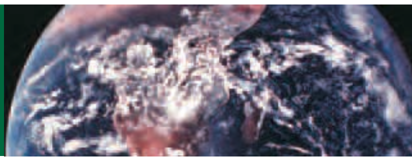


EARTHWATCH INSTITUTE

CLIMATE CHANGE:

the impact on biodiversity

This section explores:

a. How is climate change impacting on biodiversity?
b. How is climate change impacting on specific ecosystems?
c. What is the evidence from Earthwatch research projects?

Bumblebees have shifted their distribution in the UK in response to climate change

a. How is climate change impacting on biodiversity?

Climate change has already produced significant and measurable impacts on almost all ecosystems, taxa and ecological processes, including changes in species distribution, timing of biological behaviours, assemblage composition, ecological interactions and community dynamics.

Species have evolved over millions of years to adapt to specific climatic conditions as well as to variations in climate, but the current increase in temperature and differing weather patterns has occurred over an extremely short period of time which evolutionary processes are not able to match. Therefore, many species of plants and animals are not able to adapt to changing temperature and weather.

Shifts in distribution of plants and animals

At the simplest level, changing patterns of climate will alter the natural distribution limits for species or communities. In the absence of barriers it may be possible for species or communities to migrate in response to changing conditions. Vegetation zones may move towards higher latitudes or higher altitudes following shifts in average temperatures. Movements will be more pronounced at higher latitudes where temperatures are expected to rise more than nearer the equator.

Rapid changes and adaptation

Rates of climate change and species adaptation will be important, and these will vary at regional and even local levels. The maximum rates of spread for some sedentary species, including large tree species, may be slower than the predicted rates of change in climatic conditions. This is likely to lead to localised extinctions of these species.

Species interaction

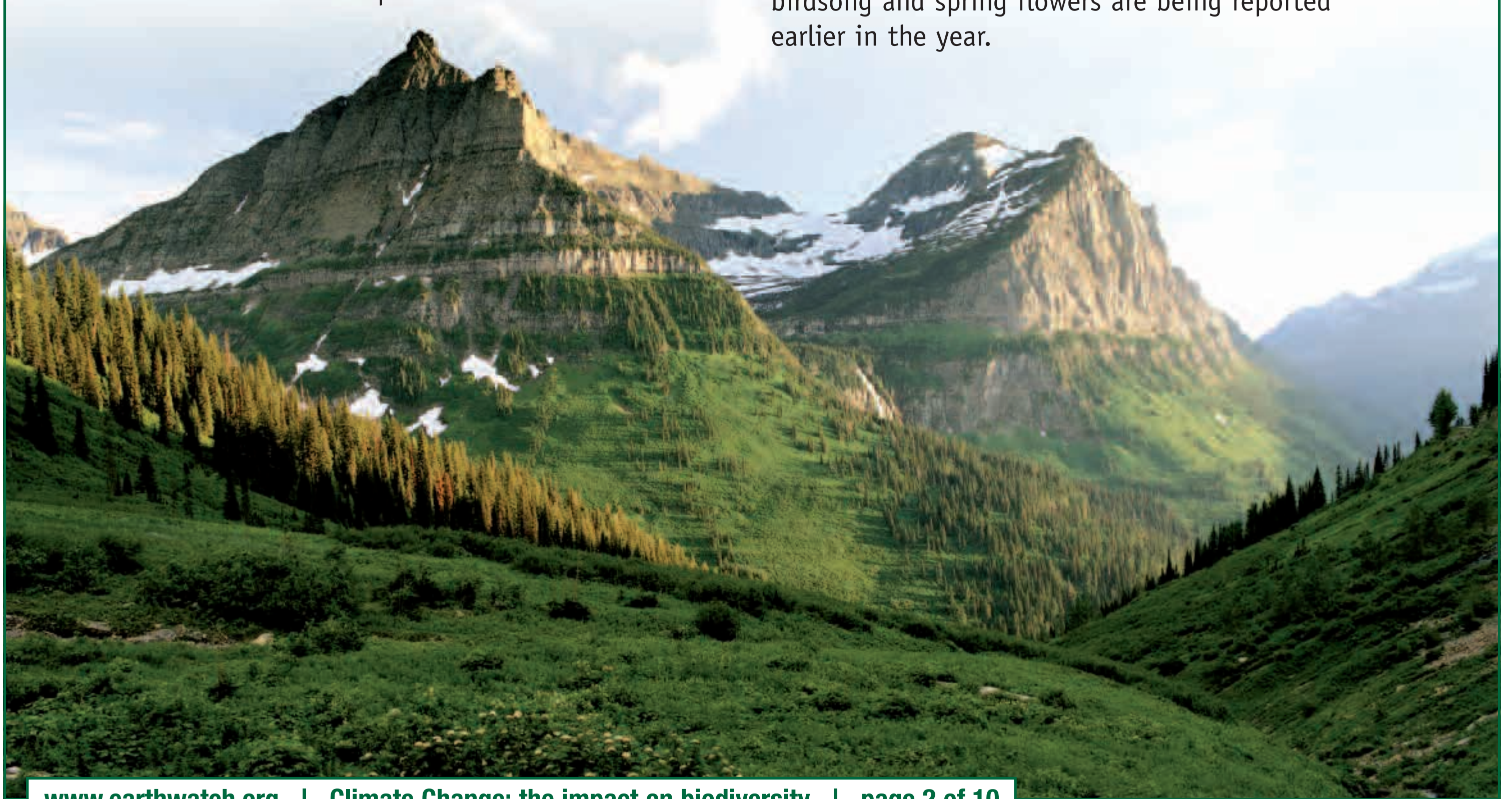
In many cases further complications will arise from the complexity of species interactions and differential sensitivities to changing conditions between species. Certain species may rapidly adapt to new conditions and may act in new competition with others.

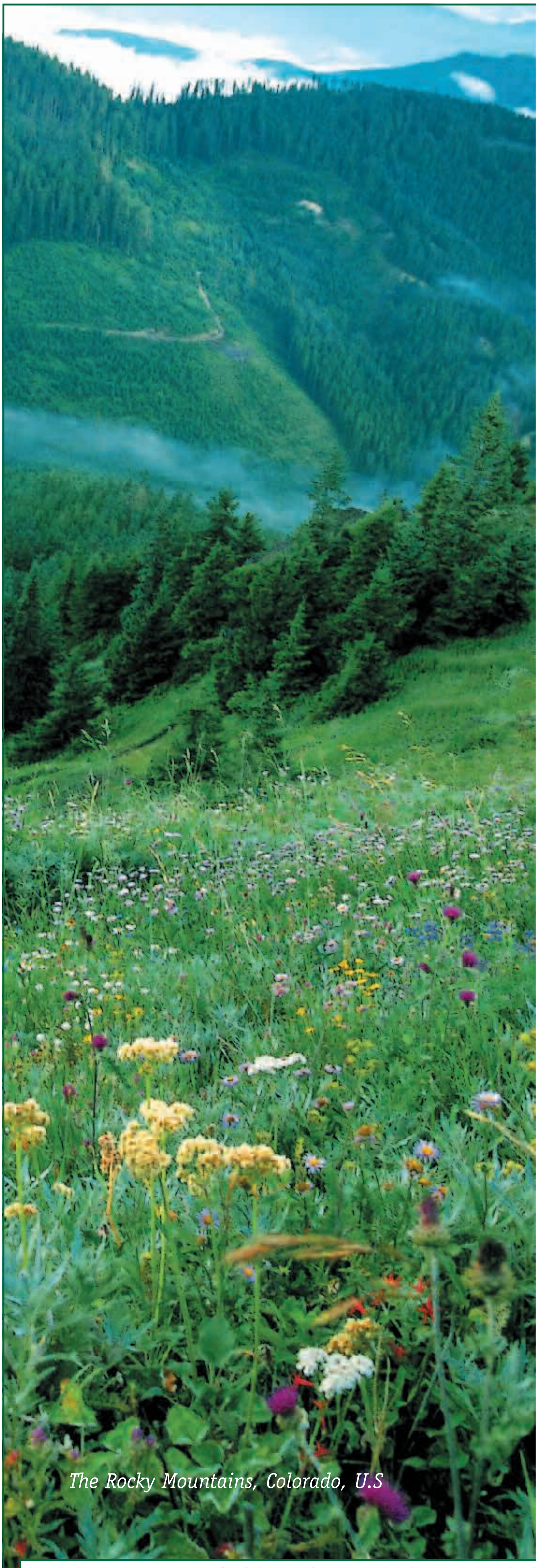
Invasive species

Humans have been introducing animals from one part of the world to another for thousands of years. Some of these introduced species can become invasive and can affect native species by eating them, competing with them, hybridising with them, or introducing pathogens or parasites. Global climate change creates conditions that may be suitable for some invasive species to become established in new areas.

Shifting seasons and phenology

Changes in seasons are already being noticed in many temperate regions. Phenology is the study of the timing or seasonality of behaviour. In the UK, birdsong and spring flowers are being reported earlier in the year.

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The Rocky Mountains, Colorado, U.S

Earthwatch case study: Plants and pollinator relationships

Earthwatch research on pollination ecology in the Colorado Rocky Mountains, United States, found that flowering time for plants is determined by the snow melt, which is likely to change in response to climate change. Earthwatch scientist Dr. Richard Inouye said *"the difference in timing between seasonal events at low and high altitudes has negatively influenced migratory pollinators such as hummingbirds, which hibernate at lower altitudes and latitudes. If climate change disturbs the timing of flowering and the behaviour of pollinators such as butterflies and bumblebees, then the intimate relationships between plants and pollinators that have co-evolved over thousands of years will be irrevocably altered"*. The research determined that climate change affects lower altitudes differently than higher ones. As a result, animals exposed to earlier warm weather may exit hibernation earlier and birds responding to earlier spring weather in their wintering grounds may flock north to find several feet of snow on the ground, risking starvation.

Changing patterns of precipitation and evaporation

It is widely expected that rainfall variability and dry season severity will increase. Extreme flooding will have implications for large areas, especially riverine and valley ecosystems. Increasing drought and desertification may occur in tropical and sub-tropical zones, and at least one model has predicted a drying out of large parts of the Amazon.

Earthwatch case study: Impact on lemurs

Earthwatch scientist Dr. Patricia Wright's research in Madagascar indicates that even subtle changes in climate affect the reproductive success of the endangered Milne-Edward's sifaka lemur *(Propithecus edwardsii)*, threatening the future of the species. Older female sifakas readily reproduce, but their infants only survive if there is sufficient rain during lactation. Sifaka milk production relies on large quantities of water and nutrients, drawn from their leaf food, so in drier years older females with worn teeth are unable to chew enough leaves to produce sufficient quantities of milk, leading to higher infant mortality. *"It is shocking that just a slight change in climate, even in the rainforest where we assume there is plenty of water, can impact infant survival so dramatically,"* says Dr. Wright. *"With a potential five more births during the latter decade of each female lemur's life, the impact of climate change and deforestation on the population will be devastating."*

The Milne-Edwards' sifaka (Propithecus edwardsi)

Chemical effects

In addition to causing a warming effect, increased concentrations of atmospheric carbon dioxide are known to increase rates of photosynthesis in many plants, as well as improving water use efficiency. In this way the climate changes may increase growth rates in some natural and agricultural communities.

Further research for students

- **Indicators of climate change in the UK:** http://www.cru.uea.ac.uk/cru/info/iccuk/
- **Effects on ecosystems:** http://www.unep-wcmc.org/climate/impacts.htm
- **UK Phenology Network:** http://www.naturescalendar.org.uk/
- **You can plot the distribution of species, and in some cases habitats, in each LBAP by linking to the National Biodiversity Network Gateway:** http://www.ukbap.org.uk/GenPageText.aspx?id=32

b. How is climate change impacting on specific ecosystems?

Forests

Tropical montane forests

Higher temperatures will cause tropical montane forests to lose humidity. This drying out may cause invasion or replacement of montane forest species by lower montane or non-montane species.

Boreal forests

Increased temperatures may cause more frequent forest fires and create conditions favourable to pests; both will lead to degradation and loss of biodiversity. Boreal forests will shift towards Arctic areas.

Polar regions

Permafrost is thawing which leads to additional release of soil carbon as CO_2, creating a positive feedback loop.

Marine Ecosystems

The coastal margins

On coastal margins, especially where these are backed by areas of intense human use, rising sea levels may lead to the reduction of important coastal habitats such as mud flats and salt marshes.

Warmer oceans

Rising sea temperatures will further affect the distribution and survival of particular marine resources. Corals are extremely sensitive to minor increases in temperature which cause coral bleaching leading to loss of coral reef structure and impact negatively on the coral reef ecosystem.

Increased acidification

The ocean is becoming more acidic as it absorbs atmospheric CO_2. This may result in organisms such as corals, plankton, shellfish and molluscs becoming less able to produce calcareous parts such as shells.

Staghorn coral (Acropora cervicornis)

Earthwatch case study: Staghorn and elkhorn coral in the Caribbean

In May 2006, staghorn and elkhorn were the first coral species ever to be registered as 'threatened' under the US Endangered Species Act (ESA), emphasising the growing concern about the health of coral reefs. Earthwatch research teams have collected data on coral decline in the Bahamas for the last 14 years. When the research began, elkhorn *(Acropora palmata)* and staghorn *(Acropora cervicornis)* species were very common in the Caribbean. In the last two decades, however, both species have practically disappeared, declining by an estimated 90 to 98% since 1980. When corals die, the reef ecosystem becomes dramatically disrupted: algae take over the reef and the associated species of fish and other fauna change.

Earthwatch scientists monitoring coral reefs

Polar bears in Manitoba, Canada

Earthwatch case study: Climate Change at the Arctic's edge

Melting of permafrost is having dramatic effects on ecosystems in the Arctic region. Of special concern are polar bear den sites, often reused over hundreds of years. Dens extend to permafrost which is important for potentially heat-stressed females. If permafrost melts, dens can collapse and their thermal advantage is significantly reduced - something which is expected to negatively affect bear reproduction. The polar bear is a keystone species; if its population declines then the ecological functions of the entire region will be affected. Another example is the melting of permafrost which has caused ground subsidence over vast areas. Ecosystems could change from dry uplands to wetlands, which will affect all aspects of the ecology of the region.

Further research for students

- **Coral bleaching and the Great Barrier Reef, Australia:** http://www.gbrmpa.gov.au/corp_site/info_services/science/climate_change
- **Marine climate change impact:** www.mccip.org.uk/arc
- **Impacts of climate change on forests:** http://www.forestresearch.gov.uk/fr/INFD-5Y2HR7
- **Climate change in Antarctica:** http://www.antarctica.ac.uk/Key_Topics/Climate_Change/ccps.html
- **Rapid temperature increases above the Antarctic (30 March 2006):** http://www.antarctica.ac.uk/News_and_Information/Press_Releases/story.php?id=281
- **Greenland's ice cap under threat:** http://news.bbc.co.uk/1/hi/sci/tech/3607335.stm

c. What is the evidence from Earthwatch research projects?

Earthwatch case study: The impact of climate change on UK mammal populations

The Earthwatch project *Mammals of Wytham Woods* collected data on the distribution and abundance of mammal species in Oxfordshire. Data on some small mammal species in this woodland have been collected since 1948, and badger datasets date back to 1976. These long term data are extremely valuable in detecting patterns of change in populations over time, particularly their responses to climate change.

What did the Earthwatch project investigate?

The objectives of the project were to monitor long-term changes in, and factors affecting, the distribution and abundance of badgers, deer, mice and voles, including responses to climatic effects, changes in habitat and interactions with other species.

Field methods for mammals

Mammals were monitored using a variety of scientific methods including trapping, identification of field signs (prints and droppings) and opportunistic sightings. All these methods help the scientists build up a picture of abundance, species diversity, feeding, reproductive behaviour and the phenology of the species involved.

What did the Earthwatch scientists find?

Results from the 2006 field season found that badger population dynamics are significantly affected by erratic weather patterns, a fact that makes these mammals vulnerable to potential impacts of climate change. Milder winters and longer springs/summers favour badger survival and increase the numbers of cubs born the next spring. Although

Scientist Dr. Chris Newman weighing small mammal species

2006 has been confirmed as the warmest year since records began, the period from January to April was unusually cold and dry. Remarkably, the female badgers of Wytham responded to this unusual weather by implanting their embryos much later than has been the norm in recent years. The result was that rather than being born in January, as in 2005, the cubs were born in mid March and did not appear above ground until late May.

Small mammals at Wytham also showed unexpected responses to the cold, dry winter and spring in 2006. Bank voles suffered a dramatic loss due to an extreme die-back of ground cover vegetation - the essential protective refuge these mammals need to hide from predators such as foxes, owls and weasels. Research revealed that vole numbers were at an all-time low. Woodmice numbers were also lower than in previous years; this is thought to be due to them having to rely for longer on their stocks of stored seeds, which became depleted well before the spring growing season and resulted in widespread starvation.

This research has highlighted that erratic weather has serious implications for UK mammal populations. As the scientists Drs. Chris Newman and Christina Buesching state: *"Data this year (2006) really reinforce that climate change is set to become one of the chief drivers in mammalian diversity in the coming years. It's not just 'warming' which will be the issue, it is the tendency for weather extremes, floods and droughts, heat waves and frosty periods that can 'catch animals out' and stretch their capacity to adapt to the limit."*

© Chris Newman

Badgers (Meles meles) in Wytham Woods

Further research for students

- **Mammals Trust UK:** http://www.mtuk.org/index.php?page=about
- **The Mammal Society (UK):** http://www.abdn.ac.uk/mammal/

Statistical tasks for students

1. **Click here** for three sets of example data from the Earthwatch project *'Mammals of Wytham Woods'*.
2. Analyse the data using graphs or charts and relevant methods of statistical analysis.
3. Discuss how the data reflects the impact of climate change.
4. Summarise the reasons for concerns about the impacts of present-day climate change on British mammal populations.

Earthwatch case study: What can the European storm petrel tell us about climate change?

The Earthwatch project *Climate Change and Seabirds* uses recent and ongoing changes in climate and oceanographic conditions to investigate the links between climate change, changes in marine ecosystems, and the migration behaviour of the European storm petrel (the smallest Atlantic seabird; *Hydrobates pelagicus)*. Data that have been collected for the last 15 years can uncover how these birds have been affected by climatic changes in the past and how they might be affected by future changes.

Long-distance migrant birds such as the storm petrel are likely to be particularly sensitive to climate change, because their ability to complete their annual migratory cycle depends on environmental conditions at widely spaced locations around the planet. Migrant birds (storm petrels migrate from their breeding grounds in the North Atlantic to Namibia, South Africa, and the Indian Ocean) must build up and maintain large fat reserves to fuel their migration journeys, but their ability to do this, and the level of fat reserves carried, depends on conditions along the migration route, which are affected by climate.

Scientists are examining how the abundance of marine life in early summer may be affected by differences in climate and sea conditions between years, and how this later affects the storm petrel.

© Rob Thomas

Scientist Rob Thomas removing a storm petrel from a mist net

How do scientists study storm petrels?

Scientists collect faecal and vomit samples from storm petrels to determine what and how much they have eaten. Birds are caught in fine mesh nets by playing recordings of their calls (which attract the birds to the coastal study site). Samples are then collected and the birds released.

What is the evidence for climate change affecting feeding and migration behaviour?

Like all migrant birds, storm petrels store energy reserves (mainly as fat) to fuel their migration. The level of body reserves carried by migrating storm petrels during their northward migration past the coast of Portugal varies greatly between years. Rather than varying erratically, the pattern of body mass changes in the population over the 15-year time series (1990-2004) follows a remarkably smooth oscillation (Fig. 1).

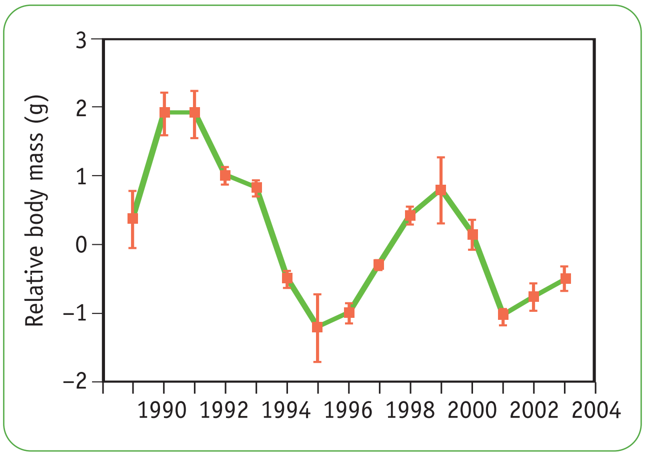


Figure 1. Changes in mean annual body mass of European storm petrels captured during northwards migration past southern Portugal, 1990-2004. Body mass is shown here corrected by regression for variation in overall body size (i.e. wing length)

The local sea surface temperature (SST) off Portugal is the prime factor associated with changes in body reserves. SST is itself influenced by a whole suite of climatic and oceanographic processes, including the North Atlantic Oscillation, the latitude of the Gulf Stream, and recent air temperatures. Furthermore, it is not SST during the migration season (late May, June and early July) that best explains the level of body reserves carried, but sea temperatures in the one to six months beforehand (Fig. 2). At this time, the storm petrels themselves are still many hundreds of miles to the south, but zooplankton biomass in Atlantic waters off Iberia is at its peak. This time-delay in the relationship between SST and seabird body reserves suggests that the birds are not putting on fat to keep warm, but that the amount of food available to them is affected by how cold the sea is earlier in the year.

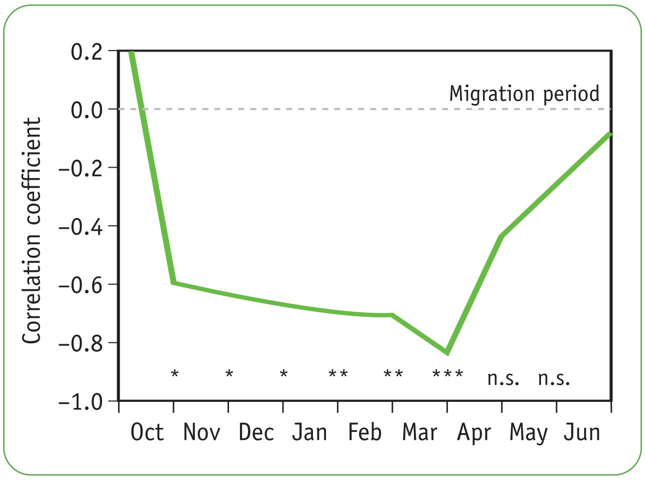
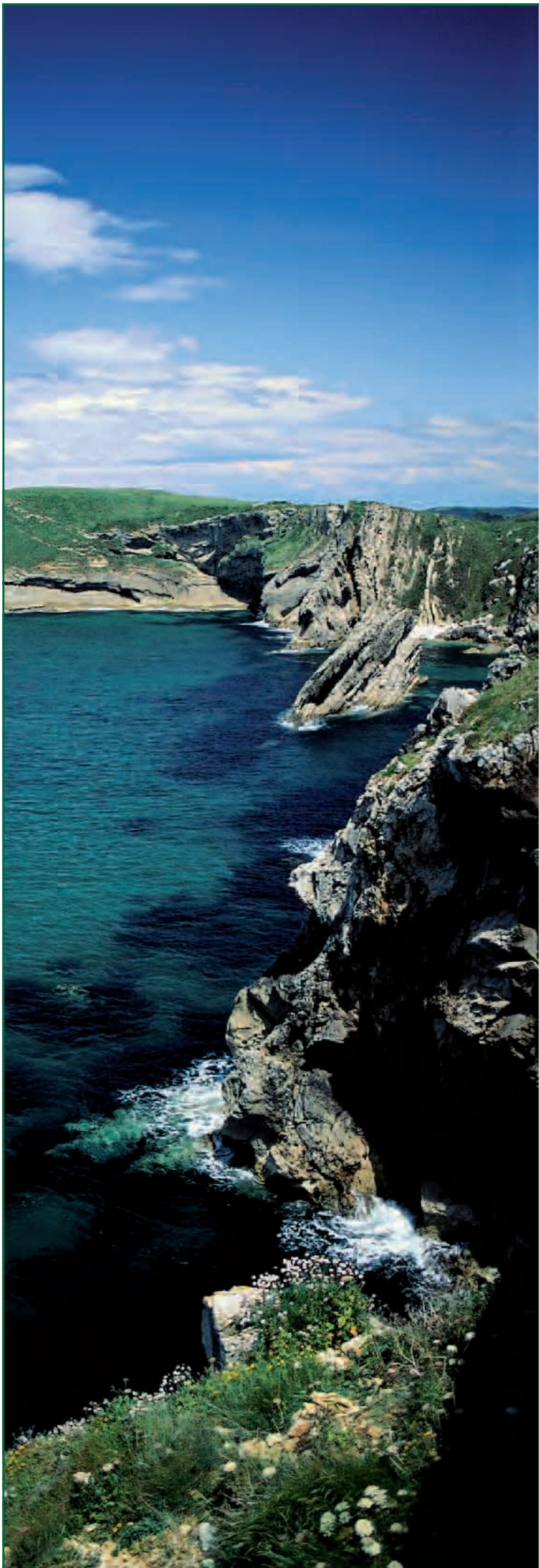


Figure 2. Variation in the strength of the association between storm petrel body reserves during May-July, and sea surface temperatures off SW Portugal in the months before and during the period of migration past SW Portugal (P<0.05, ** p<0.01, P<0.001)*

The smallest Atlantic seabird: The European storm petrel

This project reveals that the fat reserves of migrating petrels are a sensitive indicator of climate-linked biological changes in the north Atlantic. Studying the European storm petrel shows us changes in the abundance of its prey species (zooplankton etc.) which are affected by changes in sea temperature and chemical composition - a direct consequence of climate change.



Further research

- **Information about storm petrels:** http://www.rspb.org.uk/birds/guide/s/stormpetrel/index.asp
- **Blog about the Earthwatch storm petrels project:** http://stormies-online.blogspot.com/
- **Seabird populations worldwide are being affected by climate change:** http://www.peopleandplanet.net/doc.php?id=2845

Statistical tasks for students

1. **Click here** for three sets of example data from the Earthwatch project *'Climate Change and Seabirds'*.
2. Analyse the data using graphs or charts and relevant methods of statistical analysis.
3. Discuss how the data reflects the impact of climate change on seabirds and marine ecosystems.

For discussion

- How is global warming affecting biodiversity and ecosystems around the world?
- What will be the consequences of altered ecosystems and loss of biodiversity?

Earthwatch is an international environmental organisation which promotes the understanding and action necessary for a sustainable environment.

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