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Modelling Turbulence and Phytoplankton Motility in a stratified Shelf Sea

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Turbulence in shelf seas, driven by surface winds and by tidal currents, is likely to easily counteract the typically weak swimming capabilities of phytoplankton. The thermocline marks a low turbulence region, separating the nutrient-depleted surface (wind-mixed) layer and the nutrient-replete bottom (tidally-mixed) layer, and so would seem to be an ideal environment for employing a strategy of vertical migration. However, the positioning within the thermocline is crucial, as turbulence in the adjoining boundary layers removes cells that stray too close to the edges of the thermocline and mixes them into resource-limited layers of the water column. We combined a Lagrangian random walk model, a k-ε turbulence scheme and a simple photosynthesis model to track individual phytoplankton cells in a tidally-mixed, stratified water column (e.g. a summer, temperate shelf sea). By allowing motile and non-motile species to compete, we found that an ability to use motility to balance resource requirements can offset modest physiological disadvantages compared to the non-motile phytoplankton, leading to either co-existence or even dominance of the motile species. However, more severe physiological disadvantages (e.g. combinations of growth rate, nutrient uptake capabilities, and/or respiration) cannot be compensated for by motility alone, and further adaptations (such as mixotrophy) would be required. We also show that the subsurface chlorophyll maximum can be a place for significant new production (values of 1 gC m^{-2} d^{-1} and f-ratios of over 0.5 are possible), which stresses its potential importance as a source of food to the pelagic throughout summer.