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Porirua Harbour

Intertidal Macroalgal Monitoring 2016/17

Prepared for
Greater Wellington Regional Council
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Cover Photo: *Gracilaria* and *Ulva* growing near Kakaho Stream, January 2017.

Camborne, January 2017.

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Intertidal Macroalgal Monitoring 2016/17

Prepared for
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by

Leigh Stevens and Sabine O'Neill-Stevens

Wriggle Limited, PO Box 1622, Nelson 7040, NZ. Ph 03 545 6315, 021 417 936, leigh@wriggle.co.nz, www.wriggle.co.nz

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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 Porirua Harbour, 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 2013, Robertson and Stevens 2008, 2009, 2010, 2015, 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 Porirua Harbour 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.

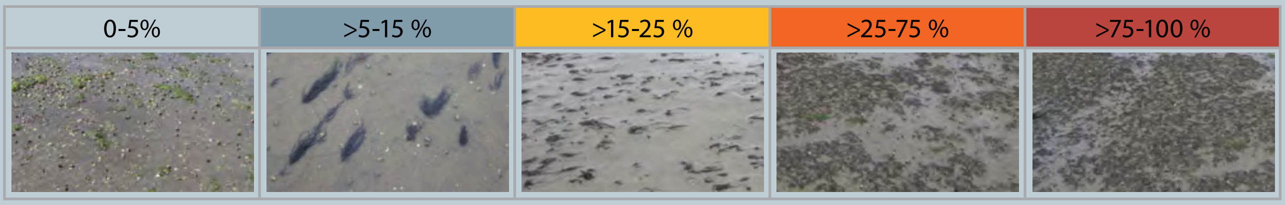
Results were interpreted using a multi-index approach that included:

- 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.



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 Porirua Harbour in January 2017 are summarised in Figure 3 and Table 2, with full data in Appendix 2. The results show:

- Of the Available Intertidal Habitat (230ha), 92% had >5% opportunistic macroalgal growth present (Affected Area = 212ha).
- The red alga *Gracilaria chilensis* was the dominant opportunistic macroalgal species present, with the green algae *Ulva lactuca and Ulva ramulosa* both commonly found growing subdominantly in the same areas as *Gracilaria*.
- In general, areas of moderate macroalgal biomass (200-500g.m-^{2}) were most concentrated on mid-tidal flats near the Pauatahanui, Kakaho and Horokiri stream deltas in the Pauatahanui Arm (Figures 3 and 4) where there have been recent widespread deposits of fine mud (Stevens and O'Neill-Stevens 2017). Biomass in the upper and lower tidal ranges was generally low (<200g.m-^{2}) in both arms of the estuary.
- Areas of high biomass (>500g.m-^{2}) were present in small enclosed and flow-restricted embayments, and near the Takapuwahia and Porirua streams in the Onepoto Arm. The most extensive high biomass area was located on the Pauatahanui Stream delta.
- There were no significant intertidal gross eutrophic zones identified (i.e. a combined presence of high macroalgal biomass and cover, soft muds, and low sediment oxygenation (e.g. surface anoxia)).
- As noted in 2015 and 2016, relatively localised, but very dense, shallow subtidal growths of *Gracilaria* (biomass >4000g.m-^{2}) have been observed in the lower reaches of both Porirua and Pauatahanui Streams. These these appeared to have been reduced in extent by flood scouring when sampled in January 2017. Outside of these areas, the harbour appears to support little subtidal opportunistic macroalgae.

The overall opportunistic macroalgal Ecological Quality Rating (EQR) for Porirua Harbour was 0.54, a quality status of "MODERATE" (Table 2). This rating was driven primarily by the widespread presence of macroalgae throughout most of the estuary - an affected area (AA) quality status of "BAD". The influence of the AA metric score on the EQR was offset by the "MODERATE" quality status of macroalgal percentage cover, "MODERATE" biomass, and "HIGH" quality status (general absence) of algal entrainment in underlying sediments. The absence of gross eutrophic zones in the estuary was reflected in a quality status of "HIGH".

Low biomass and low percentage cover of *Gracilaria* and *Ulva* near Mana.

Low biomass and low percentage cover of *Gracilaria* and *Ulva* on the Porirua Stream delta.

Figure 2. Photos showing opportunistic macroalgal growth - Porirua Harbour, January 2017.

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

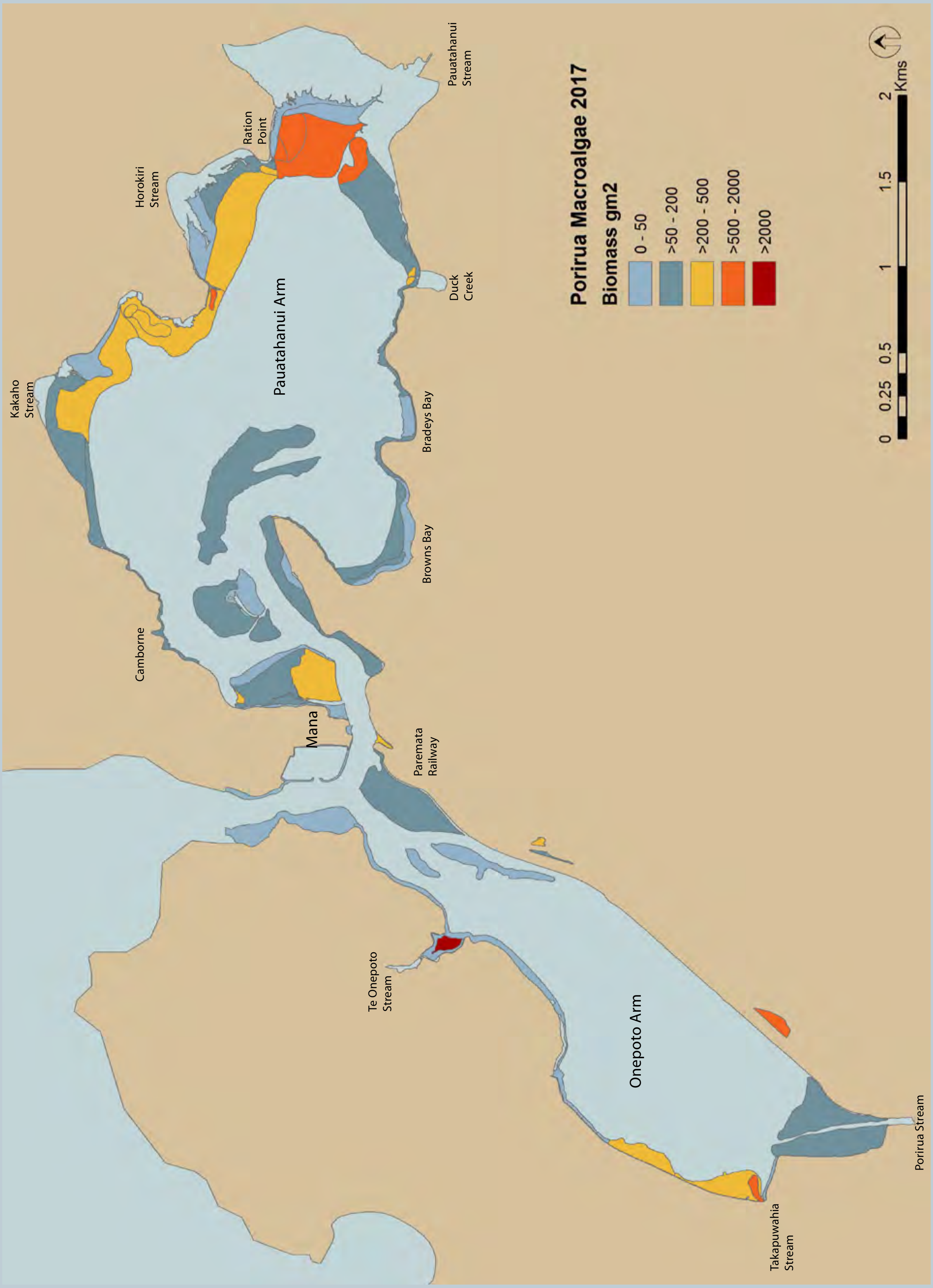


Figure 3. Map of intertidal opportunistic macroalgal biomass - Porirua Harbour, January 2017.

Figure 4. Photos showing opportunistic macroalgal growth - Pauatahanui arm, January 2017.

Top: Kakaho stream delta highlighting fresh deposits of muds, Middle: intertidal flats between Duck Creek and Pauatahanui Stream, Bottom: Pauatahanui Stream delta near Ration Point.

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

Table 2. Summary of intertidal macroalgal cover, Porirua Harbour, January 2017.

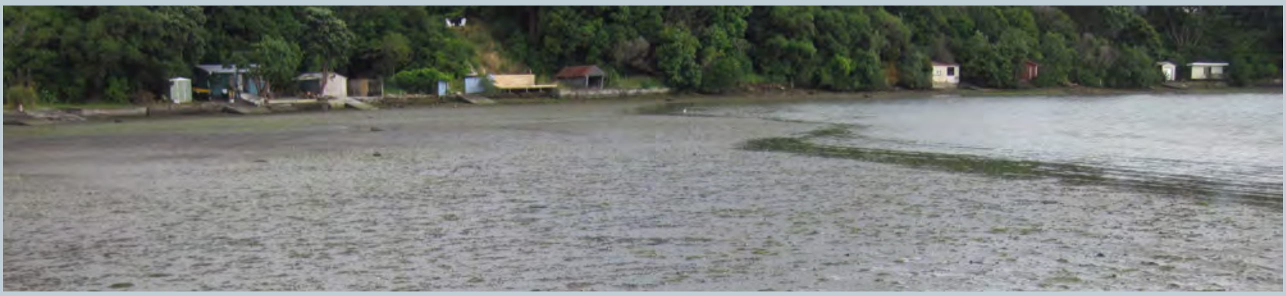
Metric	Face Value	Final Equidistant Score (FEDS)	Quality Status
AIH - Available Intertidal Habitat (ha)	230		
Percentage cover of AIH (%) = (Total % Cover / AIH} x 100 *where Total % cover = Sum of {(patch size) / 100} x average % cover for patch*	20.9	0.483	Moderate
Biomass of AIH (g.m^{-2}) = Total biomass / AIH *where Total biomass = Sum of (patch size x average patch biomass)*	186.9	0.626	Good
Biomass of Affected Area (g.m^{-2}) = Total biomass / AA *where Total biomass = Sum of (>5% cover patch size x average patch biomass)*	203.1	0.598	Moderate
Presence of Entrained Algae = (No. quadrats or area (ha) with entrained algae / total no. of quadrats or area (ha)) x 100	0.2	0.969	High
Affected Area (use the lowest of the following two metrics)		0.064	Bad
Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover >5%)	211.6	0.251	Poor
Size of AA in relation to AIH (%) = (AA / AIH) x 100	92.0	0.064	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)		**0.544**	**MODERATE**
OVERALL GROSS EUTROPHIC ZONE RATING			**HIGH**
TOTAL MACROALGAL BIOMASS (kg wet weight)			**453061 kg**
Biomass (kg) of macroalgal cover <5% = AIH - AA (ha) * mean biomass *(nominally 50g.m^{-2} unless stated otherwise)*			2851 kg
Biomass (kg) of macroalgal cover >5% = sum of patch biomass measures			450210 kg

Over the period that opportunistic macroalgae has been monitored annually in the estuary, it was consistently rated as "MODERATE" from 2008 to 2013, with high density intertidal macroalgal growths occasionally on the verge of causing nuisance conditions. EQR ratings from 2014 to 2017 indicate little change from this state. The overall 2017 EQR rating was "MODERATE", a slight decline from 2016 where it scored in the very bottom of the "GOOD" category. The change over the past 12 months has been largely driven by a doubling of macroalgal biomass compared to 2016, with the most significant biomass increase occurring on the Pauatahanui, Kakaho and, to a lesser extent, Horokiri stream deltas. While storm events over the past 12 months will have contributed to flood scouring of these delta areas, a possible reason for the increased biomass observed in January 2017 is an increase in sediment-bound nutrients associated with the deposition of fresh catchment sediments.

While the 2017 monitoring again showed there was no significant entrainment of macroalgae in sediment (a key indicator of persistent problem conditions establishing) and no significant gross eutrophic zones were present in the estuary, it continued to highlight that nutrient and sediment inputs to the estuary are clearly sufficient to sustain elevated growths of macroalgae in Porirua Harbour.

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

CONCLUSIONS	The 2017 "MODERATE" macroalgal Ecological Quality Rating, and the "HIGH" quality rating for gross eutrophic zones, reflects widespread macroalgal presence throughout the estuary, but with macroalgal growths not causing significantly degraded sediment conditions. Monitoring since 2008 has not recorded any significant gross eutrophic zones in the estuary, but highlights that localised nuisance conditions (e.g. rotting algae, poorly oxygenated and sulphide-rich sediments) can occur when there are dense accumulations (>50% cover) of macroalgae. Localised scouring following storm events, particularly on the Porirua and Pauatahanui stream flood deltas, is considered a likely reason for the recent variable macroalgal biomass observed from 2015-17. The extensive cover of macroalgae throughout the estuary, combined with ongoing mud deposition, particularly subtidally (Stevens and O'Neill-Stevens 2017), and increasing sediment muddiness remain continuing concerns within Porirua Harbour.
RECOMMENDED MONITORING AND MANAGEMENT	Although the current expression of macroalgal condition would normally suggest macroalgae should be monitored at a minimum on a 5 yearly cycle, it is recommended that the need for macroalgal assessment be reviewed annually because: i. Intertidal macroalgal cover is widespread throughout the estuary, ii. The switch from non-nuisance to nuisance macroalgal conditions can occur relatively quickly and be difficult to reverse, and iii. Over the next 2-3 years there is scheduled catchment development related to the Transmission Gully motorway development as well as exotic forest harvesting and urban developments that may contribute to increased sediment and nutrient loads entering the estuary (both important drivers of eutrophication). It is also recommended that appropriate catchment nutrient guideline criteria be developed, and that the extent to which catchment loads meet these guidelines be assessed. 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. • Assess the potential for requiring more detailed assessments of priority catchments (e.g. estuary response modelling, stream and tributary monitoring, catchment load modelling). • Develop plans for targeted management or restoration of priority catchments. GWRC is currently modelling the biophysical processes of the entire Porirua Harbour and catchment as part of the sub-regional whaitua planning process to set limits for water quality and quantity. This will include model estimates of present-day nutrient and sediment inputs to, and distribution within, the streams and harbour. Overall, the approach presented above is intended to ensure that the assimilative capacity of the estuary is not exceeded so that the estuary can flourish and provide sustainable human use and ecological values in the long term.



Low *Gracilaria* and *Ulva* biomass and percentage cover on sandy sediments in Browns Bay.

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

ACKNOWLEDGEMENT This survey and report was completed with the support of Greater Wellington Regional Council. The feedback of Megan Oliver is much appreciated.

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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 water body. 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.

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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 UK-WDT OMBT 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.

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APPENDIX 1. OPPORTUNISTIC MACROALGAL BLOOMING TOOL

Table A3. The UK-WDT OMBT 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.

Note, Face value thresholds and metrics should reflect the localised ranges anticipated for each estuary being assessed.

Gracilaria growing in muddy sediments at Kakaho.

APPENDIX 2. PORIRUA HARBOUR MACROALGAL DATA

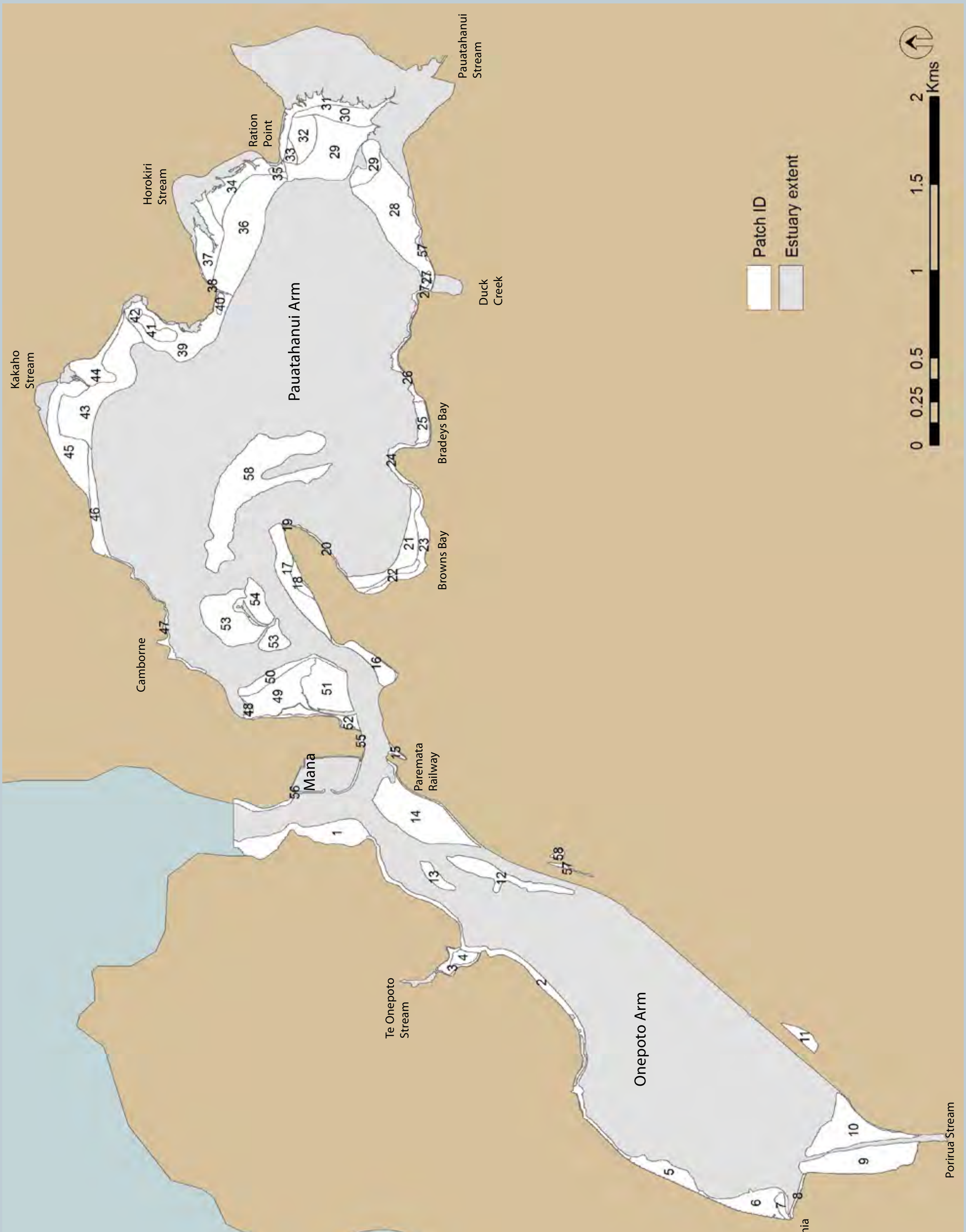

Figure A1. Location of macroalgal patches >5% cover used in assessing Porirua Harbour, January 2017.

APPENDIX 2. PORIRUA HARBOUR MACROALGAL DATA (CONTINUED)

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)	Total Patch Biomass (kg wet weight)	aRPD depth (cm)	Presence (1) or absence (0) of soft mud
1	*Ulva lactuca, Gracilaria chilensis*	7.2	20	0	50	3613	>1	0
2	*Ulva lactuca, Gracilaria chilensis*	6.2	5	0	20	1237	>1	0
3	*Gracilaria chilensis*	0.9	5	0	20	183	>1	0
4	*Gracilaria chilensis*	1.0	80	0	3000	28975	>1	1
5	*Gracilaria chilensis, Ulva lactuca*	2.9	5	0	300	8580	>1	0
6	*Gracilaria chilensis, Ulva lactuca*	4.0	80	0	300	12061	>1	0
7	*Ulva lactuca, Gracilaria chilensis*	0.6	80	0	1200	7596	1	0
8	*Ulva lactuca*	0.4	5	0	5	19	>1	0
9	*Gracilaria chilensis, Ulva lactuca, Ulva ramulosa*	8.1	15	0	150	12111	>1	0
10	*Gracilaria chilensis, Ulva lactuca, Ulva ramulosa*	7.4	5	0	120	8911	>1	0
11	*Ulva lactuca*	1.2	50	0	600	7420	0	1
12	*Ulva ramulosa, Gracilaria chilensis*	4.2	10	0	20	835	>1	0
13	*Ulva ramulosa, Gracilaria chilensis*	1.2	10	0	20	243	>1	0
14	*Gracilaria chilensis*	10.8	10	0	100	10808	>1	0
15	*Gracilaria chilensis, Ulva lactuca*	0.3	70	0	250	658	0	1
16	*Gracilaria chilensis, Ulva lactuca*	2.3	20	0	60	1367	>1	0
17	*Gracilaria chilensis, Ulva lactuca, Ulva ramulosa*	5.3	10	0	150	8004	>1	0
18	*Gracilaria chilensis*	0.9	5	0	20	186	>1	0
19	*Gracilaria chilensis*	0.1	20	0	400	258	>1	0
20	*Gracilaria chilensis*	0.5	15	0	100	456	>1	0
21	*Gracilaria chilensis*	4.4	40	0	200	8829	>1	0
22	*Gracilaria chilensis, Ulva lactuca, Ulva ramulosa*	0.9	20	0	100	941	>1	0
23	*Gracilaria chilensis, Ulva lactuca*	3.1	5	0	50	1558	>1	0
24	*Gracilaria chilensis*	1.3	30	0	100	1246	>1	0
25	*Ulva lactuca, Ulva ramulosa, Gracilaria chilensis*	1.5	5	0	50	759	>1	0
26	*Gracilaria chilensis*	1.4	30	0	100	1427	>1	0
27	*Ulva lactuca, Ulva ramulosa, Gracilaria chilensis*	0.3	60	0	300	993	>1	0
28	*Gracilaria chilensis*	12.0	10	0	110	13154	>1	0
29	*Gracilaria chilensis, Ulva ramulosa*	12.4	50	0	650	80431	>1	0
30	*Gracilaria chilensis, Ulva lactuca*	3.6	5	0	20	717	>1	1
31	*Gracilaria chilensis, Ulva lactuca*	2.8	10	0	50	1383	>1	1
32	*Gracilaria chilensis, Ulva lactuca*	3.1	80	0	900	28196	>1	1
33	*Gracilaria chilensis, Ulva lactuca*	0.7	100	0	1500	10034	>1	1
34	*Gracilaria chilensis, Ulva lactuca*	4.3	10	0	200	8541	>1	0
35	*Gracilaria chilensis, Ulva lactuca*	0.4	80	0	250	923	>1	0
36	*Gracilaria chilensis, Ulva lactuca, Ulva ramulosa*	13.5	40	0	300	40467	>1	0
37	*Gracilaria chilensis, Ulva lactuca*	4.6	5	0	20	911	>1	1
38	*Ulva lactuca*	0.3	10	0	20	50	>1	0
39	*Gracilaria chilensis, Ulva lactuca, Ulva ramulosa*	7.3	40	0	300	22014	>1	1
40	*Gracilaria chilensis*	0.3	60	1	700	2320	0	1
41	*Gracilaria chilensis, Ulva lactuca*	1.6	15	0	240	3829	>1	0
42	*Gracilaria chilensis, Ulva lactuca*	0.4	20	0	220	898	>1	0
43	*Gracilaria chilensis*	11.3	30	0	220	24885	>1	1
44	*Gracilaria chilensis*	3.3	5	0	10	334	>1	0
45	*Gracilaria chilensis*	7.2	15	0	130	9356	>1	1
46	*Gracilaria chilensis*	2.8	5	0	100	2776	>1	1
47	*Gracilaria chilensis*	1.4	15	0	130	1791	>1	0
48	*Gracilaria chilensis, Ulva lactuca*	0.2	20	0	230	517	>1	1
49	*Gracilaria chilensis*	7.2	10	0	180	12928	>1	0
50	*Ulva lactuca*	2.3	5	0	20	449	>1	0
51	*Gracilaria chilensis, Ulva lactuca, Ulva ramulosa*	6.1	20	0	250	15255	>1	0
52	*Ulva lactuca*	1.3	5	0	5	62	>1	0
53	*Gracilaria chilensis, Ulva lactuca*	8.7	25	0	200	17420	>1	0
54	*Ulva lactuca*	2.9	5	0	20	588	>1	0
55	*Ulva lactuca*	0.1	5	0	5	7	>1	0
56	*Ulva lactuca, Gracilaria chilensis*	1.6	5	0	20	316	>1	0
57	*Gracilaria chilensis, Ulva lactuca*	0.4	10	0	80	293	>1	0
58	*Ulva lactuca*	0.3	10	0	200	580	>1	1
59	*Ulva lactuca, Gracilaria chilensis*	18.5	20	0	100	18488	>1	0
60	*Ulva lactuca*	0.3	40	0	400	1023	>1	1
Total		221ha				450210 kg		