IMPACTS OF CLIMATE CHANGE ON FISH

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Executive Summary

There is substantial global evidence that climate change has impacted marine fish populations and communities. Significant fluctuations in fish abundance acting through reproduction, phenology, recruitment, growth and distribution have all been linked with climatic changes. Abundances of some fish species with southern distributions have increased in southern UK waters during recent warming periods (1950s, 1980s-2002), while declines were apparent during cooling episodes (1920s, 1960-70s). Effects of climate on species responses and community composition vary markedly between geographical regions however, making broad-scale predictions difficult. Renewed observations of rare fish migrants to UK waters may be related to recent sea warming, especially since climate-driven changes in timing and extent of annual migrations also occur. However, expected declines in northerly distributed species with recent warming remains equivocal. Boreal species may have retracted north in some regions but not in others. Current understanding suggests climate effects on fish reflect species-specific responses in addition to complex interactions between species (e.g. predator-prey relationships). Although climate influences marine fish assemblages, the precise mechanisms underlying most observed changes remain unclear.

Level of Confidence

Overall, we are ‘quite sure’ that climate change is affecting the abundance and community composition of marine fish.

However, we are ‘not sure’ whether recent climate changes are causing clear distributional changes, although we are ‘quite sure’ this has occurred in the historical past.

We are ‘not sure’ whether trends seen in some regions are applicable to other areas. This is due to limited datasets covering broad geographical areas, and spanning a long enough time period to assess patterns in relation to climate. Very few datasets exist that span >30 years and include non-target as well as target species, which is necessary to understand community (widespread) responses.

We are ‘not sure’ of the precise mechanisms underlying observed changes in fish populations to climate in all cases, but it is likely these operate between climate, environment and complex species interactions resulting in patterns that are difficult to predict or forecast. Our poor understanding in this area is caused by a lack of research using the few datasets in existence capable of supporting appropriate analyses.

Key sources of Information

See supporting evidence

Supporting Evidence

There is substantial global evidence that climate change has impacted marine fish populations and the communities they comprise (Stenseth *et al.,* 2002; Walther et al., 2002; Parmesan and Yohe 2003; Root *et al.,* 2003). Scientific studies of fish from diverse marine ecosystems (e.g. estuary, reef, open sea) demonstrate climate has influenced key ecological processes (Stenseth *et al.,* 2002), principally by acting through direct and indirect effects of changes in sea temperature. Climate-induced effects on marine fish recruitment (Beaugrand *et al.,* 2003), growth (Attrill and Power 2002), behaviour (Sims *et al.,* 2004), distribution (Perry *et al.,* 2005) and relative abundance of populations (Genner *et al.,* 2004) have been documented. Responses of fish to short-term climate fluctuations such as the North Atlantic Oscillation and the El-Nino Southern Oscillation are evident in some cases (e.g. Lehodey *et al.,* 1997; Attrill and Power 2002), whereas persistent long-term changes over longer time periods (25 – 90 years) have also been identified where appropriate monitoring data exist (Genner *et al.,* 2004; Perry *et al.,* 2005). Relatively abrupt changes in fish abundance and spawning behaviour have also occurred in response to apparent climate regime shifts (McFarlane *et al.,* 2000; Reid *et al.,* 2001).

Long-term changes show fish species can exhibit temporal 'sign-switching' (Parmesan and Yohe 2003), where relative abundances of temperate species increase during periods of sea temperature warming, and decrease when temperatures cool, whereas boreal species show the opposite trend (Southward *et al.,* 1995). For example, abundances of some warm-temperate and temperate fish species with southern distributions have increased in southern UK waters during recent warming periods (1950s, 1980s-2002), while declines were apparent during cooling episodes (1920s, 1960-70s). Analysis of 33 core fish taxa in the western English Channel over 26 years within a 91-year period shows 9 species responded strongly by increasing with sea temperature warming (Genner *et al.,* 2004). These species were: butterfly blenny *Blennius ocellaris*, dragonet *Callionymus lyra*, topknots *Phrynorhombus* sp., solenette *Buglossidium luteum*, poor cod *Trisopterturs minutus*, lesser spotted dogfish *Scyliorhinus canicula*, greater pipefish *Syngnathus acus*, thinkback sole *Microchirus variegatus*, and red bandfish *Cepola macophthalma*. In total, these species comprised, on average, 57% of the total individuals caught during sampling years emphasising how climate-linked temperature change can influence important functional components of fish communities. A parallel analysis of 33 core species in the Bristol Channel over 22 years showed similar macroscopic trends, with 10 species responding strongly to temperature, one species declining in abundance with warming (the sea snail *Liparis liparis*), and 9 increasing (sprat *Sprattus sprattus*; whiting *Merlangius merlangus*; five-bearded rockling *Ciliata mustela*; cod *Gadus morhua*; sand goby *Pomatoschistus minutus*; bass

Dicentrachus labrax; dover sole *Solea solea*; plaice *Pleuronectes platessa*, and flounder *Platichthys flesus*) (Genner *et al.,* 2004). Similarly, these species comprised a key community component making up an average of 84% of individuals caught during sampling years. In this study at least, there was a relative lack of boreal species increasing during cooling (and decreasing during warming) compared with responses to climate by southern species. The reasons for this asymmetry in responses between species of different biogeographical distribution is not known but may involve complex indirect processes (Stenseth *et al.,* 2002; Genner *et al.,* 2004).

There have been relatively few studies describing changes in the long-term spatial distribution of fish with climate-linked temperature changes, mainly due to a lack of abundance data over sufficiently large geographical areas for long enough time periods. A study of 36 species of demersal (bottom-living) fishes in the North Sea with varied biogeographical origins and distribution patterns showed centres of distribution of 15 species shifted in relation to warming over distances ranging from 48 to 403 km during the period 1977 – 2001 (Perry *et al.,* 2005). The mean latitude of species such as Atlantic cod (*Gadus morhua*) and anglerfish (*Lophius piscatorias*) shifted north in relation to warming whereas mean latitude did not change for some species; rather a shift to deeper, cooler depths with warming was evident in these (e.g. plaice *Pleuronectes platessa*, cuckoo ray *Leucoraja naevus*) (Perry *et al.,* 2005).

Despite identification of fish species trends within a region, there appears to be a lack of similarity in reponses between regions. Effects of climate on species responses and community composition vary markedly between adjacent geographical regions which indicates broad-scale predictions of future responses from extrapolations of single studies from one area will be difficult (Genner *et al.,* 2004). For example, comparison of the aforementioned studies in the English Channel and Bristol Channel demonstrate that 9 species in each region responded strongly by increasing with sea temperature warming. However, the same species did not show congruent trends between sites, possibly due to region-specific local environmental determinants, interspecific ecological interactions, habitat availability and dispersal capacity (Genner *et al.,* 2004). This highlights the need to understand the mechanisms underlying observed trends in fish populations and communities in relation to environment, which at present remain little known (Stenseth *et al.,* 2002).

Renewed observations of rare fish migrants to UK waters in recent years (Stebbing *et al.,* 2002), following earlier observations (Russell 1953), may be related to recent sea warming, especially since climate-driven changes in timing and extent of annual migrations also occur (Sims *et al.,* 2001). Change in migration phenology has been described for the flounder *Platichthys flesus*, which undertakes a spawning migration from estuarine to marine habitat some 1 – 2 months earlier in years that were up to 2^{o}C cooler (Sims *et al.,* 2004). Timing of flounder migration is driven to a large extent by short-term, climate-induced changes in thermal resources linked to negative (cool) phases of the North Atlantic Oscillation (NAO). Hence short-term climate fluctuations have significant effects on the timing of fish peak abundance in an area, which may have implications for fisheries (Sims *et al.,* 2004). Dominant effects of the NAO on ecological processes in estuarine fish assemblages are evident. Absolute growth of herring (*Clupea harengus*) and smelt (*Osmerus eperlaunus*) and mean abundance of bass (*Dicentrachus labrax*) were positively correlated with positive (warm) phases of the NAO for example, while flounder abundance showed a negative relationship (Attrill and Power 2002), opposing trends that highlight the complex responses shown by different species even within the same habitat.

Large-scale climate variability (NAO) affects recruitment processes and consequently the size of marine fish populations (Stenseth *et al.,* 2002; Walther *et al.,* 2002). Direct and indirect temperature-related effects have been identified. For example, an analysis of 45 years of *S. sprattus* data from the Baltic Sea shows recruitment depends on the direct effects of temperature conditions during the months when sprat gonads, eggs and larvae are developing (MacKenzie and Koster 2004). However, for cod in the North Sea, climate effects on recruitment are exerted indirectly through the zooplankton on which the young cod feed (Beaugrand *et al.,* 2003). Indirect effects of climate on prey abundance and availability can also alter the migration and distribution patterns of large pelagic fish such as tuna (Polovina 1996). Climate-induced changes in species interactions, such as predator-prey relationships, will make prediction of future changes in fish populations problematic (Beaugrand *et al.,* 2003), especially since the climate-envelope approach to predicting species' responses to climate change does not take into account complexities that can yield counter-intuitive species abundance changes (Davis *et al.,* 1998; Southward *et al.,* 2005). Human exploitation may exacerbate these effects because low stock biomass and truncation of age structure of populations may result in the increased vulnerability of populations which are less able to buffer the adverse effects of warming (O'Brien *et al.,* 2000; Walther *et al.,* 2002; Beaugrand *et al.,* 2003).

Taken together, the available evidence for marine fish responses to short and long-term climate variability indicates that changes in many key ecological processes, such as recruitment, growth, migration, distribution and abundance, have occurred among diverse fish species across varied environments. However, what emerges is that responses of fish to climate are complex and vary between species, even among those in the same habitat and region. Responses of the same species between regions also appear different in many cases and human exploitation may obscure natural changes and/or exacerbate declines. This complexity will make predictions of marine fish responses to climate change difficult, but argues the need for more research to determine the mechanisms responsible for observed trends. These are currently lacking but should be a priority given their clear importance to fisheries management and conservation.

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