TEMPERATURE AND THE RECRUITMENT OF ATLANTIC COD

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Introduction

Despite indications from biological studies that a number of environmental factors influence life history processes, the evidence of environmental effects on recruitment in the wild is still sparse. As a result, studies on the role of temperature on the recruitment of Atlantic cod have provided contradictory and often inconclusive results.

Here, we test the hypothesis that recruitment of Atlantic cod is connected to interannual changes in temperature, in such a way that for stocks located at the warm limit of the distribution of the species the relationship is negative, for stocks located at the cold limit the relationship is positive and there is no relationship for stocks located in the middle of the temperature range.

Fluctuations in cod recruitment and temperature across the North Atlantic

Recruitment data were derived from virtual population analysis (VPA) for nine stocks as follows: Newfoundland (NAFO 2J-3KL), West Greenland (NAFO 1), Northeast Arctic (ICES II), Iceland (ICES Va), Faeroes (ICES Vb), Georges Bank (NAFO5Z), North Sea (ICES IV), Irish Sea (ICES VIIa) and Celtic Sea (ICES VIIf-k). Temperatures were derived from the Comprehensive Ocean Atmosphere Data Set (COADS) and the Kola section in the Barents Sea.

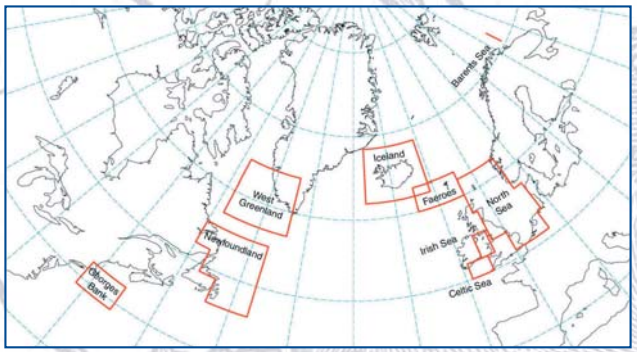

Figure 1: Location of the areas for which sea surface temperature series were selected.

Relationships between interannual changes in SST and cod recruitment for the nine stocks have been measured by Spearman rank correlation coefficient and non-parametric regression. The correlation coefficient allows to measure the significance of the temperature-recruitment relationship for a given stock whilst the regression slope indicates the amplitude of recruitment changes associated with a variation in temperature of ±1°C.

Figure 2 shows $\log_2$-recruitment anomalies plotted against temperature anomalies for each stock together with the linear regression fit and the significance of the correlation test.

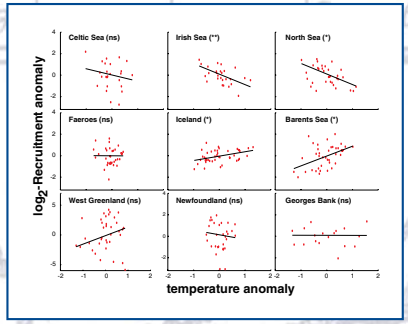

Figure 2: Scatterplots of $\log_2$ -recruitment of cod against temperature (February to June) for the nine stocks in the North Atlantic and associated regression fits.

A number of observations can be derived from these correlations: (1) there is a high degree of scatter in the data which results in difficulty in obtaining statistically significant relationships, (2) the relationship between temperature and recruitment can be negative, null or positive, and (3) the relationship between temperature and recruitment is not always significant for stocks located at the cold and warm temperature limits.

To overcome the limitation of the above correlation analysis, we have combined the data from all stocks in a single Trans-Atlantic analysis. In this analysis, we have tested that the regression between recruitment and temperature for each stock is not independent from the mean bottom temperature where the adult stock is located.

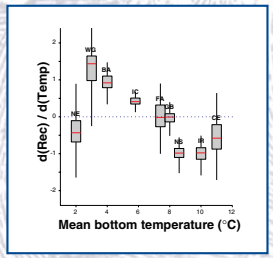

Figure 3. Link between sea surface temperature and recruitment plotted against mean bottom temperature for nine cod stocks in the North Atlantic. For each stock, the link is estimated by the slope of the non-parametric regression (from figure 2). Boxes and lines indicate the 50% and 95% limits of the empirical distribution of the slopes. Stocks are as follows: NE: Newfoundland (Northern cod), WG: West Greenland, BA: Barents Sea (North-east Arctic cod), IC: Iceland, FA: Faeroe Islands, GB: Georges Bank, NS: North Sea, IR: Irish Sea, CE: Celtic Sea.

The apparent trend is for the temperature-recruitment relationship to be positive for stocks located in cold waters and gradually decrease to negative values for stocks in warm waters. In temperate waters there is no apparent effect of temperature on recruitment, as expected. The correlation between β (the measure of the relationship between temperature and recruitment) and mean bottom temperature is r = -0.59 (p = 0.027) indicating that the null hypothesis (effect of temperature on recruitment is independent from mean temperature) can be rejected. It is clear however from figure 3 that the Northern cod stock (Newfoundland) stands out of this general pattern. For a number of reasons (non-persistence in temperature anomalies, high hydrographic heterogeneity, very low spawning stock biomass in recent years) the estimate of β for the Northern cod is highly uncertain and it would be appropriate to treat this stock separately from the others. When the Northern cod stock is removed from the analysis, the correlation between β and mean bottom temperature reaches r = -0.83 (p = 0.0016).

Perspectives

The present study demonstrates the existence of significant temperature-recruitment relationship which is consistent with the view that the effects of the environment on recruitment should be stronger at the limit of species spatial distribution. It reconciles the results from a number of studies that had apparent contradictory conclusions on the effects of temperature on cod recruitment.

The changes in temperature can have important implications for the estimation of parameters used in stock recruitment models. The recruitment can be modelled in a form similar to that proposed by Stocker *et al.* (1985, Can. J. Fish. Aquat. Sci. 42 (Suppl. 1): 174-180):

$$R = SSB \cdot e^{(\alpha - \beta . SSB)} \cdot e^{(\psi . T)}$$

Where R, SSB and T are respectively recruitment, spawning stock biomass and temperature and α, β, and ψ the associated coefficients. Figure 4 shows an example of fit for the Irish Sea cod stock. The Ricker curve is plotted for three temperatures within the range of observed values in the Irish Sea. It is clear that the fitted curves and particularly the slopes at the origin vary greatly under the distinct temperature regimes. Such information could be used to assess the impact of management strategies under various climate scenarios.

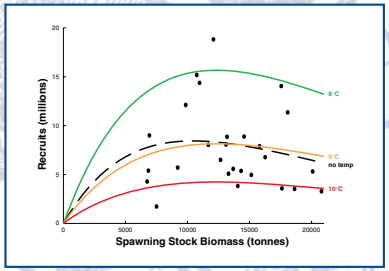

Figure 4: Recruitment of Irish Sea cod plotted against spawning stock biomass (dots). Dotted line shows the fit of a Ricker model. Plain coloured lines show fits from a combined stock/temperature-recruitment model for three distinct temperatures.

The understanding of the effects of environment on recruitment can be of great value if integrated in management procedures, and the possible ways by which this could be done have not been fully explored yet. The main difficulty will probably be to reconcile results on temperature-recruitment relationship which are evident at the Trans-Atlantic scale with management strategies which take place at the level of individual stocks only.

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