On Wastewater Treatment Plants and Earthquakes;

What ~~are~~ were the 'bloomin' seaweeds trying to tell us?

University of Canterbury and NIWA

(A Joint MSI Funded project)

Neill Barr

NIWA

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$73m waste U-turn

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In March 2010 the CWTP sewage discharge into the Avon-Heathcote Estuary was diverted to a 3km long ocean outfall

- Historically high nitrogen loading from CWTP - mainly ammonium
- Also high levels of nitrate and phosphate with a significant proportion coming from the two rivers that enter the estuary
- The diversion should have resulted in about a 90% reduction in nutrient loading
- Of course it was not expected that a prolonged series of earthquakes were going to be a major factor in the recovery of the estuary

Monitoring and modelling nutrient dose-growth responses of *Ulva*.

Two primary questions we are trying to answer by monitoring nitrogen-status in Avon-Heathcote algae:

1) Can we predict growth rates of natural populations based on their nitrogen-status?

2) Can we use the algae as a tool for measuring, or integrating, information on biologically available nutrients?

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Why is a biological indicator of nutrient loading a good idea.

Conventional seawater nutrient analysis is important but has some limits:

- it may not measure all nutrient sources available to micro- and macroalgae
- sampling often conducted over longer intervals (often weekly or monthly)
- It is often variable because of tidal influences which alias true spatial and temporal ‘biologically average’ concentrations

Why is a biological indicator of nutrient loading a good idea.

Measuring the responses of macroalgae may be a good addition to monitoring:

- **Macroalgae individuals are easy to sample and identify to species level**
- **They are generally ‘fixed’ in one place over time and can therefore be viewed as integrators of all available nutrient sources over time at one place**
- **We measure nutrients because we often use these to try predict the responses of micro- and macroalgae**

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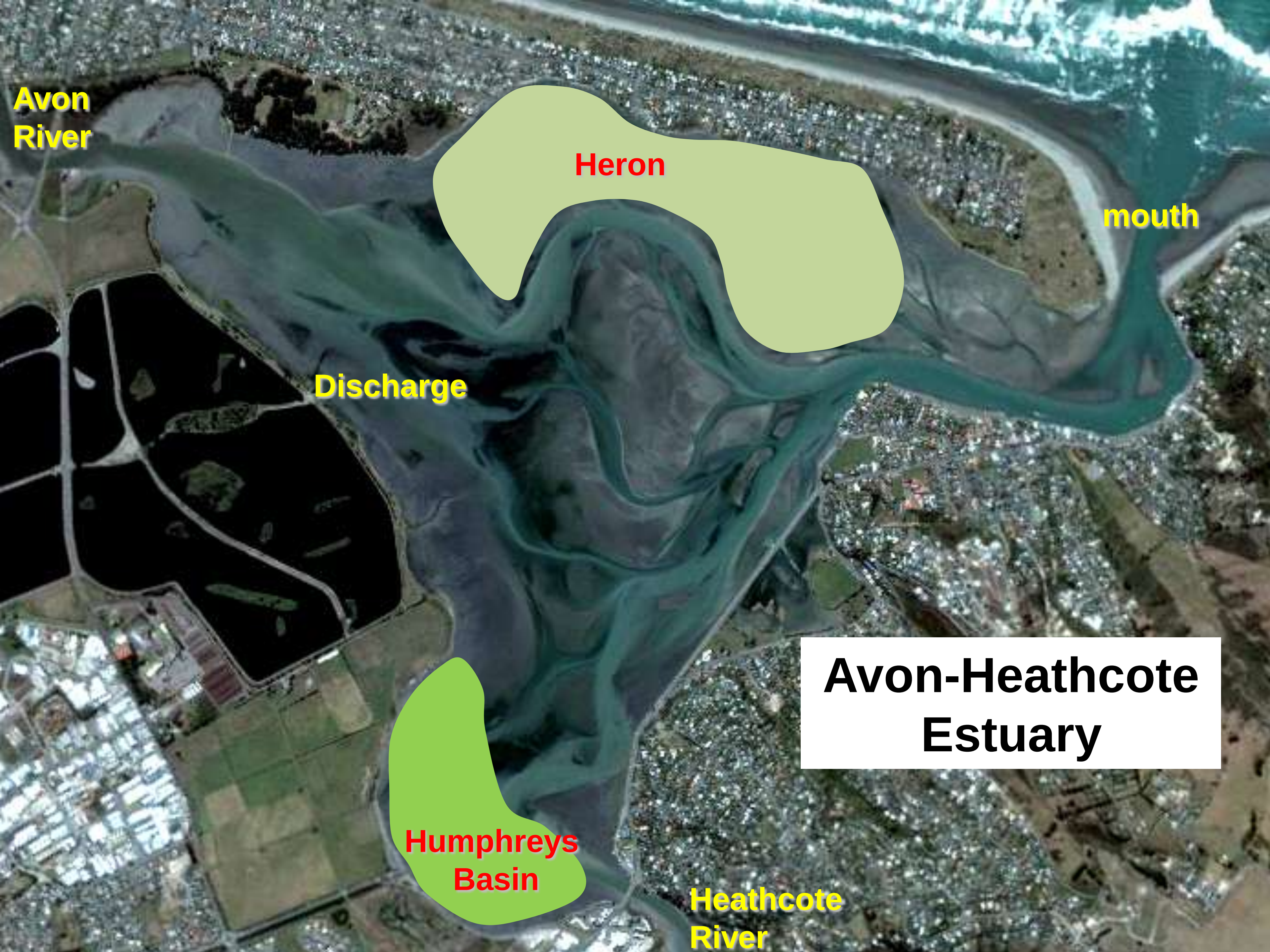
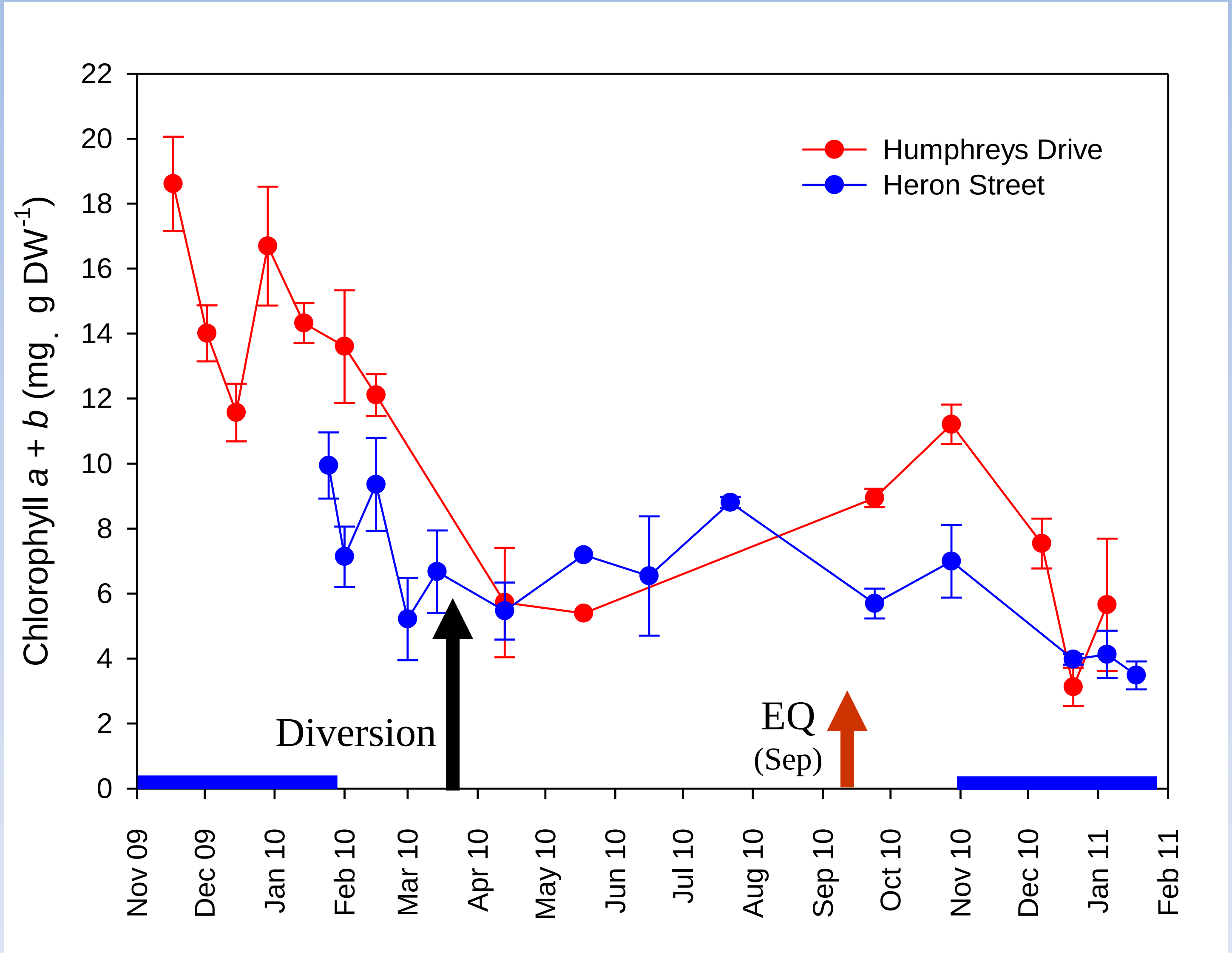
Monitoring and modelling nutrient dose-growth responses of *Ulva*.

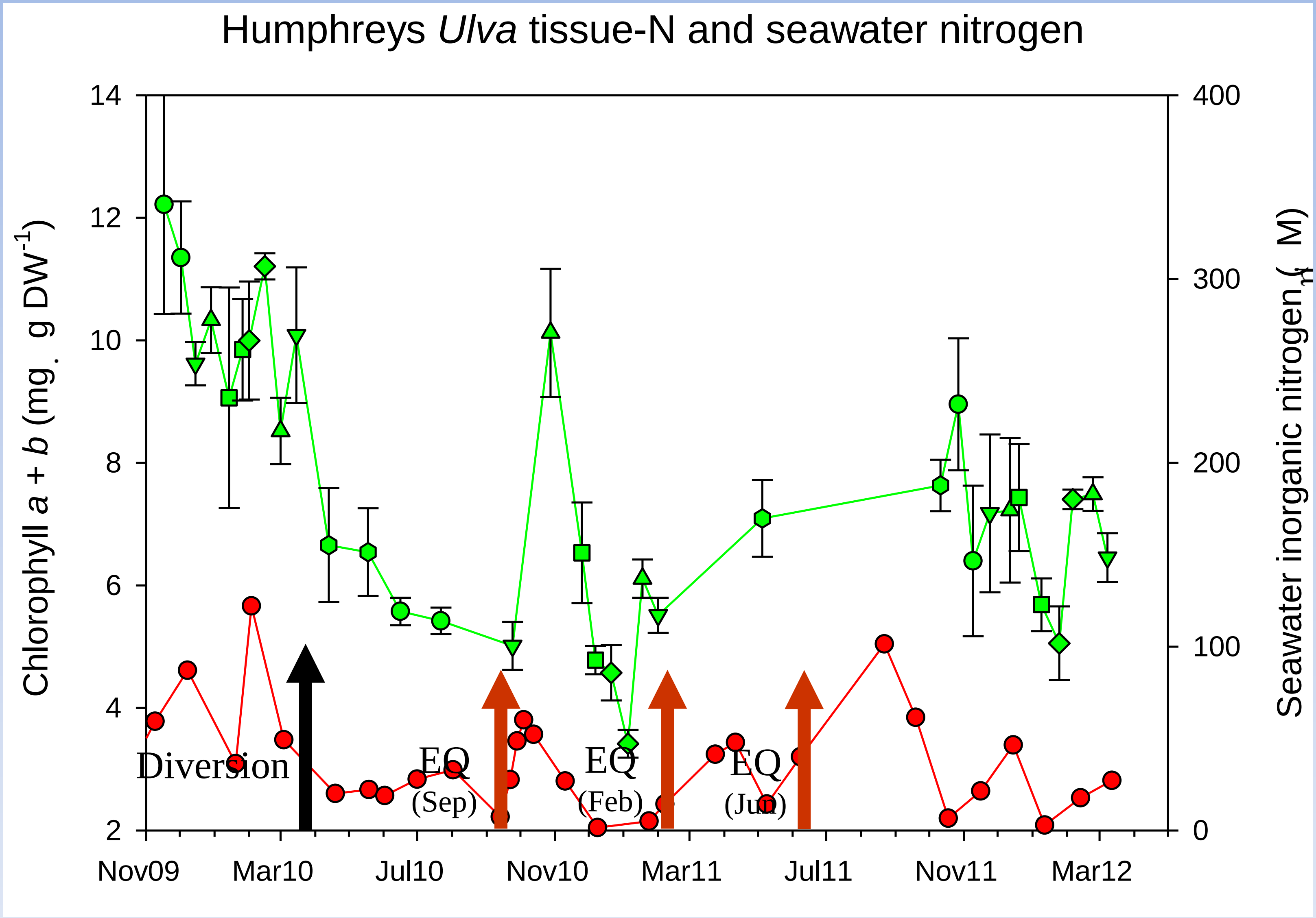
- **Collecting algal biochemical data began beginning of summer prior to diversion in November 2009**
- **Algae include, *Gracilaria chillensis*, *Ulva intestinalis* (tubular *Ulva*), *Ulva* species (frondose *Ulva*)**
- **Parameters used: Chlorophyll, Tissue-N and Tissue-δ^{15}N content in algae**
- **Most data presented today from two 'sentinel' sites; Heron Street and Humphreys basin (there are several other sites)**


Avon River
Heron
mouth
Discharge
Avon-Heathcote Estuary
Humphreys Basin
Heathcote River

Monitoring nitrogen indices in tubular *Ulva* species. Summer 09/10 to Summer 10/11.



Monitoring nitrogen indices in frondose *Ulva* species. Summer 09/10 to Summer 11/12.



Nutrient data courtesy of ECan

Selected *Ulva* biochemical indicators of seawater nitrogen availability from 27 sites around New Zealand

‘Clean’ *Ulva* baseline (summer)

	'Clean' estuaries and harbours		Clean open coastal sites		Enriched estuaries and harbours	
Nitrogen indices in *Ulva*	mean	sd	mean	sd	mean	sd
Chlorophyll *a* + *b* (µg · g DW^{-1})	**1.5**	0.5	3.9	1.3	**7.3**	3.4
Tissue-N (%)	**1.0**	0.3	2.3	0.4	**3.1**	0.5
Tissue–δ^{15}N (‰)	**7.5**	0.4	7.8	0.6	**10.2**	**3.5**

‘Enriched’ *Ulva* (summer)

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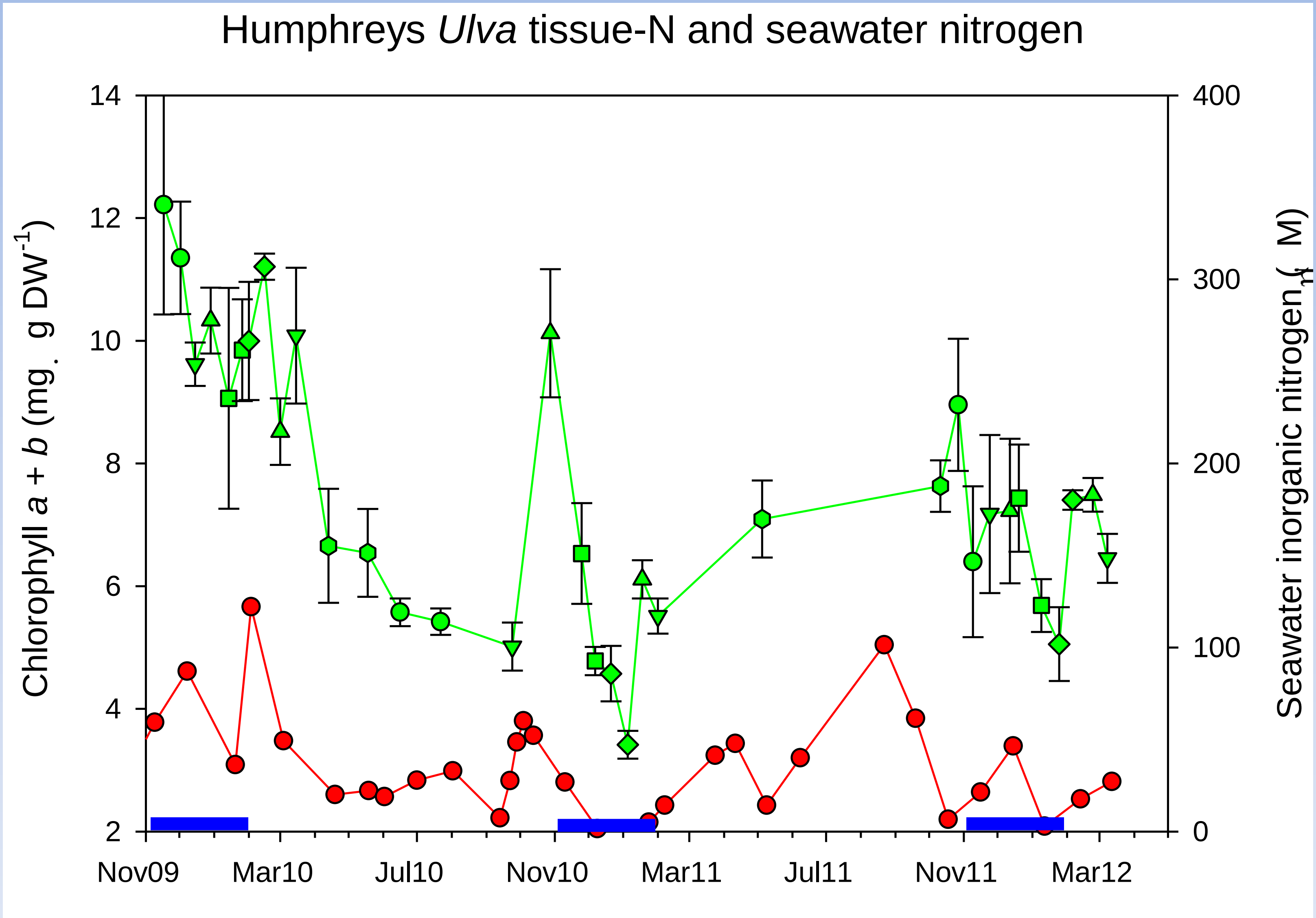
Monitoring nitrogen indices in frondose *Ulva* at Humphreys Drive.

Summer 09/10 to Summer 11/12



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‘Enriched’ *Ulva* (summer)

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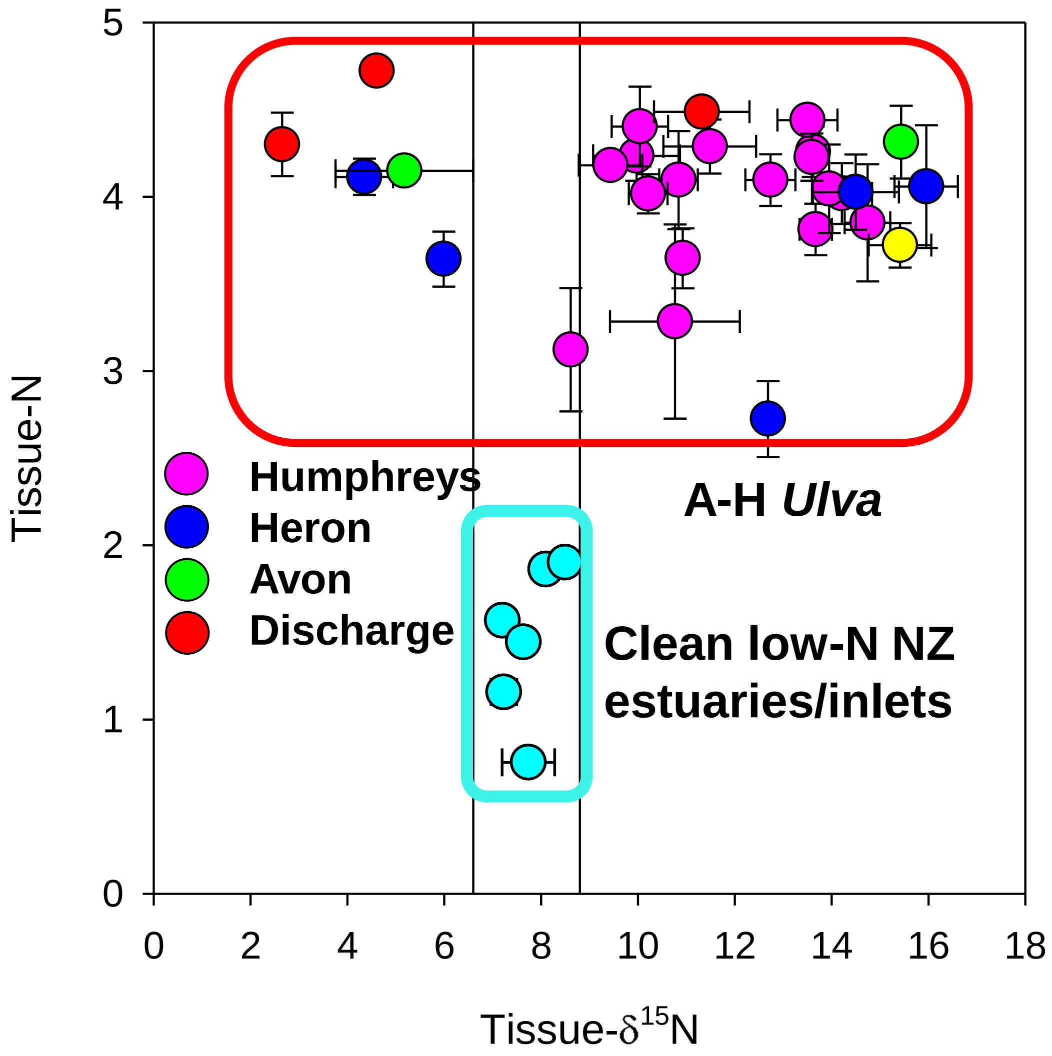
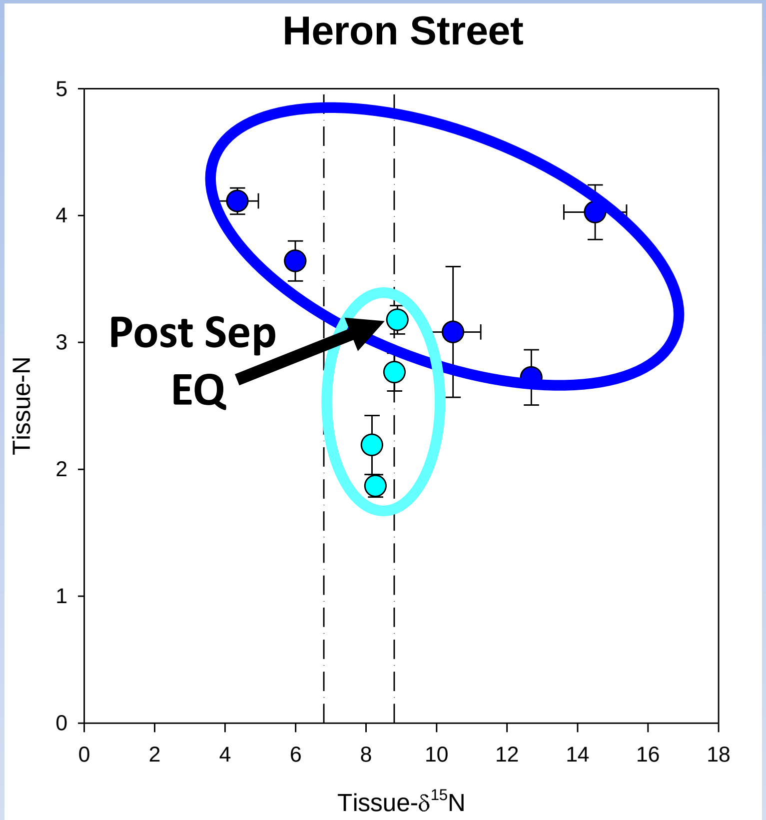
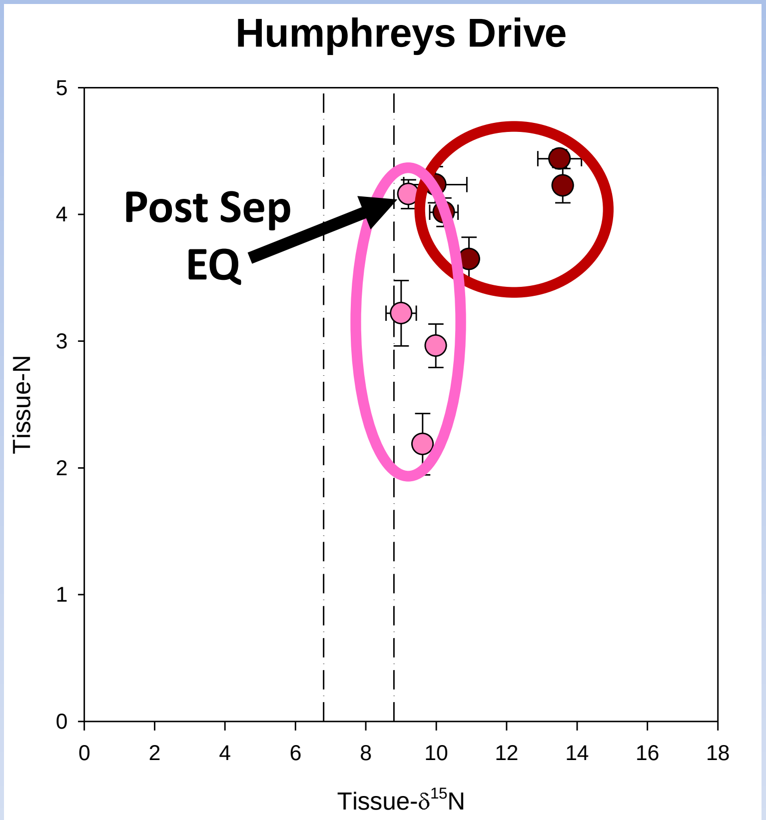
Pre-diversion patterns of tissue-$\delta^{15}N$ versus tissue-N in *Ulva*

- *Ulva* Tissue-$\delta^{15}N$ outside range of 6.7 ‰ to 8.8 ‰ indicates deviation from 'natural' coastal N
- *Ulva* Tissue-N values above about >3% in sheltered NZ estuaries in summer indicate high N-loading
- …but using *Ulva* indicators also requires understanding of other environmental factors (e.g. light and temperature)



Patterns of tissue-δ15N versus tissue-N in *Ulva from* summer 09/10 to summer 10/11; a synopsis of change in N-loading in the Avon-Heathcote estuary pre and post-diversion





Heron *Ulva* – summer 09/10
Heron *Ulva* – summer 10/11

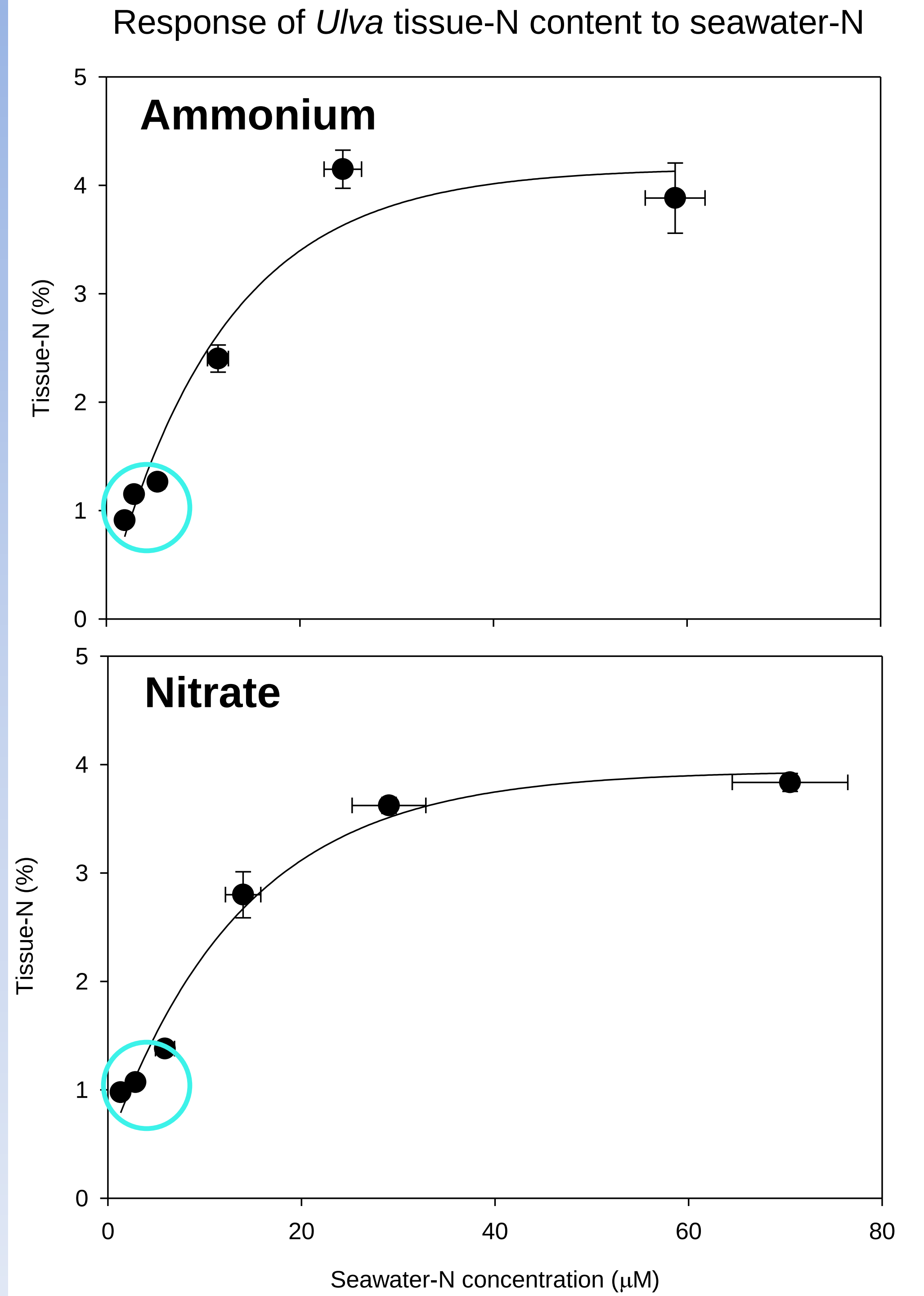
Humphreys *Ulva* – summer 09/10
Humphreys *Ulva* – summer 10/11

Effect of nitrogen concentration and source on *Ulva* growth and biochemistry in the Avon-Heathcote Estuary *Ihutai*, Christchurch.

Responses of tissue-nitrogen content in *Ulva* to seawater nitrogen concentration

- Tissue-N shows a strong but non-linear response to inorganic nitrogen (nitrate and ammonium) concentration
- Similar responses to both ammonium and nitrate (nitrate slightly lower)
- Saturating concentrations occurring above ~ 20 μM
- National baseline values for *Ulva* in clean estuaries suggest < 5 μM

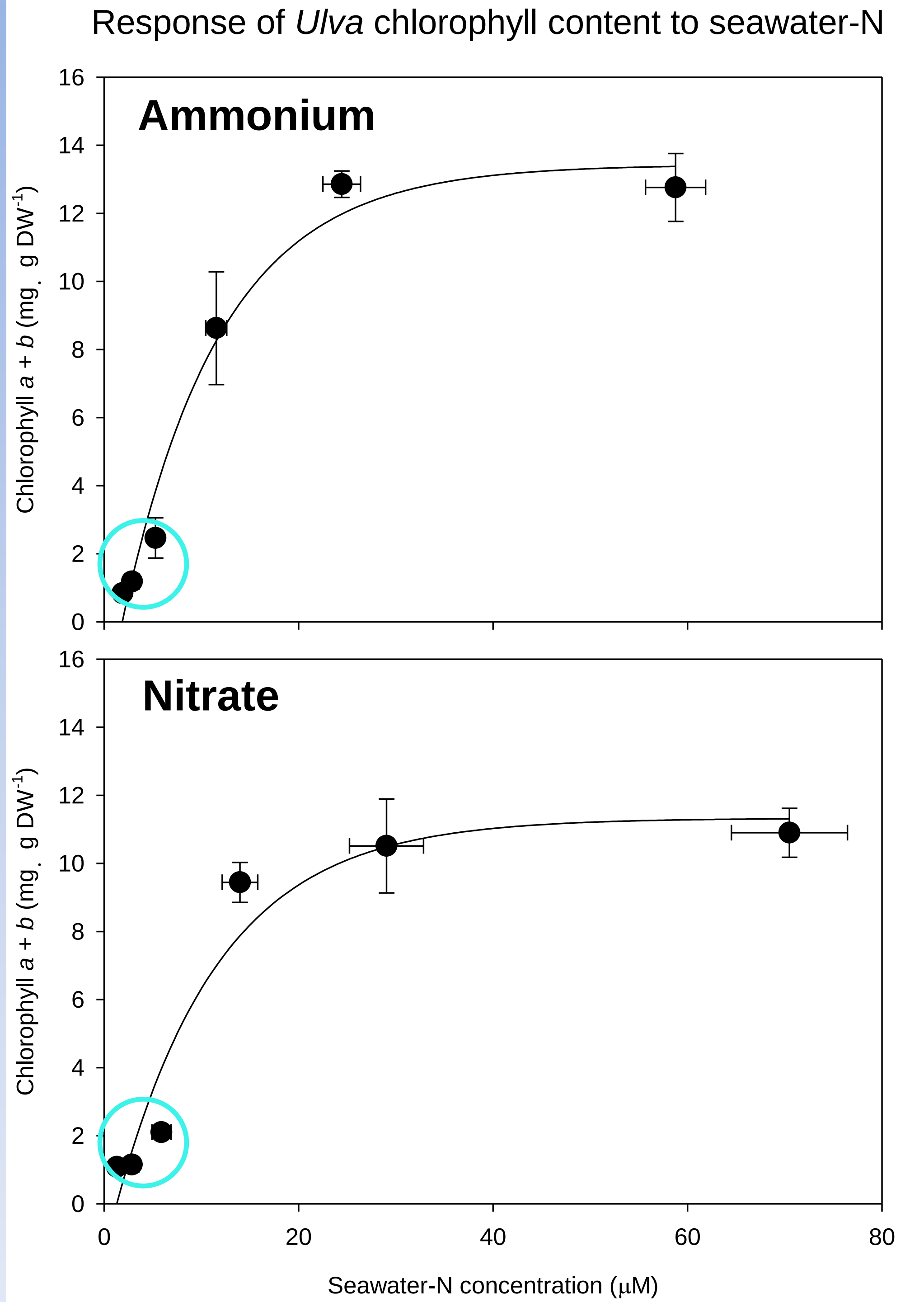
Courtesy of Ellie Caves



Responses of chlorophyll in *Ulva* to seawater nitrogen concentration

- Chlorophyll shows a strong but non-linear response to inorganic nitrogen (nitrate and ammonium) concentration
- Similar responses to both ammonium and nitrate (nitrate slightly lower)
- Saturating concentrations occurring above ~ 20 μM
- National baseline values for *Ulva* in clean estuaries suggest < 5 μM

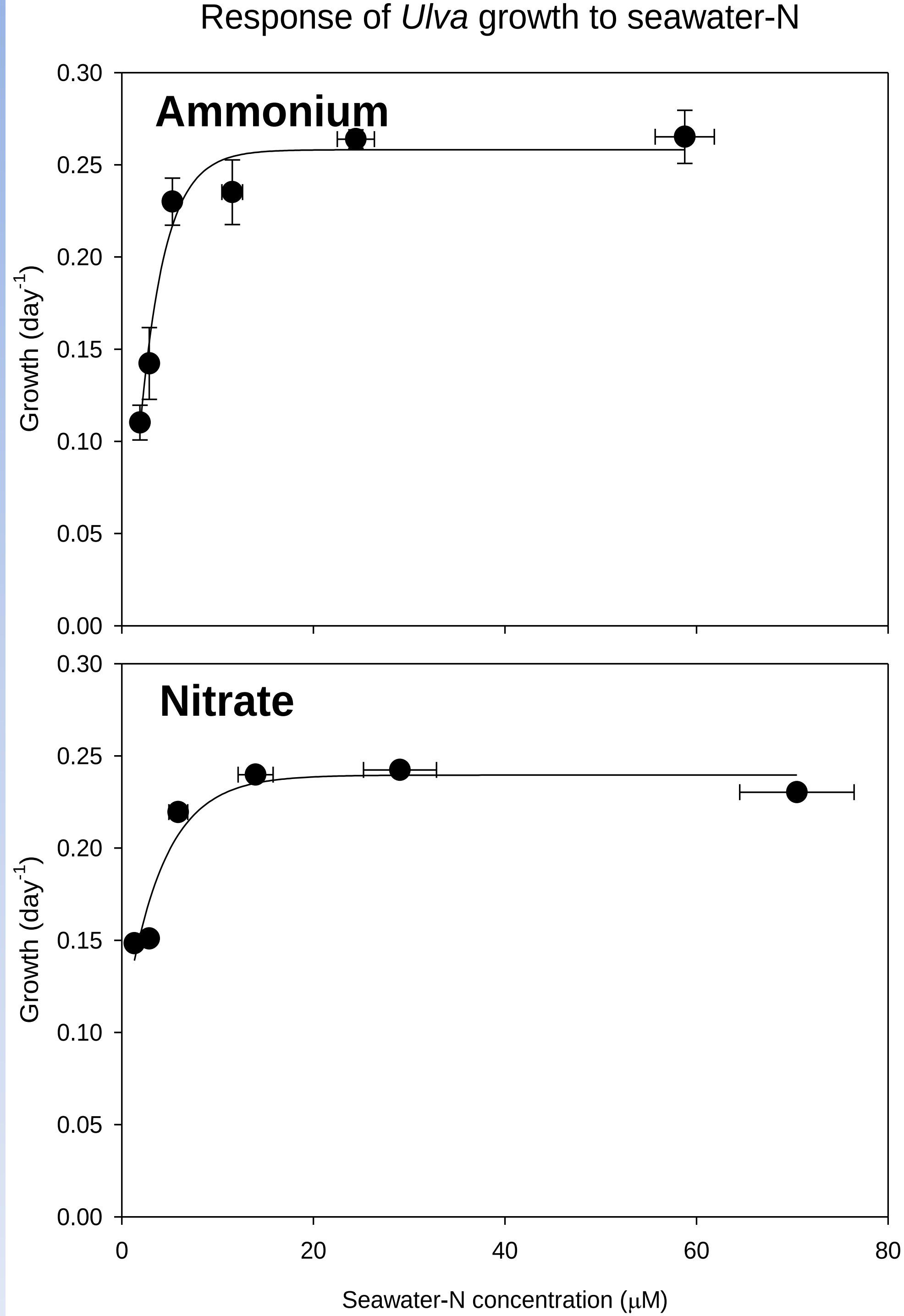
Courtesy of Ellie Caves



Responses of growth in *Ulva* to seawater nitrogen concentration

- Growth shows a strong but non-linear response to inorganic nitrogen (nitrate and ammonium) concentration
- Similar responses to both ammonium and nitrate (nitrate slightly lower)
- Saturating concentrations occurring above ~ 15 μM
- National baseline values for *Ulva* in clean estuaries suggest < 5 μM

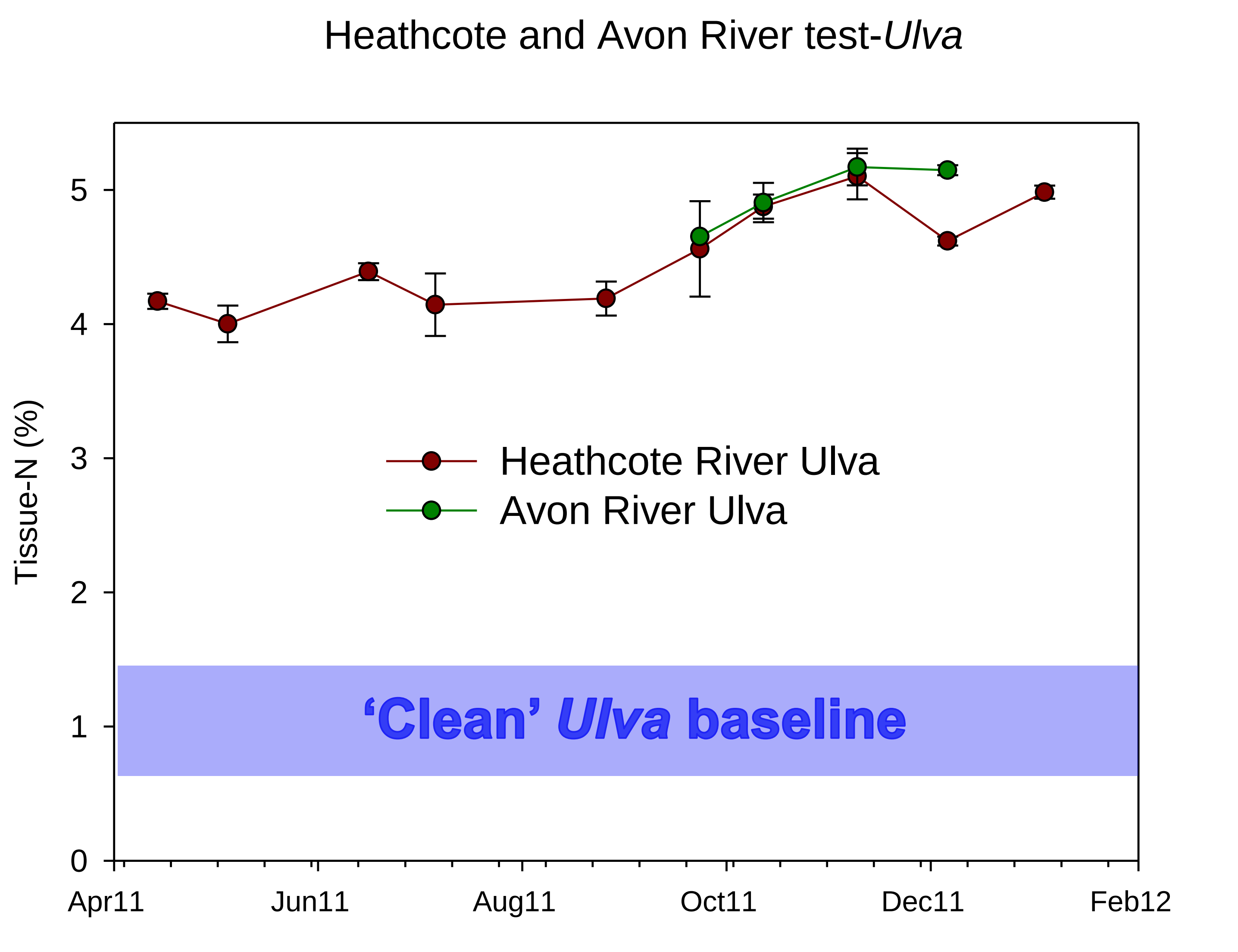
Courtesy of Ellie Caves



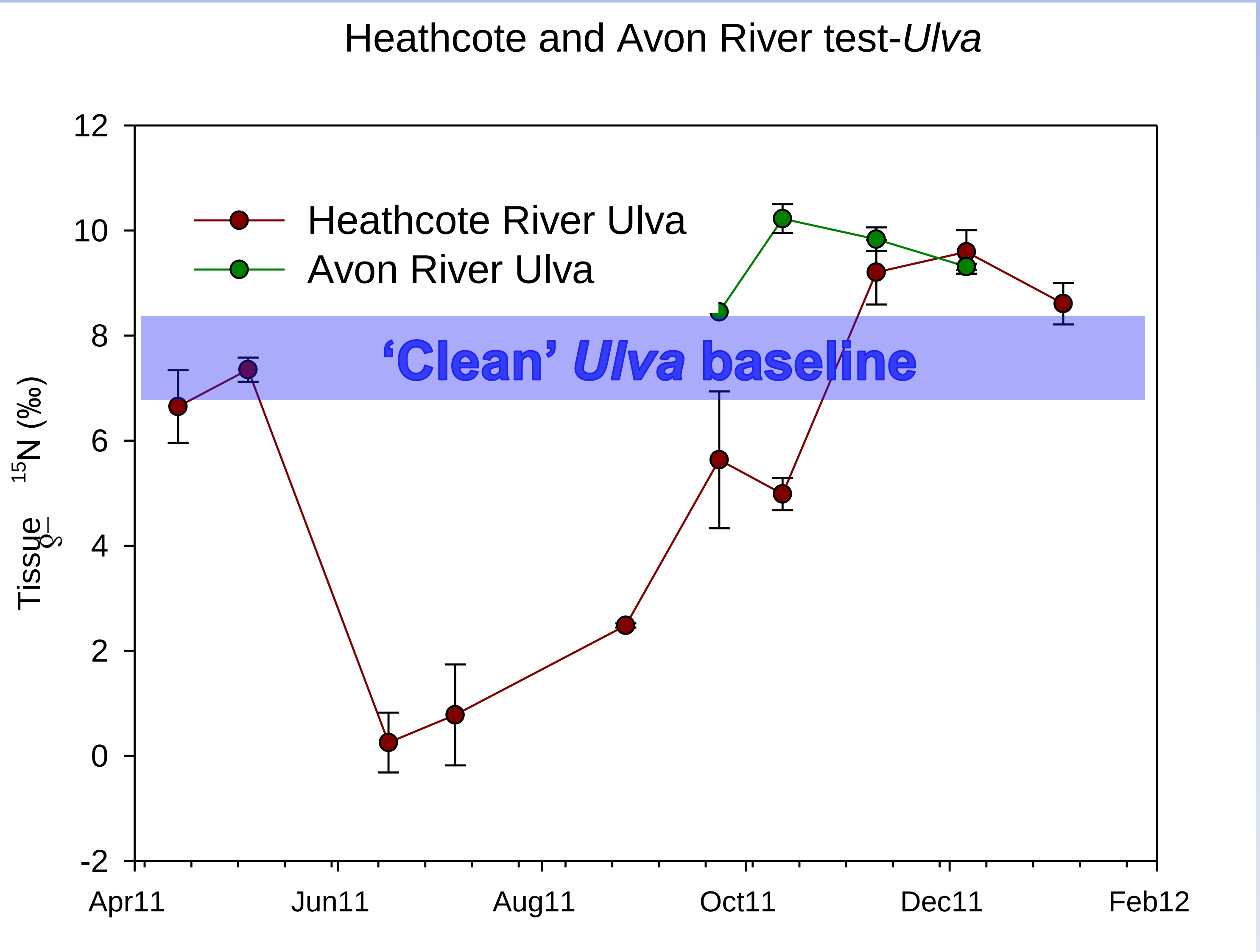
Earthquake effects on chemistry in the 'new estuary'

- Most EQ overflows of raw sewage entered to estuary via the Avon and the Heathcote rivers.
- How might these overflows influence seaweeds growing in the estuary?
- Can we 'use' these seaweeds to detect potential sources of nitrogen?

Tissue-N in *Ulva* grown in the Heathcote and Avon rivers from April 2011 to April 2012



Tissue-δ^{15}N in *Ulva* grown in the Heathcote and Avon rivers from April 2011 to April 2012

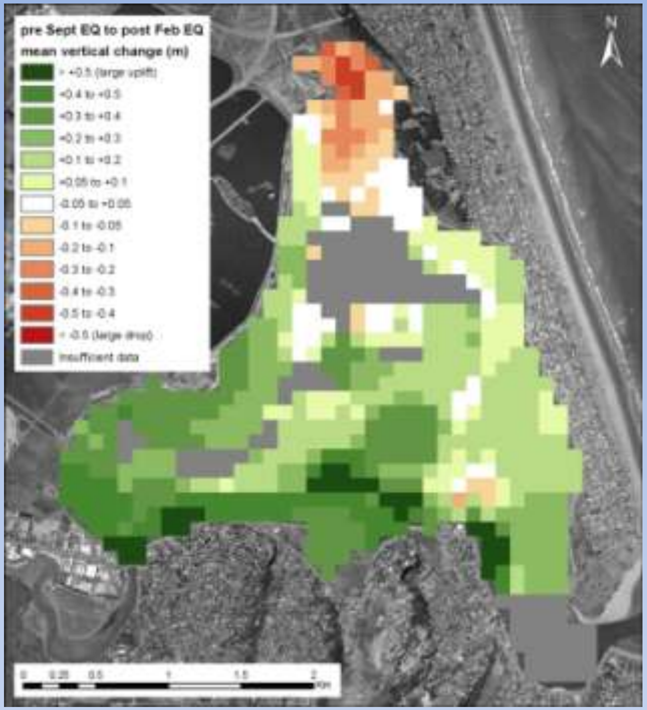


Other earthquake effects: the ‘new estuary’

- Uplift and subsidence: the estuary has risen in the south, sunk in the north, in both cases by up to 0.5 m (implications for seaweed growth at Humphreys Drive).

- Liquefaction: 20-40% of estuary bed has been covered by exhumed sediment.

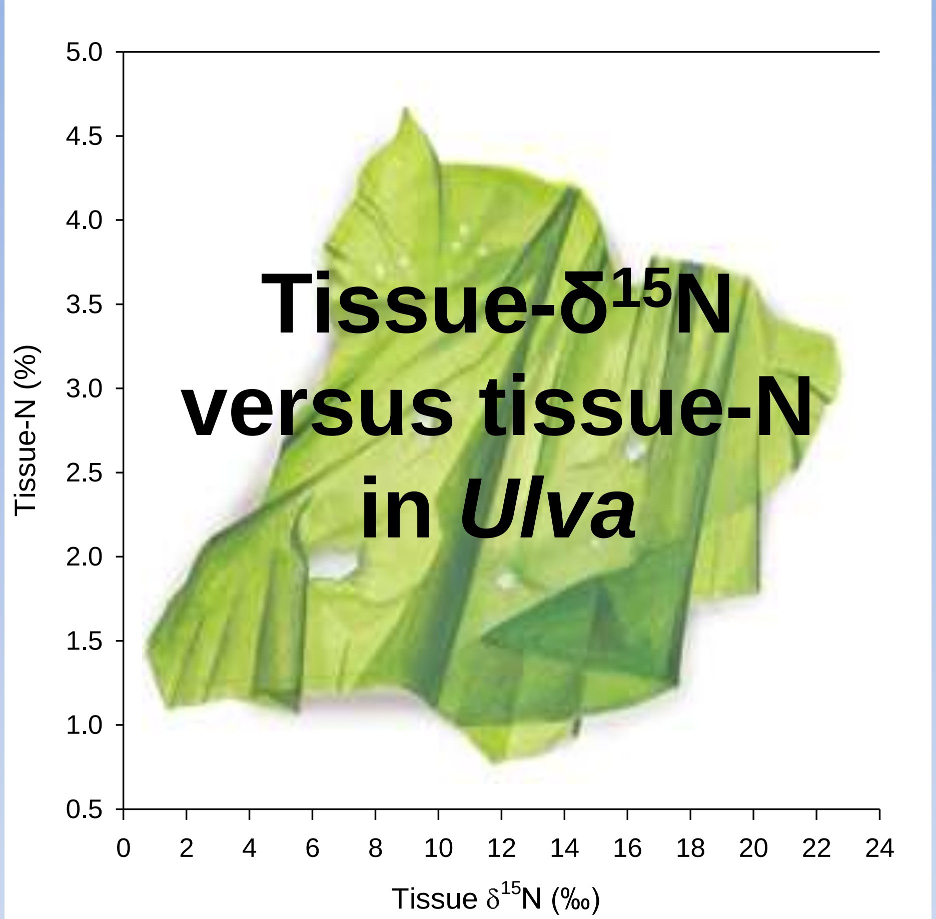
- These factors are now incorporated in our on-going study of estuary remediation.



Tissue-N indices can be directly related to the average nitrogen that *Ulva* 'sees'

High tissue-N values represents luxury N-storage that is surplus to growth in summer conditions

0.7% to 5.0% physiological range



Tissue-δ^{15}N in *Ulva* proxy for available source of nitrogen

6.6 to 8.8‰ ≈ observed coastal δ^{15}N N-source pool

Conclusions

- **Seaweeds growing in the estuary reflected the initial reduction of nitrogen loading with the wastewater diversion**
- **They also reflected the subsequent reintroduction of nutrients from raw sewage as a result of the earthquakes**
- **However the earthquakes have had multiple effects on the recovery of the estuary and on future growth/proliferation of seaweeds**
- **The rivers that feed into the estuary are probably still a major source of nutrients that will continue to effect the estuary**

Acknowledgements

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