MCCIP Marine Climate Change Impacts Partnership

Marine climate change impacts

Fish, Fisheries & Aquaculture

Understanding how climate change will have an impact on fish and shellfish around the UK and Ireland is fundamental to managing activities in our seas.

MCCIP therefore commissioned three groups of scientists to consider how climate change is affecting marine fish, fisheries and aquaculture and what the social and economic consequences could be.


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DISTRIBUTIONS

There are clear changes in the depth and latitudinal distributions, and migration and spawning behaviours of fish, many of which can be related to warming sea temperatures.

MANAGEMENT

Cultivated shellfish and finfish are susceptible to climate change, although finfish farming technologies offer good potential for adaptation.

Controlled or closed fishing areas (a type of protected area) that can be adapted in response to climate change have the potential to help protect commercial and vulnerable fish stocks.

SOCIO ECONOMICS

Marine recreational fishing is an important socio-economic activity that could be positively affected by climate change because of the increasing abundance of species that are of interest to anglers.

WIDER IMPLICATIONS

Shifting distributions of fish have led to a series of international disagreements and will continue to have implications for fisheries management across international boundaries.

2012

www.mccip.org.uk/ffa

WHERE THE INFORMATION COMES FROM...

The information presented in this report card is based upon three scientific reviews:

Review of climate change impacts on marine fish and shellfish around the UK and Ireland looks at what changes in fish and shellfish species and communities have been observed around the UK and Ireland and what could happen in the future.

Review of climate change impacts on marine fisheries in the UK and Ireland considers the implications of climate change for 'wild' sea fisheries and shell fisheries and the socio-economic consequences.

Review of climate change impacts on marine aquaculture in the UK and Ireland focuses on what the impacts of climate change could mean for this industry.

The context within which the three reviews are written is presented in a short introductory paper titled 'Impacts of climate change on fish, fisheries and aquaculture'. This provides an overview of observed and projected changes in ocean climate, including sea temperature, acidification, sea-level rise, stratification and severe weather events.

The introductory paper and three reviews are freely accessible in Volume 22-3 of 'Aquatic Conservation-Marine and Freshwater Ecosystems'

http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1099-0755

Topic index

Because many of the issues raised in the three reviews are interlinked, the key findings are summarised here under four themes:

- changes in species distributions
- implications for marine management
- social and economic consequences
- the wider (global) picture

Maps on the centre pages show some regional stories about 'what is happening now' and 'what could happen in the future'.

Some key gaps in knowledge, and why they are important, are considered on page 11.

Definitions:

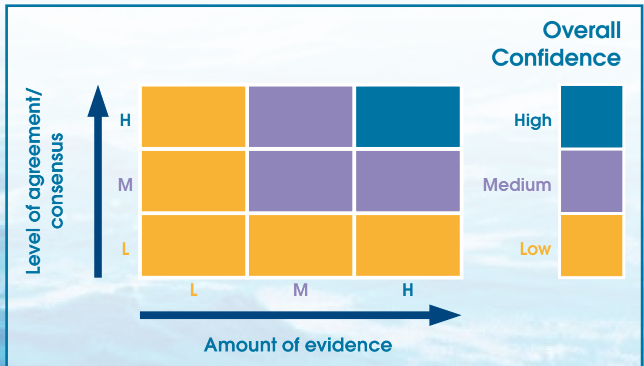
- Fish: Includes all finfish and shellfish.
- Fisheries: The commercial exploitation of wild finfish and shellfish.
- Aquaculture: The cultivation of finfish and shellfish.

Confidence Assessment

At the end of each section, key messages are highlighted, including a 'confidence' rating for each. Confidence ratings are also used for the regional snapshot 'what could happen' map.

The confidence ratings of low, medium or high are based upon the amount of evidence available and the level of scientific consensus.

High confidence
Medium confidence
Low confidence



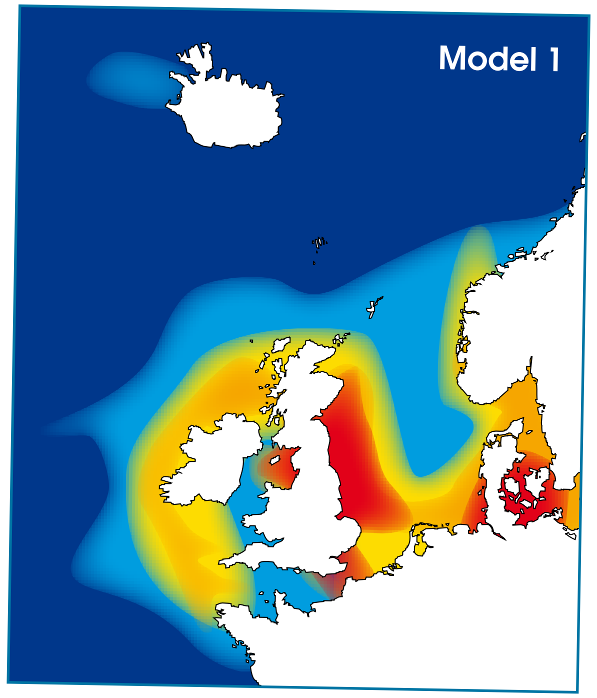
The challenge of dealing with uncertainty

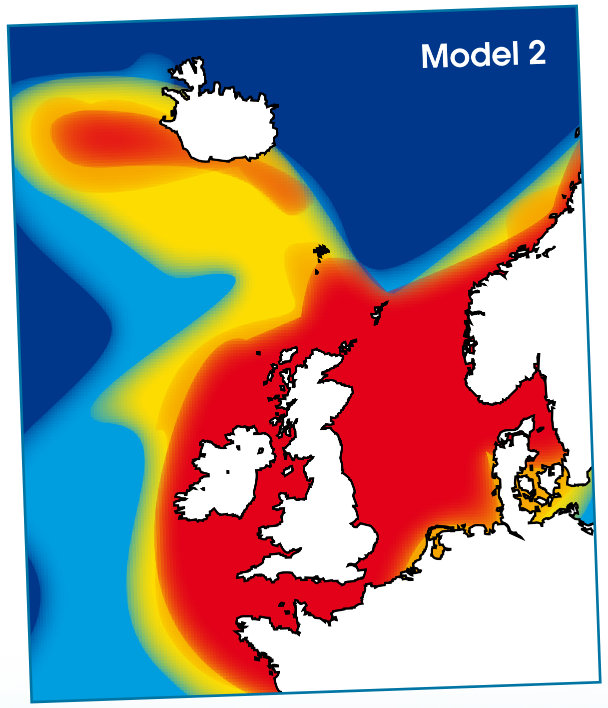
The key challenge for understanding the current and future impacts of climate change, and in particular the anthropogenic component of climate change, is identifying its relative importance compared to other factors. For example, it is very difficult to disentangle the effects of long-term fishing pressure from those of climate change, and to predict how these issues may interact in the future.

Scientists trying to understand the different drivers of change use a wide range of methods from statistical analysis of data from long-term monitoring programmes to detailed experiments examining how species respond physiologically to temperature or changes in acidity. These approaches are used to build models in order to project future impacts of climate change.

There is a variety of approaches used when analysing and interpreting data and there is not always agreement on the most suitable methods. For example, many scientists investigating the influence of climate change on distributions of species and populations use 'bioclimate envelope models', whilst others feel the limitations of this method mean that other tools and explanations are required. Even within the bioclimatic envelope approach different models can produce quite different outputs as can be seen in the example of Atlantic mackerel distributions.

Thus, there are differing degrees of uncertainty in results obtained and this is reflected in the confidence ratings.

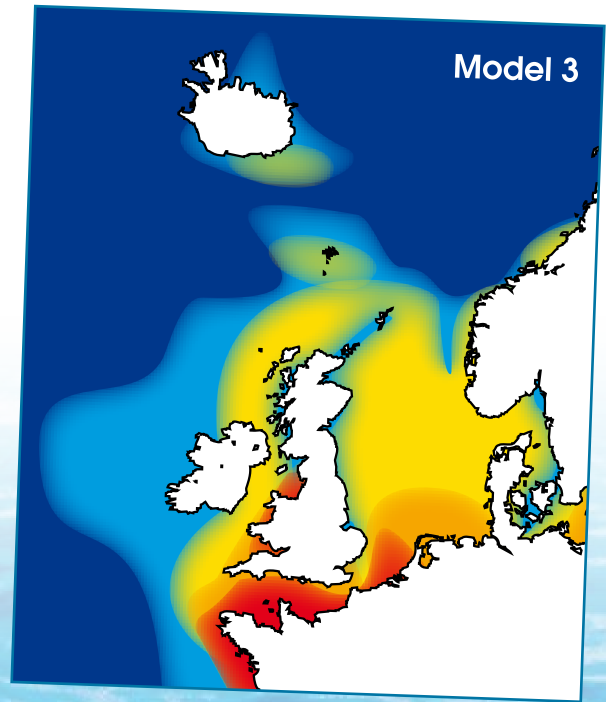




Key to Colours

UNSUITABLE → **SUITABLE**

Blue → Red – *Increasing habitat suitability*



These maps illustrate the suitability of habitats for Atlantic mackerel under current climate conditions using three different models. When tested against actual observations the models are all considered to perform well and yet the modelled distributions show some differences. This does not mean that we cannot use the models but does mean that we have to ensure that we allow for uncertainty and communicate it.

Maps modified from Jones *et al.* (2012), Modelling commercial fish distributions: Predictions and assessment using different approaches, *Ecological Modelling*, Vol. 225, pp 133-145. doi:10.1016/j.ecolmodel.2011.11.003

CHANGES IN SPECIES DISTRIBUTIONS

In the North Sea, a large number of coldwater species (e.g. grey gurnard, cod, anglerfish, lemon sole and saithe) have deepened on average by 5.5 m per decade. Conversely some warm water species have moved to shallower depths, such as sole (7.6 m per decade) and bib (6 m per decade).

Latitudinal changes have also been observed in a number of species with the southern range limits of many coldwater species moving northwards. Some more southern species have extended their overall range with a northerly extension of their northern limit, e.g. bib showed a northerly extension of 342 km from 1978-2001.

Seawater temperature can have a positive effect on the timing of spawning in various species where a threshold may need to be reached during the main period of egg development. The increase in sea bass numbers in the southern North Sea and English Channel may partly be explained by this.

Changing temperatures may affect migratory behaviour with earlier migration seen in western mackerel stocks, but for flounders their migration from some south-west estuaries is delayed by warmer conditions.


Anglerfish © Keith Hiscock

For some invertebrate species (e.g. brown shrimp, a commercially important species fished mainly in the southern North Sea) warming temperatures may result in more spawning cycles in the year.


Striped red mullet © Keith Hiscock

Opportunities and threats

Changes in water temperature will affect growth rates of farmed finfish and shellfish, the presence of parasites and pathogens and the suitability of areas for specific species. Salmon farming may be compromised in more southern areas but other warmer water species may become viable, although market pressures will ultimately determine what is grown. There might be an increase in the rearing of sea bass and turbot and opportunities for rearing Pacific oyster in waters that are currently unsuitable, although in the wild it is likely to compete with mussels and the native oyster.


Brown shrimp © John Rundle

Changes in distribution (e.g. cod shifting northwards into deeper waters in the North Sea; sole retreating away from the Dutch coast towards the eastern English Channel; sea bass and red mullet expanding their northern boundary) all present either threats or opportunities to current fishery patterns and practices. Models suggest many exploited species' distributions will continue to shift northwards over the next 50 years. Opportunities for new fisheries include sea bass, red mullet, John dory, anchovy, boarfish, octopus, cuttlefish and squid.


Pacific oyster bed © Keith Hiscock


Cuttlefish
© David Nicholson/Marine Biological Association

Non-natives

The scale of the damage from non-natives to aquaculture and the extent to which this could be attributed to climate change is unknown, but there is evidence that climate change increases the rate of invasions, especially in higher latitudes.

The slipper limpet was inadvertently moved on mussel spat from the south coast of the UK to north Wales in 2006 and could have serious implications for the culture of mussels if it becomes established. Other non-native species that cause fouling of equipment such as fish farm cages and moorings include the sea squirts *Didemnum vexillum*, *Styela clava* and *Botrylloides violaceus*. To what degree the establishment and spread of these (and other species) is enhanced by climate change is unknown, but it is clear that some introduced non-native species are benefiting from increased temperatures.

Non-native species that escape from aquaculture developments can, as a result of increasing temperature, reproduce and spread in the wild. For example the Pacific oyster now dominates areas of the French Atlantic coast and the south coast of England, causing significant change in the habitat structure and, hence, the nature of biogenic reefs in those areas.

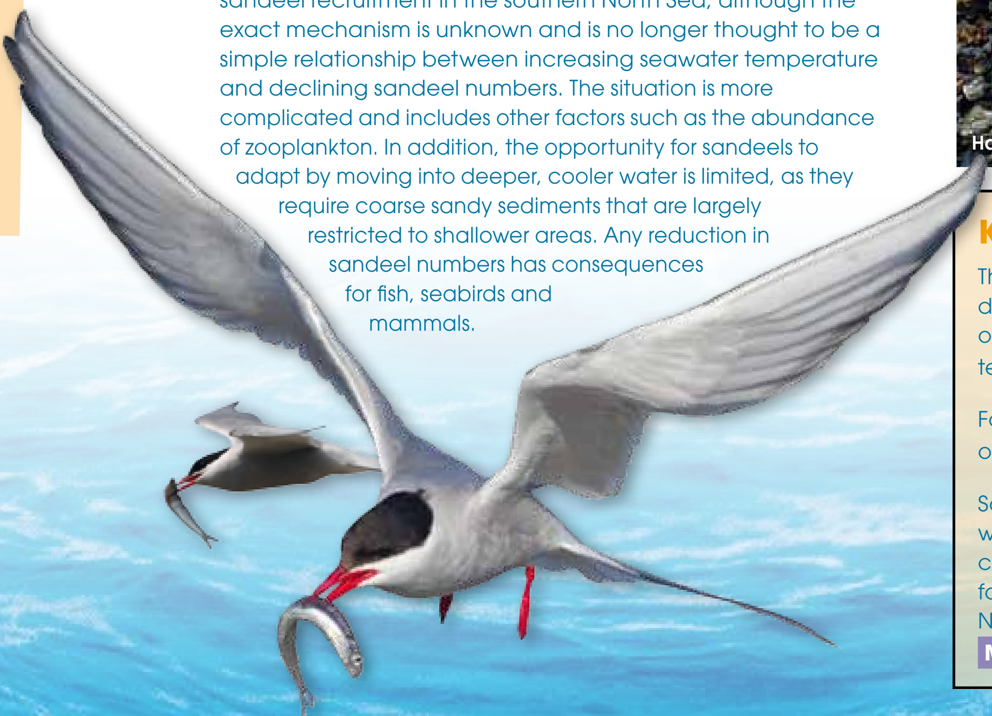

Sea squirt *Styela clava*
© Paul Kay/SNH

Food web dynamics

Food web resilience is sometimes dependent on only a few key species and if these are vulnerable to temperature changes or acidification this could have serious implications. For example, in the Pacific, the pteropod *Limacina helicina* is particularly sensitive to ocean acidification and is heavily predated by pink salmon (*Oncorhynchus gorbuscha*); it has been estimated a 10% decrease in pteropod numbers could lead to a 20% decrease in mature salmon. The impacts of changes in the abundance of various prey species as a result of climate change are difficult to predict. Some species in the past have adapted to changing prey availability, e.g. plaice switching from a diet based on calcifying organisms to one of non-calcifying organisms, with no decline in their abundance or condition.

High winter sea temperatures are associated with poor sandeel recruitment in the southern North Sea, although the exact mechanism is unknown and is no longer thought to be a simple relationship between increasing seawater temperature and declining sandeel numbers. The situation is more complicated and includes other factors such as the abundance of zooplankton. In addition, the opportunity for sandeels to adapt by moving into deeper, cooler water is limited, as they require coarse sandy sediments that are largely restricted to shallower areas. Any reduction in sandeel numbers has consequences for fish, seabirds and mammals.


Harbour seal © John M. Baxter


Arctic tern (inset) © Jim Krawiecki   Arctic tern (main) © David G Hemmings

Key messages:

There are clear changes in the depth and latitudinal distributions, and migration and spawning behaviours of fish, many of which can be related to warming sea temperatures. **High confidence**

For fisheries and aquaculture there will be both opportunities and threats. **High confidence**

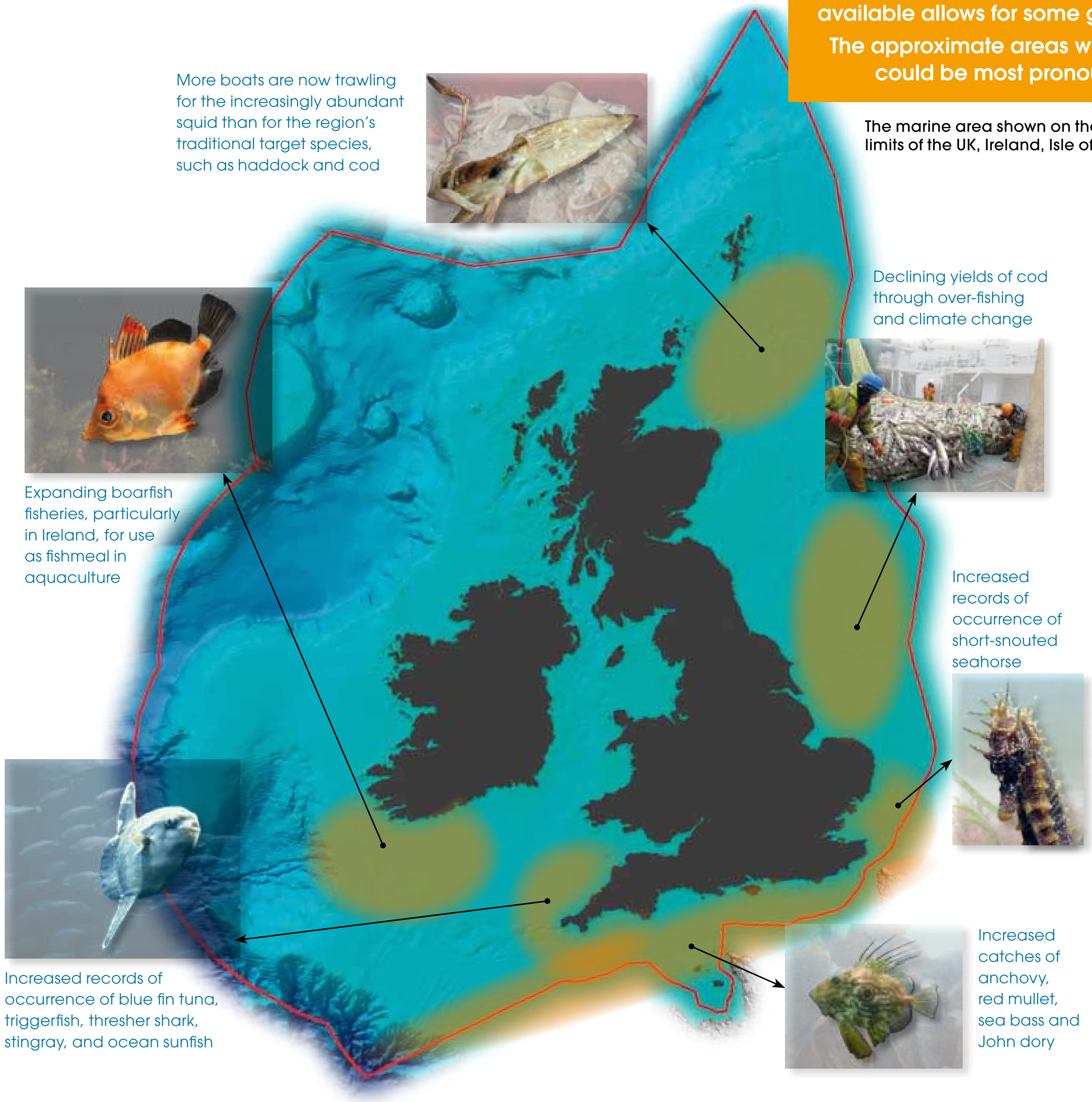
Some species are key to the integrity of marine food webs. If these are particularly affected by climate change then extensive restructuring of food webs will follow. Declines in the abundance of sandeels in the North Sea may be a particular case in point. **Medium confidence**

REGIONAL SNAPSHOTS

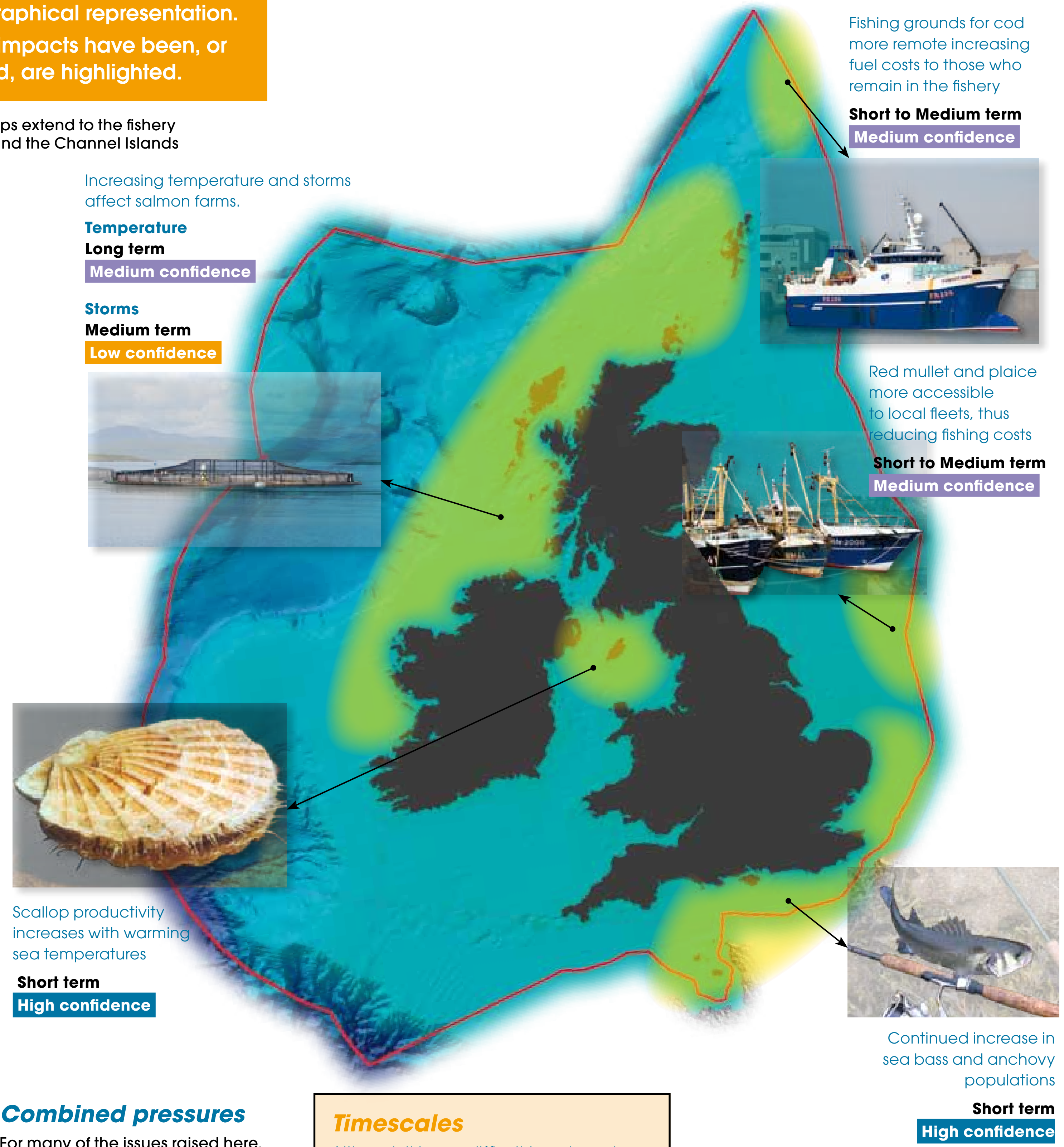
These maps show some examples where the information available allows for some geographical representation. The approximate areas where impacts have been, or could be most pronounced, are highlighted.

The marine area shown on these maps extend to the fishery limits of the UK, Ireland, Isle of Man and the Channel Islands

What is happening now



What could happen



Movement of important commercial species in the North Sea: A complex picture over the past century.

Species are not simply moving north in response to climate change, the pattern is more complex than that. E.g.

COD	Moving north-east to cooler, deeper waters.
PLAICE	Moving north-west into cooler waters in the Central North Sea.
SOLE	Apparent south-west movement as a result of warmer winter temperatures.

Combined pressures

For many of the issues raised here, climate change will not be the only causative factor. Other factors may be as, if not more, important. (e.g. over-fishing or fuel prices)

Timescales

Although it is very difficult to put precise timescales on future climate change impacts, an indication of timescale is provided for each story:

Short term	within the next 20 years
Medium term	20-50 years
Long term	over 50 years

IMPLICATIONS FOR MARINE MANAGEMENT

Adaptation


North Sea beam trawler © Crown Copyright

Changes in species distributions will alter the distance fishermen need to travel to catch their traditional target species. Economic analyses are needed on different options such as travelling further (with increased ongoing costs) vs. altering fishing gear to target different species as new opportunities arise.

In global terms, UK and Ireland fisheries are considered to have a high adaptive capacity. For some specialised fleets, however, such as the North Sea beam trawl fleet, a lack of adaptive capacity may mean it is more economic for some fishermen to leave the industry rather than follow their traditional target species northwards.


Squid at market © Laurence Hartwell

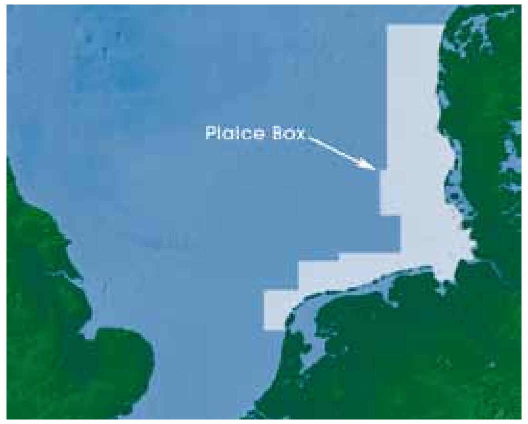

Automatic feeding barge © John M. Baxter

Shellfish farming, which depends on wild spat for stock, plankton for food and water quality for health, is highly susceptible to various effects of climate change. Finfish farming, however, is slightly less vulnerable to climate change impacts as feed is controlled, therapeutants can be administered and stock fish are reared in land-based hatcheries.

The aquaculture sector is relatively young and the ongoing rapid pace of technological progress is likely to offer innovations for climate change adaptation, particularly for finfish. For example, a move towards greater use of land-based re-circulating aquaculture systems could be anticipated in the future for both finfish and shellfish (e.g. lobster).


Rope mussel cultures © Caroline Cusack, Marine Institute

Protected Areas



Controlled or closed fishing areas are a form of protected area used specifically to protect fish stocks. These areas may need to be increasingly 'adaptive' in the future, in the face of climate change. For example, in some years the Bornholm closure area is successful in protecting much of the cod stock in the Baltic Sea, but in other years, most of the spawning population is outside of the closure area boundaries due to year to year environmental variability.

Another example is the southern North Sea 'Plaice Box', where juvenile plaice are now completely absent in some places where they were once very abundant, probably as a result of warming temperatures and changes in the productivity of the region.

In UK and Ireland waters, closed areas aimed at protecting particular fish stocks are projected to experience significant changes in temperature in the next few decades. Static closed areas are therefore likely to be less effective in the future.

Key messages:

Cultivated shellfish and finfish are susceptible to climate change, although finfish farming technologies offer good potential for adaptation. **Medium confidence**

Economic analyses would assist with decisions concerning the costs of adaptation options. **High confidence**

Controlled or closed fishing areas (a type of protected area) that can be adapted in response to climate change have the potential to help protect commercial and vulnerable fish stocks. **Medium confidence**

SOCIAL AND ECONOMIC CONSEQUENCES

Wild fisheries

In 2010, total landings of fish and shellfish in the UK and Ireland were 606,295 tonnes and 245,856 tonnes respectively. In the UK, about 60% of commercial marine fish is landed in Scotland, 30% in England, 5% in Northern Ireland, 2% in Wales and less than 1% in the Channel Islands and the Isle of Man. About 30,000 people in the UK, and over 12,000 people in Ireland depend on fishing for their livelihoods with the dependency of jobs on fishing being higher in some remote coastal communities. New fisheries are being established or expanded in some areas of the UK and Ireland as a result of changes in distribution of species such as sea bass, anchovy, red mullet, boarfish and squid, although some traditional fisheries are threatened such as North Sea cod.

Projected global redistributions of fish will affect different parts of the world unequally. By 2050, tropical regions could experience significant declines in landings with gains in some high latitudes. The overall cost of adaptation of the fisheries sector worldwide in response to climate change is predicted to be large and could lead to losses in gross fisheries revenues of $10–31 billion by 2050.

CASE STUDY

Impacts of sea temperature rise on farmed shellfish

At Strangford Lough in Northern Ireland it has been predicted that increasing sea surface temperatures will lead to significant decreases in production of farmed mussels, with smaller declines for Pacific oysters. For a 1°C increase in temperature it is predicted that mussel production will decline by 50% and for a 4°C increase by up to 70%. For Pacific oysters decreases will be less than 8% for both 1 and 4°C temperature increase scenarios.

Aquaculture

The finfish industry is concentrated in Scotland (91%), and the Republic of Ireland (8%) with small amounts elsewhere. Shellfish aquaculture is predominantly based in Ireland and Wales, together accounting for around 70% of all production. The socio-economic impacts of climate change will therefore vary according to the type of species farmed in these countries, with mussel growing areas located in shallow waters and estuaries particularly vulnerable.

CASE STUDY

Expansion of recreational sea angling

The value of marine recreational fishing in the UK is high (one billion pounds spent annually by sea anglers). First sale value of commercial fisheries by comparison was 0.7 billion pounds in 2010. As increased sea temperatures have led to a northward expansion of sea bass, angling for this valuable target species has increased.

CASE STUDY

Storm damage to salmon cages

Storm events can lead to a loss of fish stocks, and considerable economic impacts, by damaging farm cages. A total of 2.18 million fish escaped over a seven year period from Scottish fish farms, of which 38% escaped during a single storm event in 2005. The escape of farmed salmon in storm events could result in their hybridisation with wild stocks. Storm damage can also lead to the introduction of predators and disease into cages, leading to further loss of stock.

If climate change increases the frequency or intensity of storms, farm cages will be more likely to get damaged, leading to greater economic losses.


Sea bass © Crown Copyright

The UK and Ireland only accounts for about 1% of global landings of commercial marine fish and this percentage is not likely to change significantly by 2050 as a result of climate change. However, the demand for fish products (wild and farmed) in the UK and Ireland is likely to increase from 1.3 million tonnes in 2010, to more than 1.6 million tonnes in 2050 due to population growth. As a large proportion of seafood in the UK and Ireland is imported, climate change impacts on fisheries globally may well affect domestic supplies.

CASE STUDY

Cod stock recovery

Model studies suggest that climate change has little effect on cod stock recovery in the short term, but depends instead upon reducing fishing mortality to allow existing year classes to mature. In the longer term, however, climate change might be expected to have an increasingly important effect on stocks. Fishing mortality rates which were considered sustainable in the past will become unsustainable in the future as the recruitment performance of the stock declines.

Key messages:

Marine recreational fishing is an important socio-economic activity that could be positively affected by climate change because of the increasing abundance of species that are of interest to anglers. **Medium confidence**

Increasing demand for fish versus decreasing availability may be exacerbated by climate change. **Low confidence**

For cod, an important economic species in the UK, short term stock recovery will depend primarily on reducing fishing mortality. However, in the longer term, climate change might be expected to have an increasingly important effect on stocks. **Medium confidence**

THE WIDER (GLOBAL) PICTURE

International Cooperation

Shifting distributions of fish in response to climate change have implications for the allocation of quotas across international boundaries.

Mackerel:

Large changes in the migration of western mackerel have occurred over recent decades. Most recently, the migration changed to take the stock into Icelandic waters resulting in an international disagreement over the share of the stock. Iceland and the Faroe Islands unilaterally claimed quota for mackerel, since the species had expanded westwards and achieved a level that would sustain a fishery in their exclusive economic zones. This led to concern over the management of mackerel stocks since the newly declared quotas meant the amount of mackerel being caught in the NE Atlantic was beyond that advised by the International Council for the Exploration of the Seas (ICES). It is not clear how important changing climatic conditions were in causing this shift in distribution. However, the events highlight the potential for future conflict as climate changes and distributions alter.

© BBC © Ice News © Irish Times © The Telegraph

Cod and Capelin:

Greenland is one of the few countries where fisheries are anticipated to benefit significantly from climate change, both through increased exports and access agreements. For example, as a result of the northward shift of cod and capelin, access granted to fishing vessels from Germany, Denmark, UK, Spain and Portugal under "Fisheries Partnership Agreements" between the EU and Greenland, are likely to become increasingly important.

Commercial cod fishing
© www.whitbyseaanglers.co.uk

Anchovy:

Anchovy stocks have been low in recent years in the Bay of Biscay where Spanish and French vessels traditionally catch them. Anchovy are responding to changing ocean temperature by moving further north along the coasts of Ireland and Scotland and entering the North Sea through both the English Channel and the Pentland Firth. This has resulted in anchovy now being specifically targeted in the UK with about 500 tonnes of anchovy being caught in the south-west in 2011. The movement of anchovy north will provide new opportunities for EU fishermen but detailed negotiations will be needed to establish how much can be fished by each interested party.

Fishmeal on global markets

The fishery for boarfish:

A recent expansion in the number of boarfish (*Capros aper*) in the South-west approaches and Celtic Sea is thought to be a consequence of climate change. Irish and Danish fleets have invested in new gear to exploit this new fishery that produces fish oil/meal for the aquaculture market. Since 2001 there has been a dramatic increase in the amount of boarfish landed and also over the same period the global fishmeal commodity price has risen significantly. Highly adaptable fleets may well be able to take advantage of similar opportunities as different fish species respond to a changing climate.

Boarfish © Steve Trewhella / UK Coastal Wildlife

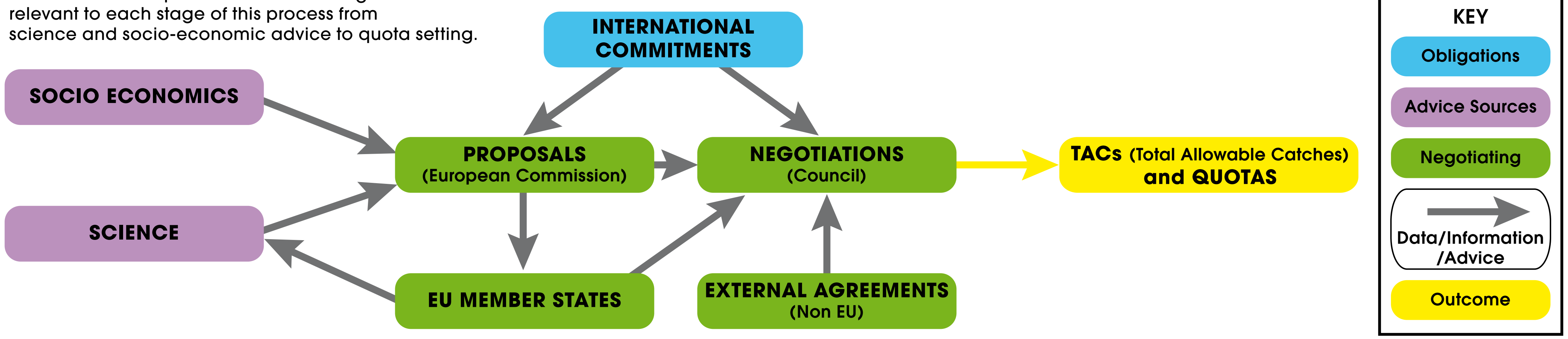
Key message:

Shifting distributions of fish have led to a series of international disagreements and will continue to have implications for fisheries management across international boundaries.

High confidence

International negotiation process for fisheries management

Information on impacts of climate change are relevant to each stage of this process from science and socio-economic advice to quota setting.



2012 REPORT CARD KNOWLEDGE GAPS

Knowledge Gap	Why is this important?
The impact of climate change on the spread of invasive species and jellyfish is not well known.	They can cause major fish kill incidents in aquaculture cages.
The link between Harmful Algal Bloom (HAB) events and climate change is not well understood.	HAB events can lead to closures of shellfisheries and marine aquaculture sites.
Quantitative forecasts of fish species distributions in response to climate change for the shelf seas around the UK and Ireland are lacking.	Better prediction of the future conditions of fish stocks can improve fisheries management.
Economic analyses of the costs and benefits of different adaptation options are needed.	Medium to long-term planning for industry and regional development.
The effects of climate change on the introduction and treatment of diseases in the marine environment are not well quantified.	There is evidence that increasing temperatures could impact in a number of ways with consequences for fish and human health.
Current evidence on direct impacts of ocean acidification is limited. Very little modelling has yet taken place to scale up from laboratory experiments to populations and wider marine ecosystems.	Consequences for fish farmers, fishermen and fleets and the marine environment in general.

What is MCCIP?

The Marine Climate Change Impacts Partnership (MCCIP) is a partnership between scientists, government, its agencies, nongovernmental organisations (NGOs) and industry. The primary aim of the MCCIP is to provide a co-ordinating framework, so as to be able to transfer high quality evidence on marine climate change impacts, and guidance on adaptation and related advice, to policy advisers and decision-makers.

Partners are: Agri-Food and Biosciences Institute, Northern Ireland; Centre for Environment, Fisheries and Aquaculture Science; Countryside Council for Wales; Department for Environment, Food and Rural Affairs; Department of the Environment, Northern Ireland; Environment Agency; International Union for Conservation of Nature; Isle of Man Government; Joint Nature Conservation Committee; Marine Scotland Science; Marine Biological Association - Marine Environmental Change Network; Marine Institute, Ireland; Marine Management Organisation; Natural England; Royal Society for the Protection of Birds; Scottish Government; Scottish Natural Heritage; SeaWeb; Sir Alister Hardy Foundation for Ocean Science; States of Guernsey; States of Jersey; UK Met Office; Welsh Assembly Government.

Further details and contact

For further details about the work of MCCIP go to **www.mccip.org.uk.** If you have any further enquiries please contact us at **office@mccip.org.uk**

The delivery of this publication was overseen by the MCCIP report card working group. The members of this group are: M. Frost (MBA); J. Baxter (SNH); P. Buckley (Cefas); M. Cox (Scottish Government); S. Dye (Cefas) and N. Withers Harvey (Defra).

Other MCCIP work

The production of the next full MCCIP report card, covering over 30 marine and coastal topics is already underway, and will be launched in 2013. An MCCIP knowledge gaps paper was published in April 2012 to help inform how marine climate change research is prioritised, whilst MCCIP Climate Smart Working is looking at how our understanding of marine climate change risks can be used to inform adaptation.

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MCCIP Marine Climate Change Impacts Partnership

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Your Feedback

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