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Fisheries

Climate variability and North Sea cod

The stock of North Sea cod is under pressure because of overfishing, and we show here that it is also threatened by a decline in the production of young cod that has paralleled warming of the North Sea over the past ten years. The combination of a diminished stock and the possible persistence of adverse warm conditions is endangering the long-term sustainability of cod in the North Sea. To decrease the risk of collapse, fishing pressure must be reduced.

Over the past four decades, cod in the North Sea has been a valuable fishery, yielding an average of 200,000 tonnes per year. Nowadays, the catch is mainly constituted of fish that are younger than three years old, most of which are immature. This resource is currently managed by imposing landing quotas based on annual stock assessment:

the latest advice from the International Council for the Exploration of the Sea (ICES) is to reduce catches by 40–60%.

For North Sea cod, apart from fish spawned in 1996 (termed the 1996 year-class), the annual number of one-year-old cod in the population (known as the recruitment) has been at or below the long-term average for over a decade¹. The recruitment of cod spawned in 1997 was the lowest for 30 years. Taking account of the dependence of recruitment on stock size alone, it has been proposed² that the collapse of this stock may be imminent, as the spawning-stock biomass is currently at a low level.

There is evidence, however, that for many fish stocks there is an environmentally driven variability in recruitment³. The recruitment of cod in the North Atlantic appears to be related to sea temperature for stocks located at the latitudinal limits of the species' distribution⁴. In the Northern Hemisphere, increasing temperatures are favourable for stocks at the highest latitudes but detrimental for those at the southern limit⁵. Cod in the North Sea are near the southern boundary of their range and, historically, strong year-classes have been associated with lower-than-average temperatures during the first half of the year (Fig. 1a).

Weak year-classes have also occurred during cold years (such as 1986 and 1987), but only when the spawning-stock biomass was low. So when the spawning-stock biomass is low, as now, the likelihood of good recruitment is low and the effect of temperature is less pronounced (Fig. 1a). A change in temperature patterns might prevent the stock from being able to produce recruitments as high as those that occurred during the 1960s and 1970s, even if the spawning-stock biomass were to rebuild to the abundant levels of that period.

Since 1988, mean sea temperatures during the first half of the year in the North Sea have been higher than during the previous three decades (Fig. 1b). During this period, annual recruitment levels have been low, with the exception of 1996, when cold conditions prevailed. Since 1997, warmer conditions have returned to the North Sea and the 1997 and 1998 year-classes have coincidentally been the poorest on record¹.

The North Sea cod stock is currently dominated by immature fish of less than five years old, and both the stock and fishery are dependent upon years of strong

recruitment. The 1996 year-class was the strongest for over a decade but, at the present high exploitation rate of young cod, few individuals have survived to reach sexual maturity.

The combination of this exploitation with the recent changes in North Sea temperature, a low spawning-stock biomass and a stock dominated by young immature individuals, means that fishery managers must take precautionary measures⁶. In order to give the mature stock a chance to rebuild, fishing mortality rates need to be reduced to at least the precautionary levels advised by ICES¹.

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Marine ecology

Bleaching patterns in reef corals

Coral reefs are under threat from the effects of bleaching, in which symbiotic algae or their photosynthetic pigments are destroyed by increased sea temperatures and solar radiation^{1,2}. Here we show that the bleaching susceptibility of *Goniastrea aspera*, a shallow-water Indo-Pacific coral, can be predicted from its history of exposure to solar radiation, demonstrating how experience can shape coral bleaching patterns.

At our study site, Phuket in Thailand, sea temperatures are maximal in May³. In 1991 and 1995 sea temperatures were anomalously high: on both occasions many coral species suffered temperature-induced bleaching, but *G. aspera* colonies were only bleached on their east-facing surfaces. *G. aspera* at Phuket also suffers annual solar bleaching, which is restricted to the west-facing surface, during January–March⁴. Solar bleaching is a photochemical effect caused by photosynthetically active radiation (PAR, of wavelengths 400–700 nm), rather than by ultraviolet radiation or solar heating effects^{4,5}.

We investigated three possible mechanisms to explain the greater susceptibility of the east rather than the west surface of

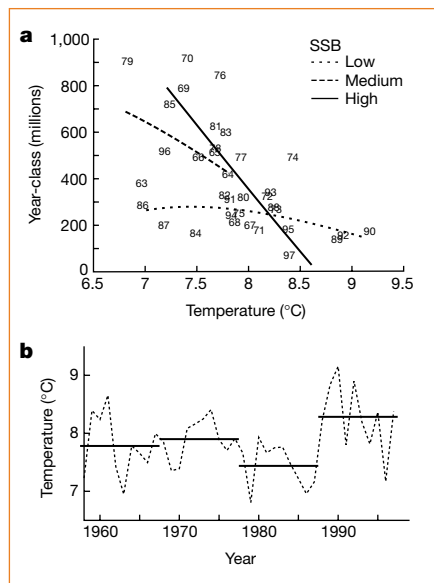


Figure 1 Cod recruitment and temperature in the North Sea. **a**, Year-class strength (millions of one-year-old fish) plotted against temperature in the year spawned. The three lines show the relationship between recruitment and temperature at three levels of spawning-stock biomass (SSB) (low: 80,000 tonnes; medium: 160,000 tonnes; high: 240,000 tonnes) based upon a three-dimensional spline fit. Recruitment and SSB are from ref. 1. **b**, Seasonal sea-surface temperature averaged over February to June (dashed line). Horizontal lines indicate decadal average. Temperatures are derived from the Comprehensive Ocean Atmosphere Dataset and provided by the National Center for Atmospheric Research (Boulder, Colorado).

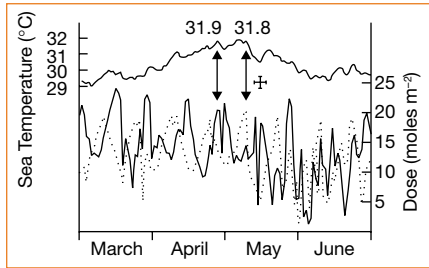


Figure 1 Daily dose of photosynthetically active radiation (PAR) underwater at the depth of *G. aspera* colonies in 1995. Solid line, west surface; dotted line, east surface. Top trace, daily mean sea temperature; double-headed arrows, maximum combined sea temperature and PAR doses for east (8 May) and west (26 April) surfaces; cross, bleaching first recorded (14 May).

G. aspera colonies to temperature bleaching in May 1995. First, given that different genotypes of the symbiotic algae on the Caribbean coral *Montastrea annularis* show differential bleaching susceptibility⁶, we tested whether the east and west surfaces of *G. aspera* hosted different algal genotypes. Molecular analysis of the ribosomal RNA gene complex revealed no variation between algae from the two surfaces, either by analysis of restriction-fragment length polymorphisms of the small-subunit-rRNA gene⁶ or by sequence analysis of the ITS1–5.8S–ITS2 region, which resolves finer molecular differences^{7,8}. We conclude that the bleaching pattern observed in *G. aspera* is not due to genetic differences between their algae of the sort previously reported in *M. annularis*⁶.

Second, we investigated whether the east surfaces of *G. aspera* colonies received more solar radiation than the west surfaces at the time of temperature bleaching in May 1995. During solar bleaching (January–March), the dose of PAR was consistently higher on the west than on the east surfaces, but from late April this difference disappeared. The maximal combined sea temperature (31.8–31.9 °C) and solar radiation were recorded on 26 April (for the west surfaces) and 8 May (for the east) — before the first observation (14 May) of temperature bleaching (Fig. 1). So the east surface did not receive more solar radiation than the west at the time of temperature bleaching.

Finally, to establish whether west surfaces are more tolerant to increased temperature, we subjected core samples from the west and east surfaces to different temperatures (elevated, 34 °C; ambient, 27 °C) under identical irradiance for 3 days (Fig. 2). At 27 °C, the algal density and chlorophyll *a* content per algal cell were similar for the east and west cores, and did not vary between the start and end of the experiment. Exposure of the east cores to 34 °C, however, resulted in significantly reduced algal density (Mann–Whitney *U*-test: $P < 0.01$) and caused an increase in the chlorophyll *a* content per algal cell

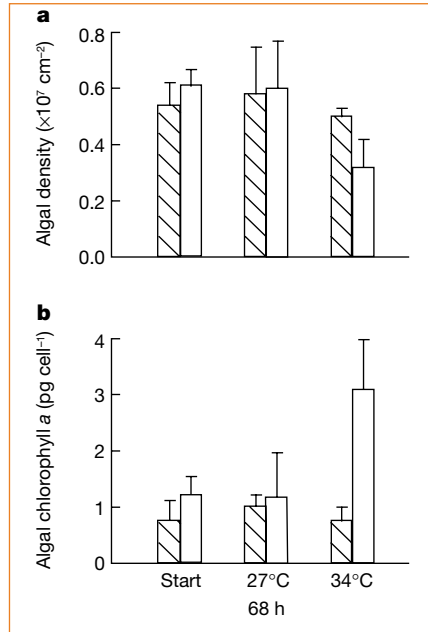


Figure 2 Physiological parameters in east and west cores of *G. aspera* before and after exposure to elevated (34 °C) and ambient (27 °C) temperatures for 68 h at an irradiance of 100 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Mean values for each parameter are shown; error bars show one standard deviation ($n=5$). **a**, Algal density in west (hatched) and east (clear) cores at the start and end of the experiment at the different temperatures. **b**, Algal chlorophyll *a* concentrations.

($P < 0.008$), whereas west cores were unaffected. Algal chlorophyll *a* was increased in other recently bleached corals^{9,10}.

Our findings indicate that the west surfaces of *G. aspera* colonies could have been protected against temperature bleaching in May 1995 because they were more tolerant than the east surfaces towards the combined stress of temperature and solar radiation. This tolerance probably arose as a result of the increased solar radiation received by the west surfaces during January–March. We conclude that experience-mediated tolerance, as well as algal genotypic differences⁶, contributes to the variation in bleaching susceptibility among reef corals. Many coral colonies are long-lived¹¹, and experience effects may have an important influence on the bleaching responses to global climate change over the coming decades.

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Vision

Myopia and ambient night-time lighting

Myopia is a common affliction (one in four adult Americans is near-sighted¹), and juvenile-onset myopia is believed to be due to a combination of genetic and environmental factors². Results from animal experiments indicate that light cycles may affect the development of myopia^{3,4}, and Quinn *et al.* claim to have extended these to humans⁵. They reported a strong association between childhood myopia and night-time lighting before the age of two: there were five times more children with myopia among those who slept with room lights on than in those who slept in the dark, and an intermediate number among those sleeping with a dim night-light⁵. However, we have been unable to find a link between night-time nursery lighting and the development of myopia in a sample of schoolchildren.

We examined the issue of nursery lighting in a subsample of children from the multicentre Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) Study. Parents reported their use of night-time lighting and their own refractive status, and the child's refractive error was measured by cycloplegic autorefraction. Our sample consisted of 1,220 children with a median age of 10.2 years: 11.5% of them were African-American, 19.1% Asian, 47.9% Caucasian and 21.6% Hispanic; overall, 18.1% of them were myopic (at least –0.50 dioptres spherical equivalent). The proportion of children with myopia did not differ across nursery-lighting groups ($\chi^2 = 2.62$, $P = 0.271$). Eighty-four of 417 children (20.0%) who slept in darkness were myopic; 128 of 758 children (16.8%) who slept with a night light before age two were myopic, and 10 of 45 children (22.2%) who slept with full room lights on before age two were myopic.

We found an association between the number of myopic parents and nursery lighting before age two ($\chi^2 = 35.02$, $P < 0.001$), as well as an association between ethnicity and room lighting ($\chi^2 = 89.22$, $P < 0.001$). This sample carries a statistical power of 0.99 to be able to detect an odds ratio of 2.00 between nursery lighting and childhood myopia.

Our results do not replicate those of Quinn *et al.*⁵. In fact, the proportion of myopic children in those subjected to a