Hauraki Gulf ecosystem function: productivity, drivers and stressors

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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.

Ecosystem productivity

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

$$CO_2 + \text{inorganic nutrients} + \text{water} \leftrightarrow \text{organic matter} + \text{oxygen}$$

- 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: 150,000 per litre

Zooplankton: (35 per litre)

P. canaliculus (0.003 per litre)

Snapper larvae 0.0005 per litre
Phytoplankton are spatially and seasonally variable

Spring  Summer  Autumn  Winter

Surface chlorophyll (mg / m³) from ship surveys 1998-2013


Zooplankton most abundant in the gulf and approaches

Snapper spawning grounds and nurseries – concentrated in the inner Gulf

1 day old snapper eggs / m²

Snapper larvae / m³ (ln scale)


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

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

Upwelling is governed by seasonal and inter-annual variation (e.g., ENSO, IPO).
Upwelled nitrate enters the Gulf and Firth in near-bed flows detected at Firth of Thames mooring

Riverine effects

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

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.

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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

\[ CO_2 + \text{inorganic nutrients} + \text{water} \leftrightarrow \text{organic matter} + \text{oxygen} \]

Recycling most active inshore – where nutrient loading is highest.


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

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).


Sediment runoff – potential to modify sub-littoral habitat

Surface suspended matter – remote sensing

Surface riverine suspended sediment – model


Nutrient runoff-driven eutrophication: excess oxygen consumption

\[ CO_2 + \text{inorganic nutrients} + \text{water} \leftrightarrow \text{organic matter} + \text{oxygen} \]

Fuelled by:
- organic matter loading and decomposition
- inorganic nutrient loading and phytoplankton bloom decomposition
Nutrient loading: comparing Gulf and Firth with Nelson Bays

<table>
<thead>
<tr>
<th>System</th>
<th>Volume (km³)</th>
<th>Catchment DIN (t N y⁻¹)</th>
<th>Catchment DON (t N y⁻¹)</th>
<th>Ocean DIN (t N y⁻¹)</th>
<th>Net DIC consumption (t C y⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firth</td>
<td>16</td>
<td>3700</td>
<td>900</td>
<td>600</td>
<td>-75,000</td>
</tr>
<tr>
<td>Gulf</td>
<td>82</td>
<td>800</td>
<td>150</td>
<td>8200</td>
<td>8500</td>
</tr>
<tr>
<td>Golden B.</td>
<td>13</td>
<td>930</td>
<td>200</td>
<td>6300</td>
<td>8000</td>
</tr>
<tr>
<td>Tasman B.</td>
<td>31</td>
<td>550</td>
<td>110</td>
<td>5000</td>
<td>6500</td>
</tr>
</tbody>
</table>

- 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.

We see $\text{O}_2$ depletion in long term monitoring in the Firth - respiration

Depressed $\text{O}_2$ 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).

\[ \Delta \text{CO}_2 = K \cdot \alpha \cdot (p\text{CO}_{2\text{atm}} - p\text{CO}_{2\text{water}}) \]

- As aqueous CO$_2$ concentration increases, pH decreases, reducing carbonate ions available for calcification → ocean acidification.

\[ \Delta pH \approx -\log \left( \frac{[\text{CO}_2]_{\text{final}}}{[\text{CO}_2]_{\text{initial}}} \right) \]

We needed measures of these effects on the gulf and Firth
In autumn 2010, we started to measure the carbon system directly.
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- 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’.

![pCO$_2$ and pH maps]
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.

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