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# Hutt Estuary

## Intertidal Macroalgal Monitoring 2016/17

Prepared for
**Greater Wellington Regional Council**
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Cover Photo: *Ulva* growing intertidally at the edge of the main Hutt River, January 2017.

Sparse cover of *Ulva* on the main intertidal flats, Hutt River, January 2017.

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Prepared for
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By

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Royal spoonbills on the upper intertidal flats at Te Mome. Macroalgal cover conspicuously absent from this area in Jan. 2017.

# 1. INTRODUCTION AND METHODS

## INTRODUCTION

Opportunistic macroalgae are a primary symptom of estuary eutrophication. They are highly effective at utilising excess nitrogen, enabling them to out-compete other seaweed species and, at nuisance levels, can form mats on the estuary surface 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 8th annual survey of intertidal opportunistic macroalgal cover in Hutt Estuary, undertaken in January 2017.
It describes an approach combining measures of i. macroalgal growth, ii. sediment oxygenation, and iii. mud content, to determine overall macroalgal condition and the presence of gross eutrophic zones. Macroalgal monitoring results (described in Section 2) are used in conjunction with the wider suite of broad and fine scale monitoring results (e.g. Stevens and Robertson 2004, 2012, Robertson and Stevens 2010, 2011, 2012, Stevens et al. 2016) when assessing overall estuary condition.

## METHODS


Measuring algal biomass:
1. collect macroalgae from quadrat,
2. place in mesh bag and squeeze out free water,
3. weigh.

The macroalgal assessment is based on the broad scale mapping of intertidal habitat in Hutt River where macroalgae is potentially able to grow. Experienced coastal scientists recorded the percentage cover (to the nearest 5%) of macroalgae directly onto laminated photos in the field guided by a 5 category percent cover rating scale (see Figure 1 below). Within these percentage cover categories, patches of comparable macroalgal growth were identified and each patch enumerated through field measures of biomass and the degree of macroalgal entrainment within sediment. In addition, the presence of soft muds and surface sediment anoxia were noted when macroalgal growth was present in order to assess whether gross nuisance conditions had established. Field data were entered into ArcMap 10.5 GIS software using a Wacom Cintiq21UX drawing tablet to spatially summarise results.

Results were interpreted using a multi-index approach that included:

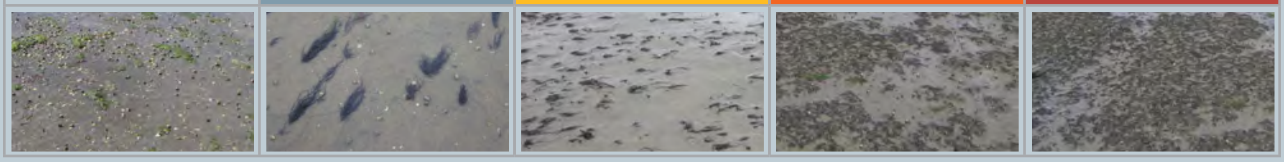
- percent cover of opportunistic macroalgae (the spatial extent and density of algal cover providing an early warning of potential eutrophication issues).
- macroalgal biomass (providing a direct measure of areas of excessive growth).
- extent of algal entrainment in sediment (highlighting where nuisance condition have a high potential for establishing and persisting).
- gross eutrophic zones (highlighting significant sediment degradation by measuring where there is a combined presence of high algal cover or biomass, low sediment oxygenation, and soft muds).

The key component of the interpretative approach is use of a modified Opportunistic Macroalgal Blooming Tool (OMBT). The OMBT, described in detail in Appendix 1, is a 5 part multimetric index that produces an overall Ecological Quality Rating (EQR) ranging from 0 (major disturbance) to 1 (minimally disturbed) and which is placed within overall quality status threshold bands (i.e. bad, poor, good, moderate, high) to rate macroalgal condition (Table 1). This integrated index provides a comprehensive measure of the combined influence of macroalgal growth and distribution in the estuary. The expression of macroalgal issues is further assessed by monitoring the presence of gross eutrophic zones which highlight where nuisance conditions have established.

The report outputs are presented as a GIS-based map of macroalgal biomass (Figure 3), a summary table, including ecological quality ratings (Table 2), with raw data in Appendix 2. Results are intended to both classify macroalgal cover in relation to the proposed quality ratings, and show changes in macroalgal growth over time by comparisons with previous surveys (e.g. annually if a problem estuary, or 5 yearly if not).

**Figure 1. Visual rating scale for percentage cover estimates of macroalgae.**

| 0-5% | >5-15 % | >15-25 % | >25-75 % | >75-100 % |
|---|---|---|---|---|



# 1. Introduction and Methods (Cont...)

**CONDITION RATINGS**

Table 1 below summarises the various parameters used to rate macroalgal ecological condition and gross eutrophic zones in the current report. Brief supporting notes explaining the use and justifications for each indicator parameter are included below Table 1, with full details on the calculation of the EQR presented in Appendix 1.

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.

**Table 1. Summary of macroalgal ecological condition ratings used in the present report.**

| MACROALGAL ECOLOGICAL QUALITY RATING (WFD_UKTAG (2014) OBMT approach - see details in Appendix 1) | | | | | |
|---|---|---|---|---|---|
| EQR (ECOLOGICAL QUALITY RATING) [1] | High | Good | Moderate | Poor | Bad |
| | ≥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) [>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 entrained >3cm deep | ≥0 - 1 | ≥1 - 5 | ≥5 - 20 | ≥20 - 50 | ≥50 - 100 |
| Gross Eutrophic Zones (ha) **[2] | ≥0-0.5ha | ≥0.5-5ha | ≥5-20ha | ≥20-30ha | ≥30ha |

*Only the lower EQR of the 2 metrics, AA or AA/AIH is used in the final EQR calculation - see Appendix 1 for further detail.

** Additional rating used to support the EQR.

NOTES TO TABLE 1:

Opportunistic macroalgae can grow to nuisance bloom proportions when nutrient levels are elevated and there is sufficient light to support growth. Opportunistic species generally survive well in conditions in which other species struggle to survive or compete and, consequently, they most commonly reach nuisance conditions in shallow estuaries, or the margins of deeper estuaries.

[1]Ecological Quality Rating: The OMBT Ecological Quality Rating (EQR) is fully described in Appendix 1. The EQR approach has been applied in place of the previous Low Density Macroalgal Coefficient developed by Wriggle for NZ estuaries because it incorporates a more comprehensive assessment of key parameters, particularly macroalgal biomass and entrainment. It provides both an early warning of increasing or widespread low density growth, as well as warning of excessive dense growth within those parts of an estuary where macroalgae can potentially establish, and conditions under which gross eutrophic conditions are likely to establish (areas with dense growths of algae entrained in sediment). Annual macroalgal monitoring is recommended when the EQR is rated either POOR or BAD, otherwise 5 yearly. EQR thresholds for a range of NZ estuary types and conditions are proposed for inclusion in the Ministry for the Environment National Objectives Framework (NOF) for estuaries, with ongoing validation being used to tailor thresholds as appropriate for individual NZ estuaries.

[2]Gross Eutrophic Zones: Gross eutrophic conditions occur when sediments exhibit combined symptoms of: a high mud content, a shallow Redox Potential Discontinuity (RPD) depth, elevated nutrient and total organic carbon concentrations, displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover) or density (>500g.m$^{-2}$). Persistent and extensive areas of gross nuisance conditions should not be present in short residence time estuaries, and their presence provides a clear signal that the assimilative capacity of the estuary is being exceeded. Consequently, the actual area exhibiting nuisance conditions, rather than the % of an estuary affected, is the primary condition indicator. Natural deposition and settlement areas, often in the upper estuary where flocculation at the freshwater/saltwater interface occurs, are commonly first affected. The gross eutrophic condition rating is based on the area affected by the combined presence of poorly oxygenated and muddy sediments, and a dense (>50%) macroalgal cover or density (>500g.m$^{-2}$).

Because of the highly undesirable and often rapidly escalating decline in estuary quality associated with gross eutrophic conditions, even relatively small changes from baseline conditions should be evaluated as a priority, while any trend of an increasing EQR or increasing area of gross eutrophic conditions indicate changes in catchment land use management are likely to be needed.

# 2. RESULTS, RATING, RECOMMENDATIONS

The results of intertidal mapping of opportunistic macroalgal in Hutt Estuary in January 2017 are summarised in Figure 3 and Table 2, with full data in Appendix 2. The results show:

- As the highly modified estuary is confined within extensive floodbanks, the available intertidal habitat is restricted to narrow bands along steep rip-rap rock walls and small areas of mudflat habitat present at the mouths of the Te Mome and Moera Streams and within Waiwhetu Stream.
- Of the Available Intertidal Habitat (7.95ha), 99% had opportunistic macroalgal growth present (Affected Area = 7.9ha).
- In general, macroalgae growing along the predominantly hard substrates of the extensively modified estuary margins had a low biomass (e.g. <50g.m-$^{2}$) and was not entrained in underlying sediment.
- 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* observed in previous years monitoring (biomass >2000g.m-$^{2}$) appeared to have been largely flushed from the estuary in Jan. 2017, most probably by flood flows. Subtidal algae was still present in the lower channel margins below Moera Stream mouth and below the Waione Street bridge, but in much lower densities than observed in 2016.
- There were no significant intertidal gross eutrophic zones identified (a combined presence of high macroalgal biomass and cover, soft muds, and sediment oxygenation at the surface).

Low *Ulva* biomass (high cover) near the Waione Street bridge.

Low *Ulva* biomass (high cover), upstream of Te Mome Stream.

Low *Ulva* biomass (high cover) near Waiwhetu Stream.

Low *Ulva* biomass (low cover) in the lower Hutt River.

**Figure 2. Photos showing opportunistic macroalgal growth - Hutt Estuary, January 2017.**

# 3. Results, Rating and Recommendations (Cont...)


Figure 3. Map of intertidal opportunistic macroalgal biomass - Hutt Estuary, January 2017.

**Table 2. Summary of intertidal macroalgal cover,** Hutt Estuary, **January 2017.**

| Metric | Face Value | Final Equidistant Score (FEDS) | Quality Status |
|---|---|---|---|
| AIH - Available Intertidal Habitat (ha) | 7.9 | | |
| Percentage cover of AIH (%) = (Total % Cover / AIH} x 100<br>*where Total % cover = Sum of {(patch size) / 100} x average % cover for patch* | 46.9 | 0.312 | Poor |
| Biomass of AIH (g.m$^{-2}$) = Total biomass / AIH<br>*where Total biomass = Sum of (patch size x average patch biomass)* | 103.0 | 0.794 | Good |
| Biomass of Affected Area (g.m$^{-2}$) = Total biomass / AA<br>*where Total biomass = Sum of (>5% cover patch size x average patch biomass)* | 103.4 | 0.793 | Good |
| Presence of Entrained Algae = (No. quadrats or area (ha) with entrained algae / total no. of quadrats or area (ha)) x 100 | 0 | 1.0 | High |
| Affected Area (use the lowest of the following two metrics) | | 0.003 | Bad |
| Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover >5%) | 7.9 | 0.842 | High |
| Size of AA in relation to AIH (%) = (AA / AIH) x 100 | 99.6 | 0.003 | Bad |
| | | | |
| Gross Eutrophic Zones (ha) (*where GEZ = combined area with soft mud, RPD =0cm, and macroalgal biomass>500g.m$^{-2}$ or percentage cover>50%)* | 0 | n/a | High |
| | | | |
| **OVERALL ECOLOGICAL QUALITY RATING - EQR (AVERAGE OF FEDS)** | | **0.58** | **MODERATE** |
| **OVERALL GROSS EUTROPHIC ZONE RISK RATING** *GEZ (ha) = combined area with soft mud, RPD =0cm, and macroalgal biomass>500g.m$^{-2}$ or % cover>50%* | 0 | n/a | **VERY LOW** |
| | | | |
| **TOTAL MACROALGAL BIOMASS (kg wet weight)** | | | **8192 kg** |
| Biomass (kg) of macroalgal cover <5% = AIH - AA (ha) * mean biomass *(5g.m$^{-2}$ unless stated otherwise)* | | | 2 kg |
| Biomass (kg) of macroalgal cover >5% = sum of patch biomass measures | | | 8190 kg |

The overall opportunistic macroalgal Ecological Quality Rating (EQR) for Hutt Estuary was 0.58, a quality status of "MODERATE" (Table 2). This rating was driven primarily by the widespread presence of macroalgae throughout most of the available habitat in the estuary - an affected area quality status of "BAD"; a "POOR" rating for percent cover; with both of these offset by a "GOOD" rating for biomass and the "HIGH" quality status (absence) of algal entrainment in underlying sediments. The gross eutrophic zone rating was "HIGH", reflecting that underlying intertidal sediments had not been significantly adversely impacted by the macroalgal growth present.

The 2017 EQR is higher (a better score) than recorded in previous years (Figure 4, see also Stevens and Robertson 2010-2015, Stevens et al. 2016), primarily because of reduced macroalgal biomass, as well as reduced macroalgal cover in the main intertidal flats of the estuary in 2017. The most likely reason for this reduction is recent flood scouring of the river dislodging and washing intertidal and shallow subtidal macroalgae into deeper subtidal zones or out to sea, as opposed to any significant reduction in macroalgal growth.

Past monitoring has provided strong evidence that nutrient inputs to the estuary are sufficient to support extensive growths of macroalgae through the consistent and very widespread presence of opportunistic macroalgae, high macroalgal biomass on the only remaining intertidal flats in the estuary, and the presence of luxuriant, very high biomass growths in shallow subtidal habitat.

Because the export of macroalgae into subtidal settling areas has also contributed to a significant deterioration of subtidal habitat (see Stevens et al. 2016), nutrient load reductions are likely to be required to reverse existing problem conditions evident in the estuary.

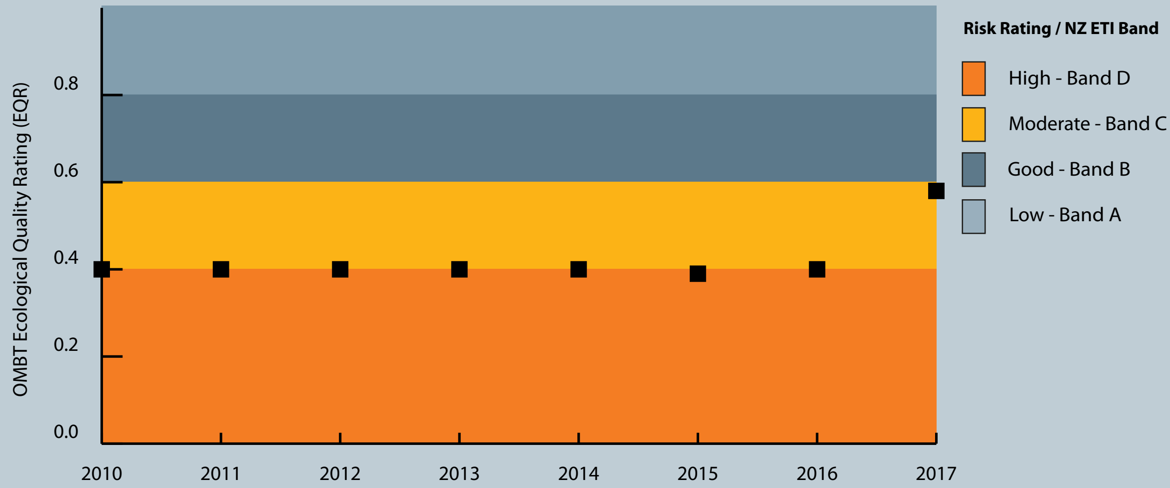



**Figure 4. Macroalgal Ecological Quality Rating (EQR), Hutt Estuary, 2010-2017.**
EQR values for 2010-2014 estimated based on previously mapped percentage cover and field photos showing very similar conditions to those quantified in 2015 and 2016.

## CONCLUSIONS

The 2017 "MODERATE" macroalgal Ecological Quality Rating (EQR) reflects the widespread presence, but low biomass and entrainment, of intertidal macroalgae in the estuary, with growths not causing significantly degraded sediment conditions.

Degraded conditions are not readily expressed because extensive historic reclamations of the estuary have restricted much of the intertidal habitat to rockwalls which limit areas where gross eutrophic conditions can establish intertidally, as well as flood scouring which regularly removes macroalgae from intertidal areas.

Regular flushing of the estuary appears to currently restrict the presence of nuisance conditions (rotting macroalgae and poorly oxygenated and sulphide rich sediments) to localised areas on intertidal flats, and in subtidal areas near the Hutt River mouth.

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

## RECOMMENDED MONITORING AND MANAGEMENT

Because of the relatively consistent presence of macroalgae in the estuary and the "MODERATE" EQR rating, it is recommended that ongoing macroalgal monitoring be on a 5 yearly cycle unless obvious changes are observed in the interim. Next monitoring is therefore recommended for Jan. 2022.

As recommended previously, to defensibly address the likely cause of macroalgal growths and subtidal habitat degradation, it is recommended that the following intensive investigation be considered:

1. Identify catchment sediment and nutrient sources (e.g. catchment wide nutrient inputs or localised sources), and derive a guideline limit for nutrient (likely to be nitrogen) inputs as the first step, followed by identification of major sources and their subsequent reduction to meet the guideline.

The key steps in such an approach are as follows:

- Assign catchment nutrient load guideline criteria to the estuary based on available catchment load/estuary response information from other relevant estuaries.
- Estimate catchment nutrient loads to the estuary using available catchment models and stream monitoring data.
- Determine the extent to which the estuary meets guideline catchment load criteria.

# 2. Results, Rating and Recommendations (Cont...)

| | |
|---|---|
| **RECOMMENDED MONITORING AND MANAGEMENT** | • Assess the potential for requiring more detailed assessments of priority catchments (e.g. estuary response modelling, stream and tributary monitoring, catchment load modelling).<br>• Develop plans for targeted management or restoration of priority catchments.<br><br>GWRC is currently 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. |
| **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.*<br>*Robertson, B.M. and Stevens, L. 2010. Hutt Estuary: Fine Scale Monitoring 2009/10. Prepared for Greater Wellington Regional Council. 24p.*<br>*Robertson, B.M. and Stevens, L. 2011. Hutt Estuary: Fine Scale Monitoring 2010/11. Prepared for Greater Wellington Regional Council. 25p.*<br>*Robertson, B.M. and Stevens, L. 2012. Hutt Estuary: Fine Scale Monitoring 2011/12. Prepared for Greater Wellington Regional Council.*<br>*Stevens, L., 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.*<br>*Stevens, L.M., Robertson, B.M. and Robertson, B.P. 2016. Hutt Estuary: 2016 Broad Scale Habitat Mapping. Report prepared by Wriggle Coastal Management for Greater Wellington Regional Council. 35p.*<br>*Stevens, L. and Robertson, B.M. 2010. Hutt River Estuary: Intertidal Macroalgal Monitoring. Prepared for Greater Wellington Regional Council. 4p.*<br>*Stevens, L. and Robertson, B.M. 2011. Hutt River Estuary: Intertidal Macroalgal Monitoring. Prepared for Greater Wellington Regional Council. 4p.*<br>*Stevens, L. and Robertson, B.M. 2012. Hutt River Estuary: Intertidal Macroalgal Monitoring. Prepared for Greater Wellington Regional Council. 4p.*<br>*Stevens, L., and Robertson, B. 2012. Waiwhetu Stream 2012. Broad and Fine Scale Monitoring in the Tidal Reaches. Prepared for Greater Wellington Regional Council. 35p.*<br>*Stevens, L. and Robertson, B.M. 2013. Hutt Estuary: Intertidal Macroalgal Monitoring 2012/13. Prepared for Greater Wellington Regional Council. 5p.*<br>*Stevens, L. and Robertson, B.M. 2014. Hutt Estuary: Intertidal Macroalgal Monitoring 2013/14. Prepared for Greater Wellington Regional Council. 6p.*<br>*Stevens, L. and Robertson, B.M. 2015. Hutt Estuary: Intertidal Macroalgal Monitoring 2014/15. Prepared for Greater Wellington Regional Council. 12p.*<br>*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.* |
| **ACKNOWLEDGEMENT** | This survey and report was completed with the support of Greater Wellington Regional Council. The feedback of Megan Oliver is much appreciated. |

# APPENDIX 1. OPPORTUNISTIC MACROALGAL BLOOMING TOOL

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. Suitable 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 >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 over 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 as entrained in muddy sediment 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 weed 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.

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), 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.

# APPENDIX 1. OPPORTUNISTIC MACROALGAL BLOOMING TOOL

**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 ICOLLs 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 (Table A2).

- **Reference Thresholds.** A UK Department of the Environment, Transport and the Regions (DETR) expert workshop suggested reference 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 un-impacted 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** 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 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 <500 g.$m^{-2}$ wet weight was an acceptable level above the reference level of <100 g.$m^{-2}$ wet weight. In Good status only slight deviation from High status is permitted so 500 g.$m^{-2}$ 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 >500 g.$m^{-2}$ but less than 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. >1kg.$m^{-2}$ 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 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.

Each metric in the OMBT has equal weighting and is combined to produce the ecological quality ratio score (EQR).

**Table A2. The final face value thresholds and metrics for levels of the ecological quality status**

| Quality Status | High | Good | Moderate | Poor | Bad |
|---|---|---|---|---|---|
| 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.

# APPENDIX 1. OPPORTUNISTIC MACROALGAL BLOOMING TOOL

## 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:

| **Quality Status** | High | Good | Moderate | Poor | Bad |
|---|---|---|---|---|---|
| **EQR (Ecological Quality Rating)** | ≥0.8 - 1.0 | ≥0.6 - <0.8 | ≥0.4 - <0.6 | ≥0.2 - <0.4 | 0.0 - <0.2 |

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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# APPENDIX 1. OPPORTUNISTIC MACROALGAL BLOOMING TOOL

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

| METRIC | QUALITY STATUS | FACE VALUE RANGES | | | EQUIDISTANT CLASS RANGE VALUES | | |
|---|---|---|---|---|---|---|---|
| | | 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 | 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 |
| | Bad | 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 |
| | Bad | ≤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 |
| | Bad | ≤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 |
| | Bad | ≤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 |
| | Bad | 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 |
| | Bad | 100 | >50 | 49.999 | 1 | <0.6 | 0.2 |

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

Shallow subtidal growths of *Ulva intestinalis* in the lower Hutt Estuary.

# APPENDIX 2. HUTT ESTUARY MACROALGAL DATA


**Figure A1. Location of macroalgal patches >5% cover used in assessing Hutt Estuary, January 2017.**

# APPENDIX 2. HUTT ESTUARY MACROALGAL DATA (CONTINUED)

| Patch ID | Dominant species | Patch area (ha) | Percent cover of macroalgae | Presence (1) or absence (0) of entrained algae | Mean Bio-mass (g.m$^{-2}$ wet weight) | Total 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 | 60 | 196 | 0 | 0 |
| 5 | *Ulva intestinalis* | 0.96 | 80 | 0 | 80 | 770 | 0 | 0 |
| 6 | *Ulva intestinalis* | 0.24 | 80 | 0 | 100 | 244 | 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 | 30 | 102 | 0 | 0 |
| 11 | *Ulva intestinalis* | 0.25 | 20 | 0 | 20 | 50 | 0 | 0 |
| 12 | *Ulva intestinalis* | 0.23 | 100 | 0 | 40 | 91 | 0 | 0 |
| 13 | *Ulva intestinalis* | 0.19 | 80 | 0 | 200 | 379 | 0 | 0 |
| 14 | *Ulva intestinalis* | 0.19 | 80 | 0 | 80 | 152 | 0 | 0 |
| 15 | *Ulva intestinalis* | 2.01 | 10 | 0 | 30 | 603 | 0 | 0 |
| 16 | *Ulva intestinalis* | 0.02 | 80 | 0 | 80 | 13 | 0 | 0 |
| 17 | *Ulva intestinalis* | 0.05 | 60 | 0 | 50 | 25 | 0 | 0 |
| 18 | *Ulva intestinalis* | 0.23 | 60 | 0 | 60 | 138 | 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 | 550 | 527 | 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 | 132 | 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 | 40 | 0 | 800 | 2290 | 0 | 0 |
| 41 | *Ulva intestinalis, U. lactuca, Gracilaria chilensis* | 0.02 | 80 | 0 | 2500 | 557 | 0 | 0 |
| 42 | *Ulva intestinalis* | 0.14 | 30 | 0 | 20 | 28 | 0 | 0 |
| | Total | 7.9ha | | | | 8190 kg | | |