4.4 Biophysical model

Figure 8 – Figure 11 present the time-averaged results from the default simulations, and also the results from the sensitivity simulation (in which mussel DIN excretion was reduced). These provide a robust summary of the 'broad-scale' results, but as with the snapper and logistic plankton results, the long-term averages mask considerable temporal variability in terms of both domain wide abundance and distribution patterns within the domain. For example, the domain-wide diatom abundance usually increases during the simulations, phytoflagellate abundance remains relatively constant and dinoflagellate abundance falls (Figure 12). There are also changes in the locations and magnitudes of depletion/enhancement during simulations. These reflect both the influence of wind upon circulation and the increasing importance of DIN excretion by mussels as ambient DIN levels decline over the first few days of each simulation.

The presence of farms has comparatively little influence upon the relative abundance of DIN during spring (when concentrations are relatively high), but during the summer, the farms raise the ambient DIN concentrations ~two fold (Figure 8). The greater apparent impact during summer arises because summertime ambient DIN concentrations are much lower. It is worth noting that whilst the summertime impact is marked if mussels are assumed to excrete DIN at rates that have been measured in chamber experiments, DIN enhancement is markedly lower if the mussels are assumed to conserve cellular N (by burning carbohydrate/lipids in preference to protein whenever possible, Figure 8d). The influence of the western firth AMA is much larger than that of the Wilson Bay farms.

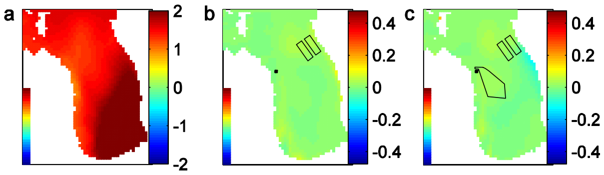
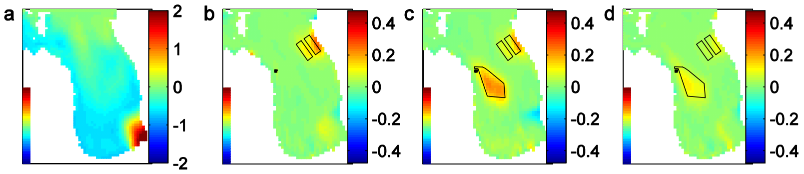
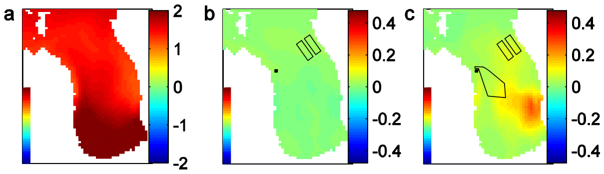
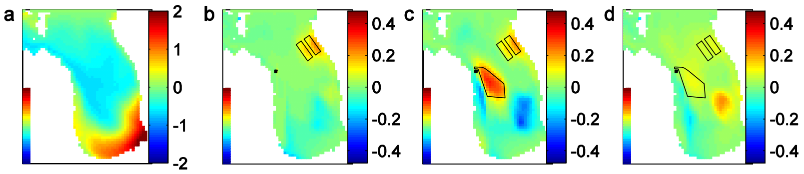
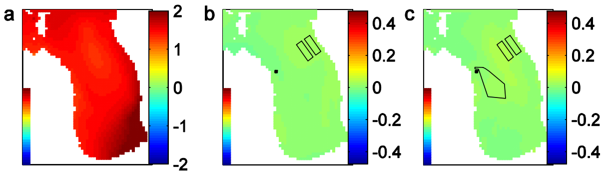
It is satisfying to note that the model predicts that diatom abundance will decline markedly between spring and summer, whilst the densities of dinoflagellates, and more especially, phytoflagellates remain more constant. Whilst we have not performed a detailed comparison of model predictions and field data, we note that the predicted phytoplankton abundances are within the range observed in the northern Firth of Thames (Broekhuizen, N. et al. 2002). Furthermore the model often predicts that phytoplankton abundance will be higher on the NE side of the firth than on the NW side. Both observations are consistent with the pattern inferred from an extensive survey carried out by NIWA in December 2002.

Phytoplankton density is usually suppressed somewhat within the farms (by up to 50% upon occasions, Figure 9 – Figure 10). The far-field impacts are more variable. Dinoflagellate concentrations are almost invariably reduced but this is not always the case for diatoms and phytoflagellates. When ambient DIN is plentiful, the far-field diatom and phytoflagellate concentrations tend to be suppressed relative to the no-farm situation, but when ambient DIN concentrations are low (and mussels are assumed to excrete plentiful DIN), far-field concentrations of diatoms and phytoflagellates can be enhanced. This enhancement sometimes occurs in different locations – reflecting the differing growth rates and average vertical positions of the two groups. The presence of farms may also seem to enhance phytoplankton populations in the extreme south of the firth. As with the snapper, this may be an artefact associated with 'sampling error', but in this case we can also envisage a mechanistic explanation. The farm-associated DIN concentration increases have two consequences: (a) phytoplankton retain higher cellular N:C ratios – making it more likely that diatoms and dinoflagellates will remain near the surface, and hence modifying their population movement patterns; (b) increasing cellular growth rates, thereby promoting greater population growth and increasing the likelihood that some cells from the central firth will survive to penetrate into the southern firth.

If mussels are assumed to excrete minimal DIN (instead of excreted at measured rates), the likelihood of both local and far-field suppression of diatom and phytoflagellate abundance is increased (Figure 9d – Figure 10d). Sensitivity trials indicate that, at least during summer, the influence of the differing initial and boundary condition DIN concentrations influences are small (Figure 12) ; the initial divergence between the 'low' and 'high' DIN simulations reflects phytoplankton growth fuelled by the initially abundant DIN in the latter simulation. Subsequently, trajectories tend to merge, indicating that the differing boundary DIN concentrations play only a very small dynamic role. In general, DIN concentrations become almost indistinguishable from one another within ~5 km of the model's oceanic boundary (approximately the tidal range).

Figure 8:

Long-term (duration of simulation) average simulated concentrations of: (a) DIN ($\log_{10}$(mg N m^{-3})) under scenario NF; and $\log_{10}$(DIN concentration-ratio relative to this default) for alternative scenarios: (b) scenario 0; (c) scenario 1 with default mussel excretion, (d) scenario 1 with minimal mussel DIN excretion. For ease of reference: $\log_{10}(100)=2$, $\log_{10}(0.01)=-2$, $\log_{10}(3.16)=0.5$, $\log_{10}(0.316)=-0.5$.

Environmental conditions	Time-averaged results
September 1999	
March 2000	
Spring, winds prevailing from ENE	
Summer, winds prevailing from ENE	
Spring, winds prevailing from WSW	
Summer, winds prevailing from WSW