quality time-series data with wide geographical coverage that has been collected over long time periods prior to and during the current period of climate warming (see supporting evidence). Modelling undertaken to date has accurately replicated past and present observed species' distributions using changes in marine climate variables.

'What could happen in the future' - Medium

We have 'moderate confidence' in our predictions for the future due to the current limitations in climate scenario forecasts and limited knowledge of the impacts at the community and ecosystem levels. The confidence level can only be increased by continuing monitoring surveys to validate model forecasts and increase the amount of baseline data for areas such as the east coasts of Scotland and England, and by investigating the bioprocesses governing species responses to climate change.

Continued annual observations are critical to prevent anomalous environmental or **anthropogenic** events from being misinterpreted as climate-induced effects on the ecosystem. The rate of temperature increase is accelerating and ecological observations therefore need to be made on a regular basis in order to accurately map and predict future responses to climatic drivers. An annual sampling periodicity has been employed throughout MarClim and subsequent surveys from 2001-2007 and is strongly recommended for future climate impact projects.

Further investigation is also required into the biological mechanisms by which species are responding to rapid climatic fluctuations, causing the resultant observed changes in distribution and abundance. The impacts of indirect effects of climate change including species' interactions require more in-depth investigation to tease apart the various driving factors causing the observed changes in biogeography and population level changes. The influence of factors other than temperature including ocean acidification, sea level rise, stormier seas and the impact of artificial coastal defence structures must also be taken into consideration in forecasts of future states of rocky intertidal ecosystems. The data shown in Table 1 was used to a) develop and test hypotheses on the impacts of climatic change on marine biodiversity in Britain and Ireland, 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). 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.

Specifically predictions on the future responses of intertidal rocky shore fauna and flora to changes in environmental temperature regimes in Britain are:

0-5 years:

- Northern species will continue to 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.

- Southern species will continue to expand their ranges northwards and abundances will continue to increase. The mechanisms underlying these responses are likely to be recruitment driven via some combination of an increase in reproductive output and/or larval and juvenile survival during warmer spring and summer periods and milder winters.

- The extent to which range extensions can occur will also be dependent on whether larval production and dispersal increases sufficiently in response to a warming climate to enable **hydrographic** barriers to be breached.

- The construction of artificial sea defences beyond existing range edges will allow range extensions in areas of unsuitable natural habitat via 'stepping stones'.

- 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 (*Chthamalus montagui, Chthamalus stellatus*) are released from competition by recruitment failure in *S. balanoides* associated with warmer spring temperatures. Such mechanisms may occur in other species.

- Biodiveristy will increase in the short term due to the increases in range and abundance of southern, warm-water species occurring faster than the decrease in abundance and retractions of southern range limits for cold-water species.

20-50 years:

- Changes will be greater during the 21st century than in the last warm period in the 1950s.

- Biodiversity will begin to decrease as northern, cold-water species are lost from shores, initially in the south west of England that are located close to the boundary between boreal and **lusitanian** waters. Major step changes may occur.

In summary, we have medium confidence in future predictions due to limitations with future climatic data predictions and incomplete knowledge of how ecosystems will be affected as changes accelerate.

Knowledge gaps

Investigations of the biological mechanisms determining species responses to climate change.

Further investigations into indirect effects of climate change via species interactions.

Commercial impacts

Potential for greater invasion of non-native species.

References

Data sources

Many species living on the coastline of the United Kingdom are either warm-water species with their northern geographical limits of distribution in the UK, or cold-water species with their southern limit in the UK or Northern Europe. These species can, therefore, be used as indicators of climate change by studying alterations in their distribution and abundance in response to changes in temperature. Rocky shore species are particularly useful as climate indicators due to the easily accessible habitat, the sedentary or sessile nature of intertidal species (i.e. do not or cannot move around) and the ease with which they can be 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, Denis Crisp and Jack Lewis and co-worksers from Robin Hoods Bay 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 current geographical distributions of key intertidal species of plants and animals 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. The final project report (from which most of the information below is taken) was published in 2005 (Burrows *et al.* 2006).

Table 1. Rocky Shore datasets utilised by the MarClim project (Source: Mieszkowska *et al.* 2006).

Geographic distribution	Original collector	Data archived	Data coverage
UK, France & Portugal	A.J. Southward D.J. Crisp S.J. Hawkins	(1) Quantitative barnacles, limpets & trochids; semi-quantitative broadscale surveys	1950-1987, 1997-date 1947-1967 1980-2006
UK, N. France	Rocky Shore Surveillance Group (J.R. Lewis et al.)	(2) Trochids	1964-1987
Southern England	R. Herbert	(3) Quantitative barnacles & trochids; semi-quantitative broadscale surveys	1987-2007
Shetland	Shetland Oil Terminal Advisory Group	(4) Broadscale and transects	1978-2005
UK, Ireland & France	MarClim Project	(5) Quantitative barnacles, limpets & trochids; semi-quantitative broadscale surveys	2001-2005
UK, Ireland, France, Portugal	S.J. Hawkins N. Mieszkowska P. Moore	(6) Quantitative barnacles, limpets & trochids; semi-quantitative broadscale surveys	2006-2007

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Other Information sources

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The source for this information is the Marine Biodiversity and Climate Change Project (MarClim) which initially ran between 2001 and 2005 and is now being continued under the umbrella of the MECN (http://www.mba.ac.uk/MECN/). 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.

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.