Pelorus Sound Hydrodynamic Models Report to the Environment Committee 23 July 2015

Purpose

1. To present to the Committee the hydrodynamic model report for the Pelorus Sound.

Background

2. Council contracted the National Institute of Water and Atmospheric Research (NIWA) in 2013 to develop hydrodynamic models of Queen Charlotte and Pelorus Sounds. This report deals with the Pelorus model. The Queen Charlotte Sound model was presented to the Committee in October 2014.

3. The Ministry for Primary Industries (MPI) jointly funded the Pelorus model with Council through its Aquaculture Planning Fund.

4. A hydrodynamic model simulates water movement from tides, wind and residual currents. NIWA has developed a 3-dimensional model which models changes in the temperature and stratification of the water column over seasonal and annual periods.

5. The model has also been linked with water quality (nutrients) and ecological (phytoplankton and zooplankton) processes. NIWA examined the effects of existing and new mussel and fish farms on the Pelorus Sound ecosystem.

6. Council’s water quality monitoring data collected monthly over the last three years was used to help validate the modelled hydrodynamics and water quality patterns.

7. The report runs to 175 pages, so only the 6 page Executive Summary is **attached**. The report, once received, will be put in its entirety on Council’s website, along with the Queen Charlotte Sound report.

Comments

Robustness of Model and Selection of Baseline

8. The model was produced by three NIWA scientists: Drs Niall Broekhuizen, Mark Hadfield and David Plew. It was peer reviewed by Dr Brett Beamsley of MetOcean Solutions at MPI’s behest. Reviews also occurred by MPI’s aquatic ecosystem working group, which included the Cawthron Institute, on 3 March 2015 in Wellington. Council’s Coastal Scientist also reviewed the model report.

9. The revised model was then the subject of a workshop held on 1 April 2015 in Blenheim, which involved members of the Sounds Advisory Group, aquaculture industry, several iwi, environmental groups and the Council. A summary of how the model was constructed, key results and implications were all discussed, along with possible refinements and improvements to the model (see Next Steps).

10. Subsequent to that workshop several additional queries were received. These related to clarity around several statements in the Executive Summary about the interpretation of the model outputs, along with technical questions on the measurement of certain parameters. However, it needs to be stated that models are merely approximations of reality and are based on a number of assumptions. They will be refined in due course as better data becomes available.

11. Nevertheless, NIWA have made further amendments to the model report, including clarifying aspects of the Executive Summary. A detailed separate response from NIWA to each technical query is forthcoming, which will be forwarded to those who made late comments. As the comments were made after the report was finalised, funding from the Envirolink advice scheme was obtained.

12. The key query related to the selection of the baseline from which a number of scenarios were run and compared. These scenarios related to including or excluding: mussel farms, fish farms and benthic denitrification (removal of nitrogen by transformation to a gas in the sediments). The selected baseline was mussel farms in the water in 2012 and fish farms that existed in the water prior to 2013.

13. This baseline recognised that aquaculture is a long-term influence on the Sounds. A baseline of no aquaculture was thereby not considered realistic. This was also because of the difficulty in defining an

original baseline, following removal of naturally occurring mussel beds in the 1960s and 1970s, which were once extensive in the Inner Sounds, and decades of fishing pressure including dredging and bottom trawling.

14. This is an important point, because a comparison of the scenario of no mussel or fish farms with the current baseline is essentially between two highly modified ecosystem states. Given the long-term deleterious changes to seabeds throughout the Pelorus from sedimentation, bottom trawling and dredging, it is misleading to view a scenario of no mussel or fish farms as somehow a pristine state.

15. That said, it is equally important to better understand how mussel farms influence nutrients and plankton at the base of the food chain; as well as how fish farms do; along with the synergistic effects of mussel and fish farms together. This is because, as the model shows, mussel farms can deplete and transform nutrients and prey on phytoplankton and zooplankton, whereas fish farms add nutrients in the form of nitrogen ammonium which lead to increased phytoplankton.

16. The significance of the discussion about baselines is that we do not want to see a change in the trophic state of Pelorus Sound. ‘Trophic’ is a way of characterising the productivity and biomass of the ecosystem. Excessive nutrients result in plankton blooms, discolouration and reduction of oxygen in the water, and a loss of diversity of fish and other organisms. This is called a eutrophic state, where nutrients are in sufficient supply to not limit plankton growth.

17. The way we measure trophic state is by the concentration of chlorophyll (which is the pigment within plankton cells that is critical to photosynthesis). The Pelorus is considered nutrient, and in particular nitrogen, limited. The Board of Inquiry for the new salmon farms accepted that the threshold for an unacceptable trophic state is 5 mg/m^3 of chlorophyll. The model examines how nutrients and chlorophyll levels may be altered by existing and new fish and mussel farms.

18. The Pelorus also receives nutrients from ocean upwelling driven up by winds and currents off the coastal shelf, which is near the entrance to the Sound. Nutrient levels fluctuate between El Nino and La Nina years. El Nino conditions supply an abundance of nutrients as nor-west winds force upwelling on the coastal shelf and increased rainfall in the Pelorus River catchment.

19. The other major source of nutrients is the Pelorus River. It is the Pelorus (and Kaituna) River that drives what is termed an estuarine circulation. In other words, how water moves in, out and around the Sound. Low river flows in summer reduce the strength of the circulation, but it is rarely absent.

Hydrodynamic Findings

20. The model showed that the Pelorus River drives approximately 5,000m^3 per second (s^{-1}) of water out of the Outer Sound. This flow consists of the river water along with water entrained into the river plume as it travels through (or ‘down’) the Sound.

21. This layer of less salty water sits on top of an incoming denser, more saline layer. In summer the surface layer is warmer, whereas in winter it is colder due to low air temperatures. In the Pelorus Sound, salinity has a larger effect on density than temperatures, and waters are therefore stratified throughout the year by differences in salinity.

22. The estuarine circulation described above is superimposed on significant tidal fluxes at the entrance of the Sound. Tidal flows range from 20,000m^{3}s^{-1} to ~30,000m^{3}s^{-1} at neap tide, and 50,000m^{3}s^{-1} to ~60,000m^{3}s^{-1} at spring tide (this is about double that of Queen Charlotte Sound). As the fresher waters exit the Sound at the surface, there is a corresponding inflow of ocean water below.

23. The volume of water entering the Sound travels at different speeds (Figure 1). Flows are significantly faster in the main channels compared to side bays, such as Tennyson Inlet, Beatrix Bay and the head of Kenepuru Sound. The speed of these flows broadly matches depth (Figure 2).

24. Flushing times vary as a result. Flushing is a measure of how long it takes water and nutrients to move through the system. Flushing was estimated by releasing virtual tracers in the model at different locations and depths, and following their path as they circulated through the system.

25. To give an idea of the amount of water entering the Sound, if the Pelorus was emptied of its 10,300,000,000m^3, the peak spring tide would refill it in two days if it ran continuously! However,

fluctuating tidal fluxes are not efficient at flushing the Sound, and the true flushing time is 25-50 days depending on location. Mahikipawa Arm and Kenepuru had the longest flushing times (40-50 days).

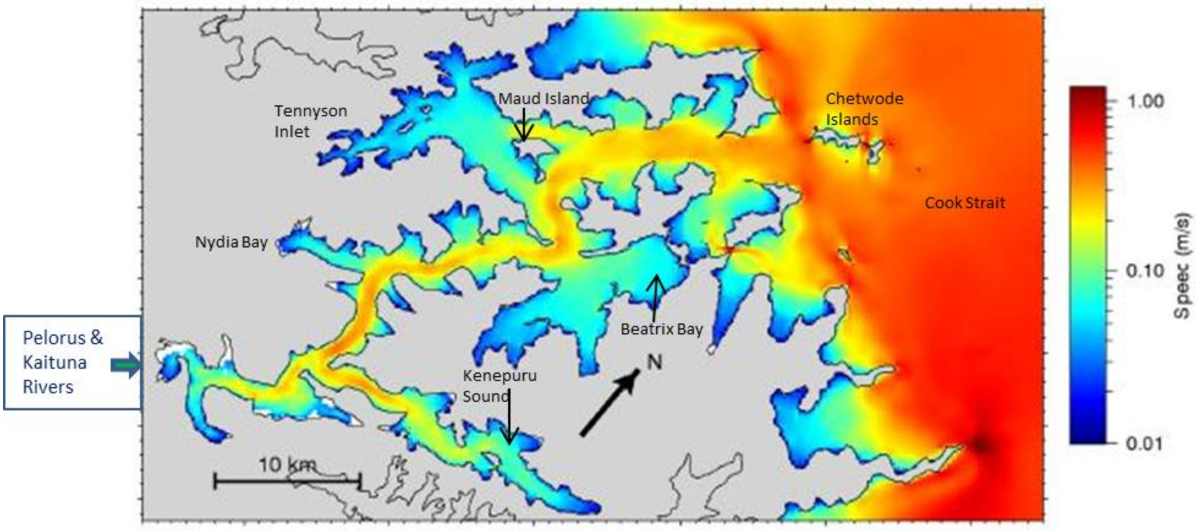

Figure 1: Model of mean current speed at 5 metres depth. The colour chart reflects the relative speed of the current in a log scale, with the dark red colour 100 times faster than the dark blue.

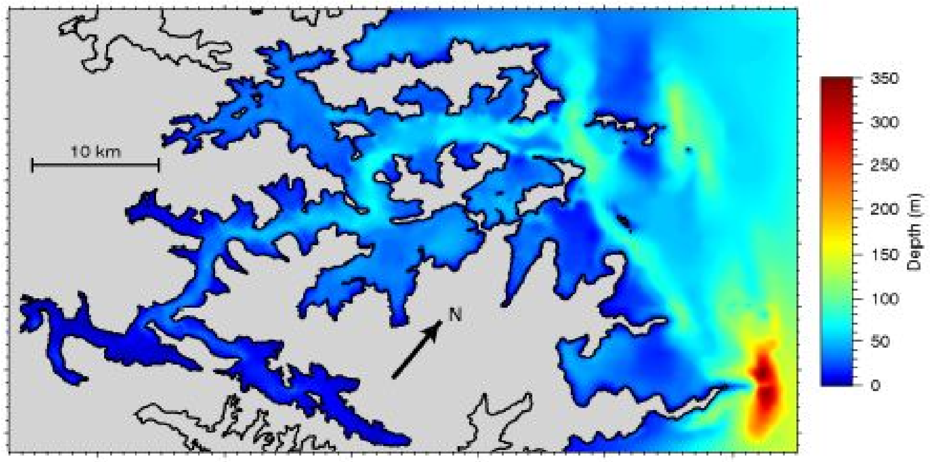

Figure 2: Pelorus Sound model domain and bathymetry. Darker colours represent shallower depths.

Biophysical Model

26. A biophysical model attempts to determine how nutrients interact with plankton. This is relevant as excessive nutrients can cause plankton to increase to levels where algal blooms may result. It is important to differentiate between naturally occurring blooms which the ecosystem has adapted to from those caused by nutrient loading as a consequence of human activities. An example of a natural bloom is the rapid increase in productivity that comes with warmer temperatures in spring (Figure 3).

27. In the Marlborough Sounds, nitrogen is the nutrient that most limits biological activity. Nitrogen is naturally at low levels in the Sounds so it is limiting to plankton growth. At certain times of the climate cycle, such as in El Nino, more nutrient-rich upwelling occurs as favourable wind conditions from the northwest force colder waters into the Sounds. A consequence of this is faster mussel growth.

28. It is when added nutrient levels significantly exceed these normal fluctuations that would be concerning. This is called a ‘trophic change’, which is another way of saying that conditions at the base of the food chain have been fundamentally altered. This would be evident in frequent algal blooms, discoloured murky water and a likely reduction in fish life from changes to the food chain.

Figure 3: 2011 summer phytoplankton bloom (in green)

29. This is one of the reasons Council undertakes regular state of the environment water quality monitoring. The time series of the data collected (since 2012) has also proved useful for modelling the scenarios of increased nitrogen discharge. Ongoing data collection will also help to validate the model predictions as the newly consented NZ King Salmon farms begin operations in 2015 at Waitata and Richmond in 2017.

30. NIWA ran seven model scenarios to better understand the effects of nitrogen originating from existing mussel farms, and from new and existing fish farms. The baseline scenario was existing mussel farms as at 2012 and existing fish farms as at 2012/13, and denitrification processes in operation.

31. Essentially the key message is that chlorophyll concentrations at the selected aquaculture baseline are within levels which are not likely to cause a trophic shift to a eutrophic state. This prediction holds when including those mussel farms which have been approved since 2012, and fish farms to be installed post 2013. At current levels of aquaculture, we do not expect to see a trophic shift. Winter-time temperatures, and relatively rapid flushing, act as a brake and effectively reset the system.

32. The model suggests that zooplankton concentrations in bays with longer residence times may have been significantly reduced by mussel farms. These areas, such as Kenepuru Sound, were also the location of previous mussel beds, so it is unknown what the relative effects have been on the ecology, although mussels in the water column would have had different effects. This highlights that our ecological understanding of the Sounds is still developing. The sediment coring project now underway in Kenepuru and Beatrix Bay will significantly advance our knowledge in this respect.

Next Steps

33. In summary, the model is a noteworthy and complex piece of work, which has advanced our collective understanding of the Pelorus Sound. However, there are still large gaps in our knowledge and the model would benefit from a range of improvements to input parameters. For example, a finer-scale wind-forcing model has now become available which would improve the hydrodynamics.

34. The desirability of further modelling refinements and advances was discussed at the 1 April 2015 community workshop. The consensus was that further modelling was necessary. However, how that stacks up against other science priorities requires a strategy to be developed. This may take 12-18 months and would ideally be a collaborative and integrated community, industry, government and Council effort.

35. In the meantime, under the MPI contract with the Council, there is an option of undertaking further modelling. A stop/go decision is due by mid December 2015. In the next few months, a number of modelling options will be evaluated to identify the most strategic use of those funds. This will also enable its relative priority to be assessed against other coastal science needs.

Summary

36. NIWA has now delivered the contracted hydrodynamic-biophysical model for Pelorus Sound. This has been independently peer reviewed and assessed as an acceptable and defensible model. The underlying circulation patterns in the Pelorus have been identified. The model tested scenarios including current and future effects of mussel and fish farms on the ecology of the Sound. NIWA conclude the permitted level of aquaculture is unlikely to cause a trophic change to the ecosystem. The Council's monthly state of the environment water quality monitoring will enable any unexpected changes to be detected. The draft model has been workshopped in Blenheim with the community and industry, and future refinements to the model were supported.