Ocean Acidification
Is aquaculture in a pickle?

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Ocean Acidification and aquaculture: should we care?

Key questions:

- What is at risk?
- What change is anticipated?
- What are the expected effects which would arise from those changes?
- Is the timing and magnitude of the anticipated change of significance to NZ aquaculture?

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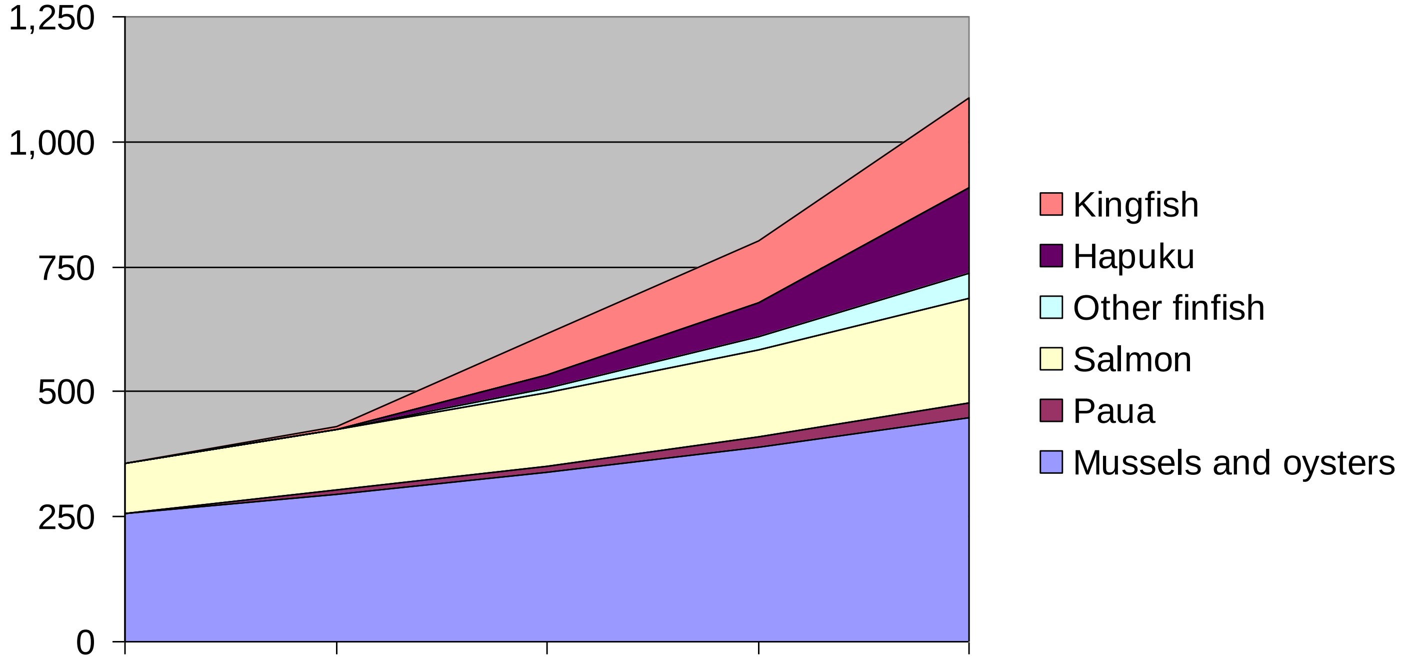
What is at stake: forecasted aquaculture value



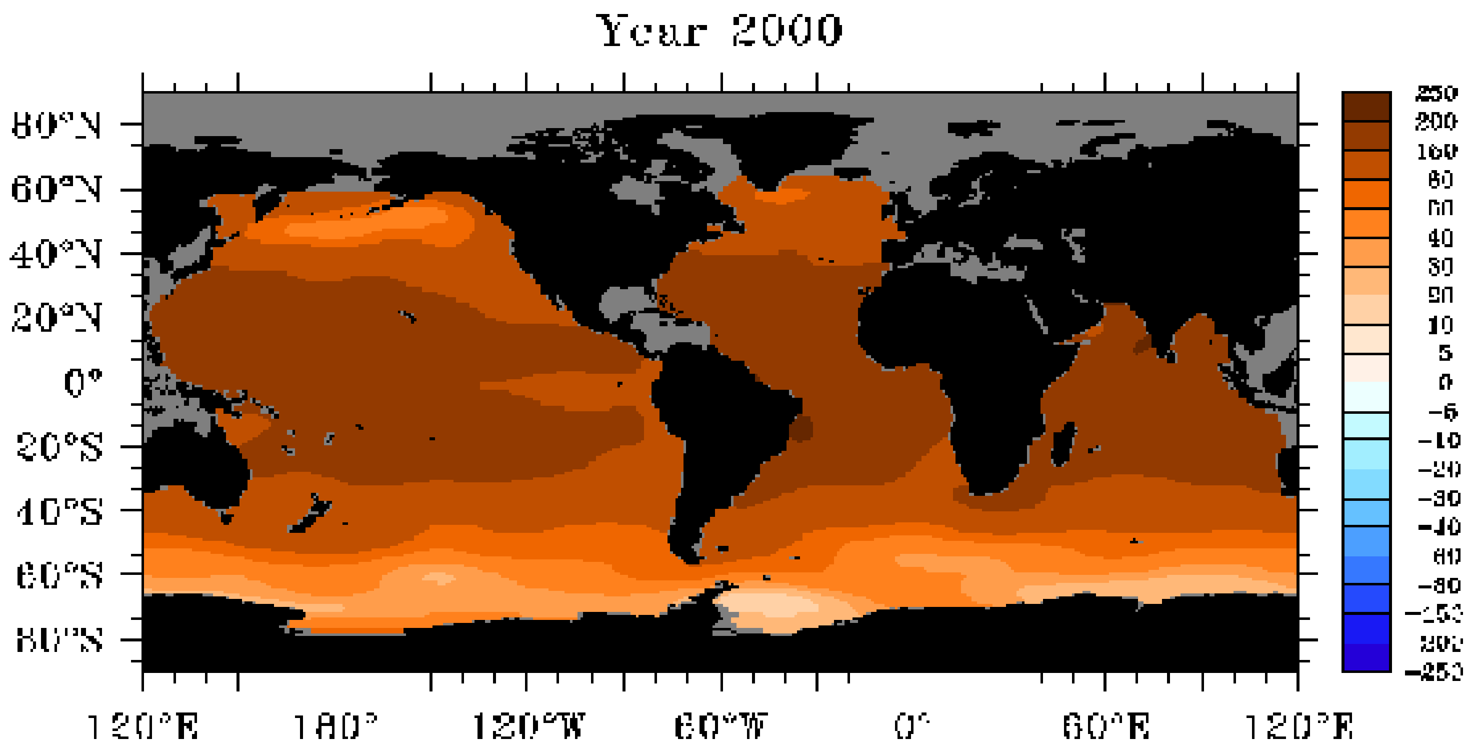
What changes should we anticipate?

- Marine chemistry and atmosphere-ocean-sediment change
- Ecosystem response
- Farmed organism response
- Societal / market response
- Regulatory response

Marine chemistry

- CO_2 from the atmosphere to the oceans
- 0.1 pH unit drop since the the pre-industrial age
- Up to 0.4 pH unit drop to the end of the century
- Aragonite saturation point
- Nutrient species shifts

Chemical state of the surface ocean



Orr et al. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms, *Nature*, Vol 437, 681--686, 29 Sept. 2005.

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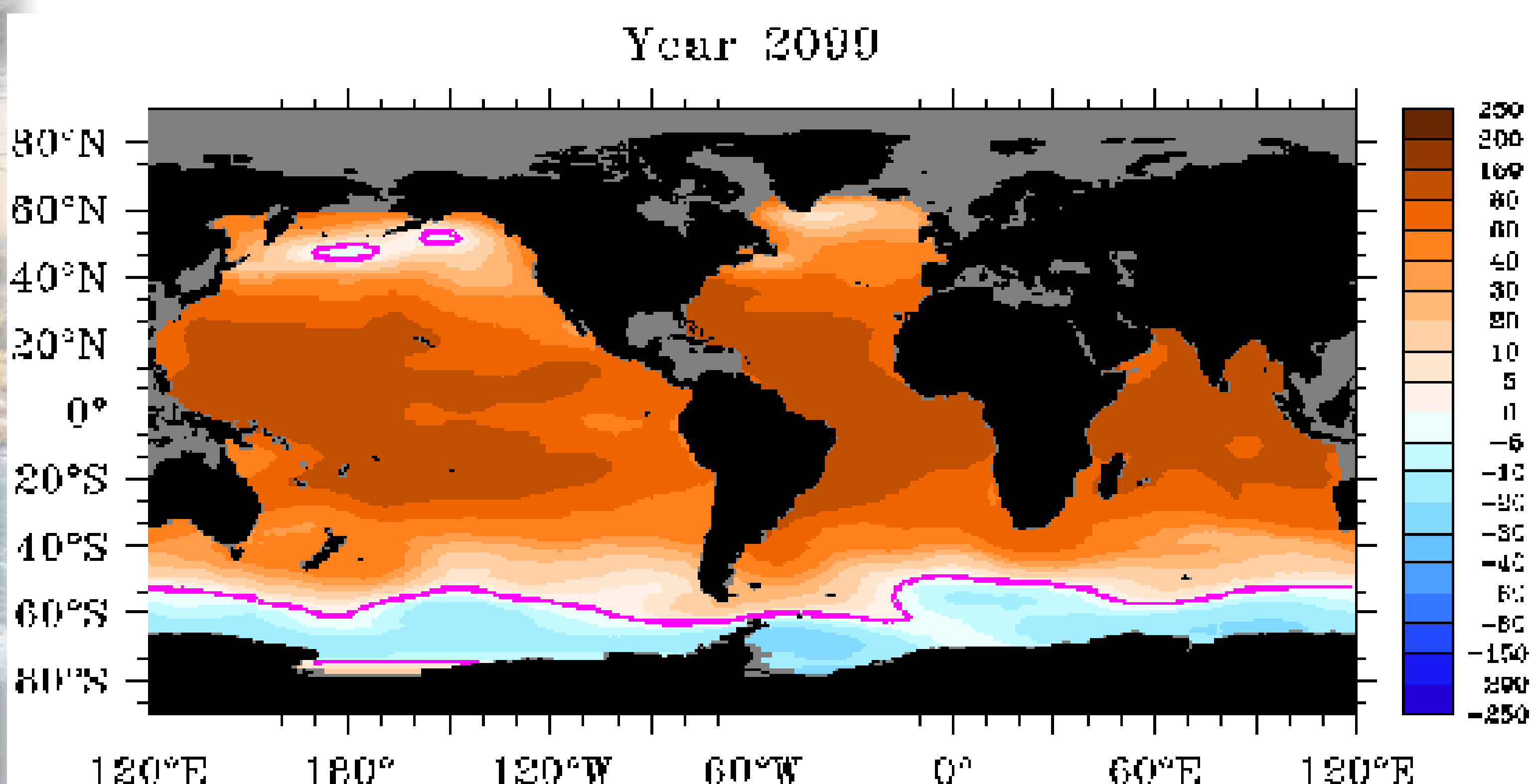

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Ecosystem Response

- Major shifts in Al speciation may affect Al uptake in diatom frustules hence dissolution of biogenic Si
- Potential to increase the dissolution of iron (may be accommodated by existing organic ligand)

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Ecosystem Response – primary productivity example effects

- Calcification (mixed)
- Photosynthesis (neutral to positive)
- Nitrogen fixation (neutral to positive)
- Reproduction (negative)

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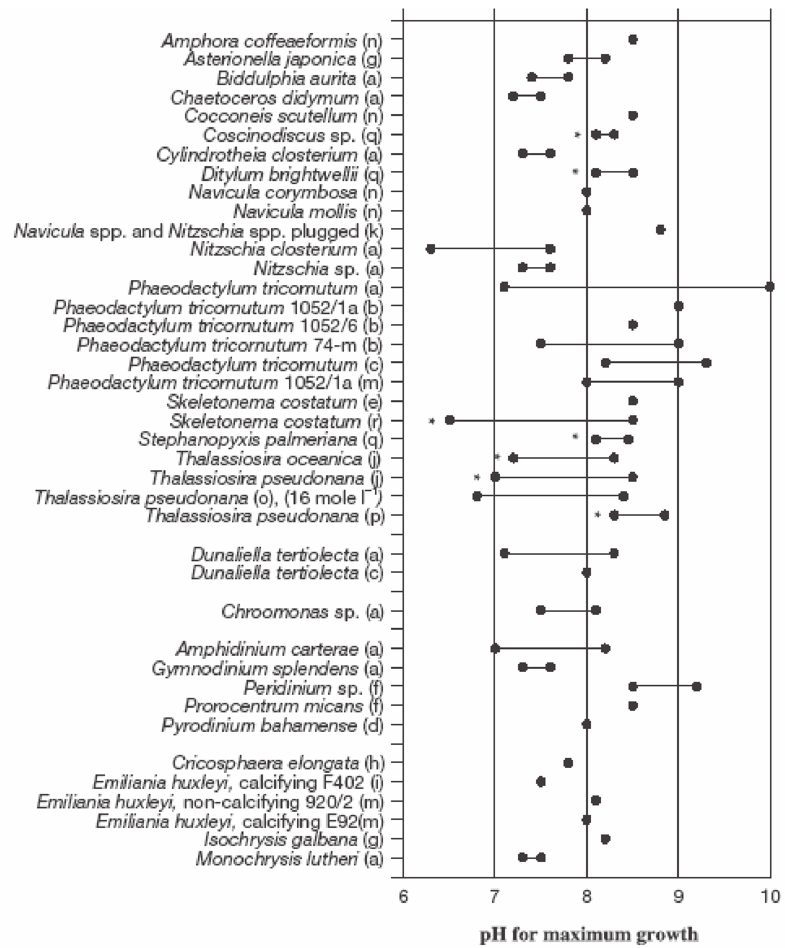
Winners (Cyanobacteria, dinoflagellates) and losers (Coccolithophores)



(Hinga 2002)

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Ecosystem response: zooplankton

- Direct influence of pH on the copepod *Acartia tonsa* life cycle dynamics has been shown to was transient (Dupont and Thorndyke 2008)
- Shift from large to smaller copepods in the North Sea as a result of ocean warming (Beaugrand et al 2003)
- Potential effects of prey size on predator survival and growth
- Phytoplankton species shifts on copepod productivity and enrichment value for species up the trophic pyramid

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Farmed species response: molluscs

Hatchery produced seed will dominate the shellfish sector in the future (independent of environmental drivers)

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Farmed species response: molluscs

- Shell malformation
- In short term manipulation experiments calcification rates for mussels and oysters have decreased linearly with increasing CO_2 (Gazeau et al 2007)

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Farmed species response: teleosts

- Fish can fully compensate for the extracellular acidosis which would be consequent to any changes in ocean pH anticipated in the next century
- CO2 and acidification can be expected to narrow the thermal tolerance window for fish. Episodic hypoxemia will manifest as reduced growth, impaired feed conversion efficiency and increased susceptibility to infectious agents.

Societal / market response

Broad based public recognition of anthropomorphic climate change

- Ocean acidification as unequivocal proof of that change
- Ocean acidification will be considered a root cause of the loss of iconic species or ecosystems – from baleen whales to coral reefs

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What to lose sleep over (in a NZ context)?

- Increased frequency of noxious or toxic phytoplankton blooms
- Loss of regional productivity due to phytoplankton species shifts
- Significant alteration of the Southern Ocean chemistry and ecology

What to lose sleep over (in a NZ context)?

- Loss of productivity in eastern boundary upwelling systems which are significant ecosystems reducing world supplies of fish meal and marine lipids
- Seasonal or episodic elevated water temperature which are outside the optimal thermal window for the species (paua, salmon)

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