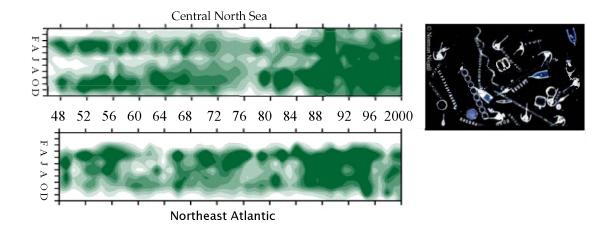
Figure 1. Changes in phytoplankton biomass and seasonality in the North Sea and northeast Atlantic as part of a regime shift in associated physical and biological parameters that began in 1987. The left hand pair of diagrams shows phytoplankton biomass (intensity of shading) in relation to month (y-axis) and calendar year (x-axis). An increase in biomass after 1987 is apparent in both the North Sea (upper) and northeast Atlantic (lower).



Climate change and fisheries

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Fisheries are the major cause of mortality for marine fish, once they have reached a catchable size. Most fish stocks have been declining for some time due to fishing. Nonetheless, climate fluctuations are also known to cause extensive shifts in species distribution and local biodiversity. Furthermore, climate change and fishing pressures may interact to exacerbate the risk of collapse of fish populations to below the level at which they can support fisheries.

The demography of marine fish tends to differ from that of terrestrial vertebrates and freshwater fish in several important respects. Marine fish have large population sizes with fewer boundaries to migration, high fecundity once mature, often have a dispersive plankton stage and they undergo large population fluctuations. There appear to be fewer barriers to migration in the sea. Hence, the constraints on distribution shifts in the sea are very different (and probably fewer) than on land or in freshwater systems, and marine populations probably maintain greater genetic exchange. Nevertheless, there is also concern about possible loss of genetic diversity (at least of genotypes), which may in turn reduce the capacity to adapt to climate change.

Fisheries' catch information provides much of our knowledge about fish populations. These data provide evidence for associations between climate change and marine fish abundance and distribution. The annual landings of cod in Greenland have varied enormously over the 20th century, ranging from very small local catches to almost 500,000 tonnes. This shows a close correlation with sea temperature fluctuations between 1 and 2.5°C, warmer temperatures being associated with bigger catches, but catches since the early 1970s have been lower than expected from temperature alone (Figure 1). Changes in the abundance and distribution of other fish species in west Greenland are also associated with the period of warming from the 1920s. New species appeared from 1920 (*Melanogrammus aeglefinus, Brosme brosme*,

Molva molva), rare species became common and extended their ranges (*Pollachis virens*, *Salmo salar*, *Squalus acanthias*) and Arctic species no longer occurred in southern areas, but shifted their range northwards (*Mallotius villosus*, *Gadus ogac*, *Reinhardtius hippoglossoides*). Thus, climate can cause extensive shifts in species distribution and in local biodiversity.

In the North Sea, fishing has reduced life expectancy of several species, most notably plaice and sole, from around 10 years to two and cod, haddock and whiting from about four years to one year or less. Fishing tends to selectively remove large individuals and species. The Scottish August Groundfish Survey has shown that maximum fish size in the North Sea has declined by a factor of nearly eight between 1920 and 2000. The southern North Sea is at the edge of the cod's southern climatic range and the combination of warming and overfishing has led to a dramatic reduction in numbers. Cod spawning biomass in the North Sea is at a historic low, but Barents Sea populations are still strong.

Climate change and fisheries can impact on biodiversity is several ways. At the most obvious level, they can cause species extinction. They can cause stock extinction, which may or may not entail the loss of alleles or genotypes, and adverse changes in genotypic frequency. They can change distribution and abundance and we have most evidence for this. Climate change and sea level rise effects are probably severe for some sensitive systems, such as coral reefs and mangroves, and these will also affect fish populations. It is also becoming clear that the North Atlantic Oscillation has a strong, but not necessarily simple, effect on phytoplankton, zooplankton and fish dynamics.

Figure 1. Landings of cod (green lines) and sea temperatures (red lines) at Greenland during the 20th century. Several large changes in cod landings coincide with changes in sea temperature. However, since the early 1970s, cod landings have been low relative to expectations from sea temperature.

