

## Paris Conference

# Is climate change moving the goalposts for fisheries management?

By Keith Brander

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.

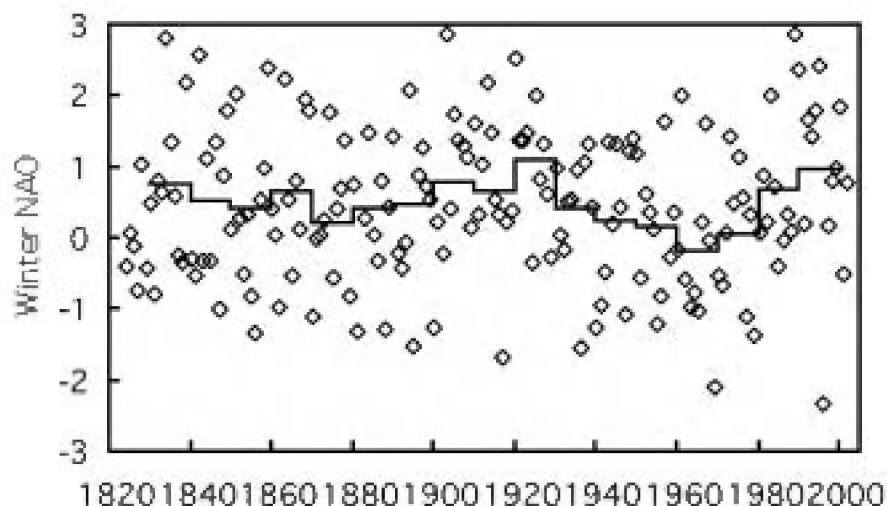
## Why does marine biodiversity matter?

Global food security provides a strong justification: it requires sustainable marine fisheries. In addition to being threatened by overfishing, climate and other aspects of global change (acidification due to CO<sub>2</sub>, 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](http://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 (optimistic objectives) are set to maximise yields, and limits (pessimistic objectives) are set to prevent biomass from being reduced to levels which affect



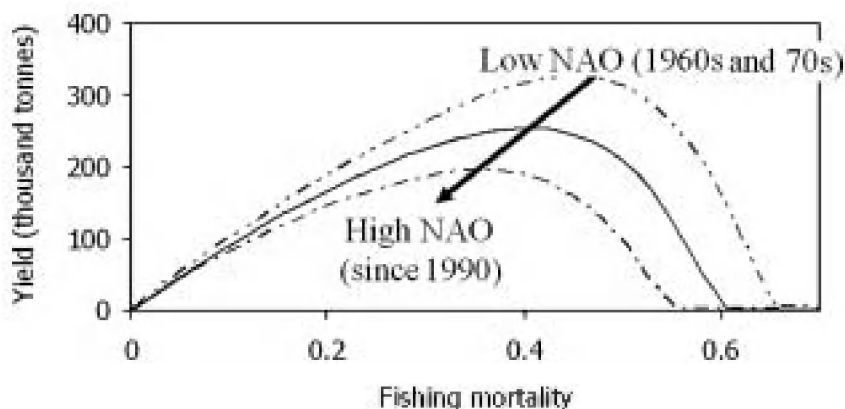
**Fig. 1.** The North Atlantic Oscillation (NAO) is an indicator of climate change based on the atmospheric pressure gradient between Iceland and the Azores. The annual values (shown by diamonds) vary a great deal, but the underlying decadal mean (shown by the line) has increased steadily from 1960 on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

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; Lluch-Cota *et al.* 1997) and the regime shifts of the N. Pacific which affect many stocks, including salmon (Francis *et al.* 1998).

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), in the Baltic (Köster *et al.* 2003) and the Norwegian spring spawning herring (Tøresen and Østvedt 2000).



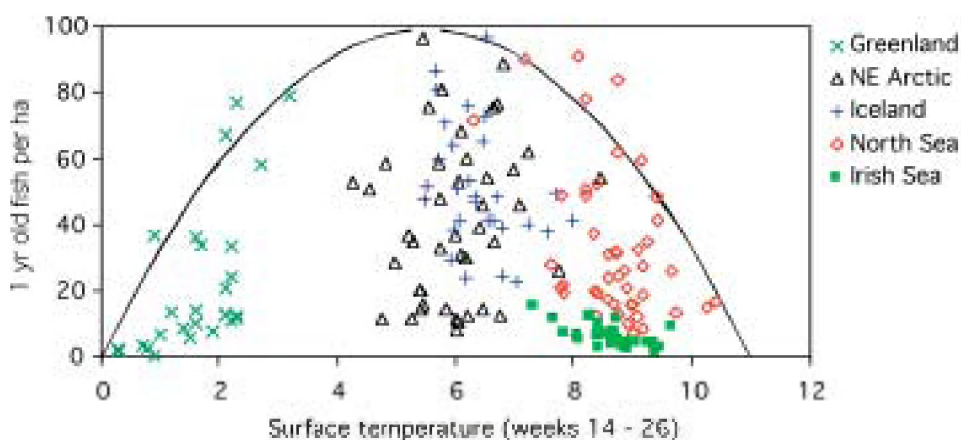
**Fig. 2.** The yield of North Sea cod is lower when the NAO is high and the maximum occurs at a lower fishing mortality. This is probably because fewer young cod survive in years when the NAO is high and the North Sea is warm (Brander & Mohn 2004).

## 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.

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 1,000km 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.



**Fig. 3.** Survival of cod larvae and subsequent recruitment of one-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).



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## 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).

(See references, next page)

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## FEATURES

### Paris Conference

# Extinctions and threat in the sea

By Nicholas K. Dulvy

THERE HAVE BEEN FEW species extinctions in the sea (18-21) compared to on land (829). Given the relatively high degree of human impact on the oceans this could be interpreted to suggest the effect of human impacts on marine biodiversity has been low. Alternatively, it could be that it is more difficult to detect extinctions of non-air-breathing marine organisms. Current evidence suggests population and species extinctions have occurred in the last 100 years and that a large number are threatened, primarily by exploitation and habitat loss or degradation. Evidence for poor detection of marine extinctions is consistent with the hypothesis that the number of marine extinctions is underestimated. Reducing fishing effort would reduce extinction risk in the sea.

## Species extinctions

Human impacts on the oceans are widespread and substantial, and concern has been growing of the possibility that marine species are being driven to extinction (Roberts & Hawkins 1999; Hutchings & Reynolds 2004). Current evidence suggests few marine organisms have become globally extinct in the past 300 years, compared to on land where 829 species have disappeared (Baillie *et al.* 2004). There is unequivocal evidence for the extinction of 12 marine species, comprising three mammals,

five seabirds and four gastropods (Carlton *et al.* 1999). An additional three bird and mammal species are listed as extinct by the World Conservation Union (IUCN) Red List (Baillie *et al.* 2004). A recent survey of marine extinctions has uncovered evidence to suggest the global extinction in the wild of a further six species comprising two fishes, two corals and two algae (Dulvy *et al.* 2003). These species – the Galapagos damselfish (*Azurina eupalama*), the Mauritius green wrasse (*Anampses viridis*), and two corals (*Millepora boschmai*, *Siderastrea glynni*), Turkish towel algae (*Gigartina australis*)

and Bennett's seaweed (*Vanvoortsia bennettiana*) – are thought to be extinct throughout their small geographic ranges.

There are a number of problems with determining the number of marine species extinctions; in particular is the uncertainty of taxonomic status and also in defining when the last individual has gone (Carlton *et al.* 1999). A number of taxa could be added to the list of global extinctions. However, it is not clear whether these are full valid species, clinal variants, hybrids or aberrant specimens (Carlton *et al.* 1999). In many cases there is little museum reference material to work with, so it is unlikely that this problem can be resolved. In summary, excluding these uncertain records, there is good evidence that between 18-21 species have become globally extinct in the last three hundred years.

## Population extinctions

There are three reasons for considering population-scale extinctions. First, populations hold unique genetic material and are