IMPACTS OF CLIMATE CHANGE ON STRATIFICATION

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Executive Summary

Stratification of the ocean can be thought of as the vertical structuring of the water column by density. The density of seawater is primarily controlled by its temperature and salinity, thus stratification can be a combination of thermal (warmer water above cooler water) and saline (fresher water above saltier water). In simple terms the water column in any location is either **mixed** or **stratified** and whether it is one or the other has profound impacts on the ecosystem. However, whilst temperature and salinity are standard oceanographic parameters there are few long-term studies or time-series observations of changes to stratification in the shelf seas around the UK.

Stratification is of direct importance to the climate at the global scale (the thermohaline circulation is essentially a vertical circulation driven by changes in density and mixing) and at the regional scale (for example heat stored in the stratified upper layers of the north Atlantic during summer is extracted by winter wind (Ellett, 1993)). Productivity in the oceans is affected by stratification, some of the most productive ecosystems around the world are located where nutrients from deep in the ocean are brought to the surface through upwelling – essentially a local reduction in the strength of stratification between coastal and deep-ocean.

In a similar way, stratification in the shelf seas around the UK has the potential to impact on processes in the ecosystem. In the shallow waters (<200 m deep) of the shelf seas around the UK the stratification of the water column is controlled by mixing from the bottom (tidal) and top (wind and convection) balanced by the stratifying influence of heating or freshwater input from the surface. Within UK waters there are areas that remain mixed all year round and others that stratify each summer, with marginal conditions at the boundaries between the two (Pingree & Griffiths,1978). These areas are fairly well defined as the strength of tidal currents and bathymetry provide a constant constraint on top of which the variable atmospheric forcing of wind and heating/cooling can act. Varying stratification through the UK shelf seas is thought to be important for a wide range of processes in the ecosystem, for example – contrasts in density can drive the circulation of the seas themselves affecting the transport pathways for contaminants and biology (e.g. Hill *et al.*, 1996; Raine *et al.,* 1998); plankton species composition is different in well-mixed and stratified regimes and consequently some toxic harmful algal blooms only occur in stratified water (e.g.

Tett *et al.,* 2003); the supply of nutrients through the water column can be inhibited by stratification; and oxygen levels can be reduced in water that is isolated from ventilation at the surface (Karlson *et al.,* 2002).

There are few modelling studies of long-term change in stratification of the UK shelf seas and the future scenarios within UKCIP02 (Hulme *et al*., 2002) only assessed surface ocean variables. A hindcast model study of the Irish Sea by Young and Holt (2006) forced a 3D model at high resolution with atmospheric conditions from the period 1950-1999. They found that the location of stratification stay broadly the same between 'warm' and 'cold' years but there is significant interannual variability in the timing and strength of thermal stratification. A significant trend towards later occurrence of the peak of the stratification cycle was also identified but the cause of this trend is not explained.

We have not considered the estuarine environment in this assessment and recommend that future MCCIP report cards contain specific information on stratification changes in this dynamic area between the land and sea environments. It might be speculated that any changes to rainfall patterns whether seasonality or occurrence of extreme events might have an impact in estuaries and the coastal regions of the shelf seas where direct freshwater inputs are important.

Level of Confidence

Our confidence in understanding long-term change in shelf sea stratification should be regarded as **low** – whilst the dynamics of stratification in the shelf seas are fairly well understood, there are few observed time-series to identify change that has happened and only one hindcast modelling study published. Shelf-sea scenarios for the future are lacking and would be influenced by wind and storm predictions which themselves are low confidence areas within scenario models (UKCIP02).

Key Sources of Information

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