

Is climate change moving the goalposts for fisheries management?

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INTRODUCTION - WHY DOES MARINE BIODIVERSITY MATTER?

Current evidence indicates that, compared with loss of biodiversity in freshwater and terrestrial ecosystems, the rate of loss in marine systems is relatively slow (N.K. Dulvy – Recent marine extinctions, this meeting). This is not a cause for complacency, and the rate of loss is probably underestimated, but it challenges us to explain why protection of marine biodiversity is an urgent concern, when assigning priorities for research and management.

Global food security provides a strong justification. It requires sustainable marine fisheries, but, in addition to being threatened by overfishing, climate and other aspects of global change (acidification due to CO₂, rapid increase in some nutrients), fish stocks are becoming less resilient due to loss of biodiversity at infra-specific as well as at species and ecosystem level. A second justification is that we know too little about biodiversity changes in marine ecosystems to make well-informed decisions (notwithstanding the Continuous Plankton Recorder, www.sahfos.org, which provides among the longest and most geographically and taxonomically extensive time series and sample archives for any ecosystem on the planet). The protection of charismatic marine mammals is of course a third justification, which has had huge popular and political support for many years.

EFFECTS OF CLIMATE CHANGE ON FISHERIES MANAGEMENT TARGETS

Until recently, the biological objectives for fisheries resource management were mainly designed to sustain the exploitation of a few of the most commercially important fish species. **Targets** (optimisation objectives) are set to maximise yields and **limits** (pessimisation objectives) are set to prevent biomass from being reduced to levels which affect reproductive capacity and hence resilience. Broader objectives are now being developed in order to protect ecosystems, their structure, function and the goods and services which they provide.

The influence of climate (which is used somewhat loosely here, to include scales from days to decades) on fish stocks, and on the ecosystems supporting them, is increasingly well understood (e.g. Stenseth et al. 2004). Examples include the pelagic fisheries in eastern boundary currents (e.g. California, Humboldt, Benguela and Canary currents; Lluich-Cota et al. 1997) and the regime shifts of the N. Pacific which affect many stocks, including salmon (Francis et al. 1998).

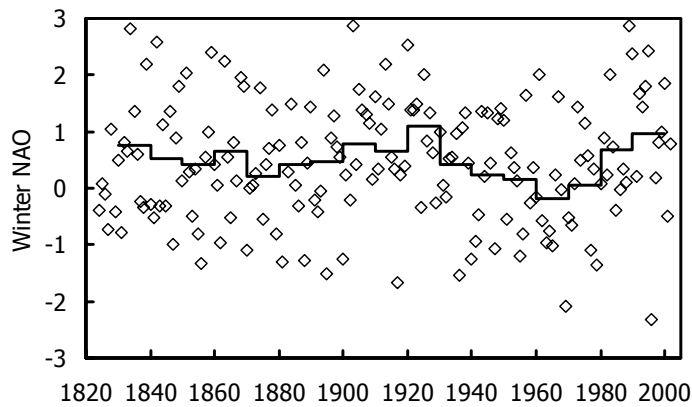


Figure 1 The North Atlantic Oscillation (NAO) is an indicator of climate change based on the atmospheric pressure gradient between Iceland and the Azores. The annual values (shown by diamonds) vary a great deal, but the underlying decadal mean (shown by the line) has increased steadily from 1960 on (Brander and Mohn, 2004).

Over the N. Atlantic and Europe a major component of climate variability is measured by the North Atlantic Oscillation (NAO), which is the atmospheric pressure gradient governing the strength and persistence of warming westerly airflow. The NAO influences the dynamics of many terrestrial and marine species and ecosystems, including plankton and fish stocks (Hurrell et al. 2003). For example the survival of cod (*Gadus morhua* L.) larvae in the North Sea is affected by the seasonal timing, size composition and abundance of plankton on which they feed (Beaugrand et al. 2003), which is partly governed by the state of the NAO. The average NAO state has increased gradually since 1960 (Figure 1) and most climate models predict that the high NAO state will persist (Gillett et al. 2003), with associated increase in sea temperatures in European shelf seas and changes in the pattern and strength of winds, rainfall and other factors. The increasing NAO contributes to reduced recruitment of cod in these areas and hence to changes in the targets and limits (the goalposts) for fisheries management (Figure 2). The resilience of these cod stocks (i.e. their capacity to sustain a particular level of exploitation without collapsing) has declined. Levels of fishing mortality, which had previously allowed stocks to remain within safe biological limits may no longer be sufficiently conservative. In many cases where fish stocks have declined severely, unfavourable environmental change has been a contributory factor, by reducing recruitment and growth and increasing mortality. This makes them vulnerable to levels of mortality to which they had previously been resilient. Examples of such adverse changes due to environment include the cod stocks in the NW Atlantic (Drinkwater, 2002), at Greenland (Brander, 1996) and in the Baltic (Köster et al. 2003) and the Norwegian spring spawning herring (Torensen, and Ostvedt, 2000).

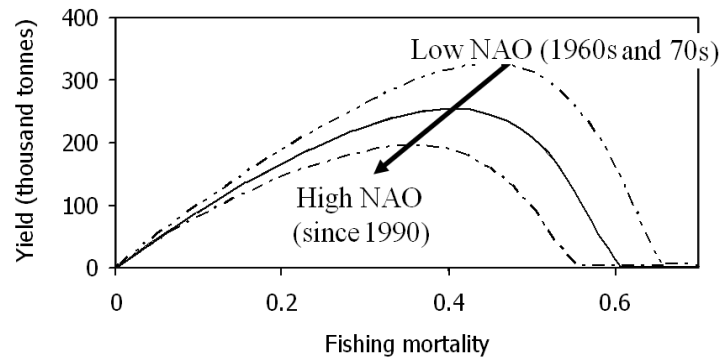


Figure 2 The yield of North Sea cod is lower when the NAO is high and the maximum occurs at a lower fishing mortality. This is probably because fewer young cod survive in years when the NAO is high and the North Sea is warm (Brander, and Mohn, 2004).

INTERACTION BETWEEN BIODIVERSITY, CLIMATE CHANGE AND SUSTAINABILITY

Marine species are less constrained than are terrestrial species by physical barriers to transport and migration; their ranges are mainly set by environmental factors (temperature, oxygen, light, salinity etc). There are many examples of plankton (Beaugrand et al. 2002) and fish species (Brander et al. 2003) extending their ranges rapidly as their environment changes. Cod stocks occur within a temperature range from roughly 0 to 11 °C (Figure 3, where temperature is the average experienced by cod larvae). Recruitment (and possibly also growth and mortality) is strongly affected by variability in temperature at the extremes of the range and changes here will have the greatest effect on resilience of populations. Populations at the edges of ranges are most adapted to extreme conditions, as alleles and genotypes are selected to confer resistance to the extremes. Intraspecific biodiversity is clearly valuable in helping species to adapt to climate change, but the populations in which such adaptation occurs are precisely those which become more vulnerable to exploitation when the climate changes and their resilience is reduced.

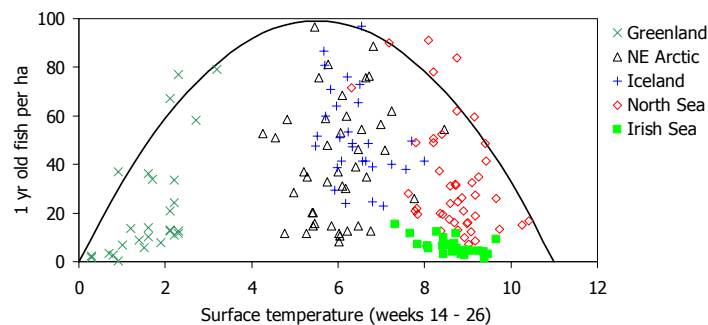


Figure 3 Survival of cod larvae and subsequent recruitment of 1 year old fish is affected by the temperature they experience as larvae (weeks 14-26). Recruitment to stocks at the cold end of the range (Greenland) increases with temperature. At the warm end of the range (North Sea) increasing temperature reduces recruitment (Brander, 2000).

There are also some positive aspects to the general model of thermal effects shown in Figure 3. The reduction in cod recruitment at the warm end of their range (the southern North Sea) may be compensated to some extent by increases in warm water species (such as red mullet, whose biomass is increasing very rapidly). A general increase in temperature will enhance survival of cod at the cold end of the range (in this case Greenland). The cod stock at Greenland increased

very rapidly from 1917 to 1930, during a warm period which lasted until the 1960s. The range extended northward by about 1000 km over twenty years and the biomass increased by several orders of magnitude, before declining again in the late 1960s. There are early signs of recovery of the Greenland cod stock as conditions once again become warmer.

CONCLUSIONS

Most of the detailed records of fish populations, on which we base our management targets and limits, come from the period after 1960. In many marine systems, including the N. Atlantic, this has been a period of underlying change in major climate indicators (temperature and NAO). There is evidence that the targets and limits set for fish stock management are sensitive to climate changes, because the survival of young fish and other aspects of population dynamics are affected. The targets and limits should take account of effects of past climate change and allow for the consequences of future change.

There have been rapid changes in distribution of plankton and fish species in the NE Atlantic since 1960. Such biogeographic changes may disrupt fish catch quota allocations, which are based on historic catches (relative stability), and may hinder local fleets in adapting to the appearance of new species.

Populations at the edges of the species range, whose genetic biodiversity is likely to be most valuable in adapting to climate change, are also most vulnerable to exploitation, because their resilience may be reduced by changes in their environment. This suggests that management should take particular care to protect populations at the edges of ranges (where the range may be defined in terms of more than one environmental factor).

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