Hauraki Gulf ecosystem function: productivity, drivers and stressors

John Zeldis

Ecosystem productivity provides provisioning and regulating ecosystem services – including wild and farmed fisheries, natural amenity, assimilation of stressors.

Drivers of these services are physical, chemical and biological.

Critical Issues affecting these services are natural variability and human-derived stressors.

MacDiarmid AB, Law CS, Pinkerton M, Zeldis J (2013). New Zealand marine ecosystem services. *In* Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

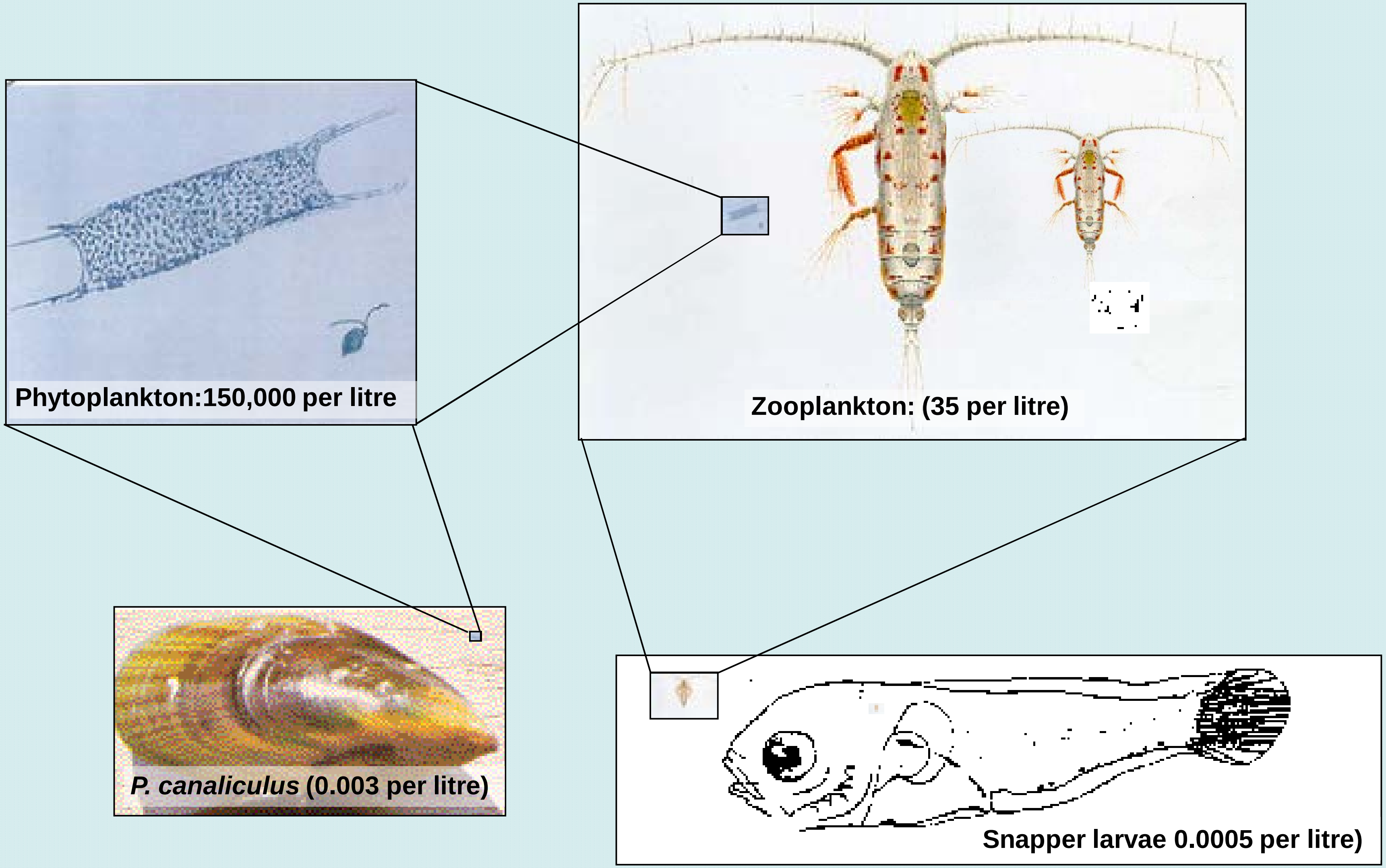
Ecosystem productivity

Defined by this fundamental equation, which describes formation of organic matter by primary producers, and its breakdown:

CO_2 + inorganic nutrients + water ↔ organic matter + oxygen

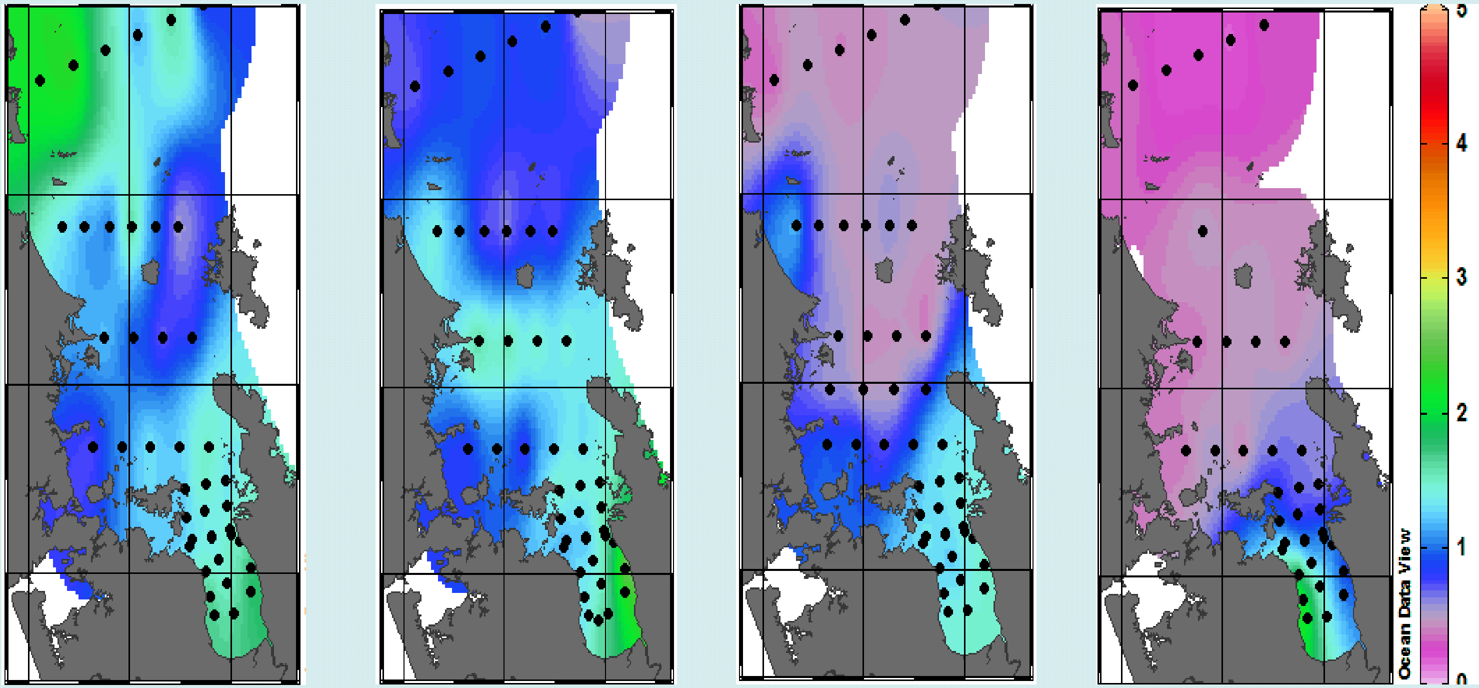
- production of organic matter for the food web.
- balance defines whether the system is net-productive or net-respiratory.

Phytoplankton drive productivity, including zooplankton, fisheries and aquaculture.



Phytoplankton are spatially and seasonally variable

Spring Summer Autumn Winter



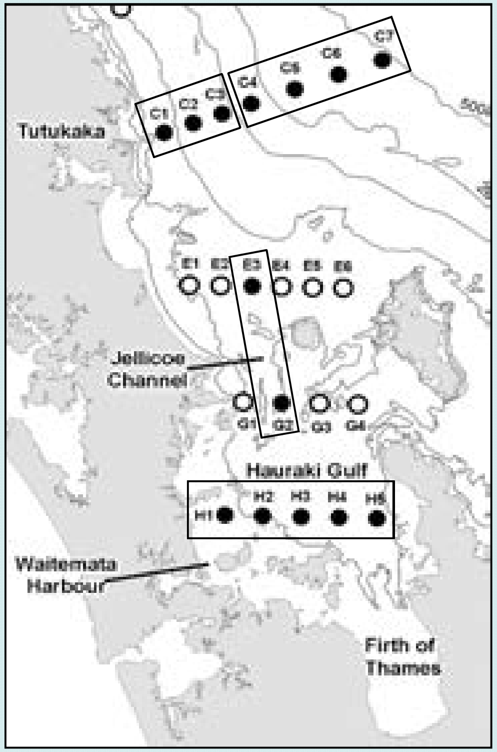
Surface chlorophyll (mg / m^3) from ship surveys 1998-2013

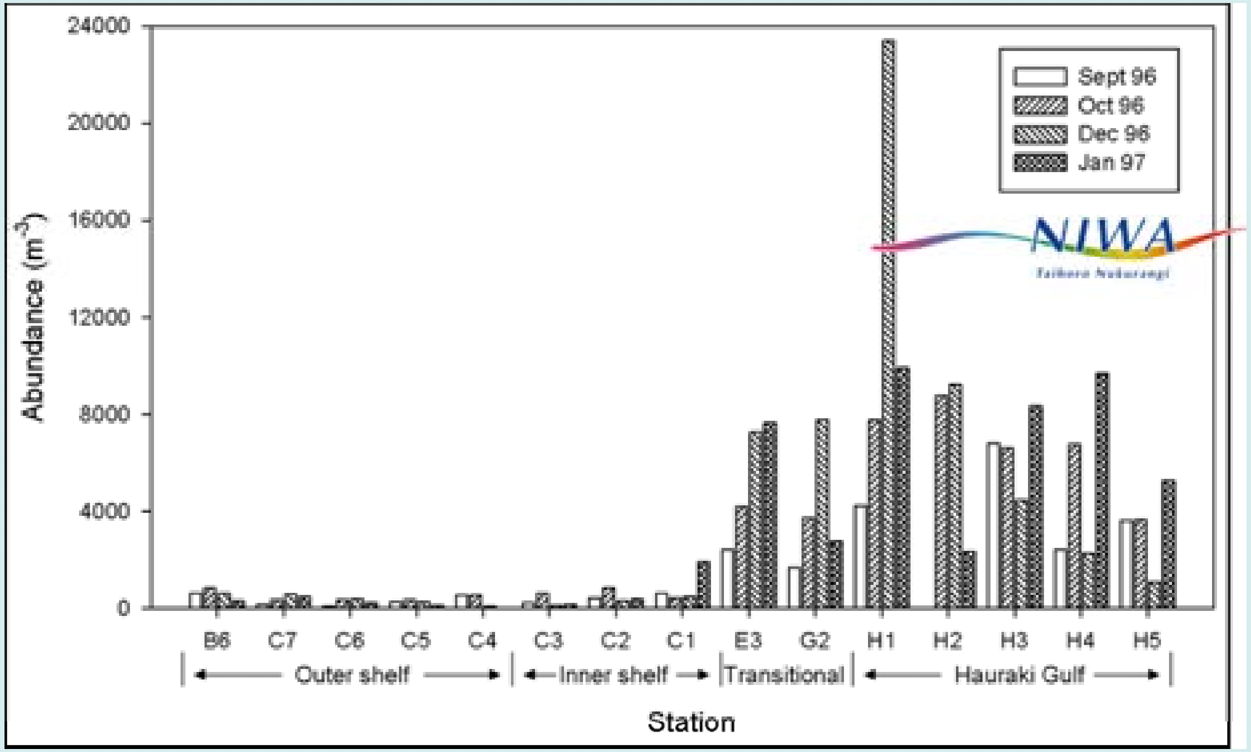
NIWA
Taihoro Nukurangi

Zeldis J, Bind J, Roulston H, Sykes J, Walkington M (2013). Visualising nutrients and phytoplankton in the Hauraki Gulf Marine Park using GIS July 2013. NIWA Client Report No. CHC2013-080. NIWA Project: WRC13503. Prepared for Waikato Regional Council.17 pp.

Chang FH, Zeldis J, Gall M, Hall J (2003). Seasonal and spatial variation of phytoplankton assemblages, biomass and cell size from spring to summer across the New Zealand northeastern continental shelf Journal of Plankton Research 25: 737-758.

Zooplankton most abundant in the gulf and approaches

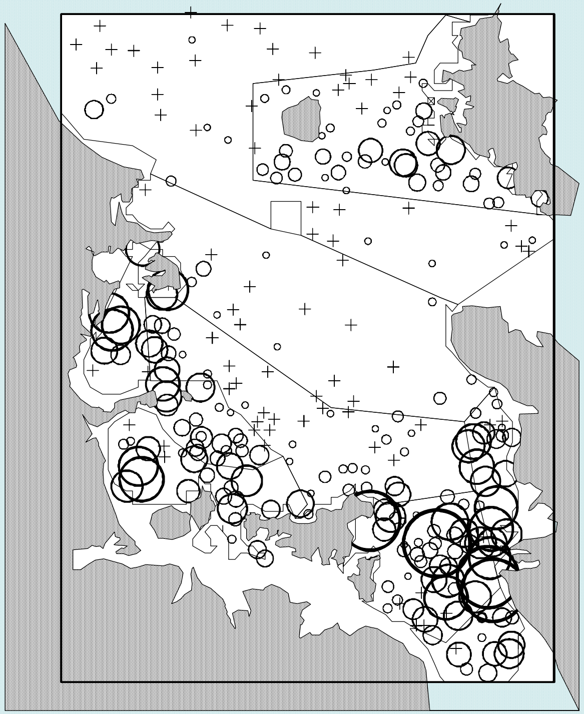




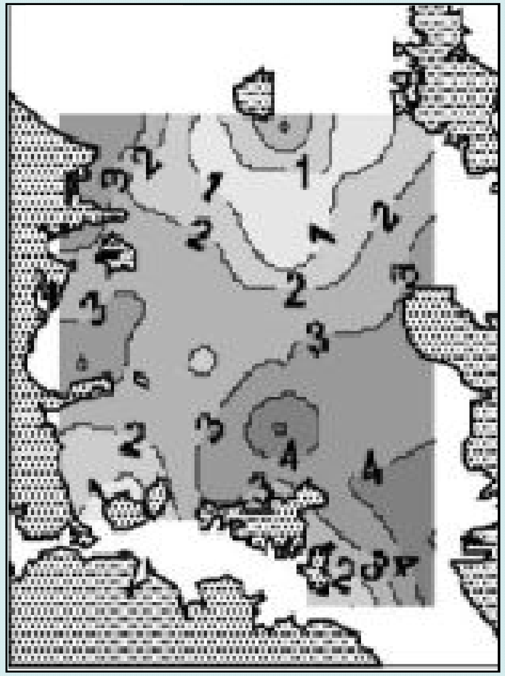
Zeldis J, Willis K (2014 submitted). Mesozooplankton distributions along hydrographic and trophic gradients on the northeastern continental shelf and in Hauraki Gulf, New Zealand. NZ J Mar Freshwat Res.

Snapper spawning grounds and nurseries – concentrated in the inner Gulf

1 day old snapper eggs / m^2



Snapper larvae / m^3 (ln scale)



Zeldis JR, Francis RICC (1998). A daily egg production method estimate of snapper biomass in the Hauraki Gulf, New Zealand. ICES Journal of Marine Science 55(3):522-534.

Zeldis J, Oldman J, Ballara S, Richards L (2005). Physical fluxes, pelagic ecosystem structure, and larval fish survival in Hauraki Gulf, New Zealand. Canadian Journal of Fisheries and Aquatic Sciences. 62: 593-610.

Aquaculture – NZ's largest mussel farms are in the Firth

~ 25% of NZ mussel production in Coromandel region, ~ 50% of NZ oyster production in Coromandel and Auckland regions.

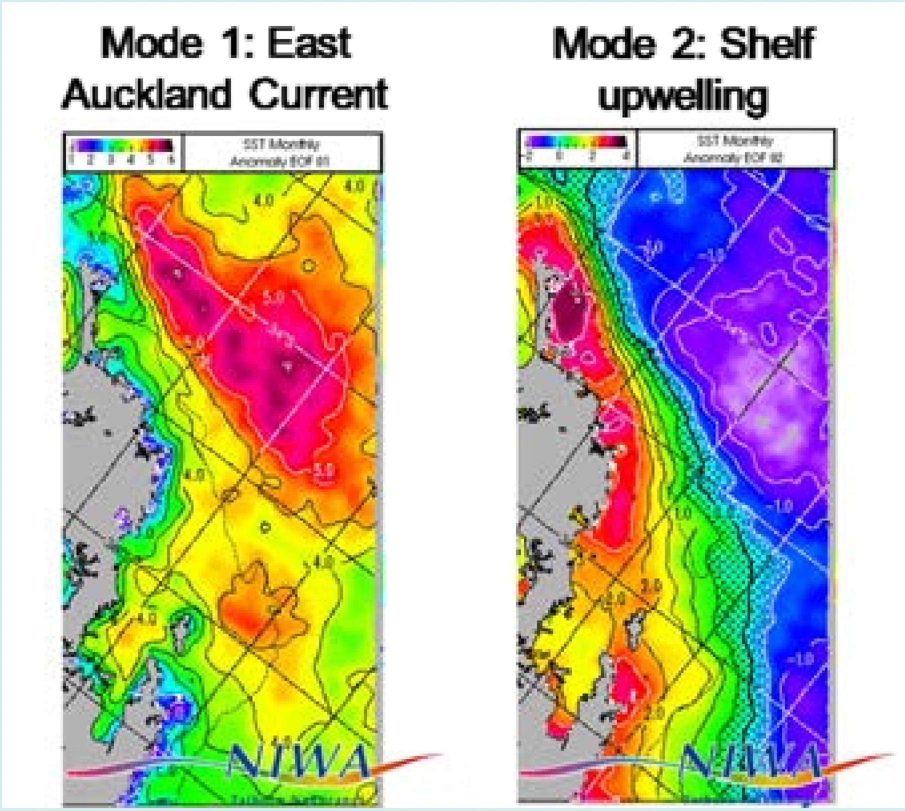
http://aquaculture.org.nz/industry/farming-areas/

Drivers and variability of ecosystem services

- Oceanic effects
- Riverine effects
- Recycling effects

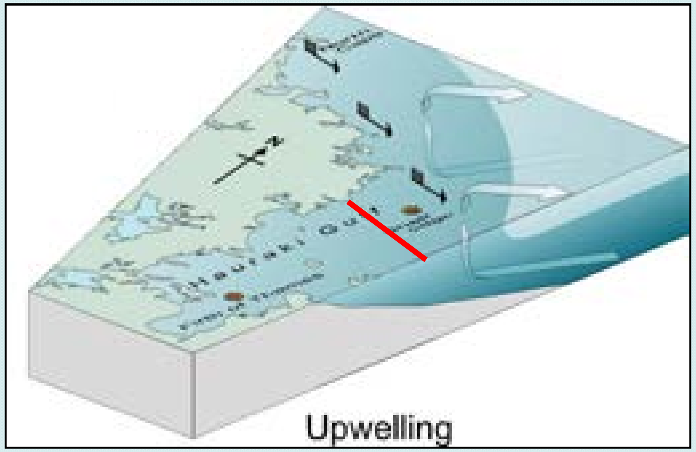
Oceanic effects

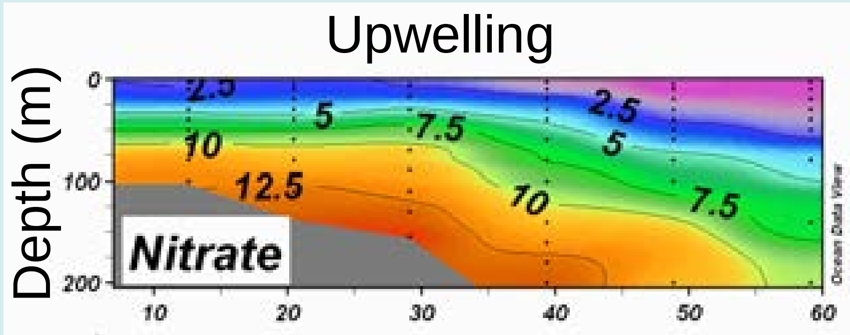
East Auckland Current and shelf upwelling are dominant modes of circulation

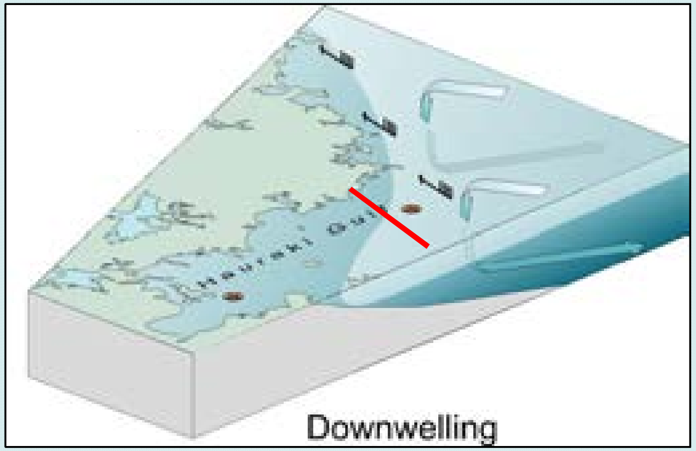


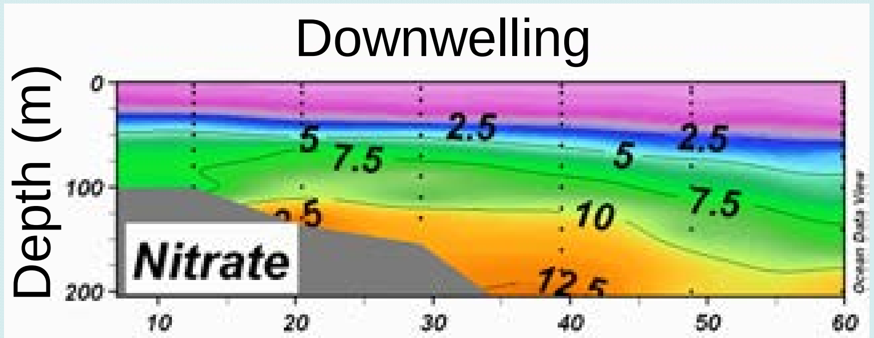
Richardson KM, Pinkerton MH,Boyd PW, Gall MP, Zeldis J, Oliver MD, Murphy RJ (2004). Validating SeaWiFS remotely-sensed bio-optical measurements of New Zealand waters. Advances in Space Research. 33: 1160-1167.

EAUC and upwelling interact, to set the nutrient climate on the shelf.



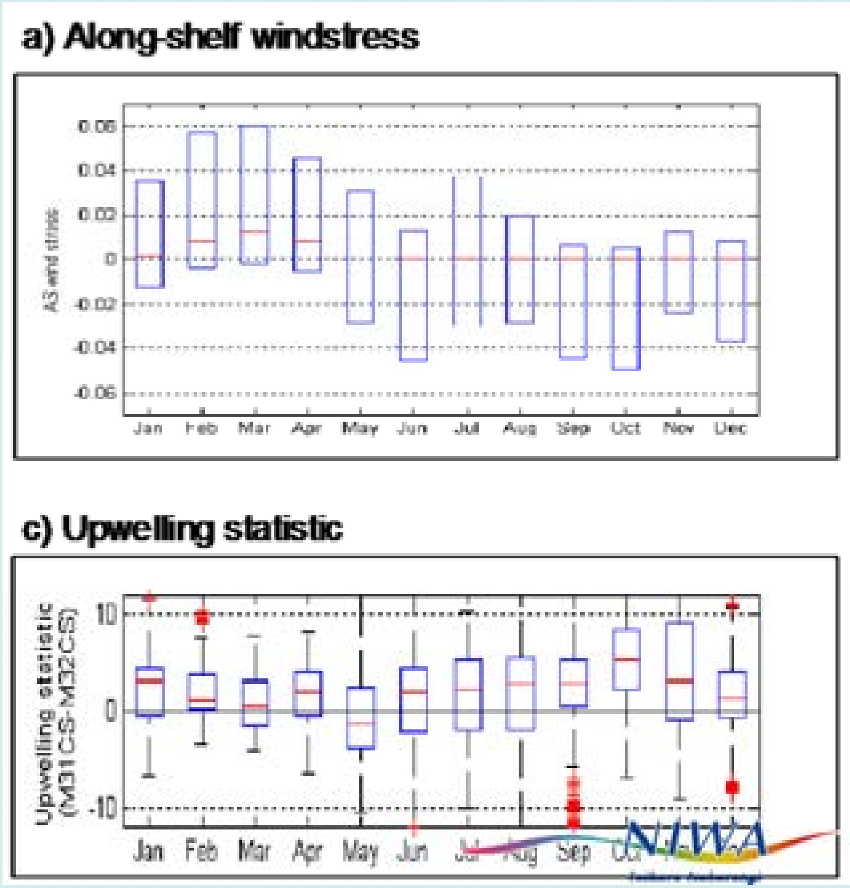






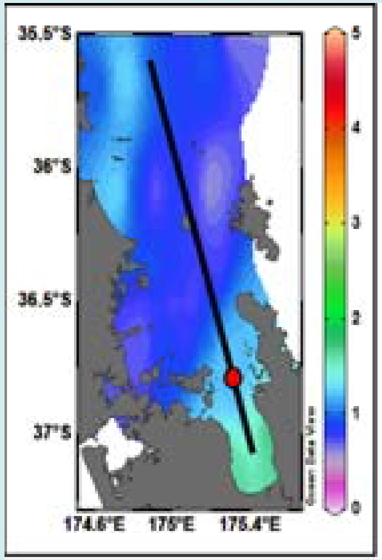
Zeldis, J.R., Walters, R.A., Greig, M.J.N., Image, K. 2004. Circulation over the northeastern New Zealand continental slope, shelf and adjacent Hauraki Gulf, from spring to summer. Continental Shelf Research (24): 543-561. http://authors.elsevier.com/sd/article/S0278434303002449

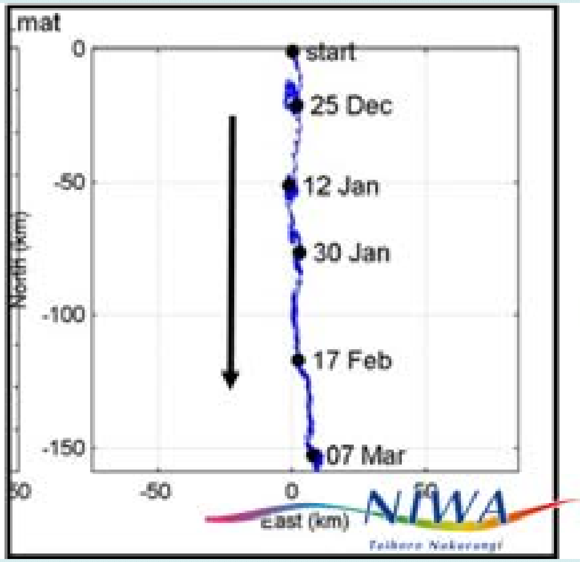
Upwelling is governed by seasonal and inter-annual variation (e.g., ENSO, IPO).

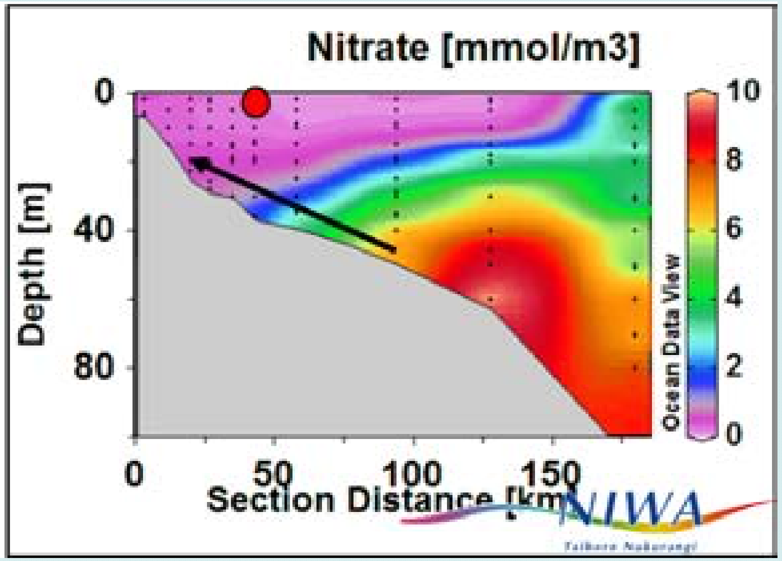


MacDiarmid, AB; Sutton P; Chiswell S, Stewart C, Zeldis J, Schwarz J, Palliser C, Harper S, Maas E, Stevens C, Taylor P, Thompson D, Torres L, Bostock H, Nodder S, MacKay, K, Hewitt J, Halliday J, Julian K, Baird S, Hancock N, Neil K, D'Archino R, Sim-Smith C, Francis M, Leathwick J, Sturman J (2009). OS2020 Bay of Islands Coastal Project: Phase 1 – Desktop study. NIWA Client Report WLG2009-3, 396 pp.

Upwelled nitrate enters the Gulf and Firth in near-bed flows detected at Firth of Thames mooring



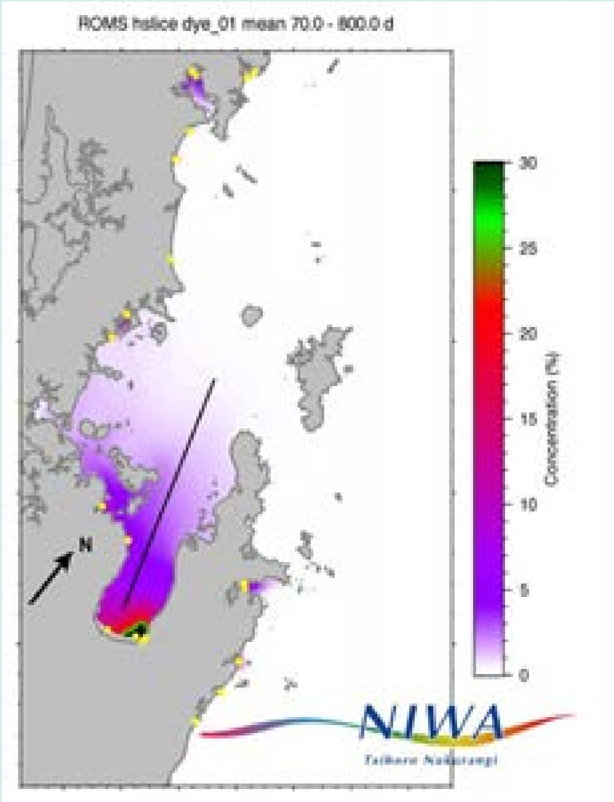


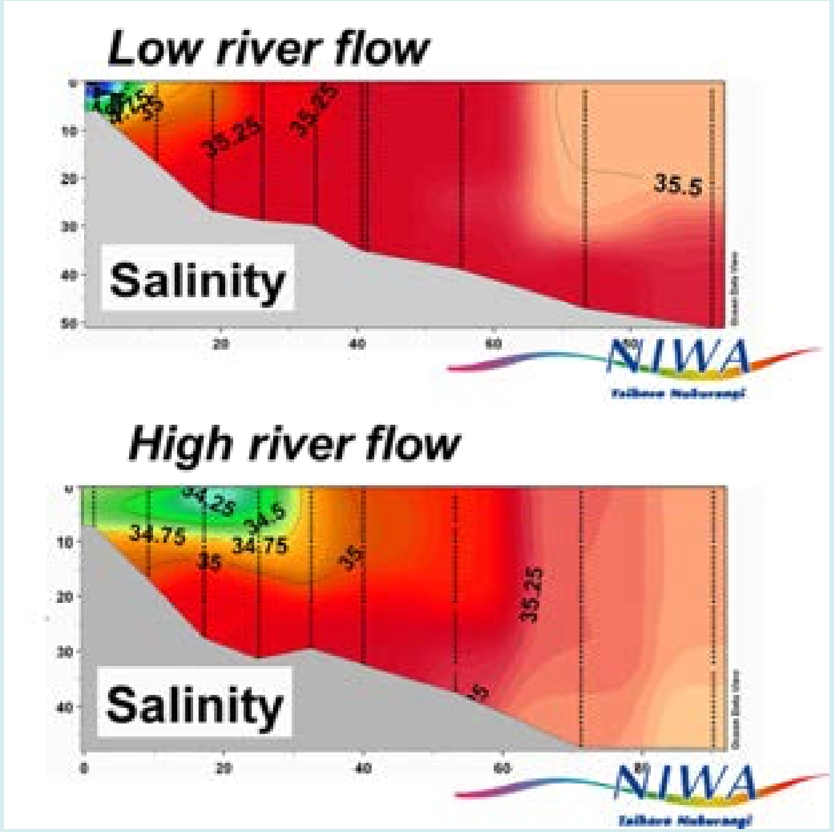


Zeldis JR, Walters RA, Greig MJN, Image K (2004). Circulation over the northeastern New Zealand continental slope, shelf and adjacent Hauraki Gulf, from spring to summer. Continental Shelf Research (24): 543-561.

Riverine effects

Main river inputs are via the Firth, and are variable.





Hadfield M, O'Callaghan JO, Pritchard M, Stevens C (2012). Sediment Transport and Deposition in the Hauraki Gulf - A Pilot Modelling Study. Prepared for Department of Conservation. NIWA Client Report No: WLG2012-29 NIWA Project: DOC12313. 28 pp.

Combining nutrient sources and loadings: Gulf and Firth

- Mass-balance budgets from ocean and hydrometric data.
- Evaluated delivery, uptake and release of carbon and nutrients.
- Gulf ocean driven, Firth catchment driven.

Zeldis, J. (2006) Water, Salt and Nutrient Budgets for Hauraki Gulf and adjacent Firth of Thames, New Zealand. LOICZ: http://nest.su.se/mnode/New_Zealand/HaurakiGulf/Hauraki_revised/Hauraki%20budget%2004revised.htm

Combining nutrient sources and loadings: Gulf and Firth

System	Volume (km^3)	Catchment inorganic N load ($t\ N\ y^{-1}$)	Catchment organic N load ($t\ N\ y^{-1}$)	Ocean inorganic N load ($t\ N\ y^{-1}$)
Firth of Thames	16	3700	900	600
Hauraki Gulf	82	800	150	8200

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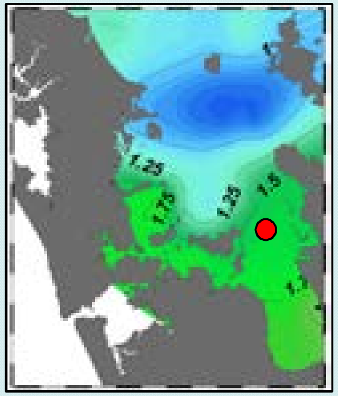
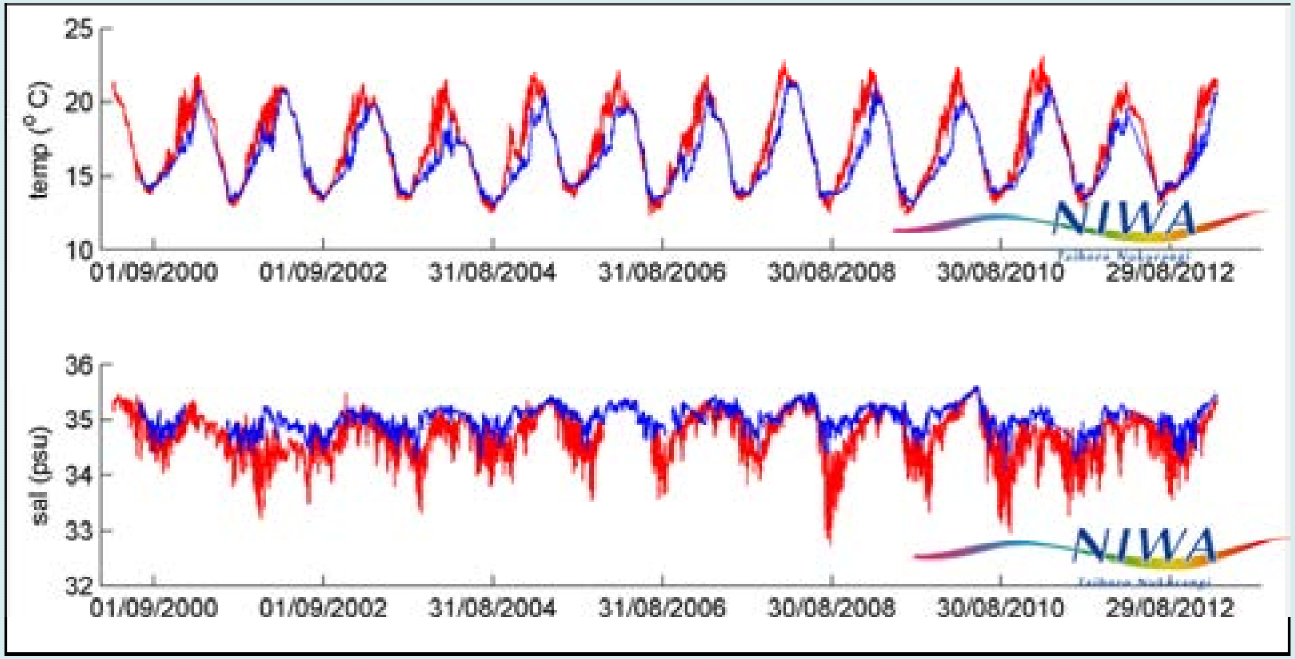
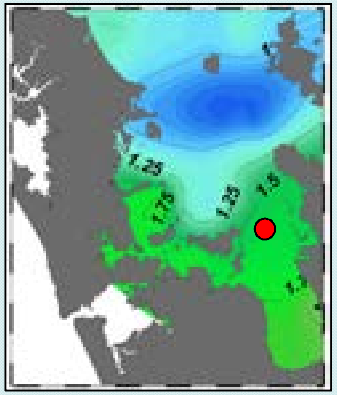
http://nest.su.se/mnode/New_Zealand/HaurakiGulf/Hauraki_revised/Hauraki%20budget%2004revised.htm

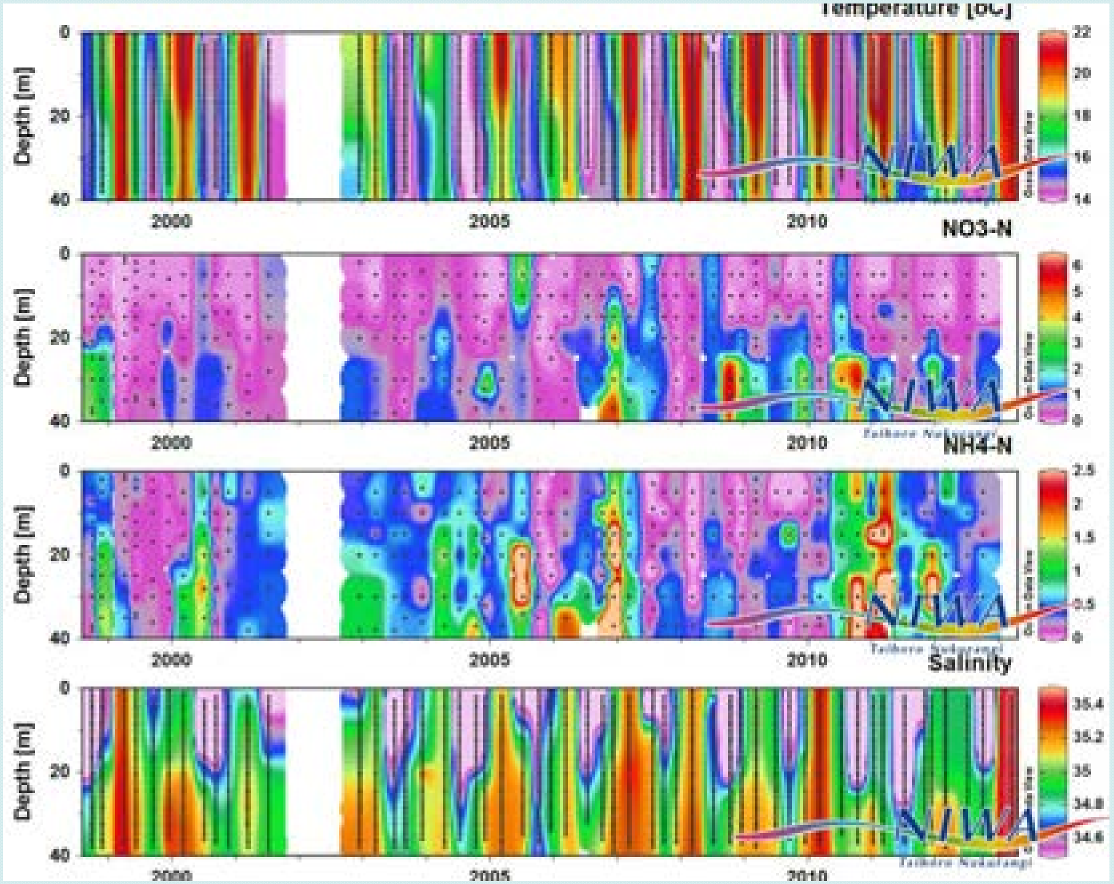
Firth of Thames mooring detects river flow variation, and gulf intrusion.





We are developing relationships of temperature and salinity with dissolved nitrogen, at the mooring.

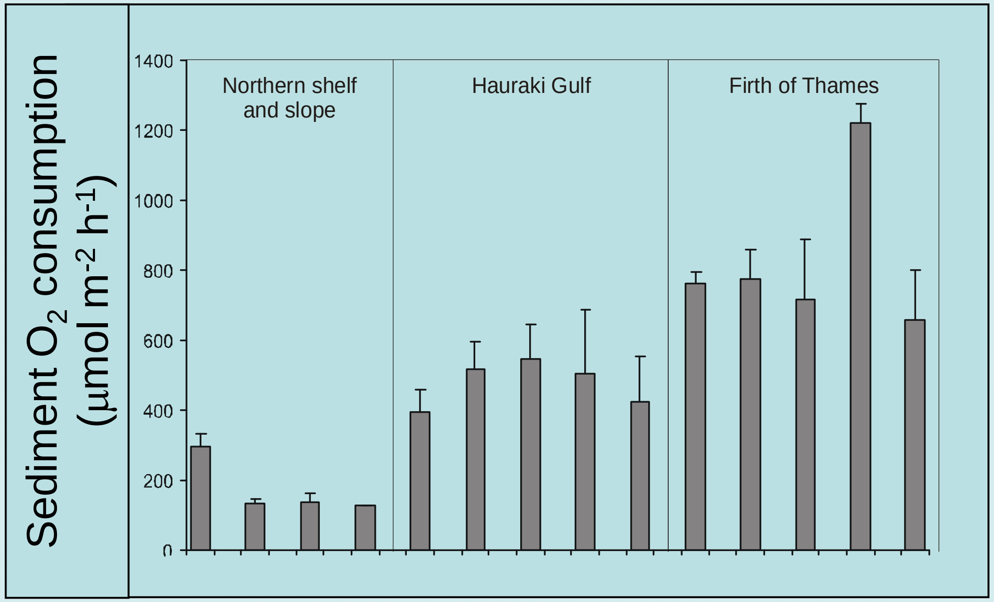




Recycling effects

CO_2 + inorganic nutrients + water ↔ organic matter + oxygen

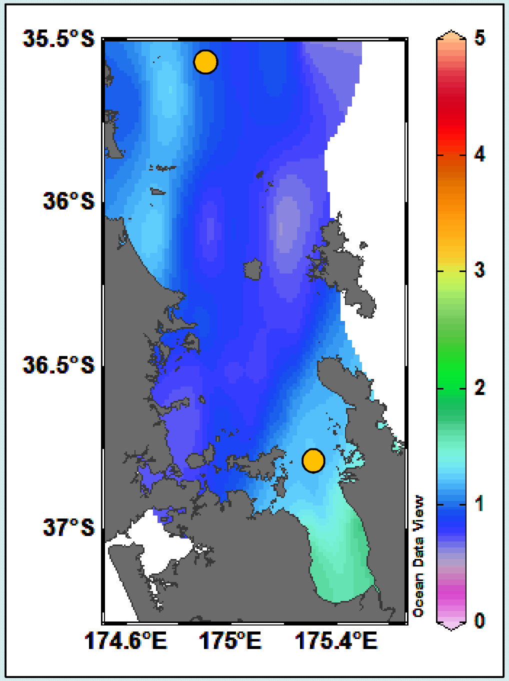
Recycling most active inshore – where nutrient loading is highest.



Zeldis JR (2004). New and remineralised nutrient supply and ecosystem metabolism on the northeastern New Zealand continental shelf. Continental Shelf Research 24: 563-581.

Giles H, Pilditch CA, Nodder SD, Zeldis J, Currie K (2007). Benthic oxygen fluxes and sediment properties on the northeastern New Zealand continental shelf. Continental Shelf Research. 27:2373-2388.

Combination of high nutrient loading + fast recycling → much higher primary productivity in the inner gulf, than on the shelf.



PP (mg C m^{-3} d^{-1})	Inner Gulf	Shelf
Spring	24	8
Summer	66	7
Autumn	27	12
Winter	19	9

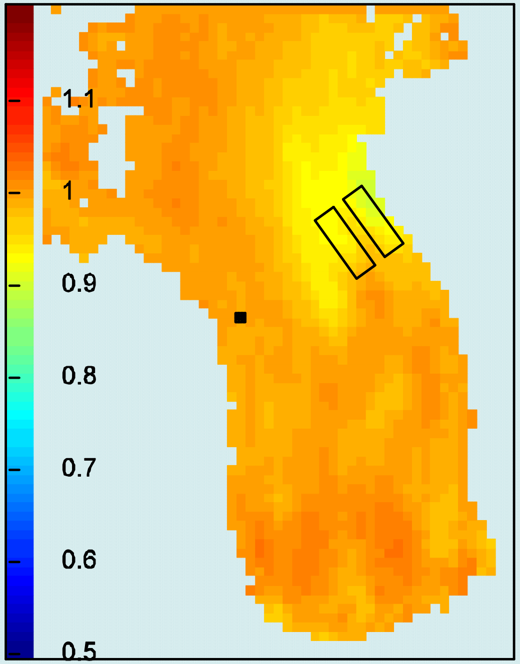
NIWA Taihoro Nukurangi

Gall M, Zeldis J (2011). Biomass and primary production responses to physico-chemical forcing across the north-eastern New Zealand continental shelf. Continental Shelf Research. 31(17), 1799-1810.

Human-derived stressors

- Aquaculture sustainability
- Sediment runoff
- Nutrient runoff-driven eutrophication and acidification

Aquaculture sustainability – mussels and phytoplankton depletion



Water quality monitoring over last decade shows no significant depletion at Area A.

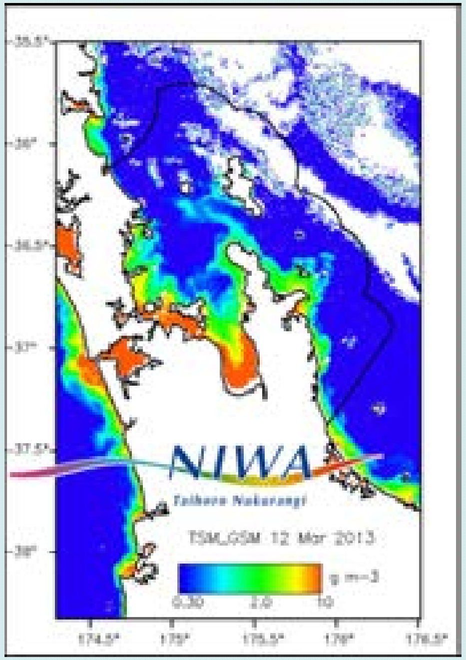
Consistent with modelling, showing at full Area A+B development (21,000 p.a.), phytoplankton depletion was minor (~7% over ~7% of the Firth).

Stenton-Dozey J, Zeldis J (2012). Wilson Bay Marine Farming Zone Area A water quality monitoring biennial report: April 2010 to April 2012 Prepared for Wilson Bay Group A Consortium NIWA Client Report No: CHC2012-062 NIWA Project: WBC09501 June 2012.

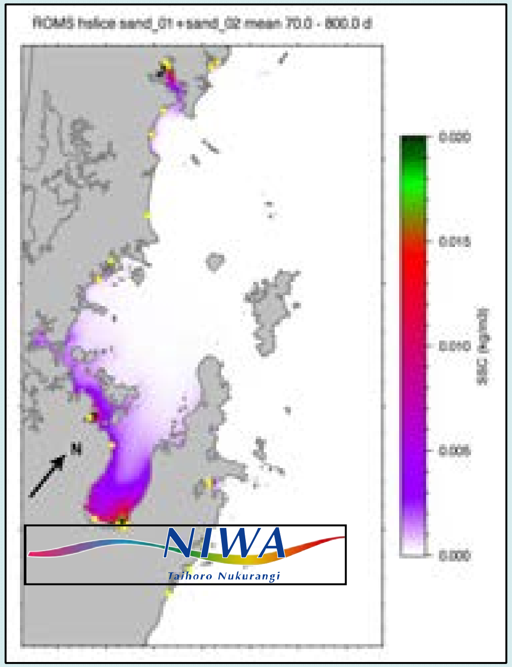
Broekhuizen N (2007). Interpretation of simulated mussel-farm induced modification of the plankton community relative to the Limits of Acceptable Change criteria: sensitivity to hydrodynamic forcing. Appendix in NIWA Client Report HAM2005-127 (ARC05243) Auckland Regional Council Technical Publication 326.

Sediment runoff – potential to modify sub-littoral habitat

Surface suspended matter – remote sensing



Surface riverine suspended sediment – model



Pinkerton M, Wood S, Zeldis J, Gall M (2013). Satellite ocean-colour remote sensing of the Hauraki Gulf Marine Park NIWA Client Report No. WLG2013-40 NIWA Project: WRC133501. Prepared for Waikato Regional Council. 29 pp.

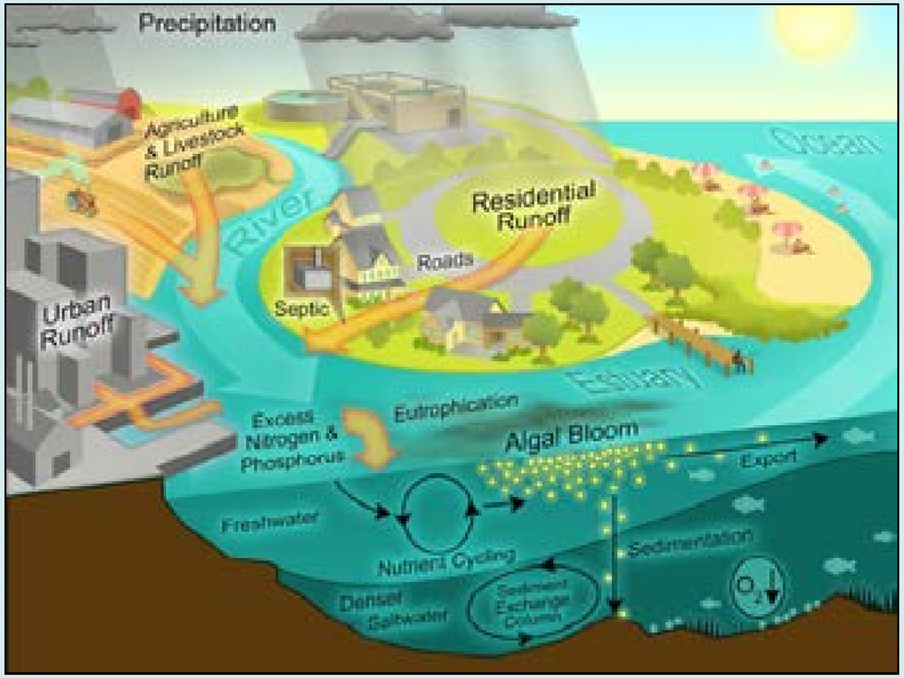
Hadfield M, O'Callaghan JO, Pritchard M, Stevens C (2012). Sediment Transport and Deposition in the Hauraki Gulf - A Pilot Modelling Study. Prepared for Department of Conservation. NIWA Client Report No: WLG2012-29 NIWA Project: DOC12313. 28 pp.

Nutrient runoff-driven eutrophication: excess oxygen consumption

CO_2 + inorganic nutrients + water ↔ organic matter + oxygen

Fuelled by:

- organic matter loading and decomposition
- inorganic nutrient loading and phytoplankton bloom decomposition

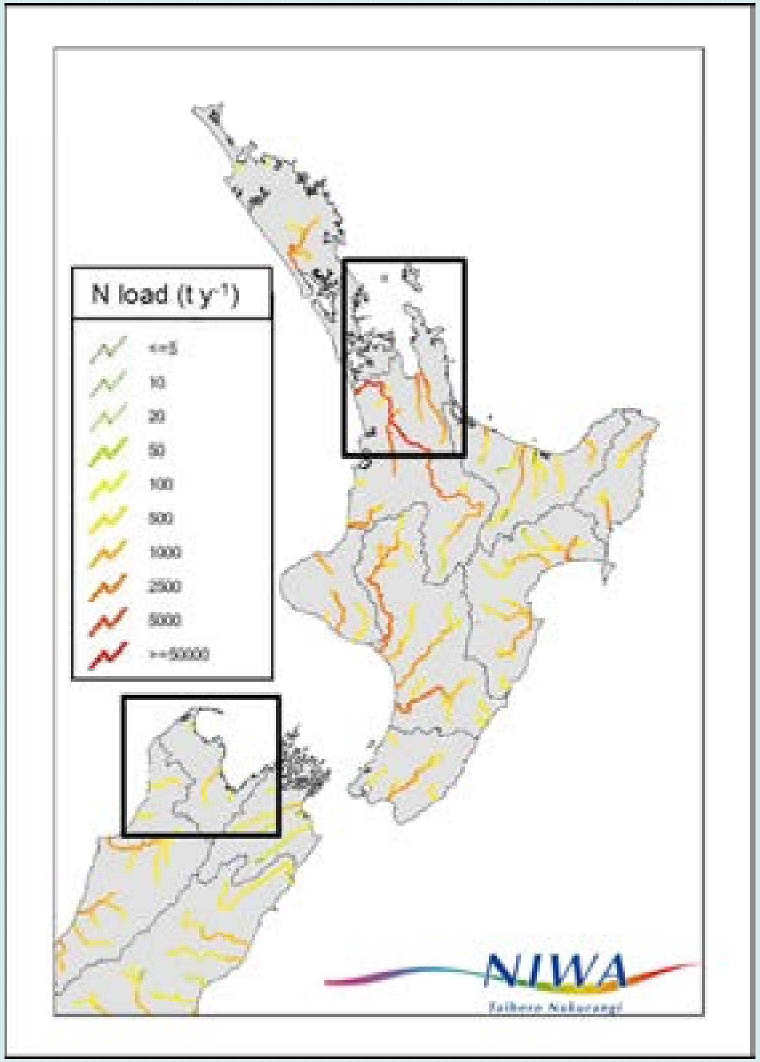


Nutrient loading: comparing Gulf and Firth with Nelson Bays

System	Volume (km^3)	Catchment DIN ($t\ N\ y^{-1}$)	Catchment DON ($t\ N\ y^{-1}$)	Ocean DIN ($t\ N\ y^{-1}$)	Net DIC consumption ($t\ C\ y^{-1}$)
Firth	16	3700	900	600	-75,000
Gulf	82	800	150	8200	8500
Golden B.	13	930	200	6300	8000
Tasman B.	31	550	110	5000	6500

- Catchment loads much higher to Firth than Gulf or Nelson Bays.
- Gulf and Nelson Bays net-productive (DIC consumed).
- Firth strongly net-respiratory (high DIC release).

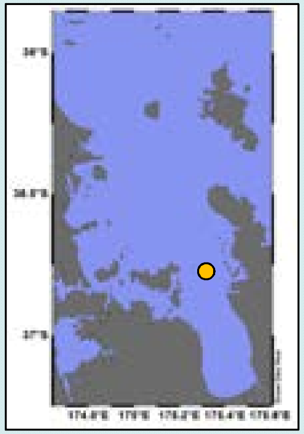
Firth rivers are heavily loaded with nitrogen from Waikato… Nelson Bays rivers are much cleaner.

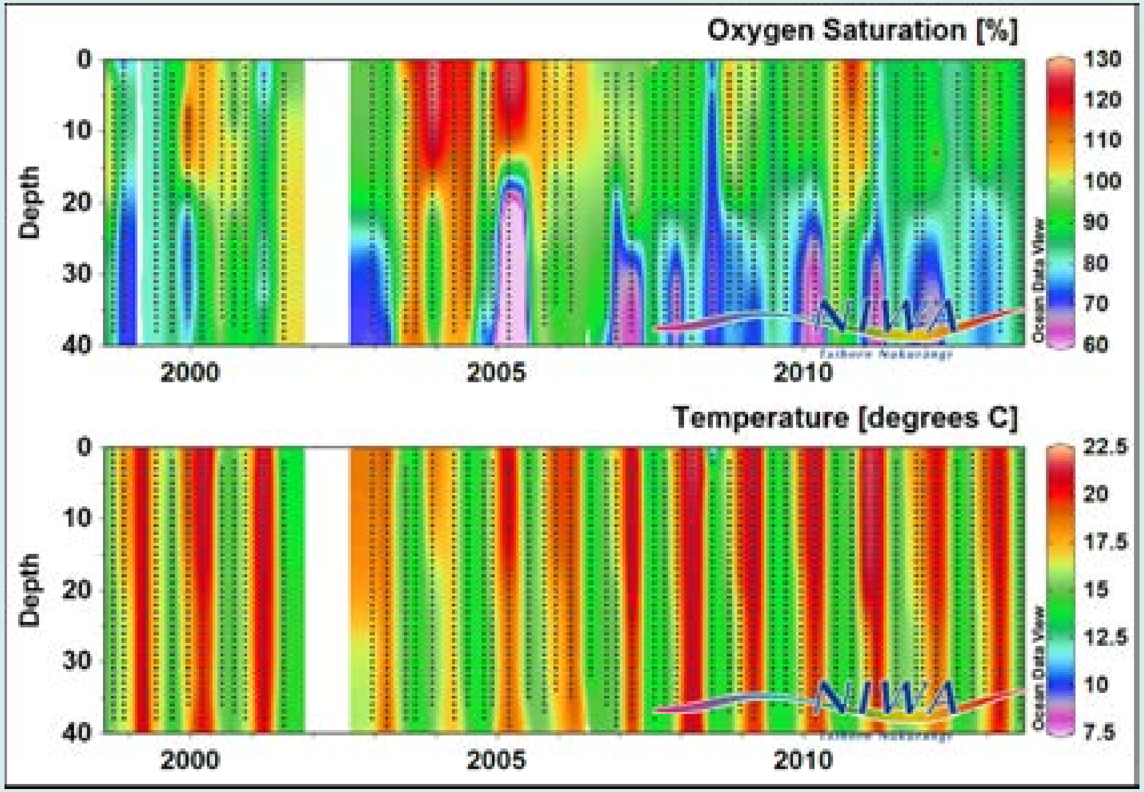


- Firth rivers annual N loads ~3700 t DIN…~ half that of Waikato River (which has 10x the flow).
- Golden Bay ~900 t, Tasman Bay ~600 t.

(CLUES tool http://www.niwa.co.nz/freshwater/our-services/clues-)

We see O_2 depletion in long term monitoring in the Firth - respiration





Depressed O_2 in Firth bottom waters, summer and autumn.

Nutrient runoff-driven acidification – coupled with oxygen depression

- The net-DIC release measures emission/consumption of CO_2 (with implications for global CO_2 budgets).

$$\Delta CO_2 = \mathrm{K} \cdot \alpha \cdot (pCO_{2atm} - pCO_{2water})$$

- As aqueous CO_2 concentration increases, pH decreases, reducing carbonate ions available for calcification → ocean acidification.

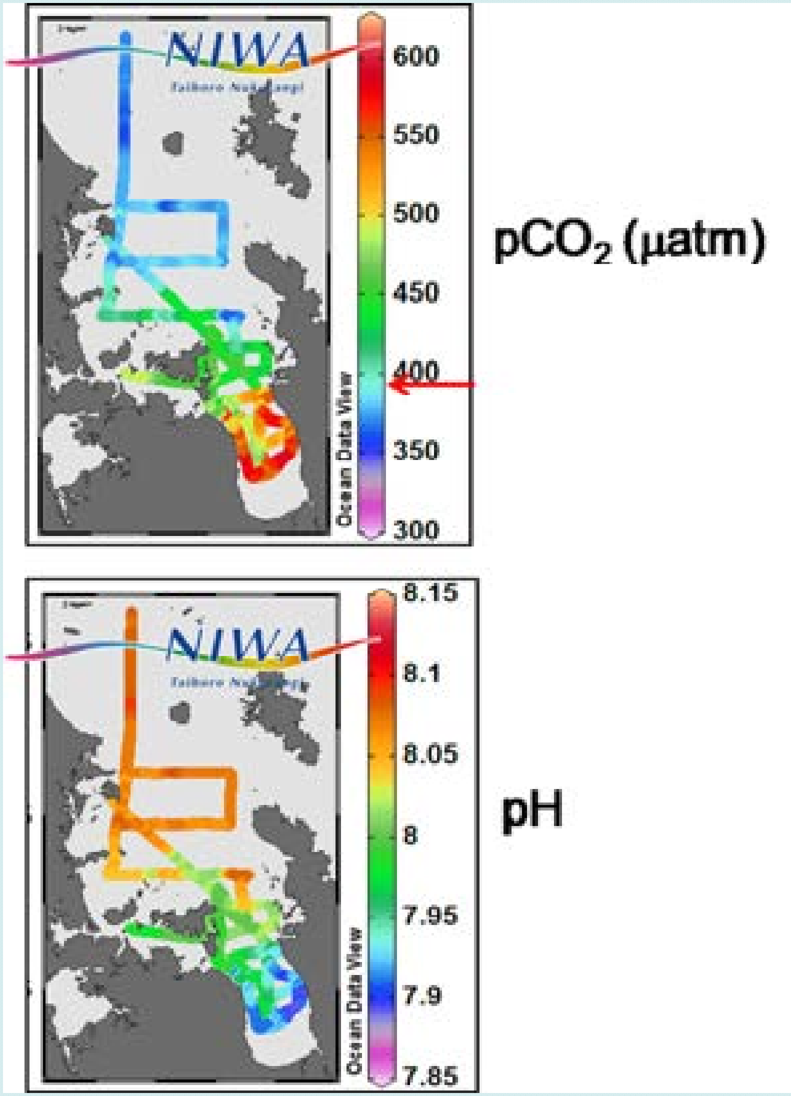
$$\Delta pH \approx -\log\left([CO_2]_{final}/[CO_2]_{initial}\right)$$

We needed measures of these effects on the gulf and Firth

In autumn 2010, we started to measure the carbon system directly.

In autumn 2010, we started to measure the carbon system directly.

- Offshore, pCO_2 below atmospheric, in Hauraki Gulf, ~neutral.
- In the Firth: pCO_2 highly oversaturated, especially off river mouths.
- Consistent with previous budget results.
- Firth pH down to 7.9 – the level forecast for the open ocean in 2060. 'Ahead of the curve'.



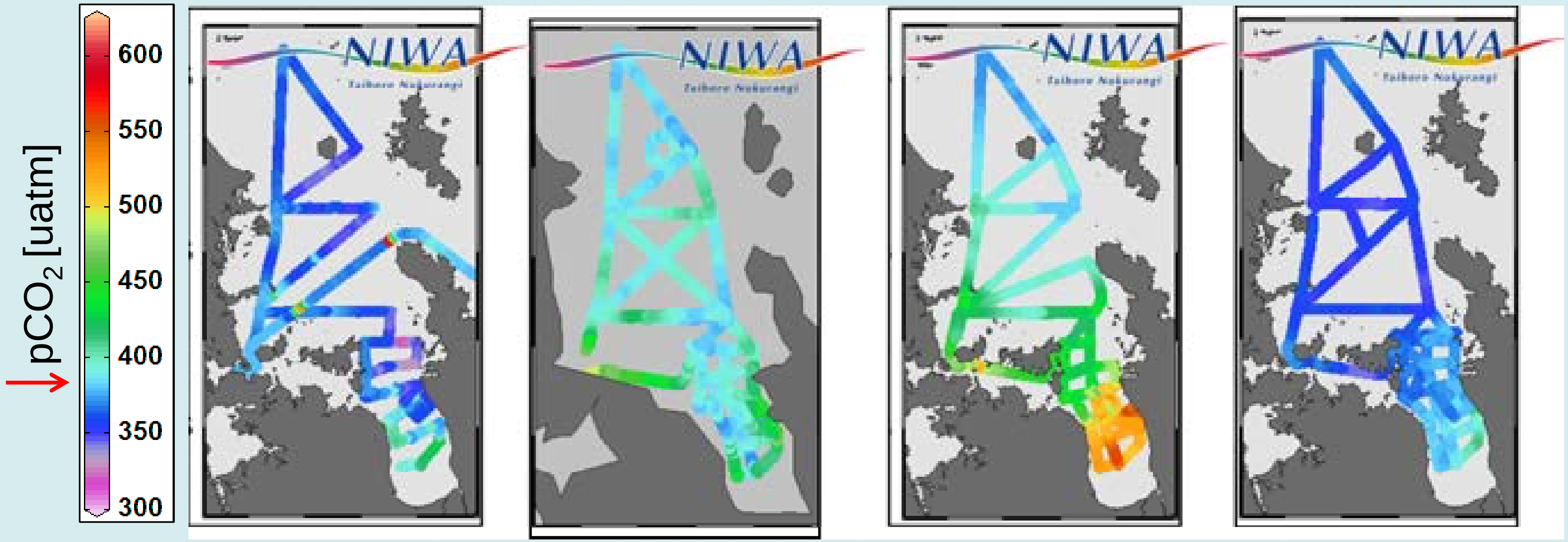
2012-13: seasonal surveys of carbon system

Spring: bloom, net-production

Summer: more respiration

Autumn: high respiration

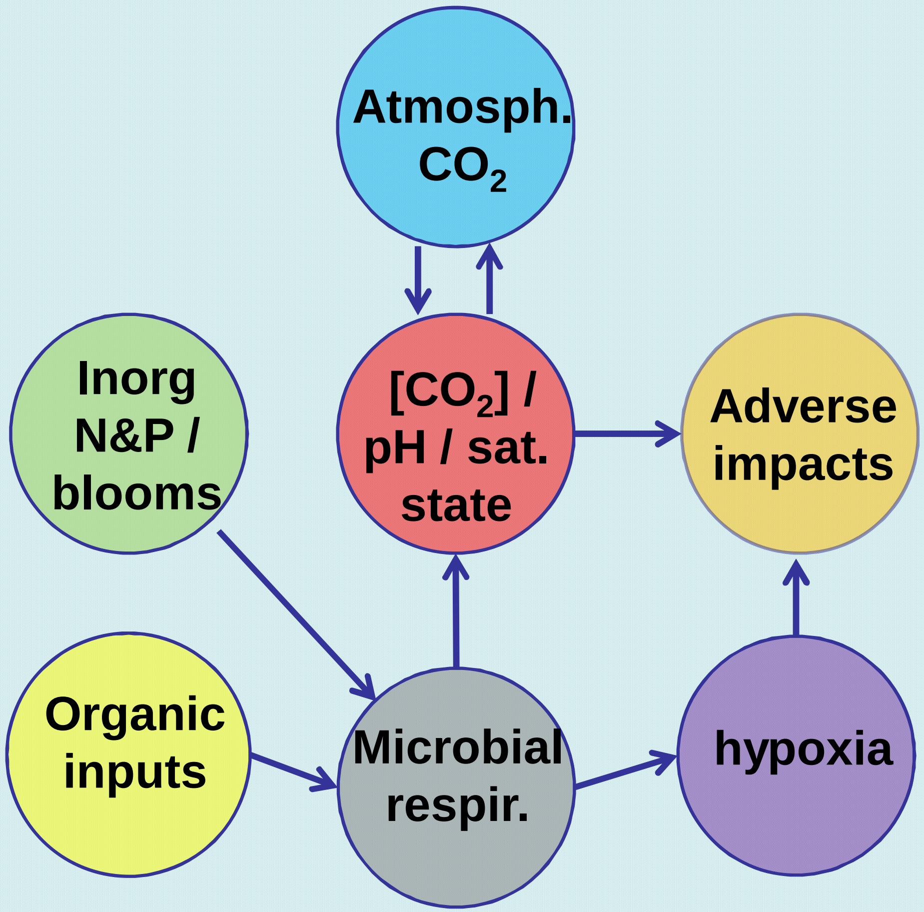
Winter: mixed, net-production



- Large seasonal swings in pCO_2, similar to O_2.
- pH is expected to vary accordingly.

Conclusion

Sedimentation, eutrophication and acidification stressors are linked within biogeochemical cycles



- Include nitrogen, carbon and oxygen cycles: acidification interacting with hypoxia.
- Variable in space and time.
- Stressors have to be understood as a package of effects.

Adapted from Sunda and Cai (2012) Environ Sci Technol 46:10651-10659

Acknowledgements

- The RV *Kaharoa* and all who have sailed with her.
- Funding: NIWA 'Coasts and Oceans' Core Fund and its predecessors, FRST and MSI.
- NIWA 'Coasts and Oceans' and 'Sustainable Aquaculture' science teams.