

3 November 2015

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Dear Belinda

***Ulva* / *Gracilari*a surveys in the Avon-Heathcote Estuary 2014-15**

Background

The marine macroalgae *Ulva* sp. and *Gracilari*a sp. are regarded as nuisance weeds in the Avon-Heathcote Estuary due to their excessive biomass negatively impacting on aesthetic, recreational and ecological values. Proliferations of these species are often associated with increased nutrient loading, in particular nitrogen, and historic discharge of treated wastewater into the Avon-Heathcote Estuary was considered to be a main driver of excessive biomass in the estuary.

In March 2010, an ocean outfall wastewater discharge pipeline became operational and discharge into the estuary ceased. It was anticipated that this diversion would reduce nitrogen loadings into the estuary by 90%, leading to a reduction in the growth of both macroalgae. In anticipation of the diversion, CCC began undertaking annual surveys of the percentage cover and distribution of *Ulva* and *Gracilari*a at 17 sentinel sites in 2001-02 summer. The purpose of these surveys was to document the change in the visual percentage cover of these seaweeds, over time. Following the diversion, the Christchurch earthquake series of 2010-12 resulted in the emergency discharge of raw sewage into the Avon and Heathcote Rivers that drain into the estuary, resulting in the re-introduction of high nitrogen loadings for a period of time.

This letter summarises the findings from the CCC 2014-15 summer-time monthly monitoring period of macroalgal growth in the Avon-Heathcote Estuary.

Methodology

The 17 sentinel survey sites are shown in Appendix A, Figure A1. Following the initial survey, the 17 sites were divided into five main zones (Zones 1-5) for *Ulva* sp. and two zones (Zones 6 & 7) for *Gracilari*a sp. These zone divisions were based on the observed differences in growth and accumulation patterns for the two macroalgae. These zones are defined as follows and their distribution is shown in Appendix A, Figures A2 - A5:

- Zone 1 - *Ulva* seed area (Causeway)
- Zone 2 – *Ulva* Northern accumulation area (Southshore)
- Zone 3 – *Ulva* SW accumulation zone (Humphreys Drive Embayment)
- Zone 4 – *Ulva* Rest of Estuary
- Zone 5 – *Ulva* McCormacks Bay
- Zone 6 - *Gracilari*a growth zone (Humphreys Drive Embayment)
- Zone 7 - *Gracilari*a Rest of Estuary

In March 2014, NIWA revisited each of the sentinel sites to determine whether their placement in each zone classification was still valid following the landscape changes that occurred as a result of the Christchurch earthquake series. As a result of that survey, while the sentinel sites were considered to still be valid, there was a slight modification to the zonation of some sites (see Appendix A, Figures A3 and A5). While the outcome does not affect the continuity of the long-term survey, it will allow for more meaningful interpretation of the results and the actual dynamics of the seaweeds. The re-zoning of sites consisted of the following:

- Zone 1 - *Ulva* seed area in Site 11 has shifted away to the east and now incorporates Site 12.
- Zone 2 - Northern accumulation area comprises of Sites 3 and 5, while Site 2 is no longer considered an accumulation site.
- Zone 3 - SW accumulation zone was originally located in the Humphreys Drive Embayment, however, this has moved to the east, and now incorporates Sites 10 and 11.
- Zone 6 - *Gracilariaria* growth zone has decreased substantially and now only includes Site 8

A rapid assessment method of determining visual percentage cover was developed during the first survey (2001-02). This method involved assessing the visual percentage cover of each seaweed in a 5 m radius in an area representative of the site in general. Information was also recorded on the percentage of plants that were attached to substrate, if any plant material had accumulated along the shoreline, and if there was a notable smell.

For consistency between surveys, all summer-time surveys have been carried out by Mr Terry Costello, CCC. This data is then provided to NIWA who summarises the monitoring data and compares with previous years. Monthly panorama photographs of the estuary during low tide were taken by Mr Joe McCarthy. These photographs were taken from Hilltop Lane and give an estuary-wide perspective of the distribution of seaweeds, over the course of the growth season.

Statistical analyses were performed using analysis of variance (ANOVA) and paired t-test. Paired t-tests were performed to compare individual months between years divided into either pre-diversion or post-diversion, while one-way ANOVAs were performed to compare years (to avoid any effect of changes in initiation of growth period). All statistical analyses were carried out using Statistica v.10 software (Statsoft Inc., Tulsa, OK, USA). No statistical analyses were performed on *Gracilariaria* data (Zones 6 & 7) due to missing historic data.

Results

- **Zone 1 – *Ulva* seed area (Causeway)**

Zone 1 is designated the seed area as it contains the most actively growing *Ulva* sp. biomass compared to the rest of the Estuary. Plants in this zone typically are attached to substrate. The percentage cover of *Ulva* sp. in Zone 1 at the start of the monitoring period was high (67%), increasing slightly (75%) throughout the growth season (Figure 1). The percentage cover in Zone 1 was significantly higher ($p < 0.01$) during the present growth season compared to 2012-13 and 2013-14 growth seasons but did not differ significantly to the pre-wastewater diversion growth seasons (Appendix B, Figure B1). From the panorama photographs the visual biomass in Zone 1 increased from November 2014 (Plate 3), reaching a maximum in January 2015 (Plate 5) before it began to recede after February 2015 (Plate 6).

- **Zone 2 – Northern accumulation area (Southshore)**

Zone 2 is designated as the northern accumulation area as most of the *Ulva* biomass in this zone originates from elsewhere in the estuary and arrives as drift plants that accumulate in this zone as a result of wind-driven water movement during high tide. The percentage cover increased slightly from a starting cover of 25% in November 2014 to a maximum cover of 37% in March 2015 (Figure 1). Despite the percentage cover being variable over the last four growth seasons, ranging from 7% to 50%, there has been a significant ($p < 0.05$) reduction in the percentage cover in this zone since the diversion, with the most notable reduction occurring immediately post-diversion (Appendix B, Figure B2).

- **Zone 3 – South-West accumulation area**

Zone 3 is designated as the South-West accumulation zone and is the zone that has undergone the greatest change since the earthquakes. Historically, Zone 3 comprised of Sites 6-8, however, as a result of the estuary bed landscape changes as a consequence of the earthquakes, this zone now comprises of Sites 10 and 11 (see Appendix A, Figures A1-A3). Percentage cover in this zone was consistent throughout the monitoring period, with approximately 27% cover of *Ulva* spp from November 2014 to March 2015. This was significantly higher ($p < 0.05$) than during the previous growth season, where percentage cover ranged from $< 5\%$ to $\sim 12\%$ during 2013-14. Prior to the diversion, initial percentage cover in this area was similarly low to post diversion percentage cover. However, at the end of the growth season, percentage cover was highly variable inter-annually, ranging from $< 5\%$ to $> 80\%$ (see Appendix B, Figure B3).

- **Zones 4 and 5 – Rest of the Estuary (Zone 4) and McCormacks Bay (Zone 5)**

Zone 4 comprises of all other monitoring sites not included in Zones 1-3 (with the exception of Site 17). Percentage cover in this zone was consistently at 12% over the monitoring period. The percentage cover in Zone 4 did not differ significantly compared to other surveys undertaken both pre - and post – diversion (Appendix B, Figure B4).

Zone 5 (Site 17) comprises of McCormacks Bay and there was no *Ulva* spp. recorded in this zone during the 2014-15 growth season. Percentage cover has been consistently low ($< 5\%$) following the wastewater diversion and modification to the culvert entering the bay and was significantly lower ($p < 0.01$) than the pre-diversion cover, which exceeded 85% over the growth period.

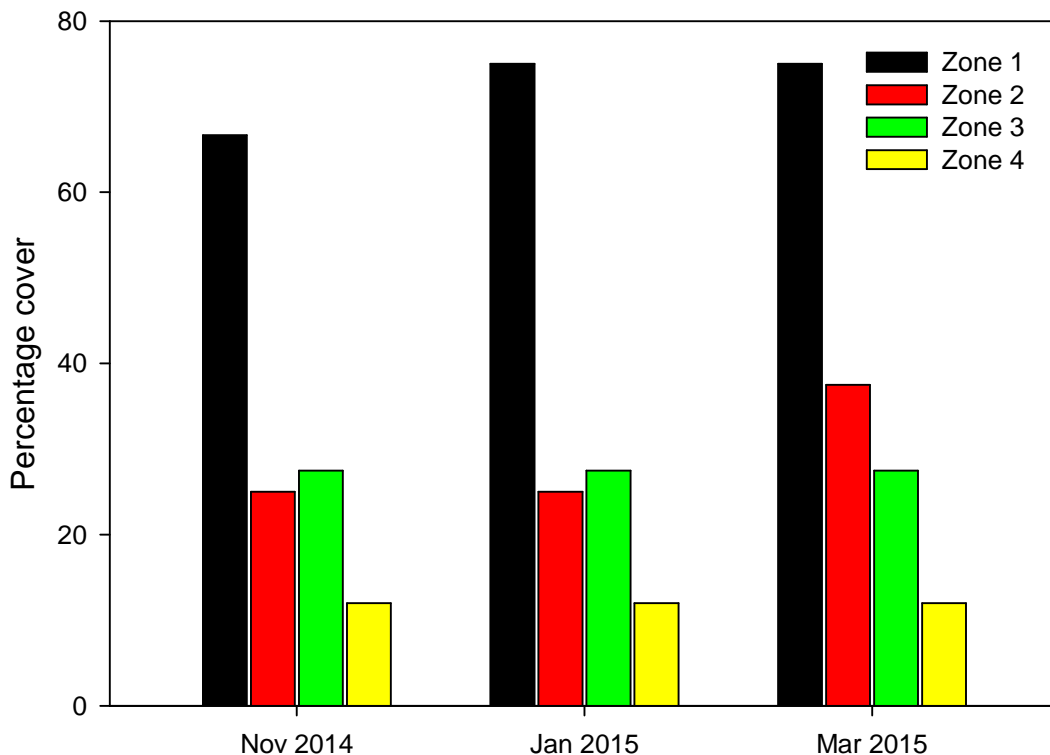


Figure 1. Bi-monthly percentage cover of *Ulva* spp. in the four zone categories during the 2014-15 growth season.

- **Zone 6 – *Gracilaria* growth zone (Humphreys Drive Embayment)**

Zone 6 represented the *Gracilaria* growth zone and historically comprised of Sites 6-8, however, as a result of the earthquake induced modification to the estuary bed, Zone 6 now comprises of Site 8 only (see Appendix A, Figures 1, 4 and 5). At the start of the monitoring period, the percentage cover of *Gracilaria* was 75%, decreasing slightly to 60% over the course of the growth season (Figure 2). While the initial percentage cover was significantly higher ($p < 0.02$) than that of the 2013-14 monitoring period (15%), there was no significant difference in the maximum percentage cover reached between the two growth seasons. While the post-diversion maximum percentage cover is similar to pre-diversion, there has been a substantial reduction in the total area within Zone 6.

- **Zone 7 – Rest of Estuary**

Across the rest of the estuary, *Gracilaria* biomass remained low at 5% cover over the course of the monitoring period (Figure 2). It should be noted, however, that the percentage cover of *Gracilaria* at Site 16 was at 50% over the course of the monitoring period. Low percentage cover over the rest of the estuary is consistent with previous surveys, although this is the first year where percentage cover has been high at Site 16.

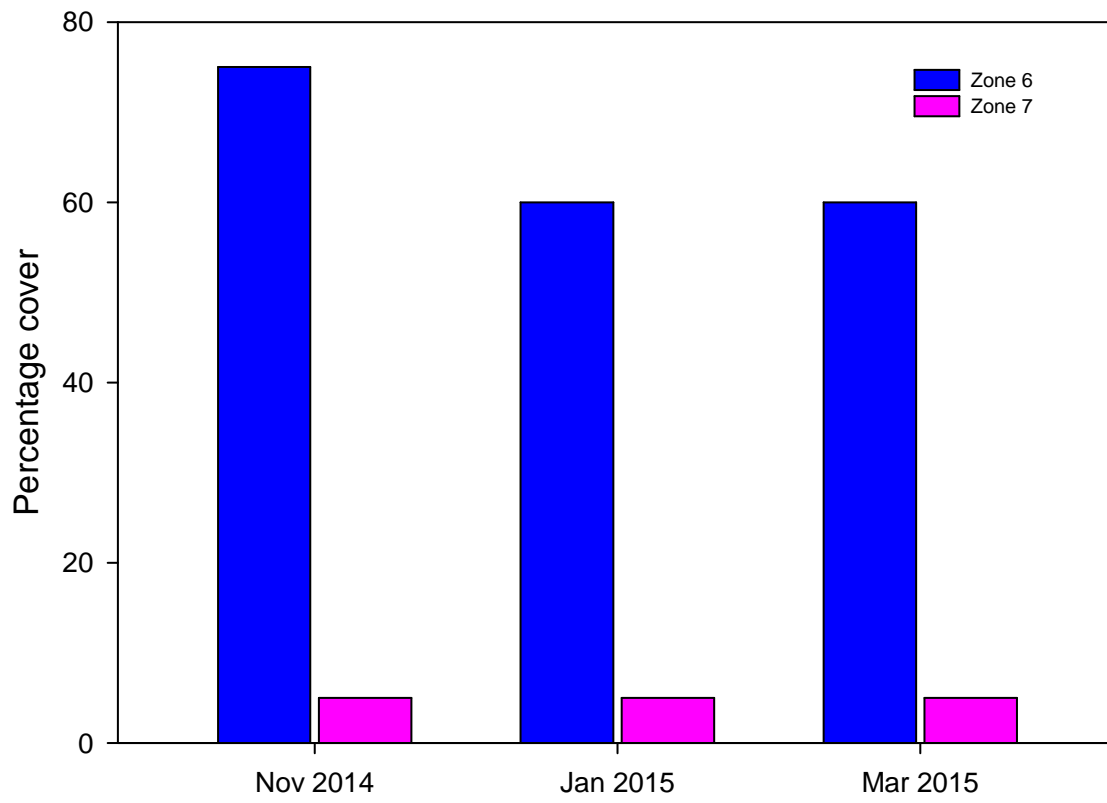


Figure 2. Bi-monthly percentage cover of *Gracilariaria* spp. in the two zone categories during the 2014-15 growth season.

Discussion

The percentage cover of *Ulva* in Zone 1 during the 2014-15 growth season was similar to pre-diversion estimates. It is unclear from the data why this is the case as there had been a decrease in percentage cover following the wastewater diversion, particularly at the peak of the growth season. Growth conditions, other than nutrient enrichment, during the 2014-15 growth period may have been more favourable than during previous growth periods.

While there was some statistically significant differences in the percentage cover between monitoring years in each zone, there is no clear significant difference between pre-diversion and post-diversion, with the exception of Zone 5 (see comments below). Disposal of raw sewage post-earthquakes may be the reason why a clear trend has not yet emerged between pre-diversion and post-diversion.

The most successful reduction in *Ulva* biomass has occurred in McCormacks Bay as a result of modifications to the culvert entering the bay. In last year's report, it was noted that seagrasses had recolonised the bay, indicating the overall improvement in its health and its aesthetic and ecological values.

While individual sites still support high percentage cover of *Gracilaria*, there has been a substantial reduction in the total area in the estuary that supports high cover of this macroalga. Earthquake driven landscape changes coupled with a reduction in nutrients as a result of the diversion are the most likely causes of this reduction.

These monitoring surveys commenced during the 2001-02 growth season and 2014-15 represents the last in this series. These surveys have provided a detailed understanding of the spatial and temporal dynamics of macroalgae within the Avon-Heathcote Estuary. These surveys have helped the CCC to address public concern regarding excessive weed growth by better understanding the dynamics of macroalgal biomass. However, some noise is present within the long-term dataset most likely a result of both earthquake induced landscape changes within the estuary bed and the release of untreated wastewater directly into the estuary (via the two rivers) following the earthquakes. This noise makes direct comparisons between pre-diversion and post-diversion somewhat challenging and a longer-term monitoring period would help reduce that noise to make for more meaningful comparisons. The survey was designed around observational monitoring based on public perception on the visual aesthetics within the estuary. Community-based organisations would be capable of undertaking this monitoring survey to help maintain the longevity of the dataset for a better understanding the dynamics of weed growth in the Avon-Heathcote Estuary.

Acknowledgements

Terry Costello (CCC) and Mr Joe McCarthy are thanked for their efforts in undertaking monthly surveys and photographic records.

Yours sincerely



Donna Sutherland
Scientist



Plate 1. Panorama of Avon-Heathcote Estuary at low tide in September 2014. Photos taken by Mr Joe McCarthy.



Plate 2. Panorama of Avon-Heathcote Estuary at low tide in October 2014. Photos taken by Mr Joe McCarthy.



Plate 3. Panorama of Avon-Heathcote Estuary at low tide in November 2014. Photos taken by Mr Joe McCarthy.



Plate 4. Panorama of Avon-Heathcote Estuary at low tide in December 2014. Photos taken by Mr Joe McCarthy.



Plate 5. Panorama of Avon-Heathcote Estuary at low tide in January 2015. Photos taken by Mr Joe McCarthy.



Plate 6. Panorama of Avon-Heathcote Estuary at low tide in February 2015. Photos taken by Mr Joe McCarthy.



Plate 7. Panorama of Avon-Heathcote Estuary at low tide in March 2015. Photos taken by Mr Joe McCarthy.



Plate 8. Panorama of Avon-Heathcote Estuary at low tide in April 2015. Photos taken by Mr Joe McCarthy.



Plate 9. Panorama of Avon-Heathcote Estuary at low tide in May 2015. Photos taken by Mr Joe McCarthy.

Appendix A. Survey sites and zones in the Avon-Heathcote Estuary.



Figure A1: Survey sites in the Avon-Heathcote Estuary.

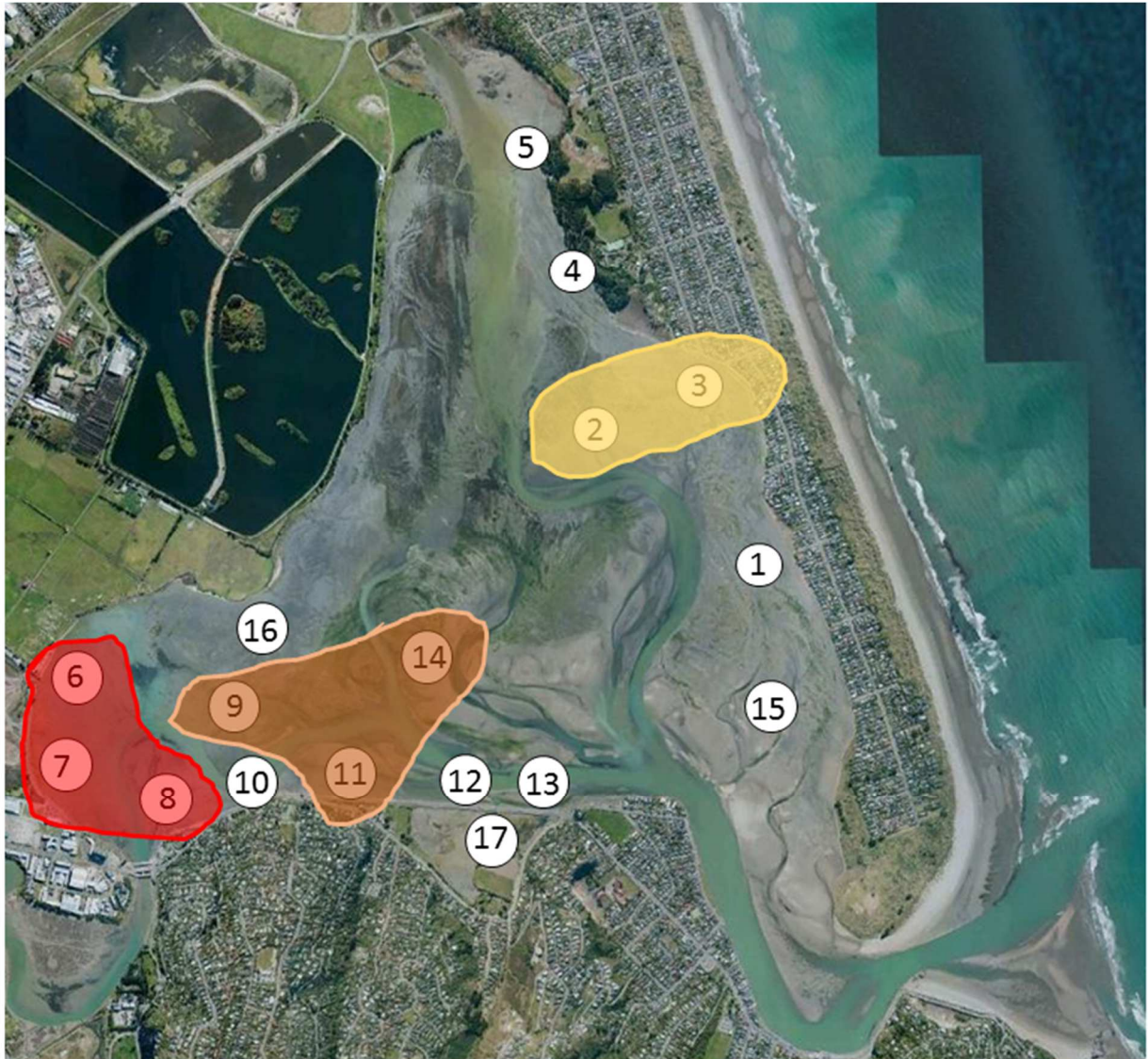


Figure A2: Location of historic *Ulva* zones in the Avon-Heathcote Estuary. Orange = Zone 1 (*Ulva* seed area); yellow = Zone 2 (Northern accumulation area) Red = Zone 3 (SW accumulation zone).



Figure A3: Location of new *Ulva* zones in the Avon-Heathcote Estuary. Orange = Zone 1 (*Ulva* seed area); yellow = Zone 2 (Northern accumulation area) Red = Zone 3 (SW accumulation zone).



Figure A4: Location of historic *Gracillaria* growth zone (purple) in the Avon-Heathcote Estuary.

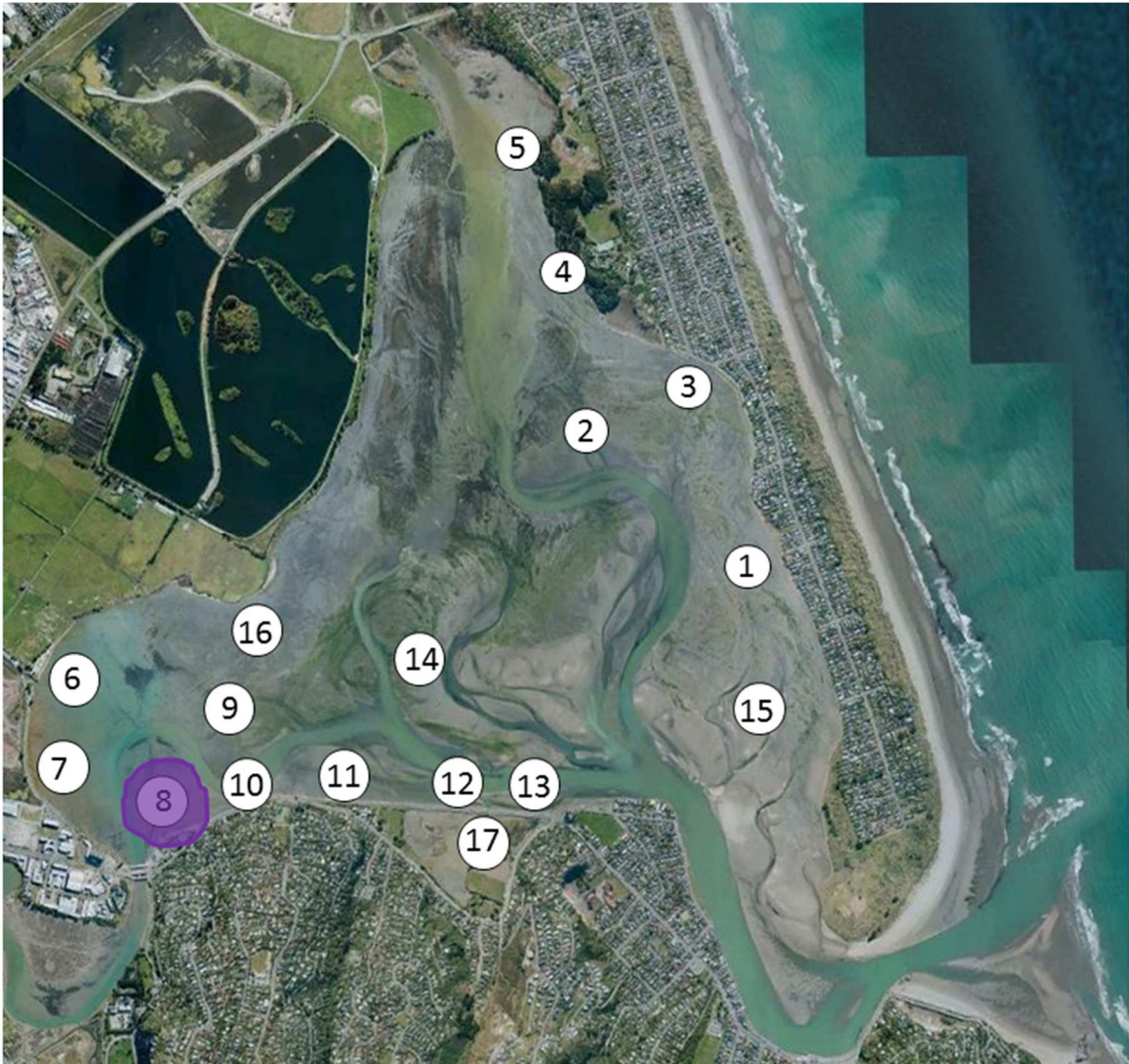


Figure A5: Location of new *Gracillaria* growth zone (purple) in the Avon-Heathcote Estuary.

Appendix B. Historic percentage cover of macroalgae in each zone in the Avon-Heathcote Estuary.

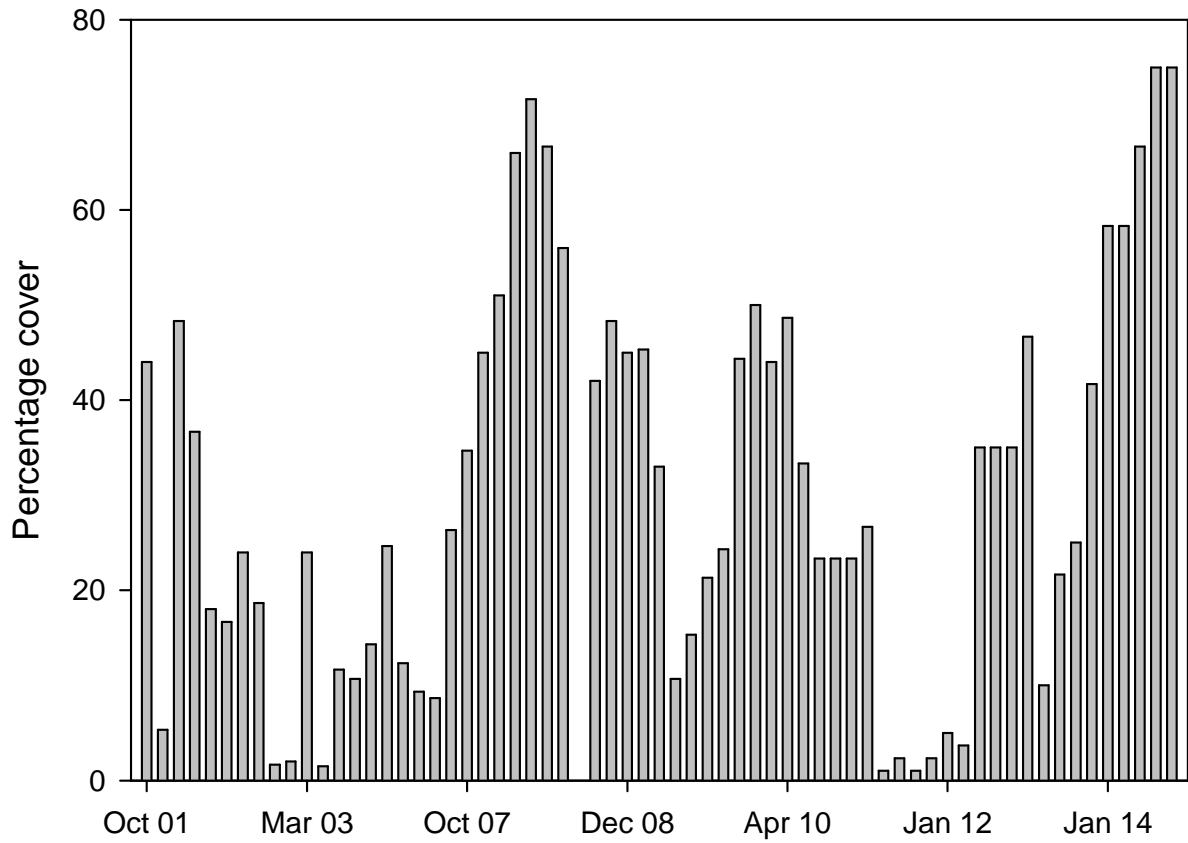


Figure B1. Observed percentage cover of *Ulva* in Zone 1 from October 2001 to March 2015.

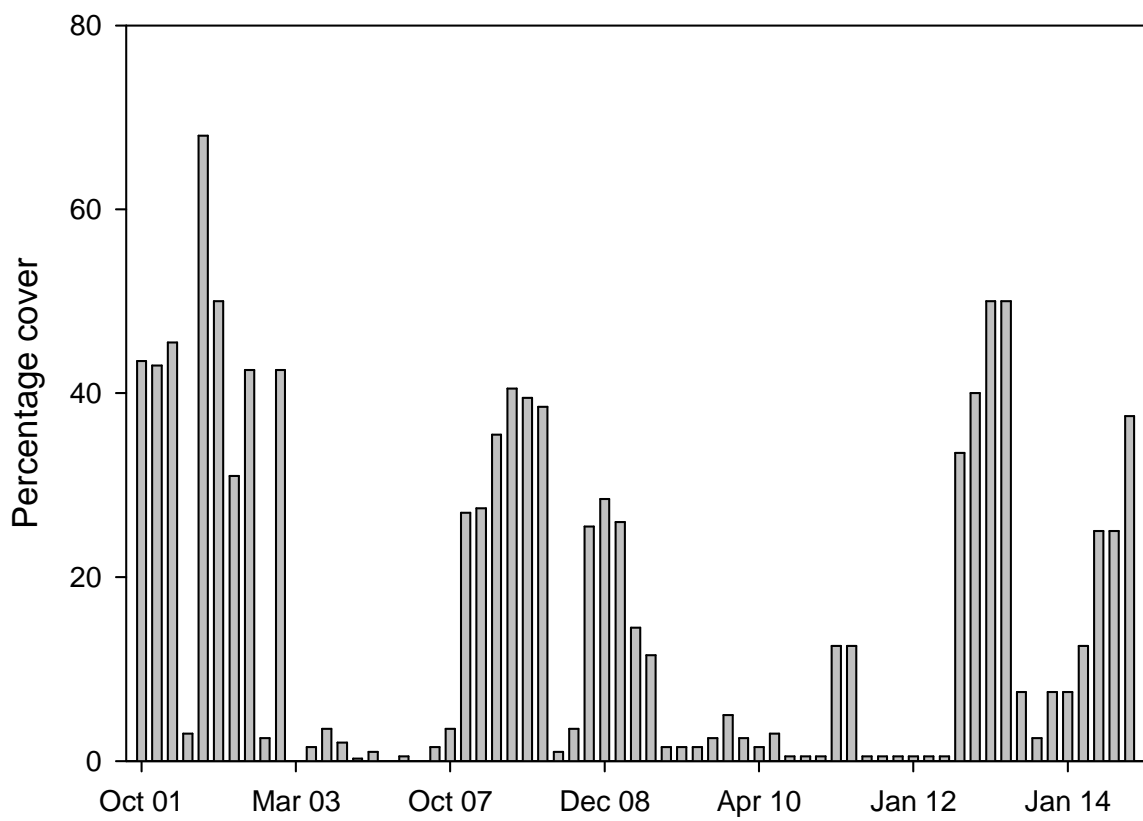


Figure B2. Observed percentage cover of *Ulva* in Zone 2 from October 2001 to March 2015.

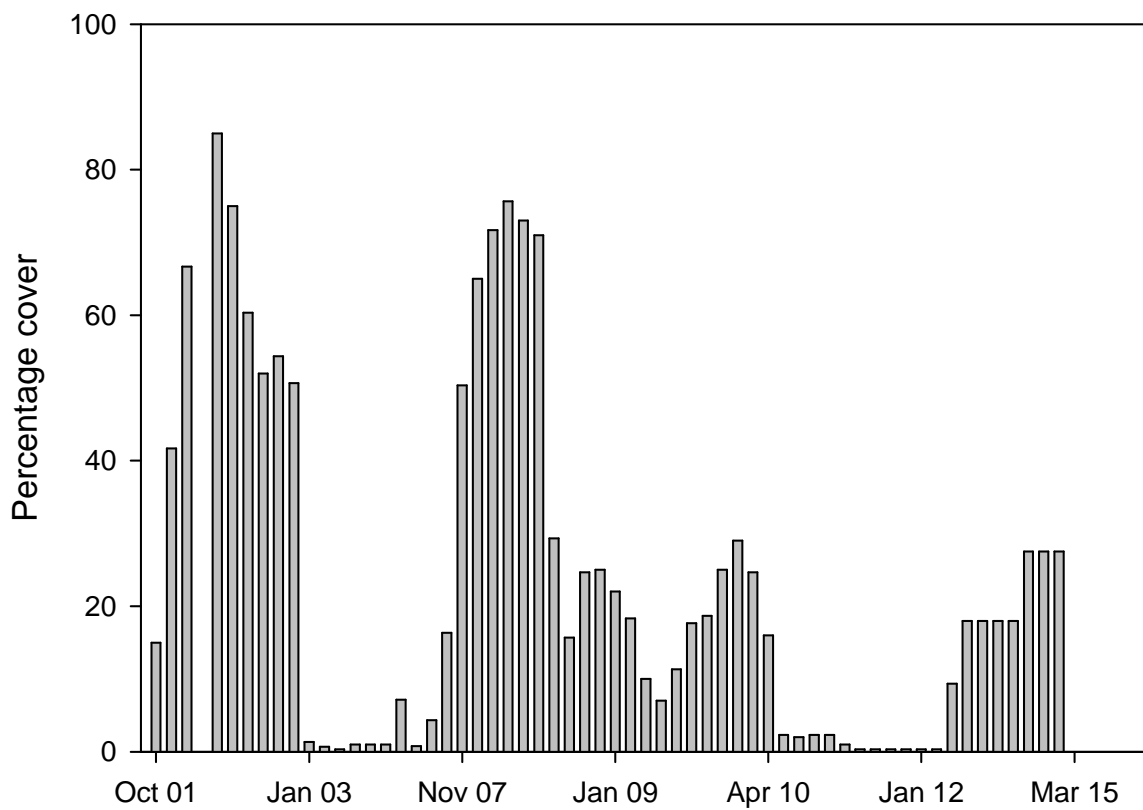


Figure B3. Observed percentage cover of *Ulva* in Zone 3 from October 2001 to March 2015.

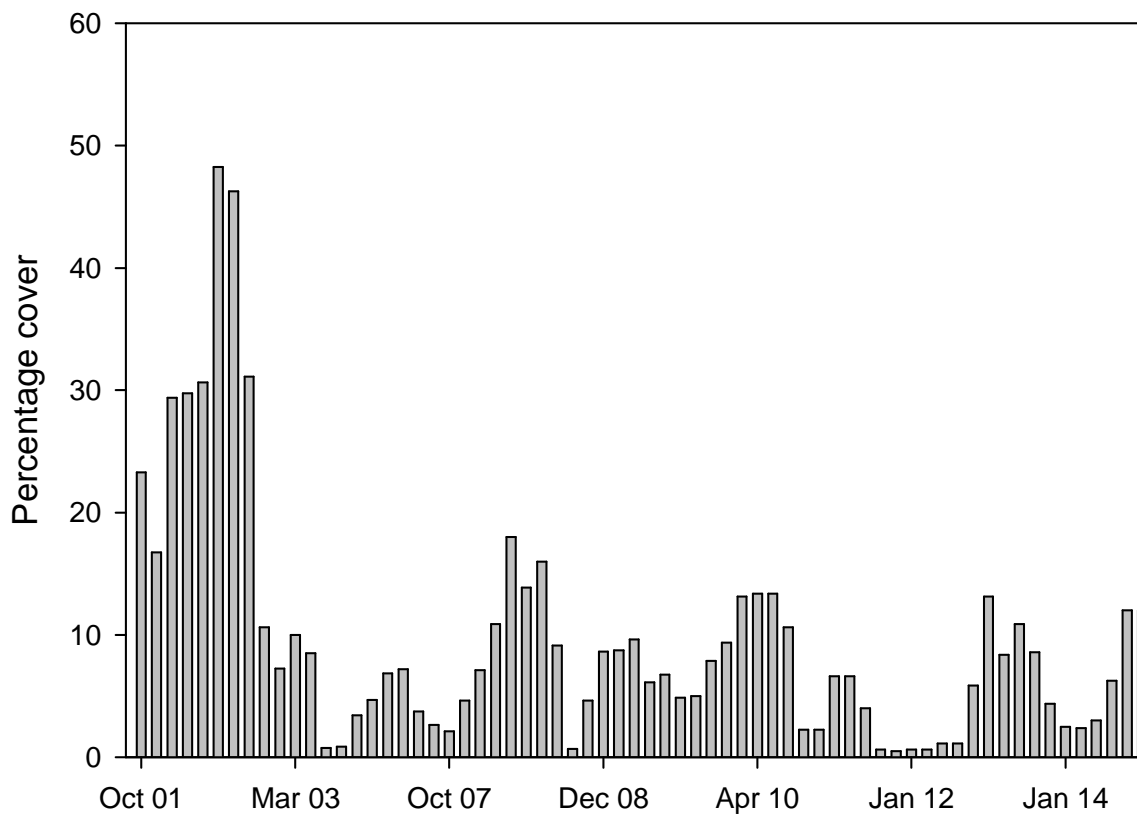


Figure B4. Observed percentage cover of *Ulva* in Zone 4 from October 2001 to March 2015.

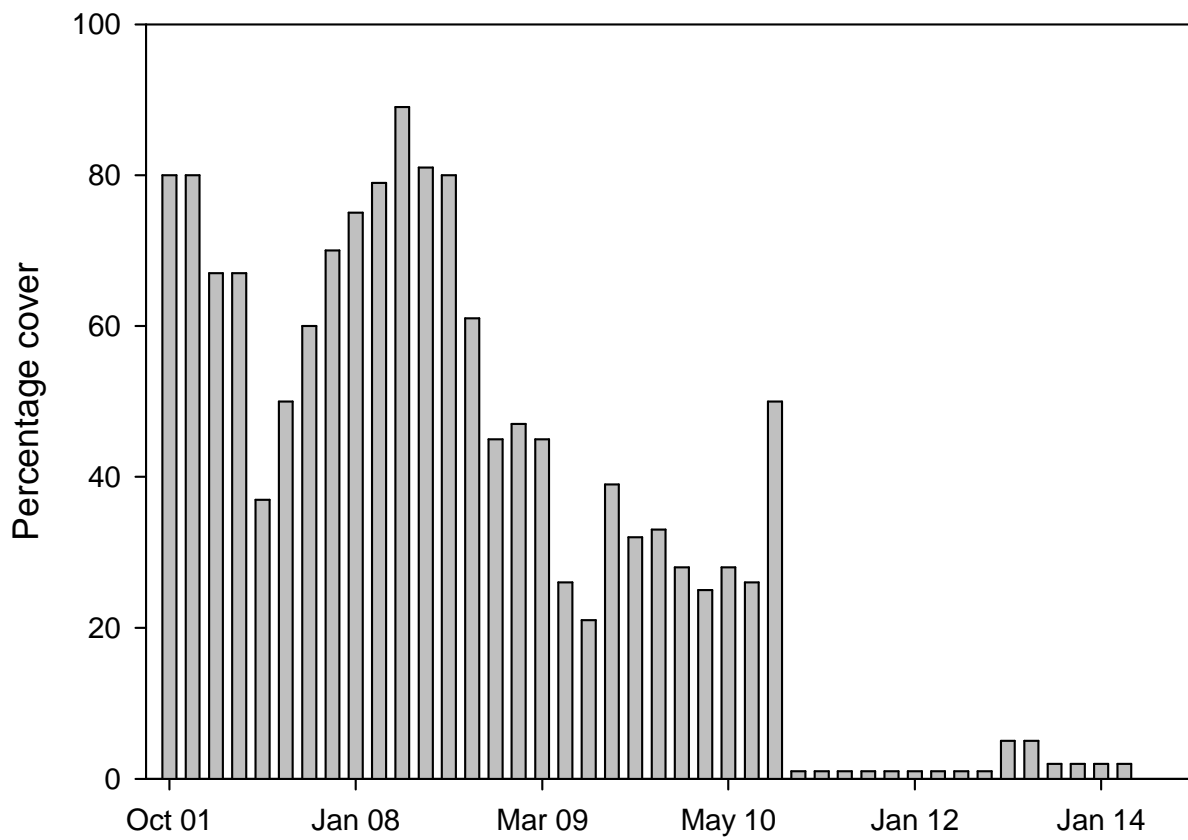


Figure B5. Observed percentage cover of *U/va* in Zone 5 from October 2001 to March 2015.