Broad Scale Condition (continued)

2.6 NEW RIVER ESTUARY

Broad scale mapping of dominant habitats in New River Estuary was first undertaken in February 2001 (Robertson et al. 2002) and was repeated in February 2007, 2012 and in 2016. Macroalgal mapping was also undertaken annually in February from 2008-2013 inclusive. Summary information for each monitoring event is presented in Table 2.7 with data overlain with condition (impairment) bands.

The 2016 results, and changes over time are discussed in more detail, beginning at the bottom of this page. As far as practicable, standardised extents and classifications have been applied when comparing changes in the estuary over time. To achieve this, the spatial extent of broad scale mapping has been standardised across all surveys in New River Estuary by updating the 2001 and 2007 extents to match those used in 2012 and 2016. At the same time, improvements in mapping classifications have been retrospectively applied. For example, the substrate beneath macroalgal beds was not recorded in 2001 (and was therefore not included in estimates of mud extent), but has been subsequently added based on field notes, photographs and expert judgement. These changes have been recorded and included in updated GIS files prepared for the estuary and, as a result, some of the summary data presented here will vary slightly from that presented in the original reports. In addition, at the time of the initial 2001 broad scale survey, macroalgae was an indicator in the early stages of development with emphasis on mapping areas of high density (>50%) cover only. To better define past macroalgal cover, original field photos, aerial photographs, field notes and observations made at the time have been used to retrospectively apply more recently developed macroalgal indicators and calculate an EQR score during years when full broad scale mapping was undertaken (i.e. 2001, 2007, 2012).

Table 2.7. Macroalgal cover, EQR , soft mud, oxygenation, GEZ, and seagrass, New River Estuary, 2001-2016.

Condition (Impairment) Band	No Rating	Band A - Very Low	Band B - Low	Band C - Moderate	Band D - High

Year	NZ ETI Score	Macroalgae		Soft Mud		Low Sed O_2 Zone		GEZ		Seagrass >20%	
		Cover >50% Ha	EQR Score	Ha	%	Ha	%	Ha	%	Ha	% loss
2001	0.67*	43	0.616*	492	17%	na	1*	23*	1%	94	baseline
2007	0.70*	186	0.532*	564	19%	na	2*	49*	2%	unreliable	na
2008	na	283	na	na	na	na	na	na	na	na	na
2009	na	337	na	na	na	na	na	na	na	na	na
2010	na	300	na	na	na	na	na	na	na	na	na
2011	na	308	na	na	na	na	na	na	na	na	na
2012	0.90*	313	0.398*	669	24%	na	9*%	240	9%	64	-32%
2013	na	393	na	na	na	na	na	na	na	na	na
2016	0.93	364	0.303	747	27%	423	15%	351	13%	56	-40%

*estimated following reanalysis of existing data. na=not assessed or data not available.

NOTE: % cover calculations are determined using the area of intertidal flats (i.e. excludes saltmarsh and subtidal water).

2.6.1 New River Estuary 2016 Overview

The 2016 broad scale habitat mapping in New River Estuary ground-truthed and mapped intertidal substrate, macroalgae and seagrass, with the dominant estuary features summarised in Table 2.8 and the extent of groundtruthing and field sampling shown in Figure 2.1.

Table 2.8 Summary of dominant broad scale features in New River Estuary, Feb. 2016.

Dominant Estuary Feature	Ha	% of Estuary
1. Intertidal flats (excluding saltmarsh)	2944	65%
2. Opportunistic macroalgal beds (>50% cover) [included in 1. above]	363.6	8%
3. Seagrass (>20% cover) [included in 1. above]	56.4	1%
4. Saltmarsh (based on 2012 data as not mapped in 2016)	461	10%
5. Subtidal waters	1152	25%
Total Estuary	**4557**	**100%**

2.6.2 New River Estuary 2016 Intertidal Substrate

Results (summarised in Figure 2.2) show that although sand was by far the most dominant substrate (72% of the unvegetated intertidal area), extensive parts of the estuary are dominated by muddy sediments (747ha, 25%). Most of the mud has deposited in or near natural settlement areas in the Waihopai arm and Daffodil Bay, as well as along the banks of the upper Oreti and Waihopai rivers, and among rushland in the east of the estuary. It is becoming increasingly pronounced among dense macroalgal beds which are very effective at trapping fine sediment.

Outside of the muddy areas, firm (often mobile) sands were dominant throughout the central basin and near the mouth of the estuary, with rock, cobble, and gravel fields located near Omaui. These habitats were in good condition and generally well oxygenated (aRPD >1cm deep, RP above -150mV at 3cm).

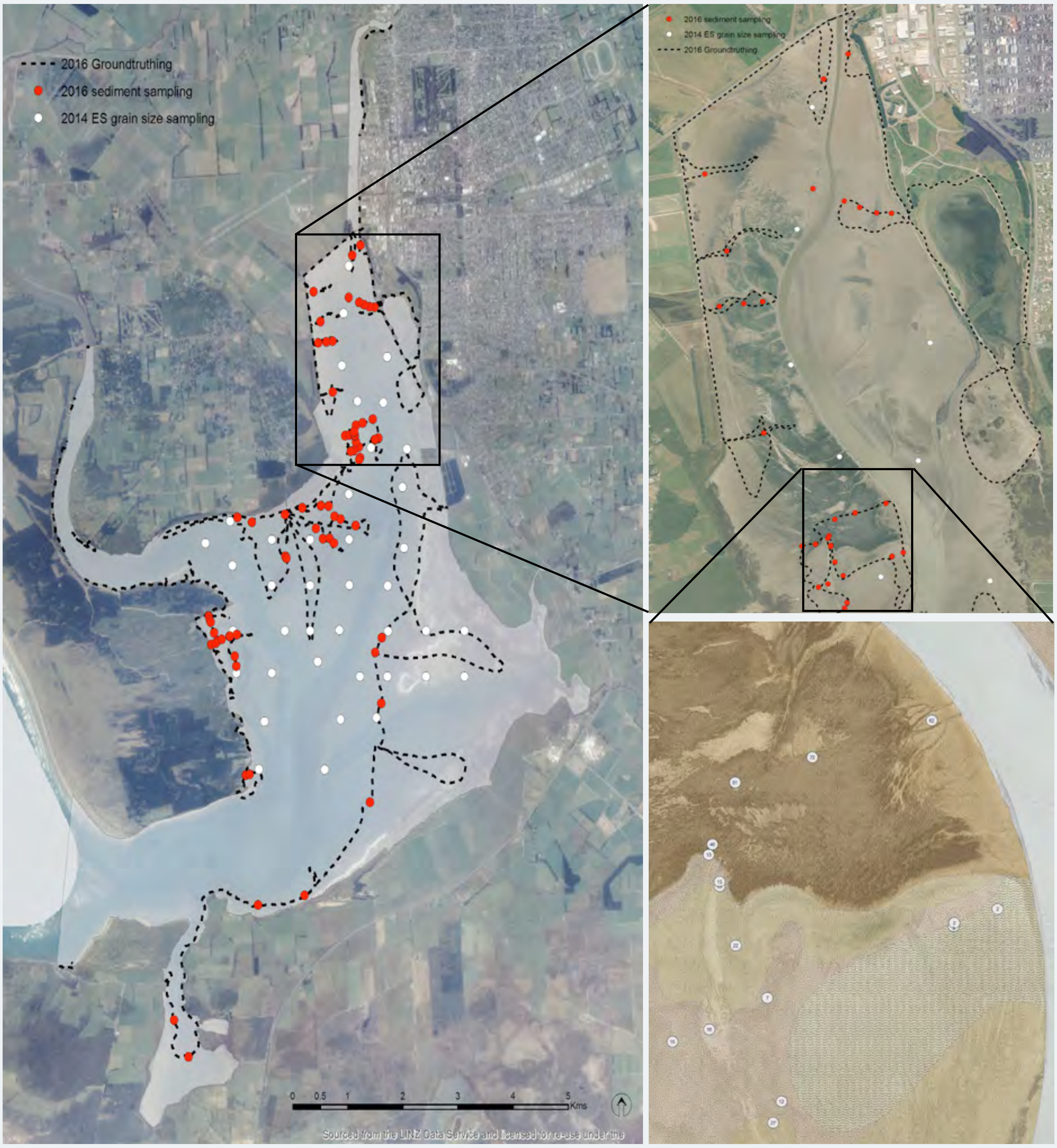


Figure 2.1. Mapped estuary extent showing 2016 groundtruthing coverage, location of grain size samples used to validate substrate classifications, and example of detailed map output across a key soft mud and eutrophication boundary in the lower Waihopai arm.

Dominant Substrate	Area Ha	Percentage
Artificial structure	3.5	0.1
Rock field	34.1	1.2
Cobble field	0.9	0.03
Gravel field	12.3	0.4
Shell bank	29.1	1.0
Mobile sand	352.2	12.0
Mobile muddy sand	955.6	32.5
Firm sand	100.9	3.4
Firm muddy sand	639.1	21.7
Firm sandy mud	69.6	2.4
Firm mud	22.6	0.8
Soft mud	377.0	12.8
Very soft mud	346.8	11.7
TOTAL	**2944**	**100**

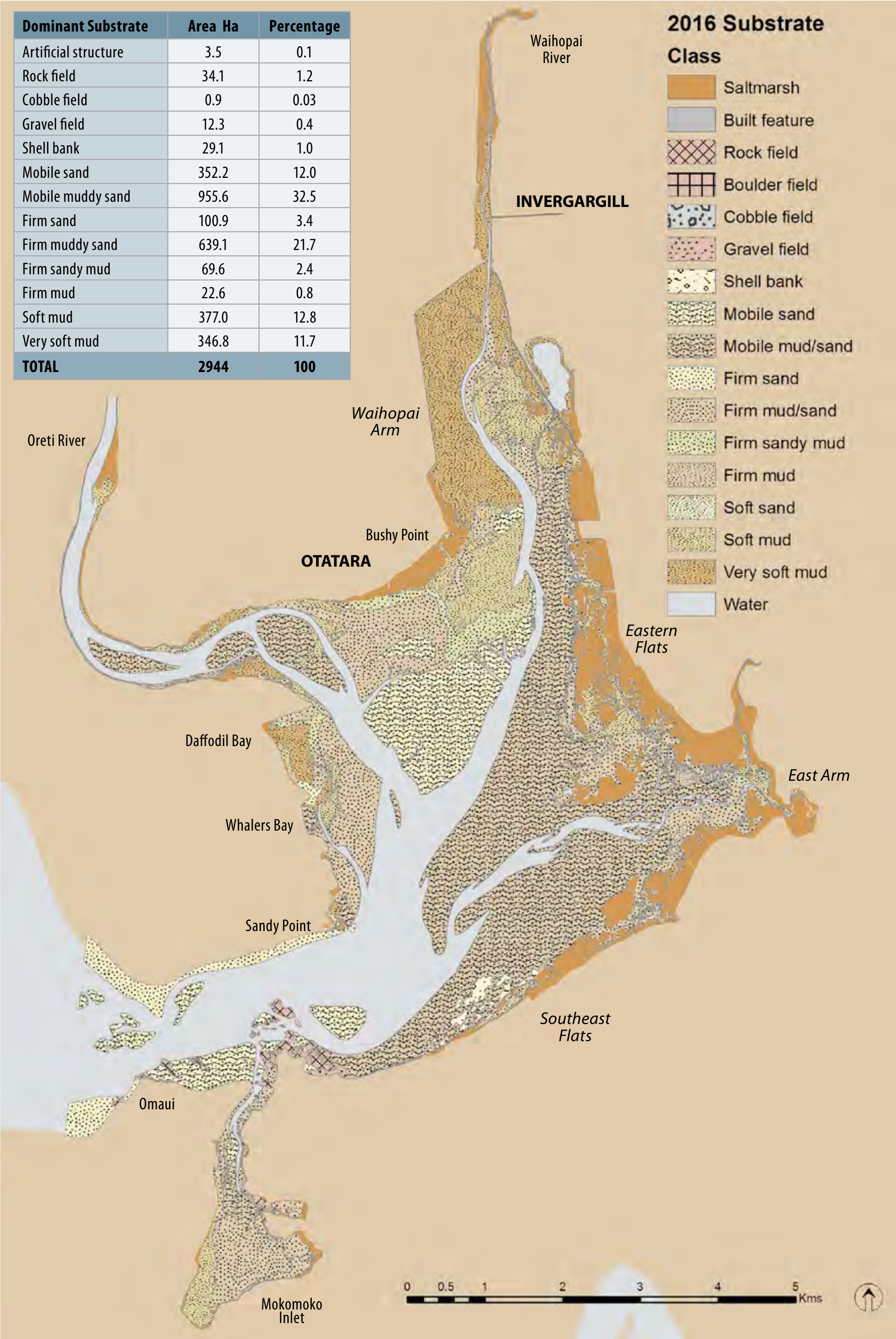


Figure 2.2. Map of Dominant Substrate Types - New River Estuary, Feb. 2016.

2.6.3 New River Estuary Changes in Soft Mud 2001-2016

The primary indicator of sediment impacts is the area of the estuary dominated by soft muds. The area of soft mud recorded from broad scale mapping in the estuary is summarised in Table 2.7. The soft mud percent cover condition band was "High" (>15%) for all years, and has been steadily increasing.

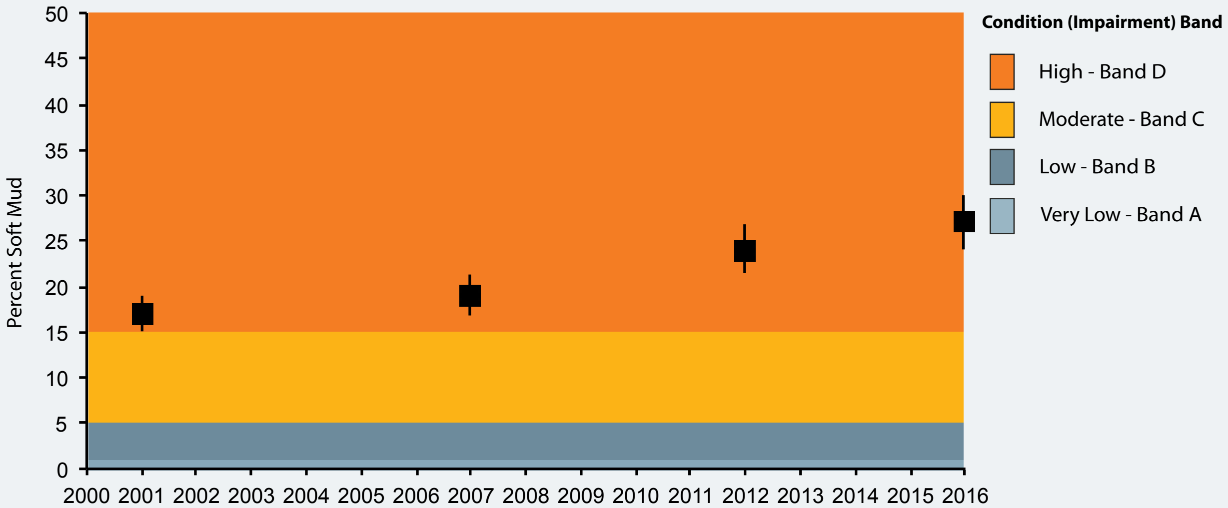


Figure 2.3. Percent of intertidal substrate comprising soft mud - New River Estuary, 2001-2016.

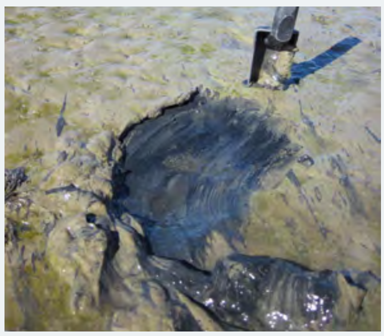
Using the 2001 data as a baseline, there was a 15% increase in the area of soft mud from 2001 to 2007, a 36% increase from 2001 to 2012, and a 52% increase from 2001 to 2016. This is consistent with field observations, with only small increases in soft mud extent evident in deposition areas from 2001-2007, but much larger increases observed from 2007-2012, and again from 2012 to 2016. Most increases in mud extent from 2007 to 2012 were associated with macroalgal (*Gracilaria*) beds in the Waihopai arm and Daffodil Bay, and to a limited extent at Bushy Point. This trend continued from 2012 to 2016 but with the most significant recent expansion in soft mud extent occurring at Bushy Point.

2.6.4 New River Estuary 2016 Sediment Mud Content

Sediment grain size has a strong influence on sediment oxygenation, macrofaunal community composition, water clarity, and public amenity values. Grain size sampling (see Figures 2.1 and 2.4, data in Appendix A1) showed sediments classified as mud (firm mud, soft mud, very soft mud) had a mean mud fraction of 56% (range 19%-92%). Such elevated mud contents, present throughout most of the Waihopai arm and Daffodil Bay, indicate a high likelihood of adverse effects occurring to macroinvertebrate communities in these areas (e.g. Robertson et al. 2016b) with such sediments also being predominantly very soft and poorly oxygenated.

Thoms (1981) sampled sites throughout the estuary and a very good baseline of sediment mud content is available from this work. To characterise changes in sediment grain size that may have occurred within broad scale substrate classes since 1981, ES resampled these sites in 2014. Unfortunately, sample QAQC results indicated the grain size analyses undertaken were unreliable and cannot be used. ES propose to address this aspect by resampling the sites in 2016/17.

Examples of soft muds built up among macroalgal beds at Bushy Point (left), and very soft mud in the Waihopai arm in 2016 (right).



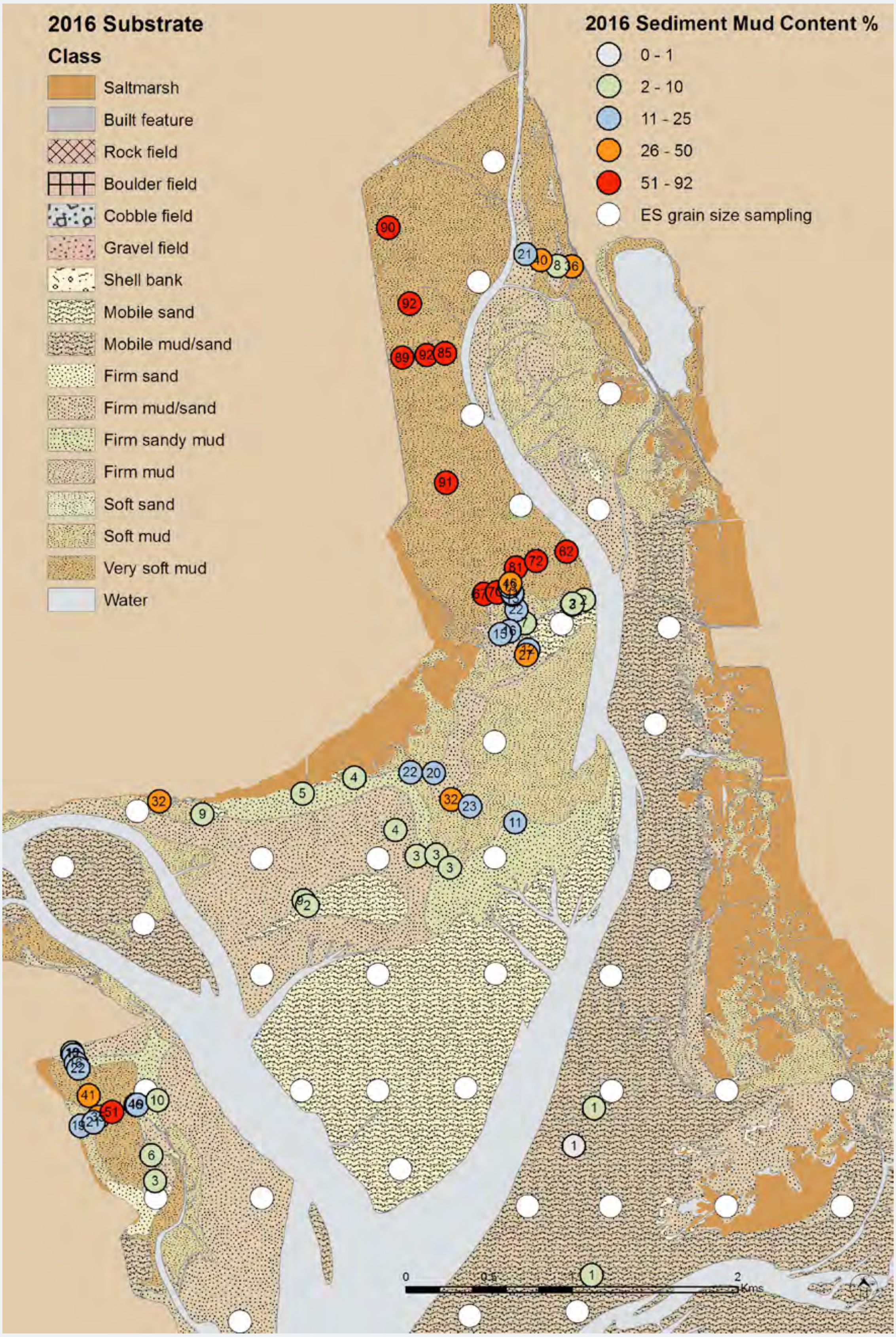


Figure 2.4. Upper estuary substrate showing measured sediment mud contents - New River Estuary, Feb. 2016.



Examples of sediment oxygenation measures: aRPD @1cm in firm sands in the eastern Waihopai arm (top), 0.5cm muddy sands at Bushy Point (middle), and measuring RP in Daffodil Bay (bottom).

2.6.5 New River Estuary 2016 Sediment Oxygenation

The primary indicators used to assess sediment oxygenation were aRPD depth or RP measured at 3cm. These indicators were measured at representative sites throughout the dominant sand and mud substrate types, and from a range of sites with variable macroalgal cover and biomass. From these measurements, broad boundaries have been drawn of estuary zones where sediment oxygen is depleted to the extent that adverse impacts to macrofauna (sediment and surface dwelling animals) are expected (Figure 2.5). These results show ~423ha (14%) of the intertidal area has substrate (mostly mud) where sediment oxygen is depleted. Because macrofauna are used as an indicator of ecological impacts to other taxa, it is expected that these zones will also be exerting adverse impacts on associated higher trophic communities including birds and fish.

The most significant areas of oxygen depletion were located in the highly eutrophic areas of Waihopai arm and Daffodil Bay. Here sediments were often characterised by strong odours of sulphur and, when disturbed near water, released black sulphide rich plumes (see photo below).

When last monitored in 2013, the majority of the western Waihopai arm was covered in dense macroalgae (80-100% cover, biomass >2000g.m^2), aRPD 0-1cm). Since then, macroalgae appear to have undergone a relatively extensive die off in the central western Waihopai arm, leaving behind a few sparse patches of macroalgae within a “soup” of very soft, highly organically enriched, anoxic muds with surface anoxia and sulphide rich sediments (see photos below). It is highly likely that sediment conditions have now become so extreme that macroalgae, the primary source of oxygenation to the underlying sediments, can no longer survive in these areas.


Examples of highly enriched anoxic sediments previously supporting dense macroalgae in the western Waihopai arm.

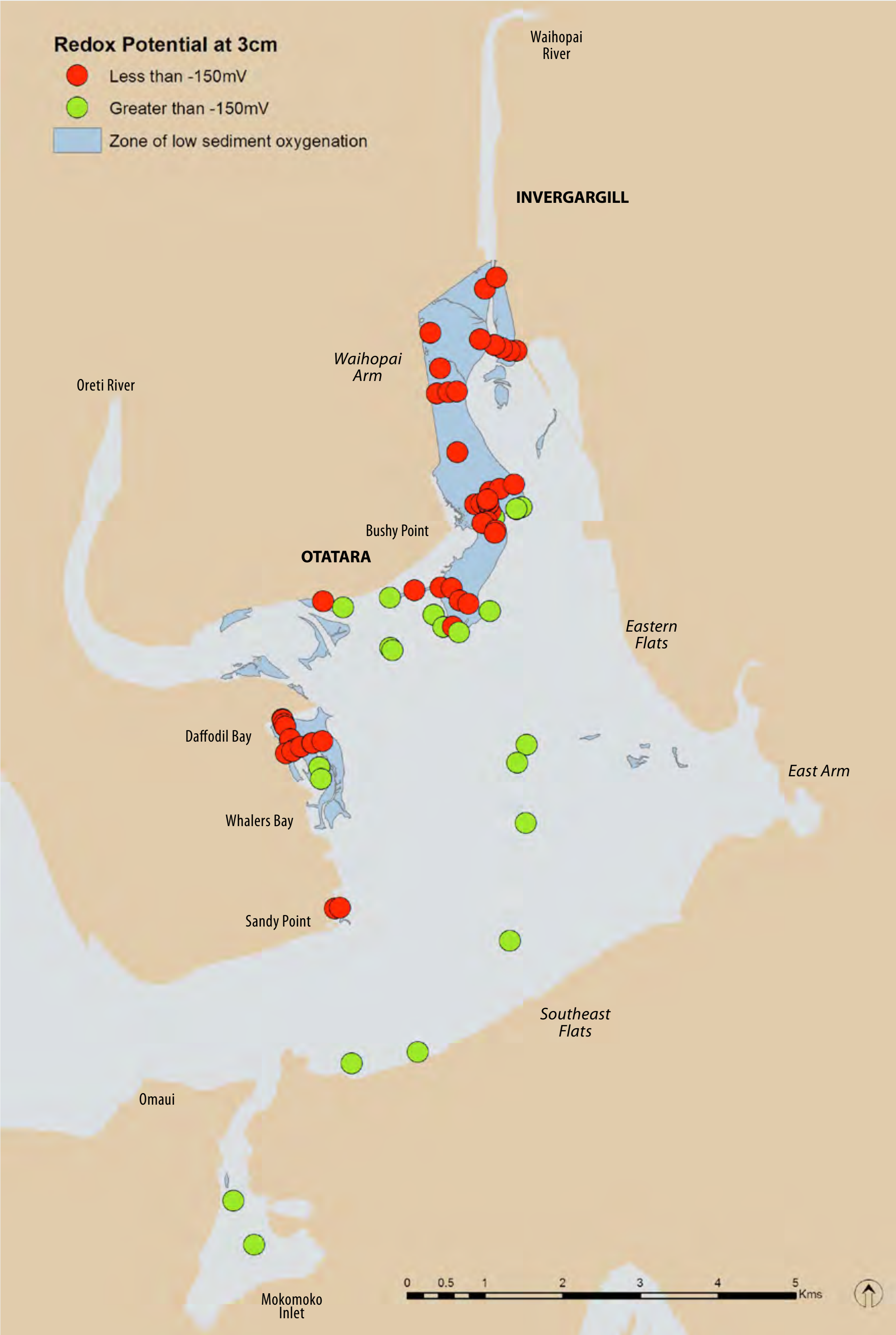


Figure 2.5. Map of Areas with depleted sediment oxygenation - New River Estuary, Feb. 2016.

2.6.6 New River Estuary 2016 Opportunistic Macroalgae

Opportunistic macroalgal growth was assessed by mapping the spatial spread and density of macroalgae in the Available Intertidal Habitat (AIH) (Figure 2.6), and calculating an "Ecological Quality Rating" (EQR) using the Opportunistic Macroalgal Blooming Tool (OMBT).

The EQR score can range from zero (major disturbance) to one (reference/minimally disturbed) and relates to a quality status threshold band (i.e. bad, poor, good, moderate, high). The individual metrics that are used to calculate the EQR (spatial extent, density, biomass, and degree of sediment entrainment of macroalgae within the affected intertidal area), are also scored and have quality status threshold bands to guide key drivers of change.

The overall opportunistic macroalgal EQR for New River Estuary in February 2016 was 0.313 (Table 2.9), a quality status of "Poor" and indicates that the estuary overall is expressing significant symptoms of eutrophication, a condition (impairment) band rating of "High".

The macroalgae present in the estuary was dominated by red alga *Gracilaria chilensis* and the green alga *Ulva lactuca* and *U. intestinalis*. *Ulva* tended to have a relatively low biomass (<500g.m^2) and was most common on sands, the decaying roots of old *Spartina* beds, and rocks in the lower estuary. *Gracilaria* was present throughout the estuary, but was most obvious in very extensive high biomass (>2000g.m^2) beds in the soft mud depositional zones in Waihopai arm and Daffodil Bay, and in establishing beds near the Oreti River mouth and at Bushy Point. In many areas *Ulva* was growing on top of *Gracilaria* beds. The strong relationship between soft mud deposition zones in the estuary, and the expression of macroalgal problems, was also clear. The OMBT for mud dominated sediments was 0.182, a quality status of "Bad", while sand dominated sediments had an OMBT of 0.454, a quality status of "Moderate".

EQR scores have been determined for previous years of broad scale sampling based on maps of percent cover, supported by field photographs and personal observations to estimate biomass. These are presented in Figure 2.7, and changes in >50% macroalgal cover in Figure 2.8. To balance against the uncertainty associated with retrospective estimates of biomass, conservative values have been used so that any bias will tend to underestimate possible adverse impacts rather than overstate problems. To this end, macroalgal cover in the embayment adjacent to the landfill has been excluded from all estimates as this area may be confounded by local point source impacts and restricted water flows.

It is also noted that the 2016 EQR (Table 2.10 below) does not take into account the significant reduction in macroalgal biomass evident in the Waihopai arm since 2013 that is likely driven by extreme sediment anoxia and high sulphide levels. As such the 2016 EQR likely underestimates the extent of macroalgal related degradation evident in the estuary.

Table 2.9. Summary of intertidal opportunistic macroalgal cover, New River Estuary, Feb. 2016.

Metric	Face Value	Final Equidistant Score (FEDS)	Quality Status
AIH - Available Intertidal Habitat (ha)	2944		
Percentage cover of AIH (%) = (Total % Cover / AIH) x 100 *where Total % cover = Sum of {(patch size) / 100} x average % cover for patch*	14.2	0.616	Good
Biomass of AIH (g.m^{-2}) = Total biomass / AIH *where Total biomass = Sum of (patch size x average patch biomass)*	793	0.338	Poor
Biomass of Affected Area (g.m^{-2}) = Total biomass / AA *where Total biomass = Sum of (>5% cover patch size x average patch biomass)*	2005	0.192	Bad
Presence of Entrained Algae = (No. quadrats or area (ha) with entrained algae / total no. of quadrats or area (ha)) x 100	37.2	0.285	Poor
Affected Area (use the lowest of the following two metrics)		0.133	Bad
Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover >5%)	1164	0.133	Bad
Size of AA in relation to AIH (%) = (AA / AIH) x 100	39.6	0.460	Moderate
OVERALL MACROALGAL ECOLOGICAL QUALITY RATING - EQR (AVERAGE OF FEDS)		**0.313**	POOR

Broad Scale Condition (continued)

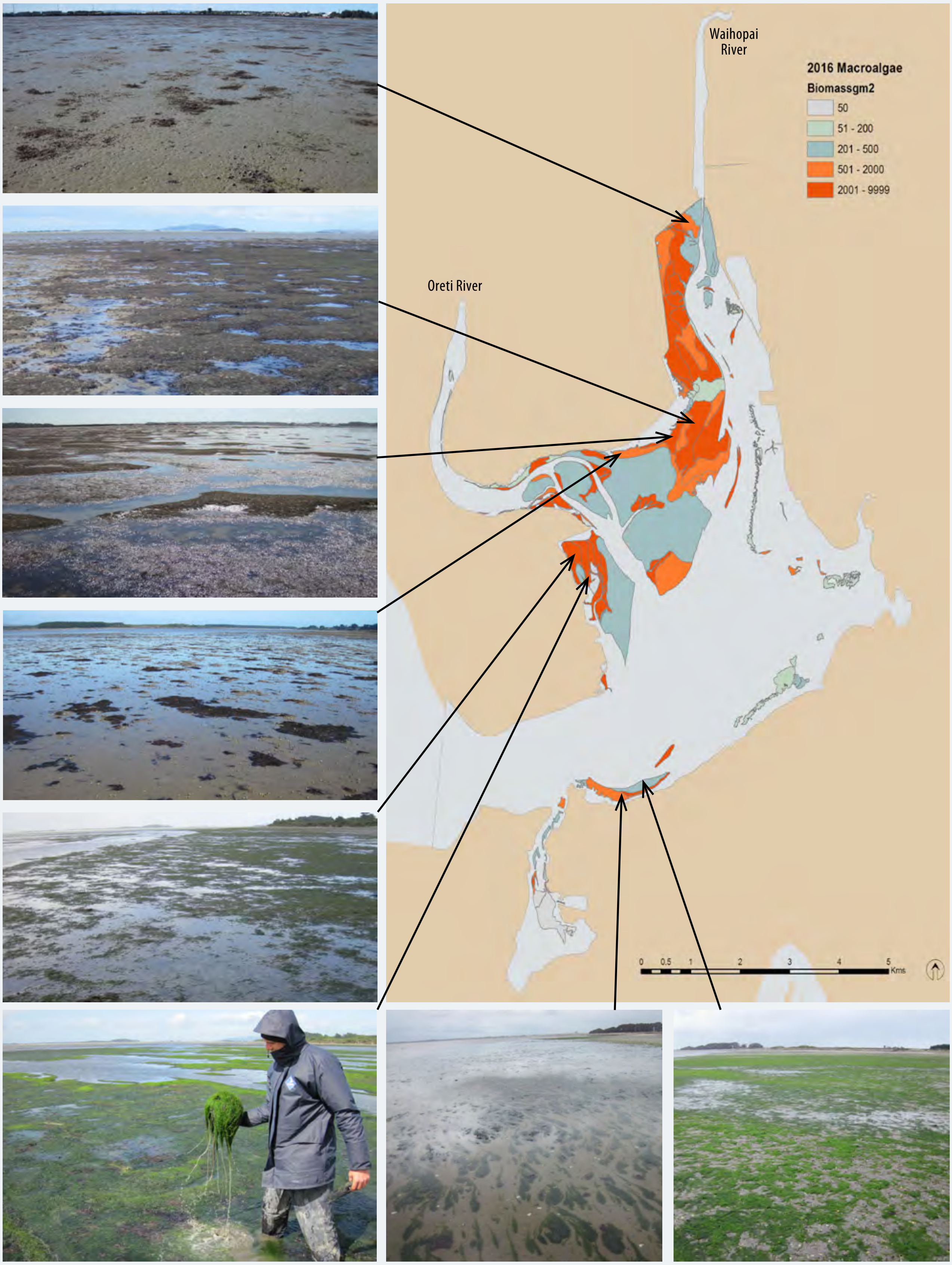


Figure 2.6. Map of Macroalgal Biomass (g.m²) and representative photos - New River Estuary, Feb. 2016.

2.6.7 New River Estuary Changes in Macroalgal Condition 2001-2016

Figure 2.7 shows a consistent and significant decline in the macroalgal EQR over the 2001-2016 period, reflecting a large expansion in the area affected by macroalgae, increasing macroalgal biomass and entrainment in sediment when present, and rapidly deteriorating sediment quality - all indicators of significant eutrophication impacts. The changes reflect an increase of macroalgae throughout the estuary over time (Figure 2.9), but particularly the establishment and expansion of problem growths at Bushy Point (e.g. Figures 2.8 and 2.9) and near the Oreti River mouth, on the western side of the Waihopai arm, and Daffodil Bay (e.g. Figures 2.10-2.14).

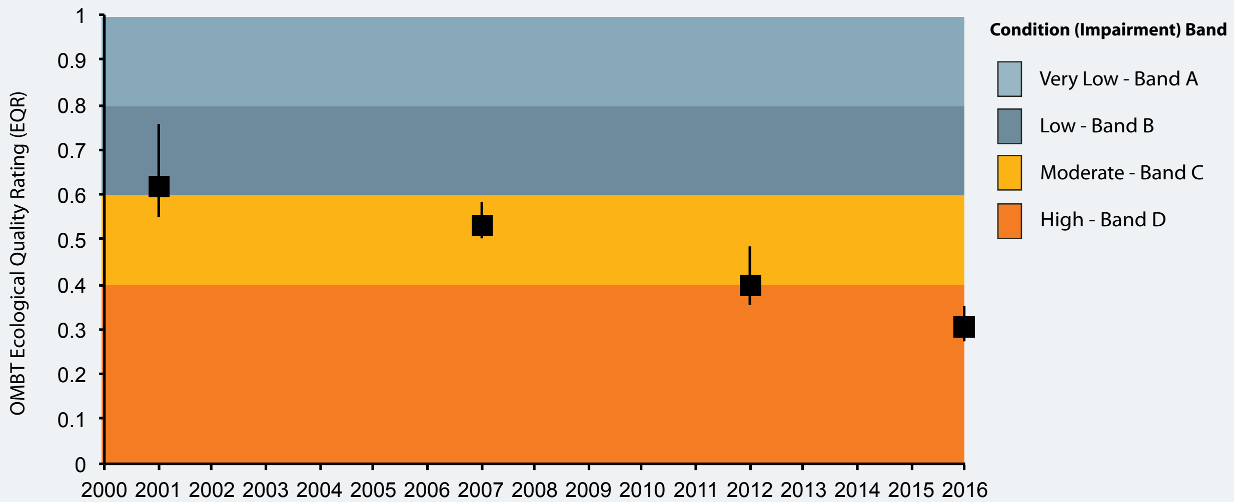


Figure 2.7. OMBT EQR (90% upper and lower Confidence Interval) - New River Estuary, Feb. 2001-2016.

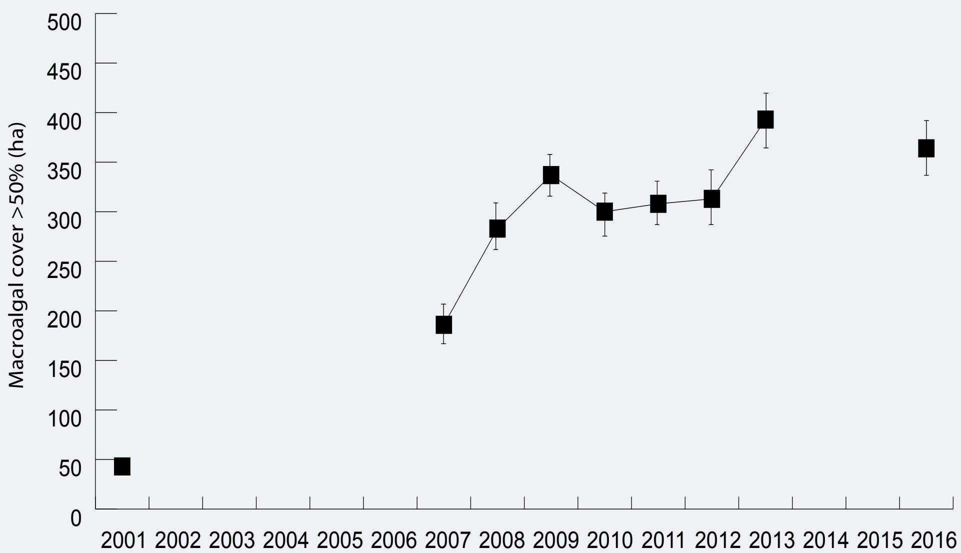


Figure 2.8. Areas of >50% macroalgal cover in New River Estuary 2001-2016.

Figure 2.9. Field photos illustrating changes in macroalgal cover at Bushy Point in 2007, 2012 and 2016.

Figure 2.10. Field photos illustrating changes in macroalgal cover at Bushy Point from 2012 to 2016.

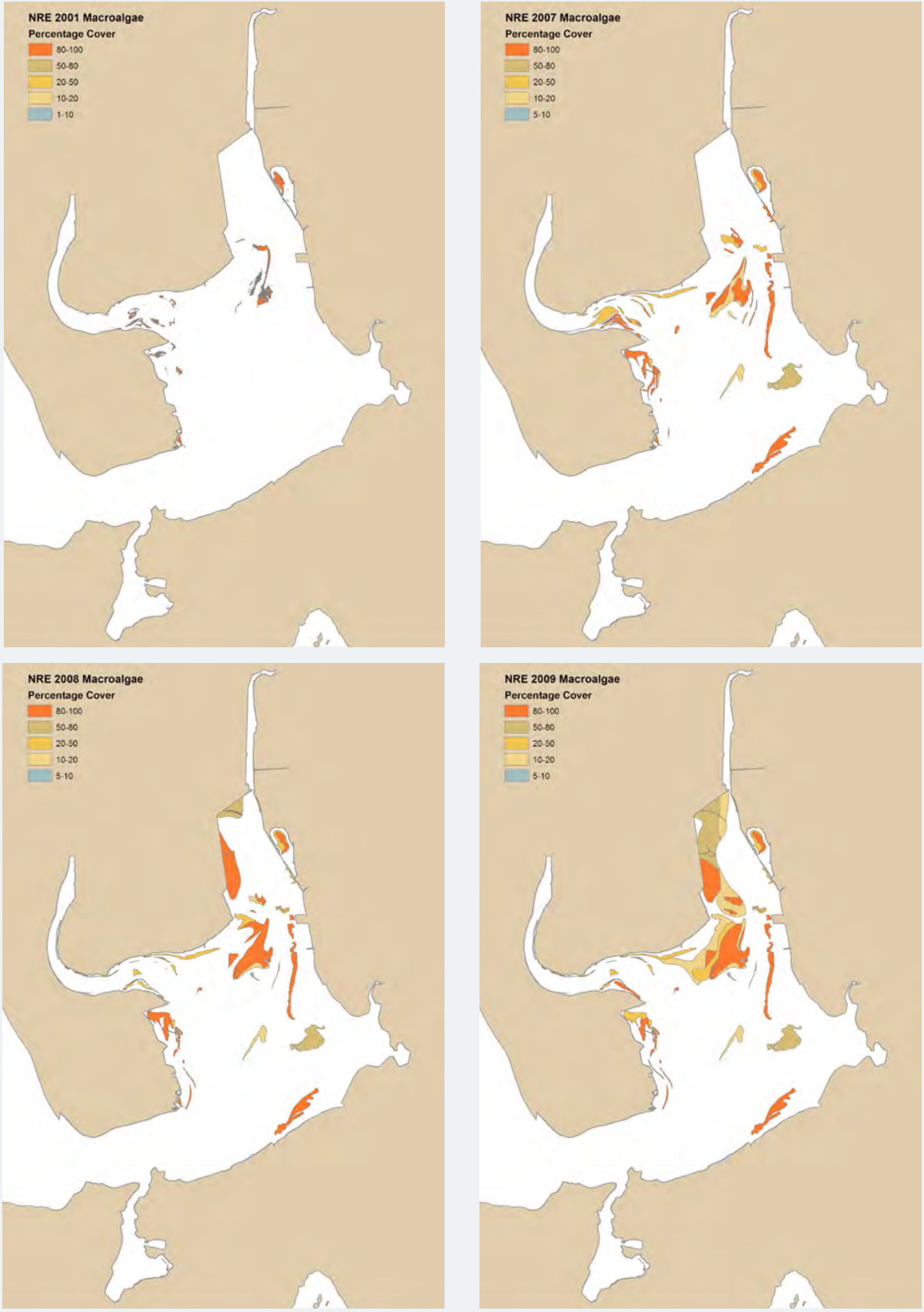


Figure 2.11. Map of Macroalgal Percentage Cover - New River Estuary, Feb. 2001-2016.

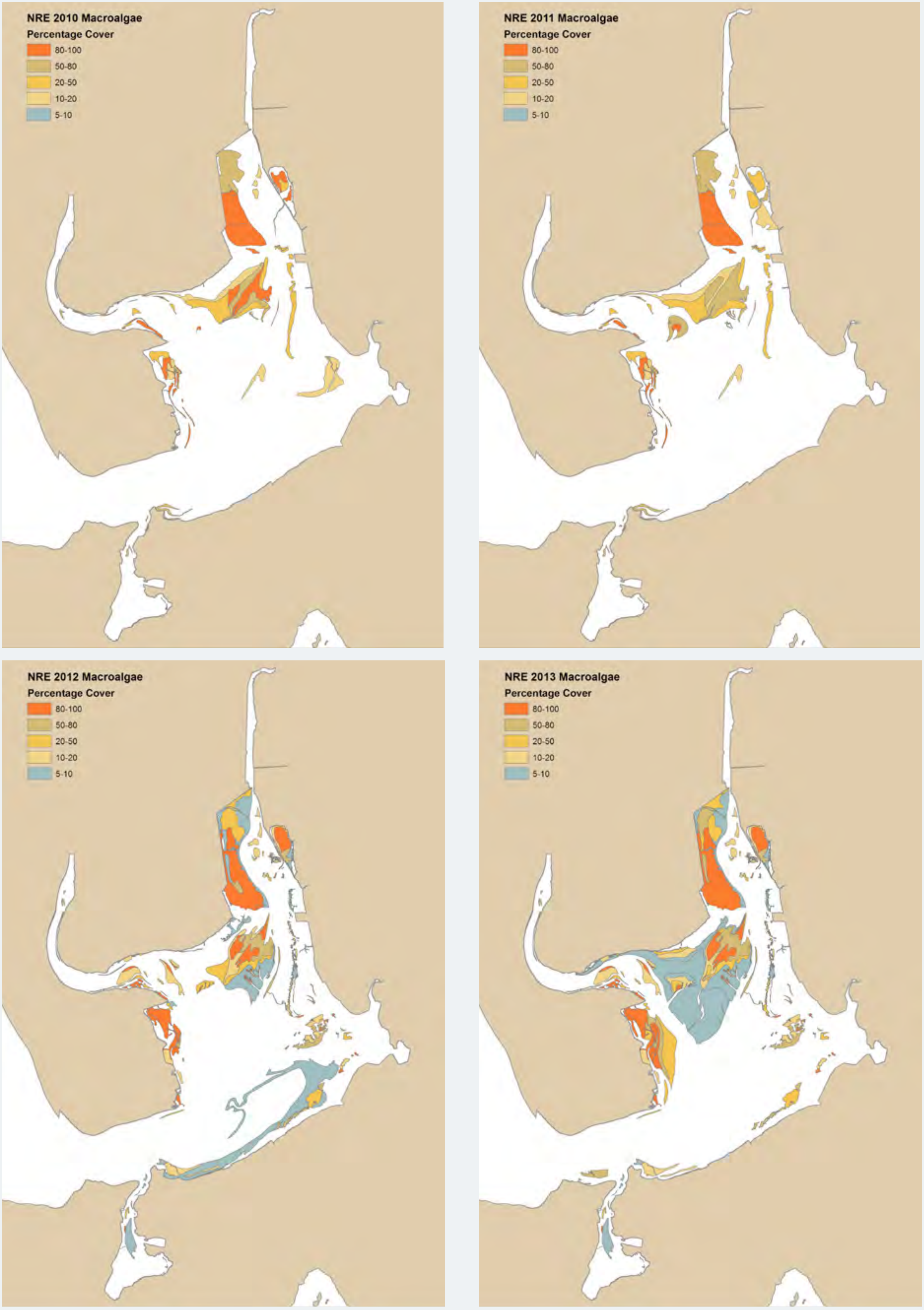


Figure 2.11. cont. Map of Macroalgal Percentage Cover - New River Estuary, Feb. 2001-2016.

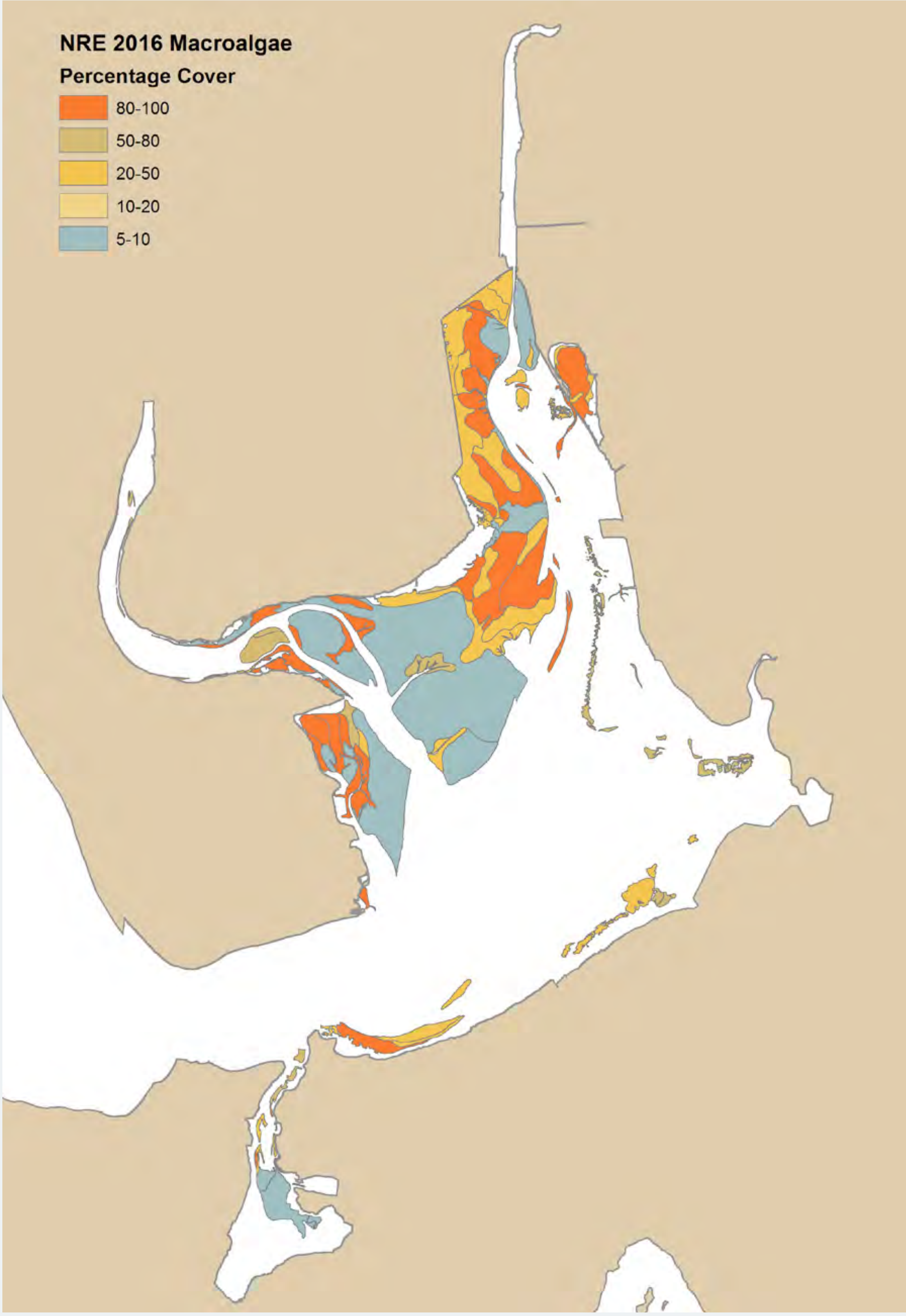


Figure 2.11. cont. Map of Macroalgal Percentage Cover - New River Estuary, Feb. 2001-2016.

Figure 2.12. Aerial photos showing changes in macroalgal cover in the Waihopai Arm, 2006 and 2011. General coverage of nuisance macroalgae indicated by the yellow line.

Very soft muds, 10% macroalgal cover, aRPD 1cm.

Very soft muds, 100% macroalgal cover, aRPD 0cm.

Very soft muds, 30% macroalgal cover, aRPD 0cm, high sediment organic and sulphur content.

Figure 2.13. Field photos illustrating changes in macroalgal cover at the southern Waihopai Arm in 2007, 2012 and 2016.

Broad Scale Condition (continued)

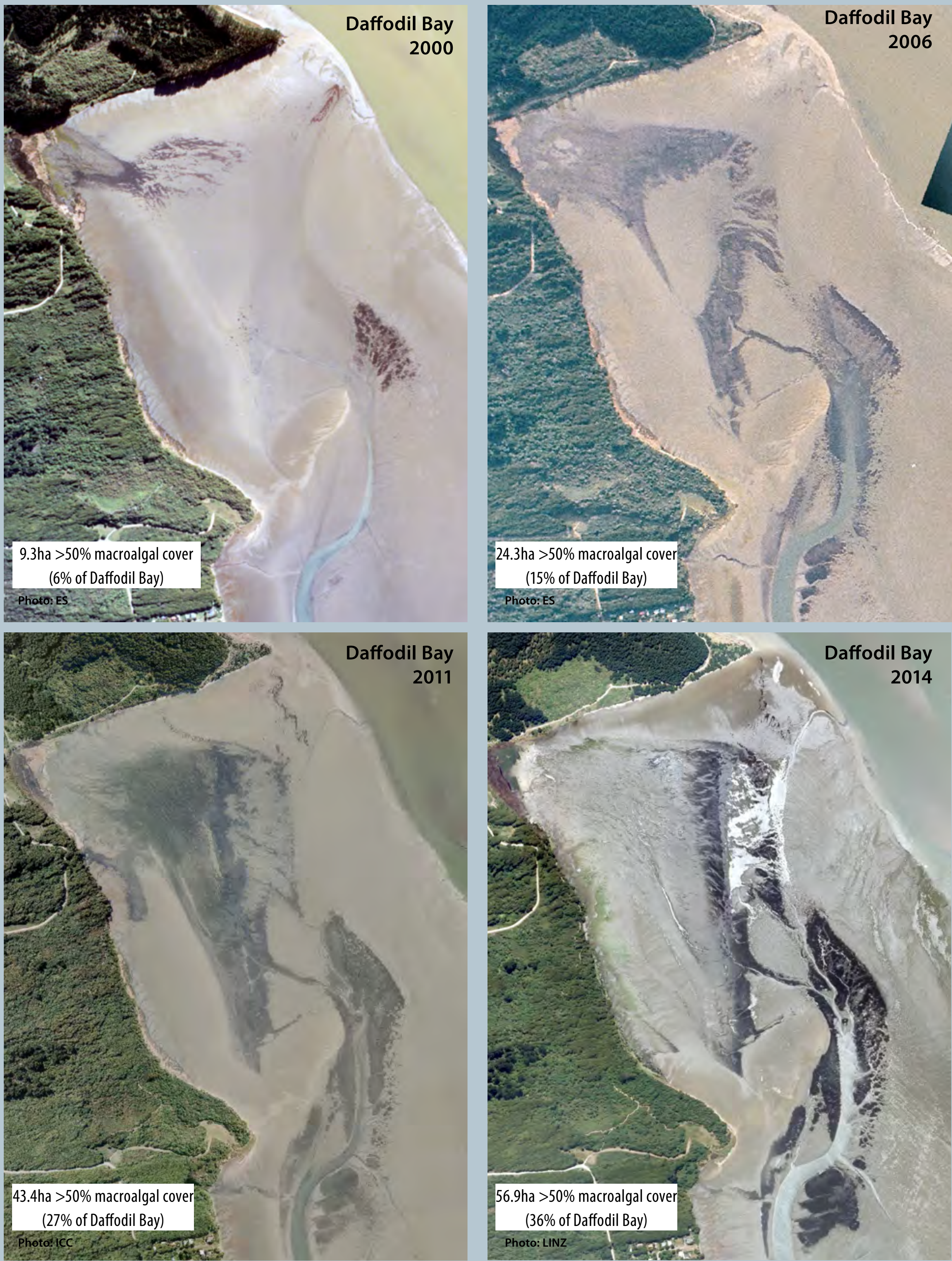


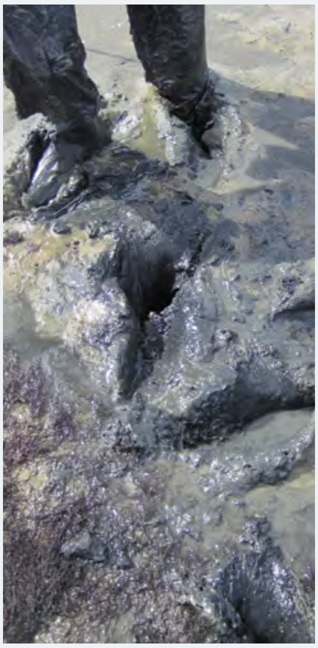
Figure 2.14. Aerial photos showing increase in macroalgal cover in Daffodil Bay, 2000, 2006, 2011 and 2014.

2.6.8 New River Estuary Changes in Gross Eutrophic Zones

Gross eutrophic zones, those where sediments exhibit combined symptoms of a high mud content, a shallow RPD (<1cm), and >50% macroalgal cover have been determined for each year full broad scale mapping has been undertaken. Results, summarised in Table 2.10 and Figure 2.15, show a trend of expanding gross eutrophic conditions since 2001, a clear illustration of worsening conditions in New River Estuary over the last 15 years.

Table 2.10. Gross eutrophic intertidal zones, New River Estuary, 2001, 2007, 2012, and 2016.

Year	Ha	%
2001	23	1
2007	49	2%
2012	240	8%
2016	351	13%



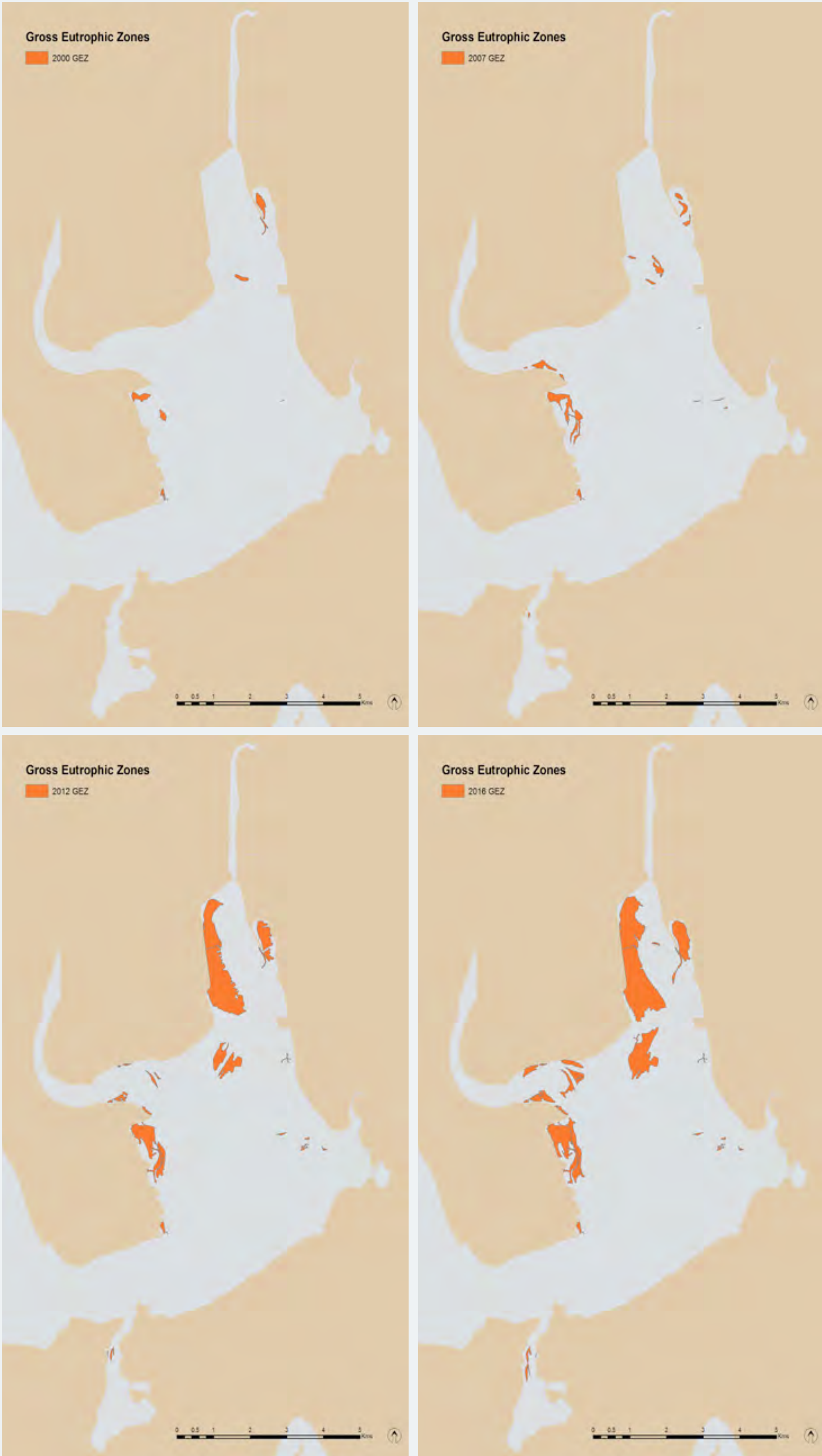


Figure 2.15. Location and extent of gross eutrophic zones in New River Estuary in 2001, 2007, 2012 and 2016.

2.6.9 New River Estuary 2016 Seagrass Cover

The results of the 2016 intertidal seagrass survey are summarised in Table 2.11 and Figure 2.16. While the percentage cover of seagrass with a density >20% is relatively low (2% of the estuary) it still represents a relatively large area (56ha) because of the size of New River Estuary. Highest densities were located in well flushed areas on the east side of the estuary, in the lower estuary near Omaui, and in narrow beds along the banks of the Oreti River. In these locations seagrass appeared in relatively good condition with luscious growths, little fine mud, and no obvious macroalgal smothering.

Seagrass remaining in the Waihopai arm and in the lower Oreti River near Otatara was under obvious stress from excessive enrichment and sedimentation.

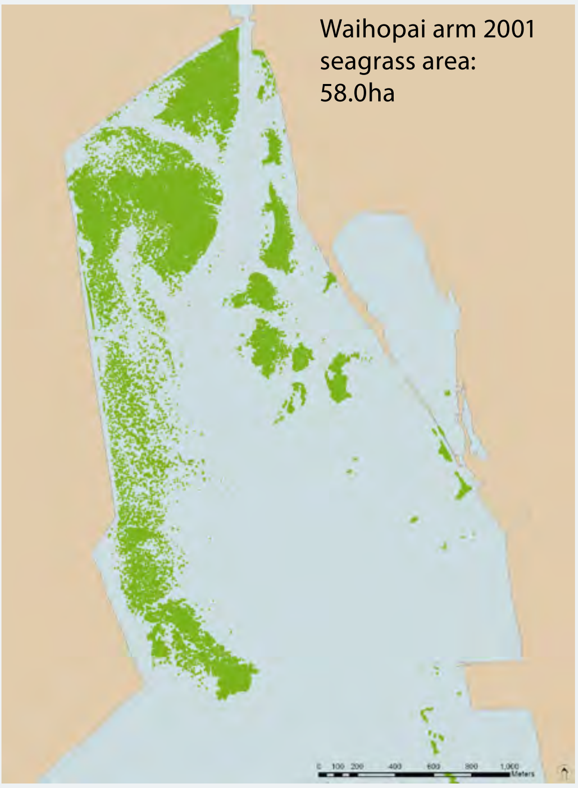
Throughout the east side of the estuary, sparse *Zostera* shoots (<1% cover) were present, densities likely remaining low because of mobile sands constantly modifying the area. Subtidal beds (not mapped) were present in the lower Oreti River.

Table 2.11. Summary of seagrass *(Z. muelleri)* cover, New River Estuary, Jan. 2016.

Density	Ha	%
<1%	2,873	97.6
1-5%	0	0.0
5-10%	12	0.4
10-20%	3	0.1
20-50%	14	0.5
50-80%	0	0.0
>80%	42	1.4
	2,944	**100**

Figure 2.16. Map of Seagrass Cover - New River Estuary, Feb. 2016.

Broad Scale Condition (continued)



2.6.10 New River Estuary 2016 Changes in Seagrass Cover 2001-2016

A comparison of seagrass area with >20% cover in 2001, 2012 and 2016 (Table 2.12) shows a 38ha (40%) reduction in the estuary, a condition (impairment) band of "High". Seagrass cover mapped in 2007 has not been included as the low resolution aerial photos provided at that time precluded accurate mapping of seagrass beds.

Seagrass losses have occurred almost exclusively in the Waihopai Arm (Figure 2.17) where there has been an 83% reduction in seagrass overall from 2001 to 2016, particularly on the western intertidal flats where there has been an almost complete loss of seagrass which is attributed to seagrass beds being covered in fine muds, often in combination with smothering by macroalgae. Since 2007, rotting macroalgae has been creating degraded sediment conditions with black, sulphide rich and anoxic muds dominating the surface sediments throughout this part of the estuary.

Table 2.12. Dense (>20%) Seagrass Cover, New River Estuary, 2001, 2012, and 2016.

Year	Ha	% loss
2001	94	baseline
2012	64	-32%
2016	56	-40%

Figure 2.17. Map of dense seagrass cover in the Waihopai arm, 2001, 2012 and 2016.

2.6.11 New River Estuary General Summary 2001-2016

- The February 2001 results show that the estuary had 43ha of high density cover, and that where dense mats were present, sediments were commonly very soft, anaerobic, and sulphide rich. Based on these records and a review of the aerial photos of the time, GEZ areas have been estimated as ~23ha (with a likely error of ± 5-10ha). Seagrass (>20% density) covered 94ha.
- In February 2007, dense macroalgal growth had expanded from existing areas compared with 2001, and included new areas in Daffodil Bay, and areas of high cover but low biomass growth on top of the residual root systems of recently eradicated *Spartina* beds, predominantly along the east of the estuary. Of the reported 186ha of high density cover (i.e. >50% macroalgal cover), 49ha was estimated to be GEZ (Stevens and Robertson 2012). Low resolution aerial photographs available at the time precluded an accurate assessment of seagrass cover.
- Annual monitoring of macroalgal cover between 2008 and 2013 inclusive showed expansion of high density cover (i.e. >50% macroalgal cover) to 283ha in 2008, and eventually to 313ha in 2012, with the latter including 240ha of GEZ. In 2013, mean macroalgal biomass in the GEZ areas was 7900gm^{-2} wet wgt in Daffodil Bay and 5600gm^{-2} wet wgt in Waihopai Arm (Robertson and Stevens 2013). Seagrass (>20% density) had reduced to 64ha, most losses occurring in the western Waihopai arm.
- In February 2016, high density macroalgal cover had continued to expand and covered 364ha, including 351ha of GEZ. Significant macroalgal cover had established on the well flushed flats between the Oreti River mouth and Bush Point with trapped fine sediment beginning to rapidly build up in some areas. Seagrass (>20% density) had reduced to 56ha, losses continuing to occur in the western Waihopai arm and also along the lower Oreti River banks.

The results for all years indicate an elevated presence and increasing trend of high density (>50% cover) opportunistic macroalgae which, by 2016, had increased by ~800% since 2001 and ~100% since 2007. At the same time, the extent of the estuary classified as gross eutrophic zone had increased by ~1400% since 2001 and ~600% since 2007, whereas seagrass cover had decreased by ~50% across the whole estuary, with losses >80% recorded in the Waihopai arm. The overall NZ ETI score of 0.93 places the estuary in a "High" state of impairment in 2016 (Band D - High Eutrophic Symptoms), with a significant increase in eutrophic symptoms occurring since 2001.