SALT ECOLOGY

Hutt Estuary
Intertidal Macroalgal Monitoring
January 2018

Prepared for:
Greater Wellington Regional Council
June 2018

Salt Ecology Report 009

ACKNOWLEDGEMENTS

Many thanks to Megan Oliver (GWRC) for her peer review and support in undertaking this work, and to the Salt Ecology team - Sabine O'Neill-Stevens for field sampling and Sally O'Neill for reporting.

Moera Stream mouth, Hutt Estuary, January 2018.

RECOMMENDED CITATION

Stevens, L.M. 2018. Hutt Estuary Intertidal Macroalgal Monitoring, January 2018. Salt Ecology Report 009. Prepared for Greater Wellington Council, May 2018. 13p.

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

Since 2010 Greater Wellington Regional Council (GWRC) has undertaken annual monitoring of intertidal opportunistic macroalgal growth in the Hutt Estuary as a primary indicator of estuary eutrophication. Opportunistic macroalgae are highly effective at utilising excess nitrogen, enabling them to out-compete other seaweed species. At nuisance levels they can form dense mats which adversely impact underlying sediments and fauna, other algae, fish, birds, seagrass, and saltmarsh. Decaying macroalgae can also accumulate subtidally and on shorelines causing oxygen depletion and nuisance odours and conditions. The greater the macroalgal cover, biomass, persistence, and extent of entrainment within sediments, the greater the subsequent impacts. This brief report summarises the results of the 9th annual survey of intertidal opportunistic macroalgal cover in Hutt Estuary, undertaken in January 2018.

2. METHODS

The assessment of macroalgae follows the UK WDF-UKTAG (2014) Opportunistic Macroalgal Blooming Tool (OMBT) approach recommended for use in NZ as part of the NZ Estuary Trophic Index (ETI) (Robertson et al. 2016a,b). The OMBT, described in detail in Appendix 1, is a 5 part multimetric index which rates macroalgal condition through calculation of an Ecological Quality Rating (EQR) ranging from 0 (major disturbance) to 1 (minimally disturbed). The score, placed within overall quality status threshold bands (i.e. low, poor, good, moderate, high), provides a comprehensive measure of the combined influence of estuary macroalgal growth and distribution.

On 20 January 2018, experienced coastal scientists walked the estuary at low tide and mapped the percentage cover of macroalgae (to the nearest 5%) directly onto laminated photos guided by a 6 category percent cover rating scale (see Figure 1 below). Within these percentage cover categories, patches of comparable macroalgal growth were identified and enumerated through field measures of biomass and the degree of macroalgal entrainment within sediment (macroalgae growing >3cm deep within sediment).

Patch biomass was measured by collecting macroalgae from within a defined area (e.g. 25 x 25cm quadrat) and placing it into a mesh bag. Sediment was rinsed from the sample and free water squeezed from the algae before it was weighed using field scales. Triplicate measures were collected from each patch and values used to derive the mean patch biomass per square metre.

If present, gross eutrophic zones (GEZs) which highlight where nuisance macroalgal conditions coincide with the presence of soft muds and the depletion of sediment oxygenation, were recorded. Sediment oxygenation was visually assessed by removing a core of sediment to reveal the depth at which sediments show a change in colour to grey/black - the apparent Redox Potential Discontinuity (aRPD) depth.

Field data were entered into ArcMap 10.5 GIS software using a Wacom Cintiq21UX drawing tablet to spatially summarise results, and values exported to a spreadsheet calculator to derive OMBT EQR values.

The report outputs are presented as a GIS-based map of macroalgal biomass (Figure 2), and an OMBT summary table including EQRs for each metric (Table 1). Raw data are in Appendix 2. Results classify macroalgal cover in relation to the EQR quality status threshold bands, and show changes in macroalgal growth over time by comparisons with previous surveys (generally annually if a problem estuary, or 5 yearly if not).

Work is ongoing in NZ to refine the observed relationships between indicators and the presence of commonly degraded estuary conditions, in particular, reviewing threshold values for macroalgal issues in different NZ estuary types and under different states of modification.

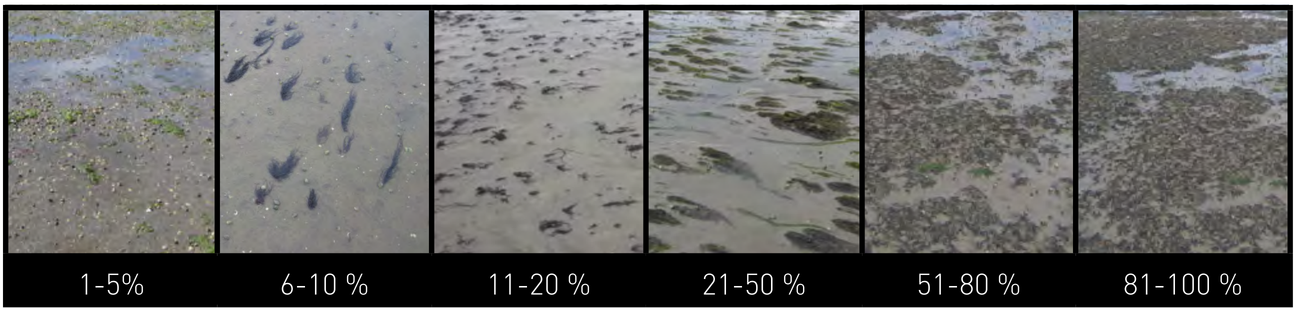


Figure 1. Visual rating scale for percentage cover estimates for opportunistic macroalgae.

3. RESULTS

The results of 20 January 2018 intertidal mapping of opportunistic macroalgal in Hutt Estuary in are summarised in Table 1 and Figure 2, with raw data in Appendix 2. The results show the highly modified estuary is confined within extensive floodbanks, with the available intertidal habitat restricted to small areas of mudflat habitat present at the mouths of the Te Mome and Moera Streams and within Waiwhetu Stream, and in narrow bands along steep rip-rap rock walls or cobble and gravel substrate. The OMBT guidance recommends areas dominated by hard substrates be excluded from calculations as algae cannot become entrained and cause degradation of underlying sediment. However, these areas have been included due to the dominance of this habitat type in the estuary, noting that the resultant macroalgal EQR scores will be conservative as the quality status metric for entrainment will be rated 'high' (i.e. no problems).

Of the 7.95ha Available Intertidal Habitat (AIH), 99% had opportunistic macroalgal growth present (Affected Area (AA) = 7.8ha).

In general, macroalgae growing along the predominantly hard substrates of the extensively modified estuary margins had low biomass (e.g. ‹50g.m^2) and could not become entrained in underlying sediment.

Low biomass growths of Ulva on cobble and gravel in the lower reaches of the estuary.

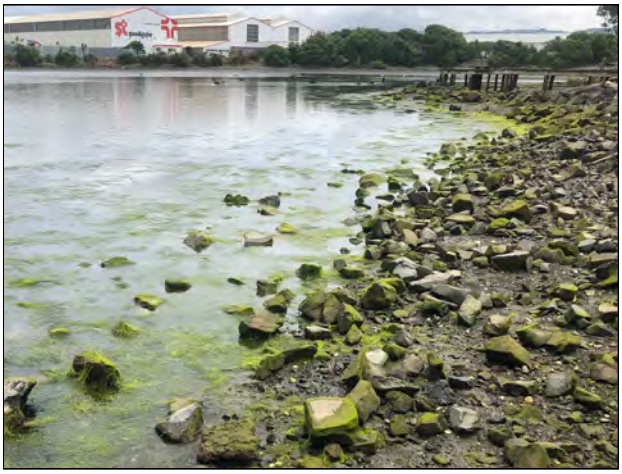
The green alga Ulva intestinalis was the dominant opportunistic macroalgal species present, growing on almost every area of available habitat. Ulva lactuca (sea lettuce) and the red alga Gracilaria were also observed as subdominant growths near the estuary mouth.

Dense intertidal and shallow subtidal growths of Ulva (biomass ›2000g.m^2) observed in 2016 (and in previous years monitoring) appeared to have been largely flushed from the estuary in January 2017, most probably by flood flows. In January 2018, monitoring showed that intertidal densities and cover remained relatively low but dense subtidal beds of algae had re-established.

Table 1. Summary of intertidal macroalgal cover, Hutt Estuary, 20 January 2018.

Opportunistic Macroalgal Blooming Tool Metric	Face Value	Final Equidistant Score	Quality Status
Available Intertidal Habitat - AIH (ha)	7.9	-	-
Percentage cover of AIH (%) = (Total % Cover / AIH} x 100 where Total % cover = Sum of {(patch size) / 100} x average % cover for patch	44.5	0.322	Poor
Biomass of AIH (g.m^2) = Total biomass / AIH where Total biomass = Sum of (patch size x average patch biomass)	91.1	0.818	High
Biomass of Affected Area - AA (g.m^2) = Total biomass / AA where Total biomass = Sum of (›5% cover patch size x average patch biomass)	93.1	0.814	High
Presence of Entrained Algae = (No. quadrats or area (ha) with entrained algae / total No. of quadrats or area (ha)) x 100	0.0	1.000	High
Affected Area (use the lowest of the following two metrics)	-	0.017	Low
Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover ›5%)	7.8	0.844	High
Size of AA in relation to AIH (%) = (AA / AIH) x 100	97.9	0.017	Low
Overall Ecological Quality Rating (EQR) (Average of Final Equidistant Scores)		0.59	**MODERATE**
Overall Gross Eutrophic Zone (GEZ) Rating	0	-	**VERY GOOD**

Figure 2. **Map of intertidal opportunistic macroalgal biomass - Hutt Estuary, 20 January 2018.**



Low biomass intertidal growth and high biomass shallow subtidal growth of Ulva near the Te Mome Stream mouth.

There were no significant intertidal GEZs identified (i.e. where high macroalgal biomass and cover is present in combination with soft muds, and depleted sediment oxygenation).

The 2018 opportunistic macroalgal EQR for Hutt Estuary was 0.59, a quality status of MODERATE and on the transition to GOOD (Table 1, Figure 3). This rating was driven primarily by the widespread presence and percent cover of macroalgae throughout most of the available habitat in the estuary - an affected area quality status of LOW and a POOR rating for percent cover respectively. These were offset by a HIGH quality status rating for biomass (low biomass) and the absence of algal entrainment in underlying sediments (principally because of the rock dominated substrate that dominates the intertidal margins). The latter pushes the EQR score upwards indicating better overall macroalgal quality than is commonly evident in the estuary.

Figure 3 shows that in 2018 the EQR score was very similar to that recorded in 2017 and remained higher (a better score) than recorded in previous years (see also Stevens and Robertson 2010-2015, Stevens et al. 2016, Stevens and O'Neill-Stevens 2017), primarily because of reduced macroalgal biomass, as well as reduced macroalgal cover on the main intertidal flats of the estuary in 2017 and 2018.

The absence of GEZs, reflecting that underlying intertidal sediments had not been significantly adversely impacted by the macroalgal growth present, met a NZ ETI condition rating of VERY GOOD.

High flushing rates in tidal river estuaries mean phytoplankton blooms are unlikely to be a significant issue in unstratified main channels and this was borne out by synoptic measurements on 20 and 22 January 2018 which showed chlorophyll-a measures <2ug/L in the Hutt River (ETI Band A, VERY GOOD), and 5-10ug/L in Moera

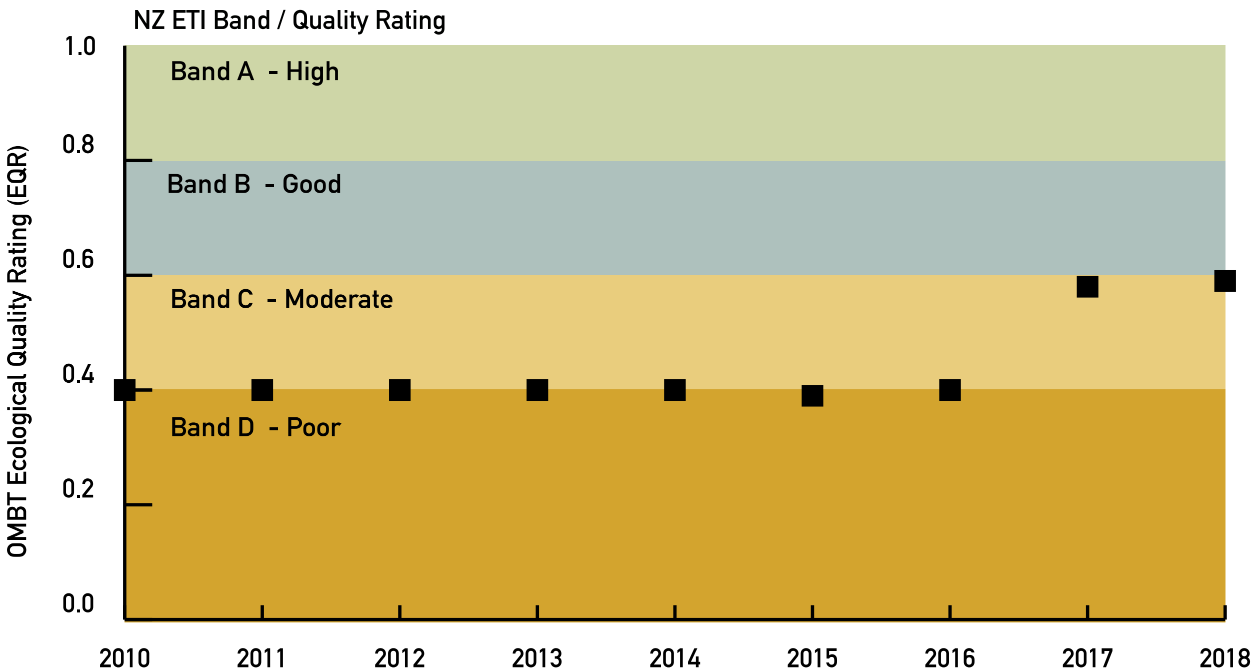


Figure 3. Macroalgal Ecological Quality Rating (EQR), Hutt Estuary, 2010-2018.

EQR values for 2010-2014 estimated based on previously mapped percentage cover and field photos showing very similar conditions to those quantified in 2015 and 2016.

and Waiwhetu Streams (ETI Band B, GOOD). However, where estuary waters were constrained by tidal flapgates in Te Mome Stream, chlorophyll-a concentrations were significantly elevated: 17-40ug/L (ETI Band D, POOR).

The export of macroalgae into subtidal settling areas (see Stevens et al. 2016) has also contributed to a significant deterioration of subtidal habitat with extensive subtidal GEZs in the lower estuary.

Luxuriant high biomass growth of <u>Ulva</u> growing on the channel edge near the Waione Street bridge.

Overall, monitoring results provide clear evidence that nutrient inputs to the estuary are sufficient to maintain consistent widespread intertidal macroalgal growth, luxuriant high biomass shallow subtidal growths, and elevated phytoplankton in flow restricted areas.

If the high level of opportunistic algal growth in the estuary is to be reduced, then nutrient load reductions are likely to be required.

4. SYNTHESIS OF RESULTS

The 2018 MODERATE macroalgal EQR reflects the widespread presence, but low biomass and entrainment, of intertidal macroalgae in the estuary, with growths not causing significantly degraded intertidal sediment conditions.

Because extensive historic reclamations of the estuary have restricted much of the intertidal habitat to rockwalls which limit areas where intertidal gross eutrophic conditions can establish, degraded conditions are not readily expressed in intertidal areas.

This is likely due to regular flushing of the estuary which appears to remove macroalgae from intertidal areas and limit the presence of nuisance conditions (rotting macroalgae and poorly oxygenated and sulphide rich sediments) to very localised areas on intertidal flats.

Synoptic monitoring in 2016 (Stevens et al. 2016) found significantly organically enriched and degraded subtidal areas near the Hutt River mouth commonly associated with the presence of rotting macroalgae.

The consistent widespread cover of opportunistic green macroalgae throughout the intertidal estuary (monitored annually since 2010) strongly suggests elevated catchment nutrient inputs (from both water column and sediment sources) are driving the observed growths.

5. CONSIDERATIONS FOR MONITORING

Because intertidal macroalgal growth in the estuary is relatively consistent, it is recommended that ongoing monitoring be moved to a 5 yearly cycle unless obvious changes are observed in the interim. Next monitoring is therefore recommended for January 2023.

As recommended previously (e.g. Stevens and O'Neill Stevens 2017, Stevens et al. 2016), to defensibly address the likely cause of opportunistic algal growths and subtidal habitat degradation GWRC has begun investigating the sources of nutrients in the Hutt River catchment with a focus on nitrogen. Following a review of research and investigations related to cyanobacteria blooms in the Hutt River (Heath & Greenfield 2016), the key sources of in-stream nitrogen (DIN) were found to be the Pakuratahi and Mangaroa streams and groundwater. In reaches of the river where groundwater upwelling occurs, the in-stream nitrogen load may increase three to six-fold during summer low flows.

Stormwater sampling undertaken during dry weather did not indicate any significant contribution of nutrients, although this requires further investigation along with nutrient contribution from the wastewater network.

Results from SoE water quality monitoring shows that the Waiwhetu Stream has the highest nutrient concentrations of all the Hutt River tributaries and though this won't contribute to cyanobacteria blooms upstream, this may promote the persistence of macroalgae in the Hutt Estuary. This report also recommends further investigation of Hutt River nitrogen sources.

In conjunction with nutrient source investigations it is recommended that a guideline limit for catchment nutrient inputs (likely to be nitrogen) be assigned to the estuary based on available catchment load/estuary response information from other relevant estuaries. This will then enable assessment of the extent to which the estuary meets guideline criteria and the potential for requiring more detailed assessments of priority catchments (e.g. estuary response modelling, stream and tributary monitoring, catchment load modelling) to support targeted management or restoration goals.

6. REFERENCES

Heath, M.W., and Greenfield, S. 2016. Benthic cyanobacteria blooms in the rivers in the Wellington Region. Greater Wellington Regional Council, Publication No. GW/ESCI-T-16/32.

Robertson, B.M., Stevens, L., Robertson, B.P., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Hume, T. and Oliver, M. 2016a. NZ Estuary Trophic Index. Screening Tool 1. Determining eutrophication susceptibility using physical and nutrient load data. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 47p.

Robertson, B.M., Stevens, L., Robertson, B.P., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Hume, T. and Oliver, M. 2016b. NZ Estuary Trophic Index. Screening Tool 2. Screening Tool 2. Determining Monitoring Indicators and Assessing Estuary Trophic State. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 68p.

Stevens, L.M. and O'Neill-Stevens, S. 2017. Hutt Estuary: Intertidal Macroalgal Monitoring 2016/17. Prepared for Greater Wellington Regional Council. 13p.

Stevens, L.M. and Robertson, B.M. 2010. Hutt River Estuary: Intertidal Macroalgal Monitoring. Prepared for Greater Wellington Regional Council. 4p.

Stevens, L.M. and Robertson, B.M. 2011. Hutt River Estuary: Intertidal Macroalgal Monitoring. Prepared for Greater Wellington Regional Council. 4p.

Stevens, L.M. and Robertson, B.M. 2012. Hutt River Estuary: Intertidal Macroalgal Monitoring. Prepared for Greater Wellington Regional Council. 4p.

Stevens, L.M., and Robertson, B. 2012. Waiwhetu Stream 2012. Broad and Fine Scale Monitoring in the Tidal Reaches. Prepared for Greater Wellington Regional Council. 35p.

Stevens, L.M. and Robertson, B.M. 2013. Hutt Estuary: Intertidal Macroalgal Monitoring 2012/13. Prepared for Greater Wellington Regional Council. 5p.

Stevens, L.M. and Robertson, B.M. 2014. Hutt Estuary: Intertidal Macroalgal Monitoring 2013/14. Prepared for Greater Wellington Regional Council. 6p.

Stevens, L.M. and Robertson, B.M. 2015. Hutt Estuary: Intertidal Macroalgal Monitoring 2014/15. Prepared for Greater Wellington Regional Council. 12p.

Stevens, L.M., Robertson, B.M. and Robertson, B.P. 2016. Hutt Estuary: 2016 Broad Scale Habitat Mapping. Prepared for Greater Wellington Regional Council. 35p.

WFD-UKTAG (Water Framework Directive – United Kingdom Technical Advisory Group). 2014. UKTAG Transitional and Coastal Water Assessment Method Macroalgae Opportunistic Macroalgal Blooming Tool. Retrieved from http://www.wfduk.org/sites/default/files/Media/Characterisation of the water environment/Biological Method Statements/TraC Macroalgae OMBT UKTAG Method Statement.PDF.

Further information also contained in:

Robertson, B.M. and Stevens, L.M. 2007. Kapiti, Southwest, South Coasts and Wellington Harbour - Risk Assessment and Monitoring Recommendations. Prepared by Wriggle Coastal Management for Greater Wellington Regional Council. 46p + appendices.

Robertson, B.M. and Stevens, L.M. 2010. Hutt Estuary: Fine Scale Monitoring 2009/10. Prepared for Greater Wellington Regional Council. 24p.

Robertson, B.M. and Stevens, L.M. 2011. Hutt Estuary: Fine Scale Monitoring 2010/11. Prepared for Greater Wellington Regional Council. 25p.

Robertson, B.M. and Stevens, L.M. 2012. Hutt Estuary: Fine Scale Monitoring 2011/12. Prepared for Greater Wellington Regional Council.

Robertson, B.M. and Stevens, L.M. 2017. Hutt Estuary: Fine Scale Monitoring 2016/17. Prepared for Greater Wellington Regional Council. 34p.

Stevens, L.M., Robertson, B.M., and Robertson, B. 2004. Broad scale mapping of sandy beaches and river estuaries - Wellington Harbour and South Coast, 2004. Prepared for Greater Wellington Regional Council. 69p.

APPENDIX 1. OPPORTUNISTIC MACROALGAL BLOOMING TOOL

OVERVIEW

The UK-WFD (Water Framework Directive) Opportunistic Macroalgal Blooming Tool (OMBT) (WFD-UKTAG 2014) is a comprehensive 5 part multimetric index approach suitable for characterising the different types of estuaries and related macroalgal issues found in NZ. The tool allows simple adjustment of underpinning threshold values to calibrate it to the observed relationships between macroalgal condition and the ecological response of different estuary types. It incorporates sediment entrained macroalgae, a key indicator of estuary degradation, and addresses limitations associated with percentage cover estimates that do not incorporate biomass e.g. where high cover but low biomass are not resulting in significantly degraded sediment conditions. It is supported by extensive studies of the macroalgal condition in relation to ecological responses in a wide range of estuaries.

The 5 part multimetric OMBT, modified for NZ estuary types, is fully described below. It is based on macroalgal growth within the Available Intertidal Habitat (AIH) - the estuary area between high and low water spring tide able to support opportunistic macroalgal growth. uitable areas are considered to consist of mud, muddy sand, sandy mud, sand, stony mud and mussel beds. Areas which are judged unsuitable for algal blooms e.g. channels and channel edges subject to constant scouring, need to be excluded from the AIH. The following measures are then taken:

1. PERCENTAGE COVER OF THE AVAILABLE INTERTIDAL HABITAT (AIH).

The percent cover of opportunistic macroalgal within the AIH is assessed. While a range of methods are described, visual rating by experienced ecologists, with independent validation of results is a reliable and rapid method. All areas within the AIH where macroalgal cover is ›5% are mapped spatially.

2. TOTAL EXTENT OF AREA COVERED BY ALGAL MATS (AFFECTED AREA (AA)) OR AFFECTED AREA AS A PERCENTAGE OF THE AIH (AA/AIH, %).

In large water bodies with proportionately small patches of macroalgal coverage, the rating for total area covered by macroalgae (Affected Area - AA) might indicate high or good status, while the total area covered could actually be quite substantial and could still affect the surrounding and underlying communities. In order to account for this, an additional metric established is the affected area as a percentage of the AIH (i.e. (AA/AIH)*100). This helps to scale the area of impact to the size of the waterbody. In the final assessment the lower of the two metrics (the AA or percentage AA/AIH) is used, i.e. whichever reflects the worse case scenario.

3. BIOMASS OF AIH ($g.m^{-2}$).

Assessment of the spatial extent of the algal bed alone will not indicate the level of risk to a water body. For example, a very thin (low biomass) layer covering 75% of a shore might have little impact on underlying sediments and fauna. The influence of biomass is therefore incorporated. Biomass is calculated as a mean for (i) the whole of the AIH and (ii) for the Affected Areas. The potential use of maximum biomass was rejected, as it could falsely classify a water body by giving undue weighting to a small, localised blooming problem. Algae growing on the surface of the sediment are collected for biomass assessment, thoroughly rinsed to remove sediment and invertebrate fauna, hand squeezed until water stops running, and the wet weight of algae recorded. For quality assurance of the percentage cover estimates, two independent readings should be within +/- 5%. A photograph should be taken of every quadrat for inter-calibration and cross-checking of percent cover determination. Measures of biomass should be calculated to 1 decimal place of wet weight of sample. For both procedures the accuracy should be demonstrated with the use of quality assurance checks and procedures.

4. BIOMASS OF AA ($g.m^{-2}$).

Mean biomass of the Affected Area (AA), with the AA defined as the total area with macroalgal cover ›5%.

5. PRESENCE OF ENTRAINED ALGAE (PERCENTAGE OF QUADRATS).

Algae are considered entrained when they are found growing ›3cm deep within muddy sediments. The persistence of algae within sediments provides both a means for over-wintering of algal spores and a source of nutrients within the sediments. Build-up of algae within sediments therefore implies that blooms can become self-regenerating given the right conditions (Raffaelli et al. 1989). Absence of weed within the sediments lessens the likelihood of bloom persistence, while its presence gives greater opportunity for nutrient exchange with sediments. Consequently, the presence of opportunistic macroalgae growing within the surface sediment was included in the tool.

Scoring:

All the metrics are equally weighted and combined within the multimetric in order to best describe the changes in the nature and degree of opportunist macroalgae growth on sedimentary shores due to nutrient pressure.

Timing:

The OMBT has been developed to classify data over the maximum growing season so sampling should target the peak bloom in summer (Dec-March in NZ), although peak timing may vary among water bodies, so local knowledge is required to identify the maximum growth period. Sampling is not recommended outside the summer period due to seasonal variations that could affect the outcome of the tool and possibly lead to misclassification; e.g. blooms may become disrupted by stormy autumn weather and often die back in winter. Sampling should be carried out during spring low tides in order to access the maximum area of the AIH.

Suitable Locations:

The OMBT is suitable for use in estuaries and coastal waters which have intertidal areas of soft sedimentary substratum (i.e. areas of AIH for opportunistic macroalgal growth). The tool is not currently used for assessing estuaries with intermittently closed mouths due to the particular challenges in setting suitable reference conditions for these water bodies.

Derivation of Threshold Values:

Published and unpublished literature, along with expert opinion, was used to derive critical threshold values suitable for defining quality status classes as part of the OMBT (Table A1) and for specific use in NZ (Table A2).

Reference Thresholds

A UK Department of the Environment, Transport and the Regions (DETR) expert workshop suggested reference threshold levels of ‹5% cover of AIH of climax and opportunistic species for high quality sites (DETR, 2001). In line with this approach, the WFD adopted ‹5% cover of opportunistic macroalgae in the AIH as equivalent to High status. From the WFD North East Atlantic intercalibration phase 1 results, German research into large sized water bodies revealed that areas over 50ha may often show signs of adverse effects, however if the overall area was less than 1/5th of this adverse effects were not seen, so the High/Good boundary was set at 10ha. In all cases a reference of 0% cover for truly un-impacted areas was assumed. Note: opportunistic algae may occur even in pristine water bodies as part of the natural community functioning. The proposal of reference conditions for levels of biomass took a similar approach, considering existing guidelines and suggestions from DETR (2001), with a tentative reference level of ‹100g.m^{-2} wet weight. This reference level was used for both the average biomass over the affected area and the average biomass over the AIH. As with area measurements, a reference of zero was assumed. An ideal of no entrainment (i.e. no quadrats revealing entrained macroalgae) was assumed to be reference for unimpacted waters. After some empirical testing in a number of UK water bodies a High / Good boundary of 1% of quadrats was set.

Class Thresholds for Percent Cover:

High / Good boundary was set at 5% based on the finding that a symptom of the potential start of eutrophication is when: (i) 25% of the available intertidal habitat has opportunistic macroalgae and (ii) at least 25% of the sediment (i.e. 25% in a quadrat) is covered (Comprehensive Studies Task Team (DETR, 2001)). This implies that an overall cover of the AIH of 6.25% (25*25%) represents the start of a potential problem. Good / Moderate boundary set at 15%. True problem areas often have a ›60% cover within the affected area of 25% of the water body (Wither 2003). This equates to 15% overall cover of the AIH (i.e. 25% of the water body covered with algal mats at a density of 60%). Poor / Bad (or Low) boundary is set at ›75%. The Environment Agency has considered ›75% cover as seriously affecting an area (Foden et al. 2010).

Class Thresholds for Biomass.

Class boundaries for biomass values were derived from DETR (2001) recommendations that ‹500g.m^{-2} wet weight was an acceptable level above the reference level of ‹100g.m^{-2} wet weight. In Good status only slight deviation from High status is permitted so $500g.m^{-2}$ represents the Good / Moderate boundary. Moderate quality status requires moderate signs of distortion and significantly greater deviation from High status to be observed. The presence of $>500g.m^{-2}$ but $<1,000$ $g.m^{-2}$ would lead to a classification of Moderate quality status at best, but would depend on the percentage of the AIH covered. $>1000g.m^{-2}$ wet weight causes significant harmful effects on biota (DETR 2001, Lowthion et al. 1985, Hull 1987, Wither 2003).

Thresholds for Entrained Algae.

Empirical studies testing a number of scales were undertaken on a number of impacted waters. Seriously impacted waters have a very high percentage (>75%) of the beds showing entrainment (Poor / Bad [or Low] boundary). Entrainment was felt to be an early warning sign of potential eutrophication problems so a tight High / Good standard of 1% was selected (this allows for the odd change in a quadrat or error to be taken into account). Consequently the Good / Moderate boundary was set at 5% where (assuming sufficient quadrats were taken) it would be clear that entrainment and potential over wintering of macroalgae had started.

:

EQR Calculation:

Each metric in the OMBT has equal weighting and is combined to produce the Ecological Quality Ratio score (EQR).

The face value metrics work on a sliding scale to enable an accurate metric EQR value to be calculated; an average of these values is then used to establish the final water body level EQR and classification status. The EQR determining the final water body classification ranges between a value of zero to one and is converted to a Quality Status by using the following categories:

Bad [or Low] 0.0 - <0.2, Poor >0.2 - <0.4, Moderate >0.4 - <0.6, Good >0.6 - <0.8, High >0.8 - 1.0.

The EQR calculation process is as follows:

1. Calculation of the face value (e.g. percentage cover of AIH) for each metric. To calculate the individual metric face values:

Percentage cover of AIH (%) = (Total % Cover / AIH} x 100 - where Total % cover = Sum of {(patch size) / 100} x average % cover for patch.

Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover >5%).

Biomass of AIH ($g.m^{-2}$) = Total biomass / AIH - where Total biomass = Sum of (patch size x average biomass for the patch).

Biomass of Affected Area ($g.m^{-2}$) = Total biomass / AA - where Total biomass = Sum of (patch size x average biomass for the patch).

Presence of Entrained Algae = (No. quadrats with entrained algae / total no. of quadrats) x 100.

Size of AA in relation to AIH (%) = (AA/AIH) x 100.

2. Normalisation and rescaling to convert the face value to an equidistant index score (0-1 value) for each index (Table A3).

The face values are converted to an equidistant EQR scale to allow combination of the metrics. These steps have been mathematically combined in the following equation:

Final Equidistant Index score = Upper Equidistant range value – ({Face Value - Upper Face value range} * (Equidistant class range / Face Value Class Range)).

Table A3 gives the critical values at each class range required for the above equation. The first three numeric columns contain the face values (FV) for the range of the index in question, the last three numeric columns contain the values of the equidistant 0-1 scale and are the same for each index. The face value class range is derived by subtracting the upper face value of the range from the lower face value of the range. Note: the table is "simplified" with rounded numbers for display purposes. The face values in each class band may have greater than (>) or less than (<) symbols associated with them, for calculation a value of <5 is given a value of 4.999'.

The final EQR score is calculated as the average of equidistant metric scores.

A spreadsheet calculator is available to download from the UK WFD website to undertake the calculation of EQR scores.

REFERENCES

DETR, 2001. Development of ecological quality objectives with regard to eutrophication. Final report, unpublished.

Foden, J., Wells, E., Scanlan, C., Best M.A. 2010. Water Framework Directive development of classification tools for ecological assessment: Opportunistic Macroalgae Blooming. UK TAG Report for Marine Plants Task Team, January 2010, Publ. UK TAG.

Hull, S.C., 1987. Macroalgal mats and species abundance: a field experiment. Estuar. Coast. Shelf Sci. 25, 519-532.

Lowthion, D., Soulsby, P.G., and Houston, M.C.M. 1985. Investigation of a eutrophic tidal basin: 1. Factors affecting the distribution and biomass of macroalgae. Marine Environmental Research 15: 263–284.

Raffaelli, D., Hull, S., Milne, H., 1989. Long-term changes in nutrients, weedmats and shore birds in an estuarine system. Cah. Biol. Mar. 30, 259–270.

WFD-UKTAG (Water Framework Directive – United Kingdom Technical Advisory Group) 2014. UK-TAG Transitional and Coastal Water Assessment Method Macroalgae Opportunistic Macroalgal Blooming Tool. Retrieved from http://www.wfduk.org/sites/default/files/Media/Characterisation of the water environment/Biological Method Statements/TraC Macroalgae OMBT UKTAG Method Statement.PDF.

Wither, A., 2003. Guidance for sites potentially impacted by algal mats (green seaweed). EC Habitats Directive Technical Advisory Group report WQTAG07c.

Table A1. The final face value thresholds and metrics for levels of the ecological quality status.

Quality Status	High	Good	Moderate	Poor	Low#
EQR (Ecological Quality Rating)	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	≥0.2 - <0.4	0.0 - <0.2
% cover on Available Intertidal Habitat (AIH)	0 - ≤5	>5 - ≤15	>15 -≤25	>25 - ≤75	>75 - 100
Affected Area (AA) of ›5% macroalgae (ha)*	≥0 - 10	≥10 - 50	≥50 - 100	≥100 - 250	≥250
AA/AIH (%)*	≥0 - 5	≥5 - 15	≥15 - 50	≥50 - 75	≥75 - 100
Average biomass (g.m^{-2}) of AIH	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000
Average biomass (g.m^{-2}) of AA	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000
% algae ›3cm deep	≥0 - 1	≥1 - 5	≥5 - 20	≥20 - 50	≥50 - 100

*N.B. Only the lower EQR of the 2 metrics, AA or AA/AIH is used in the final EQR calculation.

Table A2. The final face value thresholds and metrics for levels of ecological quality status used to rate opportunistic macroalgae in the current in the study (modified from UK-WFD 2014).

Quality Status	High	Good	Moderate	Poor	Low#
EQR (Ecological Quality Rating)	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	≥0.2 - <0.4	0.0 - <0.2
% cover on Available Intertidal Habitat (AIH)	0 - ≤5	>5 - ≤15	>15 -≤25	>25 - ≤75	>75 - 100
Affected Area (AA) of ›5% macroalgae (ha)*	≥0 - 10	≥10 - 50	≥50 - 100	≥100 - 250	≥250
AA/AIH (%)*	≥0 - 5	≥5 - 15	≥15 - 50	≥50 - 75	≥75 - 100
Average biomass (g.m^{-2}) of AIH	≥0 - 100	≥100 - 200	≥200 - 500	≥500 - 1450	≥1450
Average biomass (g.m^{-2}) of AA	≥0 - 100	≥100 - 200	≥200 - 500	≥500 - 1450	≥1450
% algae ›3cm deep	≥0 - 1	≥1 - 5	≥5 - 20	≥20 - 50	≥50 - 100

*N.B. Only the lower EQR of the 2 metrics, AA or AA/AIH is used in the final EQR calculation.

[#] The UK-WFD term "Bad" has been replaced with "Low".

Table A3. Values for the normalisation and re-scaling of face values to EQR metric.

Metric	QUALITY STATUS	FACE VALUE RANGES: Lower face value range (measurements towards the "Bad" end of this class range)	Upper face value range (measurements towards the "High" end of this class range)	Face Value Class Range	EQUIDISTANT CLASS RANGE: Lower 0-1 Equidistant range value	Upper 0-1 Equidistant range value	Equidistant Class Range
% Cover of Available Intertidal Habitat (AIH)	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.999	≥0.6	<0.8	0.2
	Moderate	≤25	>15	9.999	≥0.4	<0.6	0.2
	Poor	≤75	>25	49.999	≥0.2	<0.4	0.2
	Low[#]	100	>75	24.999	0	<0.2	0.2
Average Biomass of AIH ($g\ m^{-2}$)	High	≤100	0	100	≥0.8	1	0.2
	Good	≤500	>100	399.999	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.999	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.999	≥0.2	<0.4	0.2
	Low[#]	≤6000	>3000	2999.999	0	<0.2	0.2
Average Biomass of Affected Area (AA) ($g\ m^{-2}$)	High	≤100	0	100	≥0.8	1	0.2
	Good	≤500	>100	399.999	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.999	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.999	≥0.2	<0.4	0.2
	Low[#]	≤6000	>3000	2999.999	0	<0.2	0.2
Affected Area (Ha)*	High	≤10	0	100	≥0.8	1	0.2
	Good	≤50	>10	39.999	≥0.6	<0.8	0.2
	Moderate	≤100	>50	49.999	≥0.4	<0.6	0.2
	Poor	≤250	>100	149.999	≥0.2	<0.4	0.2
	Low[#]	≤6000	>250	5749.999	0	<0.2	0.2
AA/AIH (%)*	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.999	≥0.6	<0.8	0.2
	Moderate	≤50	>15	34.999	≥0.4	<0.6	0.2
	Poor	≤75	>50	24.999	≥0.2	<0.4	0.2
	Low[#]	100	>75	27.999	0	<0.2	0.2
% Entrained Algae	High	≤1	0	1	≥0.0	1	0.2
	Good	≤5	>1	3.999	≥0.2	<0.0	0.2
	Moderate	≤20	>5	14.999	≥0.4	<0.2	0.2
	Poor	≤50	>20	29.999	≥0.6	<0.4	0.2
	Low[#]	100	>50	49.999	1	<0.6	0.2

[#] The UK-WFD term "Bad" has been replaced with "Low".

APPENDIX 2. RAW DATA

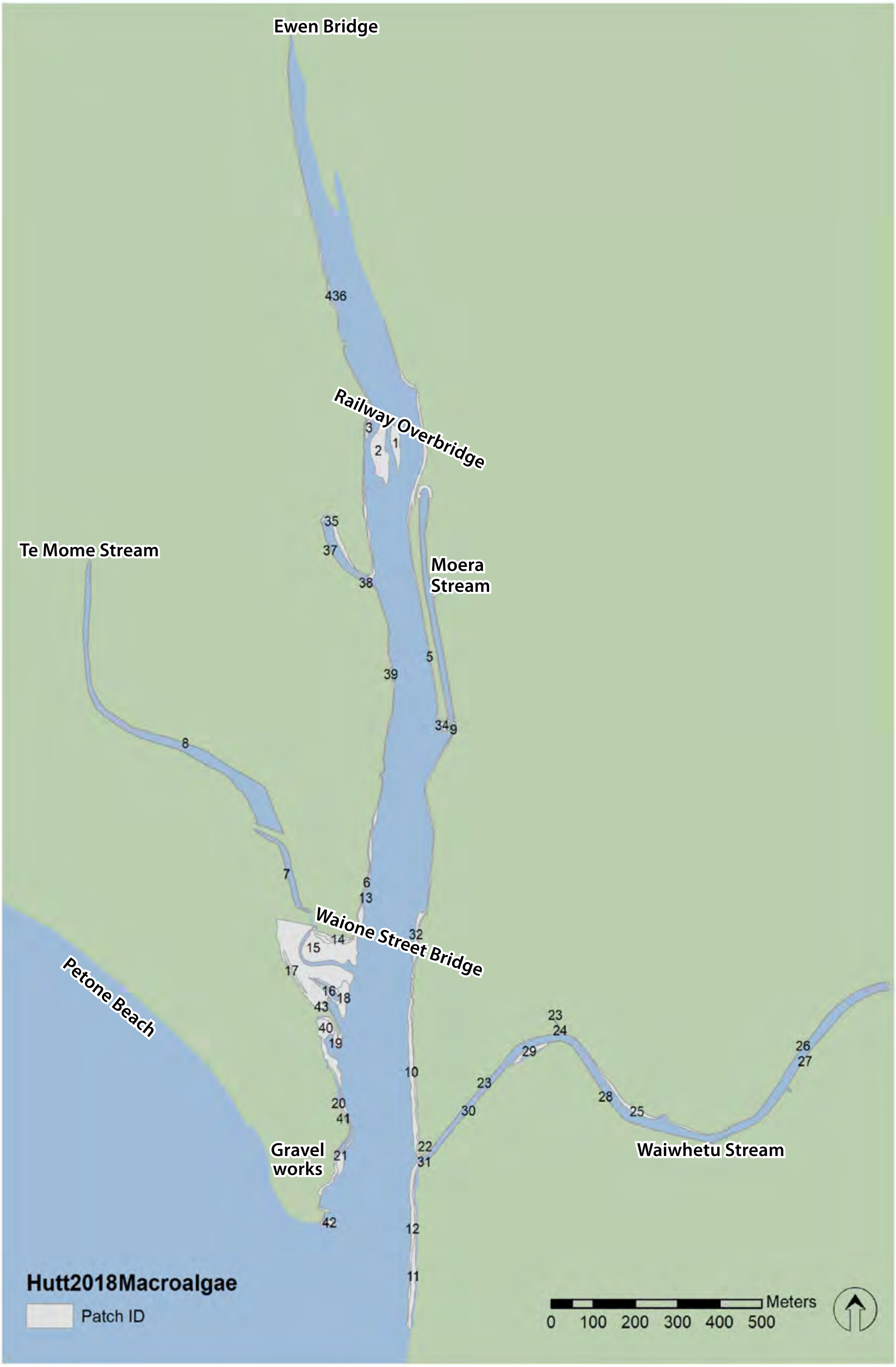


Figure A1. Location of macroalgal patches ›5% cover used in assessing Hutt Estuary, 20 January 2018.

Patch ID	Dominant species	Patch area (ha)	Percent cover of macroalgae	Presence (1) or absence (0) of entrained algae	Mean Biomass (g.m^{-2} wet weight)	Patch Biomass (kg wet weight)	Presence (1) or absence (0) of sed anoxia	Presence (1) or absence (0) of soft mud
1	Ulva intestinalis	0.16	50	0	30	47	0	0
2	Ulva intestinalis	0.44	50	0	30	132	0	0
3	Ulva intestinalis	0.05	50	0	30	14	0	0
4	Ulva intestinalis	0.33	50	0	50	163	0	0
5	Ulva intestinalis	0.96	80	0	80	770	0	0
6	Ulva intestinalis	0.22	80	0	100	225	0	0
7	Ulva intestinalis	0.05	75	0	10	5	0	0
8	Ulva intestinalis	0.18	75	0	10	18	0	0
9	Ulva intestinalis	0.02	100	0	200	41	0	0
10	Ulva intestinalis	0.34	50	0	50	169	0	0
11	Ulva intestinalis	0.25	20	0	20	50	0	0
12	Ulva intestinalis	0.23	100	0	50	114	0	0
13	Ulva intestinalis	0.18	80	0	100	177	0	0
14	Ulva intestinalis	0.08	80	0	800	630	0	0
15	Ulva intestinalis	2.00	10	0	50	998	0	0
16	Ulva intestinalis	0.09	100	0	200	178	0	0
17	Ulva intestinalis	0.05	60	0	300	148	0	0
18	Ulva intestinalis	0.14	30	0	50	71	0	0
19	Ulva intestinalis, U. lactuca, Gracilaria chilensis	0.11	20	0	10	11	0	0
20	Ulva intestinalis, U. lactuca, Gracilaria chilensis	0.06	65	0	1200	708	0	0
21	Ulva intestinalis, U. lactuca, Gracilaria chilensis	0.10	20	0	75	72	0	0
22	Ulva intestinalis	0.01	50	0	80	6	0	0
23	Ulva intestinalis	0.03	20	0	10	3	0	0
24	Ulva intestinalis	0.01	80	0	50	5	0	0
25	Ulva intestinalis	0.20	40	0	75	147	0	0
26	Ulva intestinalis	0.05	70	0	30	15	0	0
27	Ulva intestinalis	0.04	70	0	30	13	0	0
28	Ulva intestinalis	0.03	90	0	30	10	0	0
29	Ulva intestinalis	0.10	30	0	80	77	0	0
30	Ulva intestinalis	0.02	20	0	10	2	0	0
31	Ulva intestinalis	0.01	50	0	80	7	0	0
32	Ulva intestinalis	0.10	30	0	450	434	0	0
33	Ulva intestinalis	0.01	20	0	50	5	0	0
34	Ulva intestinalis	0.04	50	0	100	42	0	0
35	Ulva intestinalis	0.26	50	0	50	131	0	0
36	Ulva intestinalis	0.33	80	0	40	131	0	0
37	Ulva intestinalis	0.02	80	0	60	10	0	0
38	Ulva intestinalis	0.01	40	0	30	3	0	0
39	Ulva intestinalis	0.01	30	0	50	6	0	0
40	Ulva intestinalis, U. lactuca, Gracilaria chilensis	0.29	10	0	200	572	0	0
41	Ulva intestinalis, U. lactuca, Gracilaria chilensis	0.02	80	0	2500	558	0	0
42	Ulva intestinalis	0.14	30	0	10	14	0	0
42	Ulva intestinalis	0.03	80		900	310		
	Total	7.9ha				7246 kg		