LARGE-SCALE ENVIRONMENTAL EFFECTS ON RECRUITMENT OF COMMERCIALLY EXPLOITED FISH STOCKS IN THE NORTHEAST ATLANTIC

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Introduction

Large-scale studies are particularly useful in detecting climate effects in the ocean and combined with process studies they might provide insights on the synergistic nature of ecosystem functioning. Several studies have examined large-scale variability in north Atlantic plankton (Colebrook 1982, Reid *et al.* 1998, Planque & Taylor 1998) and some fish stocks (Garrod & Colebrook 1978, Shepherd *et al.* 1984, Rodionov 1995, Sundby 2000) in relation to climate.

In this study we analyse multiple fish stock data series searching for evidence of large-scale temporal and spatial patterns and regime shifts.

Data

Recruitment time-series of commercially exploited fish stocks from the ICES area (Northeast Atlantic) including several sub-areas like the North Sea, English Channel, Celtic Sea, Irish Sea, West of Scotland, Faroe, Islands, Iceland and European Arctic were analysed (Figure 1, Table). Fish recruitment has been estimated by the ICES working groups using age-structured population analyses (e.g. VPA, ICES 2004). Recruitment time-series were logarithmically transformed, standardised (zero mean, unit variance), and linear trends were removed in order to reduce the effects of specific long-term influences (e.g. fishing). Exploratory correlation and principal component analyses (PCA) between stocks in different areas were performed.

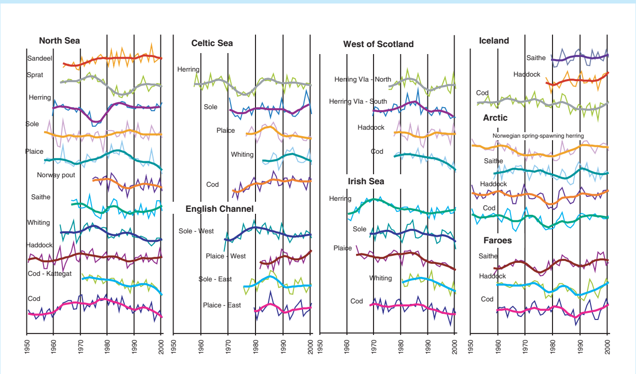

Figure 1: Standardised (zero mean, unit variance) log recruitment time-series smoothed by loess

Table: Comparison of significant correlations of fish stocks within and between major areas in the Northeast Atlantic

	North Sea	English Channel	Celtic Sea	Irish Sea	West of Scotland	Faroe	Iceland	Arctic	All
Stocks	10	4	6	5	4	3	3	4	39
Comparisons									741
Within area	45	6	15	10	6	3	3	6	94
Between areas	290	140	198	170	140	108	108	140	647
Significant correlations	64	19	29	22	19	15	11	14	193
Within area	12	2	2	0	1	1	1	4	23
Between areas	52	17	27	22	18	14	10	10	85
% Significant correlations/number of comparisons									
Within area	27%	33%	13%	0%	17%	33%	33%	67%	24%
Between areas	18%	12%	14%	13%	13%	13%	9%	7%	13%

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Correlation analyses

Pearson correlation analyses were performed between stocks within and between areas and the number of the significant correlations was related to the total number of pair-wise correlation analyses following the approach by Shepherd *et al.* (1984, Table). 193 significant ($p<0.05$) correlations between 39 stocks were found: 171 positive and 22 negative. A greater number of significant correlations between stocks were found within areas than between areas, that is similar to the conclusion of Shepherd *et al.* (1984), although the percentage of significant correlations between areas is higher in this study: 13% comparing to 5% in Shepherd *et al.* 1984. In general the stocks around British Isles (BI) were positively correlated between them, as were stocks in the north (Faroe, Iceland, and Arctic – FIA), but BI and FIA stocks were negatively correlated between them. The causal mechanism of these correlations is not entirely clear and needs more detailed analysis of individual stocks in relation to environmental data.

Principal component analyses (PCA)

PCAs were performed separately on 1977-2000 BI and FIA standardised and detrended time-series. The first two PCs in both areas were further analysed. PC1 of the stocks around the British Isles was mainly correlated with plaice, sole, herring and sprat stocks and PC2 mainly with round fish across the area (Figure 2A). PC1 of FIA stocks wss significantly correlated with the arctic stocks and Icelandic herring and PC2 – with Faroe and Iceland cod and haddock (Figure 2B). PC1s in both BI and FIA seem to account for longer-term variability in recruitment time-series (Figure 3A). A prominent feature of the PC1 series is the change in 1987-1990: decrease in BI stocks and increase in FIA stocks. This change corresponds to transition from a low to high NAO regime and highest NAO values during the 20th century. The time of the change also correspond to a suspected regime shift (Beaugrand 2004). The correlations between the first PCs from the two areas and SST in the North Atlantic present inverse patterns (Figure 4). The highest correlations are in the North Sea and the central North Atlantic.

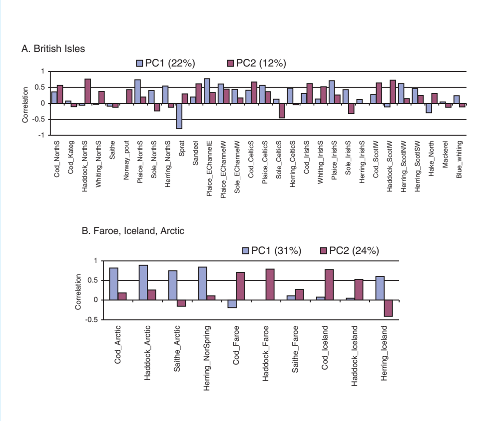

Figure 2: Correlations of fish recruitment data (standardised, linear trend removed) with the first two principal components (PC1 and 2) in: A. British Isles (BI), B. Faroe Islands, and Arctic (FIA)

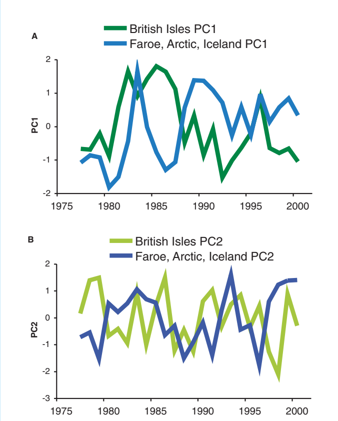

Figure 3: PC scores against time from BI and FIA: A. PCs 1, B. PCs 2

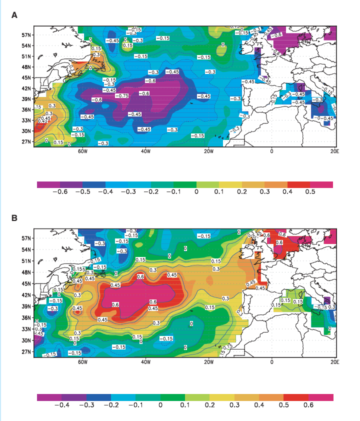

Figure 4: Correlations between principal component scores and gridded SST in the North Atlantic: A. PC1 of the fish stocks around British Isles (BI), B. PC1 of the fish stocks in Faroes, Iceland, Arctic (FIA)

Discussion

Fish recruitment time-series were explored for consistent spatial and temporal patterns in relation to the marine environment. Comparative analyses discriminated between the stocks around British Isles (BI) stocks in the north (Faroes, Iceland, Arctic: FIA). The geographical location of the two groups of stocks roughly corresponds to the NAO dipole: Northern stocks are situated in the low SLP zone and those around British Isles – in the high SLP zone. Temporal variation in most of the series was dominated by a consistent decadal pattern. The two groups of stocks presented a reverse temporal pattern: recruitment of the stocks around British Isles was relatively high in the late 1980s but decreased during the 1990s, in opposite to the northern stocks where recruitment was relatively high during the 1990s. The timing of the change (late 1980s-early 1990s) corresponded to increase in NAO and a climate driven regime shift (Reid *et al.* 2001, Beaugrand 2004). The highest correlations with SST in the central north Atlantic are suggestive that Gulf Stream influence might be related to recruitment success in the northeast Atlantic

Our results indicate that large-scale climate driven processes in the north Atlantic can be associated with variation in fish stocks. At this stage there is no obvious explanation for the inverse relationship between northern stocks and those around British Isles to SST and other indices (NAO, position of the Gulf Stream). Referring to the current knowledge different interpretations could be proposed: inverse relation to the temperature by stocks in different parts of the distribution area, differential effects of ocean circulation and stratification, onset of spring, match-mismatch of plankton blooms, zooplankton productivity and transport (Planque & Fredou 1999, Sundby 2000, Reid & Beaugrand 2002, Taylor 2002,),

We believe that elucidating the causes of the observed patterns will greatly improve our understanding of the effects of environmental change on fish stocks and provide a sound base for ecosystem based fisheries management.

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