Te Awarua-o-Porirua Harbour monitoring

Greater Wellington
Te Pane Matua Taiao

Contents

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Overview

Te Awarua-o-Porirua Harbour is located 21 km north of Wellington City and comprises two inlets; Onepoto, which extends from Mana to the shoreline of Porirua City and Pāuatahanui, which stretches eastwards from the Paremata Bridge towards the Pāuatahanui Wildlife Reserve. The Harbour was originally named Pari-ā-Rua, which translates to "twin flowings of the tide". Entrances to both inlets provide a calm and accessible area for recreational use, while the head of Pāuatahanui Inlet is home to a world-class wetland reserve that is being threatened by sea level rise.

This system is of great cultural importance to Ngāti Toa Rangātira who have kaitiakitanga (guardianship) over the area and historically used the Estuary as mahinga kai. This area is also of significant economic and ecological value with a catchment that includes 18,470 ha of rural farmland, lifestyle blocks, urban settlement, parkland, and rail and road corridors that present ongoing pressures on the estuarine ecosystem. The key issues facing this sensitive environment are excessive sedimentation rates, pollution, and ecological degradation.

Currently Greater Wellington (GW) monitor intertidal estuary sediment quality annually to understand the natural variation within the environment and the impacts of human activities. Other studies such as subtidal sediment and macrofaunal assessments, habitat mapping, and bathymetry surveys are undertaken every four years or when substantial shifts are recorded during sediment plate surveys. Current and historical data are presented on maps within this web report to provide an indication of the health of the Harbour over time.

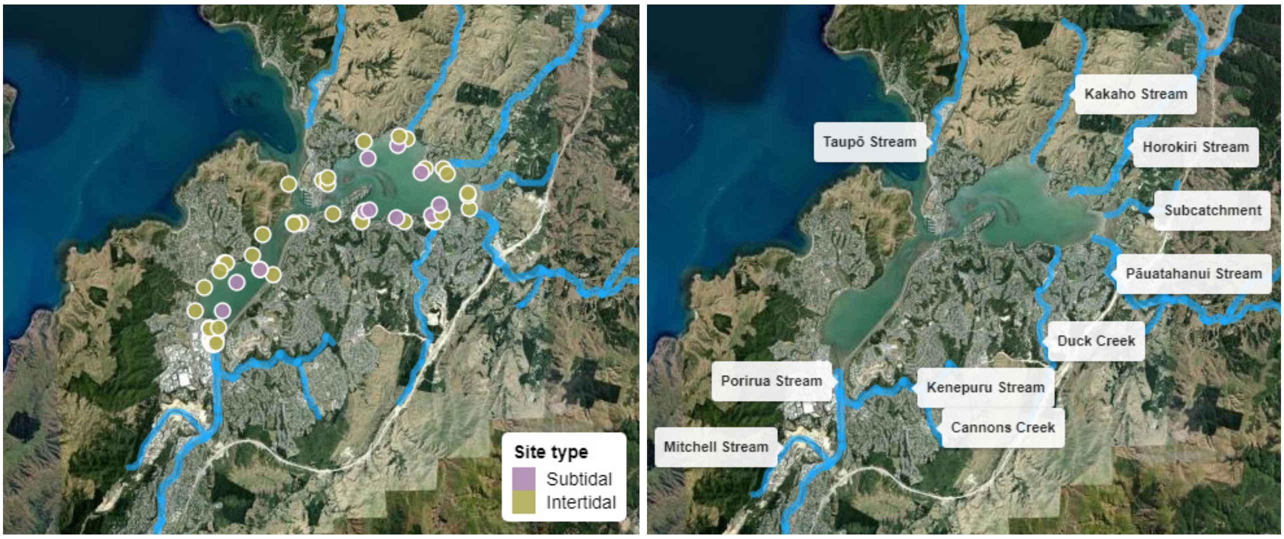

Figure 1: Te Awarua-o-Porirua Harbour monitoring sites and the main stream/creek inputs flowing into the harbour. Note that sites and indicators vary across the sampling period.

Methods

Full details of methods, guideline comparisons, and data tables are accessible in coastal monitoring reports. Relevant reports are also linked above each results section.

Habitat surveys describe and map estuaries according to dominant habitat features combining aerial photography, detailed ground truthing, and Geographic Information System (GIS) data. Changes in the position, size, or type of dominant habitats are monitored over time by repeating the mapping exercise every five years. Once an estuary has been classified according to its main habitats and their condition, representative habitats can be selected and targeted for sediment quality and ecological monitoring.

The environmental characteristics assessed in fine scale surveys include biological attributes (e.g. number of animals) and physical and chemical characteristics (e.g. sediment mud content, metals, nutrients) to assess ecological condition. We also measure the amount of sediment depositing in the harbour using plates buried below the soft sediment in intertidal and subtidal areas to tell us where and how much mud is settling. Results across all years are assessed using estuarine health metrics or condition ratings, which are used to assign one of four ‘health status’ bands (e.g. poor, fair, good, very good) to track changes over time. These data are used to make informed environmental management decisions to protect and improve the resilience of Te Awarua-o-Porirua Harbour.

Annual executive summaries

2021/22

Our annual intertidal and subtidal sediment rate survey (18 sites) and an intertidal fine scale environmental health survey (four sites) were both conducted in the Te Awarua-o-Porirua Harbour in January 2022.

Annual sediment rate survey

Sediment accrual rates in Te Awarua-o-Porirua Harbour remain elevated, particularly in the Pāuatahanui Inlet. Between December 2020 and January 2022 there was high accretion associated with a ‘poor’ condition rating at two Onepoto subtidal sites, and two intertidal and three subtidal sites in Pāuatahanui. Accretion is commonly associated with elevated mud content and poor sediment oxygenation, which makes sediment unsuitable for many sediment dwelling organisms. There has been some recovery from the widespread intertidal deposition of soft muds recorded in January 2020 in Pāuatahanui Inlet near Kakaho and Ration Point, but increased deposition was evident at Horokiri, along with a trend of increasing intertidal sediment mud content. Greater sedimentation is still occurring at subtidal sites relative to intertidal sites (Stevens et al. 2022).

Environmental health fine scale intertidal survey

Despite intertidal sedimentation rates exceeding the 2 mm/year national guideline value at three of the four state of the environment (SoE) monitoring sites, almost all sediment quality indicators except sediment oxygenation and mud content were consistent with ‘good’ or ‘very good’ condition (Forrest et al. 2022). Mud and sediment oxygenation showed an improvement since 2020 despite a weak overall trend of increasing mud content at Onepoto B and Pāuatahanui B in the inner Harbour.

Concentrations of trace metal contaminants remained low and semi-volatile organic compound screening for contaminants such as the pesticide DDT returned nondetectable results. Overall, fine scale monitoring shows that Porirua SoE sites remain in a relatively healthy condition and are in a better state than SoE sites monitored in other estuaries regionally in terms of mud, trophic state and macrofaunal indicators.

Reasons for the apparent improvement of most environmental health indicators in Te Awarua-o-Porirua Harbour in 2022, including the macrofaunal community, are unclear and there appear to be drivers of spatial and temporal change that are not reflected in any of the sediment constituents measured. It is likely that these temporal changes reflect a combination of drivers including local natural variability and catchment wide external environmental factors. An upcoming review of the SoE monitoring programme will inform selection of future monitoring sites and variables to ensure improved quantification of ecological condition in estuary locations that are most vulnerable.

2020/21

As part of ongoing monitoring in Te Awarua-o-Porirua Harbour, annual sediment plate measurements were recorded in December 2020. While there was some intertidal recovery from the widespread deposition of soft muds recorded in January 2020, there was also degradation observed in new areas. Of particular concern was a thick slurry of deposited fine sediment covering previously sandy intertidal flats at Kakaho (Site P7) with 21.5 mm of intertidal deposition over the previous eleven months, the largest mean annual increase recorded for that site since monitoring began in 2007 (Roberts et al. 2021). Mud content increased from an already very high 63.5% to 67.3% and sediment oxygenation was ‘poor’. Decreases in the spatial extent of intertidal mud near Horokiri and Pāuatahanui streams coincided with significant increases in subtidal deposition - Kakaho (Site PS1; 41 mm), Horokiri (Site PS2; 30 mm) and Duck Creek (Site PS3; 13 mm). Mud mobilised from the intertidal zone was likely deposited in nearby subtidal areas, which is consistent with trends in the estuary-wide bathymetric surveys of predominantly subtidal areas and with NIWA’s estuary sediment load estimator.

Results from our four-yearly subtidal sediment survey of Porirua Harbour (samples collected in November 2020) showed that bottom sediments at all sampling sites were mostly mud (66-97% mud), except for the site located off Camborne, which was mostly fine sand. Organic matter content was very similar across sites, ranging from 4.6-8.0% (Cummings et al. 2022). Any contaminants that may enter the Harbour via rivers, stormwater, or road runoff, are likely to collect in the deeper muddy areas in the Onepoto Inlet and at the southern end of the Pāuatahanui Inlet. None of the sites exceeded guideline ‘safe’ concentrations for the heavy metals arsenic, cadmium, chromium, nickel or mercury; although in the Onepoto Inlet guidelines were exceeded for lead, zinc and copper, while mercury concentrations were close to exceedance. Overall, the Pāuatahanui Inlet was found to be less contaminated than the Onepoto Inlet, likely due to its distance from the Porirua City Centre.

Total organic carbon (TOC), sediment phosphorus concentrations and sediment nitrogen concentrations are all measures of nutrient content and are used as indicators of water or sediment quality - high values may suggest that sediments are anoxic or unsuitable for most living organisms. TOC concentrations varied around the Harbour, with the highest levels recorded in the Onepoto Inlet. The site near Camborne had the lowest percentage TOC and was rated as ‘good’, while Browns Bay, Duck Creek and one site in the Onepoto Inlet were rated ‘fair’, and the site closest to Porirua City rated ‘poor’. Sediment phosphorus levels were ‘poor’ in the Onepoto Inlet and at Browns Bay, but ‘fair’ at Duck Creek and Camborne, while sediment nitrogen levels were ‘fair’ at all five sites. This indicated that the Onepoto Inlet is receiving high nutrient inputs, likely from the Porirua Stream and stormwater outlets around the Harbour edge.

Again the Onepoto Inlet scored lower than the more rural Pāuatahanui Inlet, fewer species of sediment dwelling invertebrates were found closer to Porirua City. On average, 16 different species were found within each sample collected, with worms and bivalve shellfish most common

(Cummings et al. 2022). Each of the sites had distinct communities but there were double the number of animals in the Onepoto Inlet compared to the Pāuatahanui Inlet (average of 268 and 145 individuals per sample respectively). Although the two sites in the Onepoto Inlet were in poorer health than those in the Pāuatahanui Inlet as indicated by the concentrations of contaminants and nutrients measured and the very high proportion of muddy sediments, the benthic communities at all sites contained a mix of organisms, from species sensitive to mud and organic enrichment to mud-loving species.

Our long-term monitoring shows that pressures on the Harbour do not appear to be localised in a particular area of the estuary. Encouragingly, the proportion of fine sediments has decreased over time at sites near Porirua City as well as close to Camborne. Average concentrations of lead have also declined at these sites, as have copper in sediments at some sites within both sections of the Harbour. While there is difficulty with statistically comparing changes over time with the small dataset available, these slight improvements in the subtidal are encouraging.

2019/20

Between January 2019 and January 2020, the Pāuatahanui Inlet experienced a doubling of the amount of mud settling on the estuary floor and the largest annual increase of intertidal sediment deposition since monitoring began in 2008. Intertidal sites in the Onepoto Inlet also experienced an increase in sediment deposition but to a lesser extent. Average annual sedimentation rate across all intertidal sites and all monitoring years shows a sediment increase of 1.2 and 3.2 mm per year respectively. Increased deposition appears to be associated with occasional inputs of disturbed sediment from the catchment above the Estuary (Stevens & Forrest 2020a - Sediment plate monitoring). Most subtidal sites within the Harbour experienced an increase in sediment deposition, as sediments are washed into deeper areas where they settle. These results are consistent with those of the bathymetry survey carried out in June 2019 (Waller & Stubbing 2019 - Bathymetry), which indicated moderate to high sediment deposition rates in both inlets of the Harbour, particularly in Pāuatahanui, warning us of the increased likelihood of significant environmental damage.

Sediment quality is generally related to mud content as muddy sediments have less oxygen, so don’t support healthy communities, and contaminants easily attach to the greater surface area provided by fine particles. Despite the increase in sediment mud content, intertidal sediment quality assessed in 2020 was mostly good with low levels of metal contaminants and little evidence of nutrient enrichment (Forrest et al. 2020 - Intertidal monitoring). Sediments were found to be poorly oxygenated, largely due to the high mud content, which excludes species that aerate the sediments and fills air spaces that would usually be present between coarser sand particles.

The habitat survey, undertaken every five years, not only maps the spatial extent of mud but also macroalgae, seagrass, and salt marsh (Stevens & Forrest 2020b - habitat mapping). During the January 2020 survey nuisance seaweeds were uncommon, however, over the last year there has been an apparent ‘bloom’ of a green mat-forming species near the two sites closest to the

Paremata Bridge. Despite massive historical losses of seagrass (*Zostera muelleri*), densities have changed little in extent since 2008. In contrast, a 43% decline in salt marsh extent between 2013 and 2020 was recorded, with the decline primarily located in the eastern Pāuatahanui Inlet where this habitat is artificially drained.

Looking at a finer scale, the invertebrate animals living within the sediments are experiencing a gradual decline in diversity and abundance, which again appears to be partially due to increased sediment mud content. At the eastern end of the Pāuatahanui Inlet, several previously common species intolerant of mud were no longer present in 2020 (Forrest et al. 2020 - Intertidal monitoring). These results are inconsistent with the findings of the most recent volunteer cockle survey coordinated by the Guardians of Pāuatahanui Inlet which found that cockle (*Austrovenus stutchburyi*) counts increased by 40.9% between 2016 and 2019, with densities being the highest recorded since 1992 (Michael & Lyon 2020 - Cockle report). In 2019, population size estimates were the highest since 1976, while the percentage of juvenile cockles declined. The increase in terrestrial sediments considered harmful to cockles do not appear to have affected the overall intertidal cockle population, although the more sensitive juvenile cockles may have been impacted. Results suggest that other influences may be causing shifts in invertebrate communities and might be worth investigating in future studies.

Overall, the health of the Harbour is in gradual decline, largely due to the increased pressure of sedimentation. Our monitoring reveals a long-term harbour-wide increase in the extent of mud-dominated sediments indicating that targeted investigations and remedial action is urgently required. Whaitua objectives were set in 2019 (Te Awarua-o-Porirua Whaitua Committee 2019) to address the most pertinent problems facing Te Awarua-o-Porirua Harbour and implementation is ongoing through numerous community projects.

Sedimentation & bathymetry

Sediment (particularly muddy sediments) discharged into rivers, streams and harbours can negatively impact a range of values, including ecosystem health and the way people use water for recreational, cultural and spiritual purposes.

Sedimentation rate

The depth of sediment overlying concrete pavers buried at discrete sites provides an indicator of estuary sedimentation. The map shows monitoring site (circles) annual sedimentation over a rolling five year period and the whole harbour average of these values (shaded region). Positive values indicate where there has been sediment deposition (accumulation) and negative values indicate erosion. See Stevens et al. 2022 for technical methods, data tables, and further information

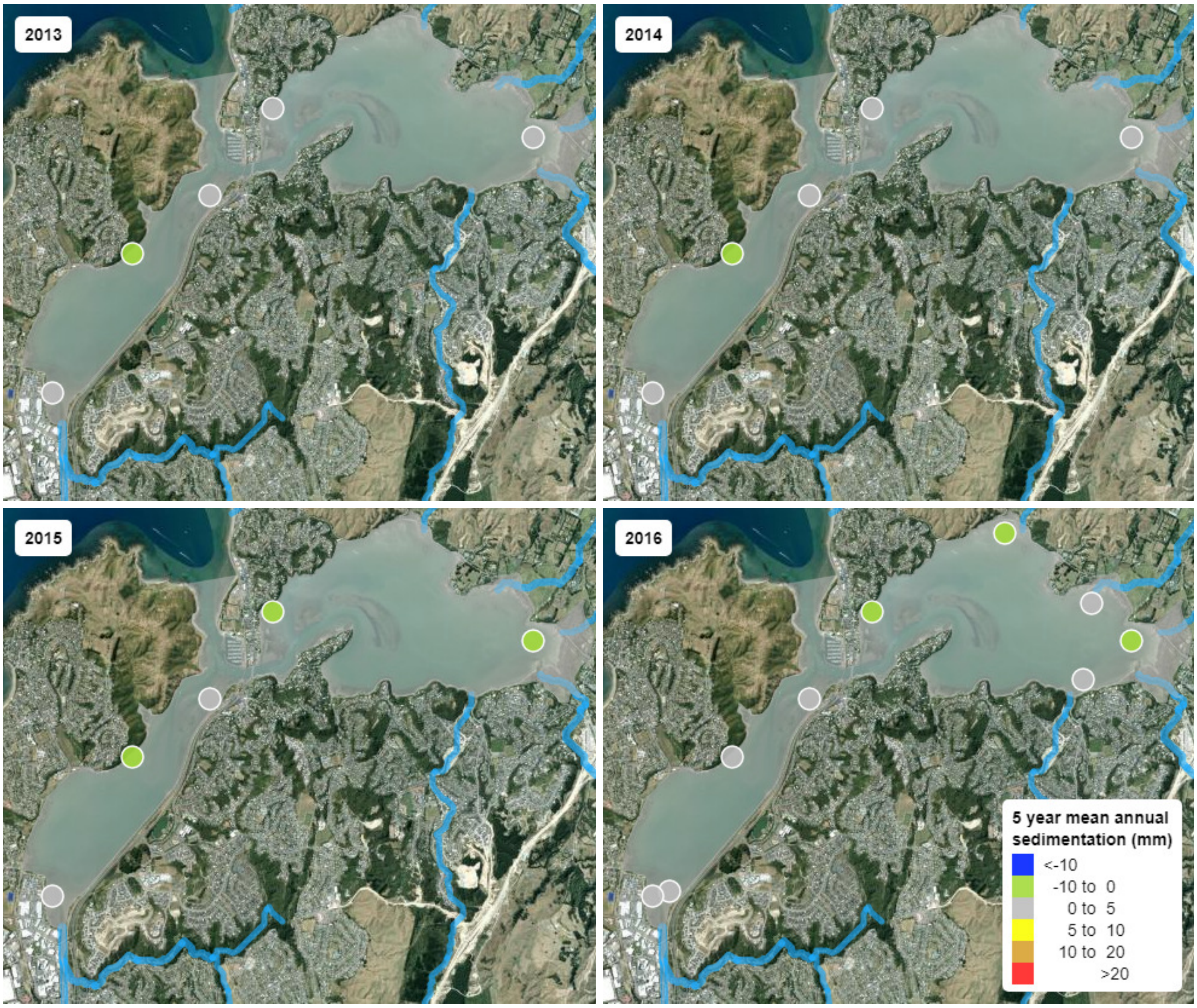

Figure 2: Five year mean annual sedimentation rate (mm) results for the periods ending 2013 to 2016.

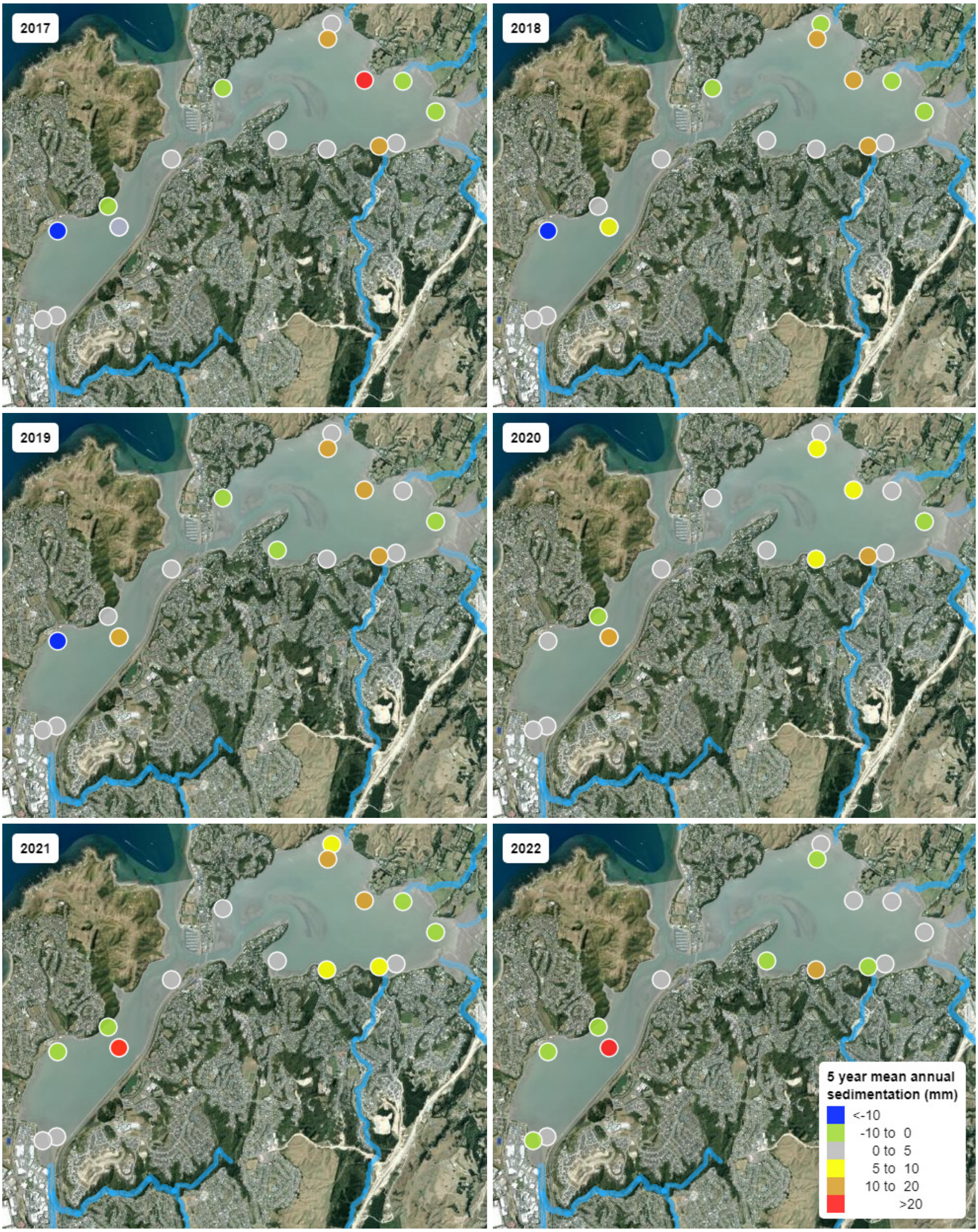

Figure 3: Five year mean annual sedimentation rate (mm) results for the periods ending 2017 to 2022.

Bathymetry

Contours displayed at 0.25 m intervals derived from depth databases gridded at 10 m resolution. Bathymetry depths (m) are referenced to Porirua Sounding Datum (SD) which is linked to Porirua Chart Datum (CD), defined as 2.55 m below Land Information New Zealand (LINZ) steel pin C1K1 at the Mana Cruising Clubrooms.

Due to the wide spaced survey lines and irregularly shaped seabed, some gridding artefacts can be seen along the outer edges of the survey area. For example, along the northern channel of the Onepoto Inlet where it appears there are ridges in the channel and along the southern edge of the Pāuatahanui Inlet where some flat areas show raised unnatural features.

See Waller & Stubbing 2019 - Bathymetry for technical methods, data tables, and further information

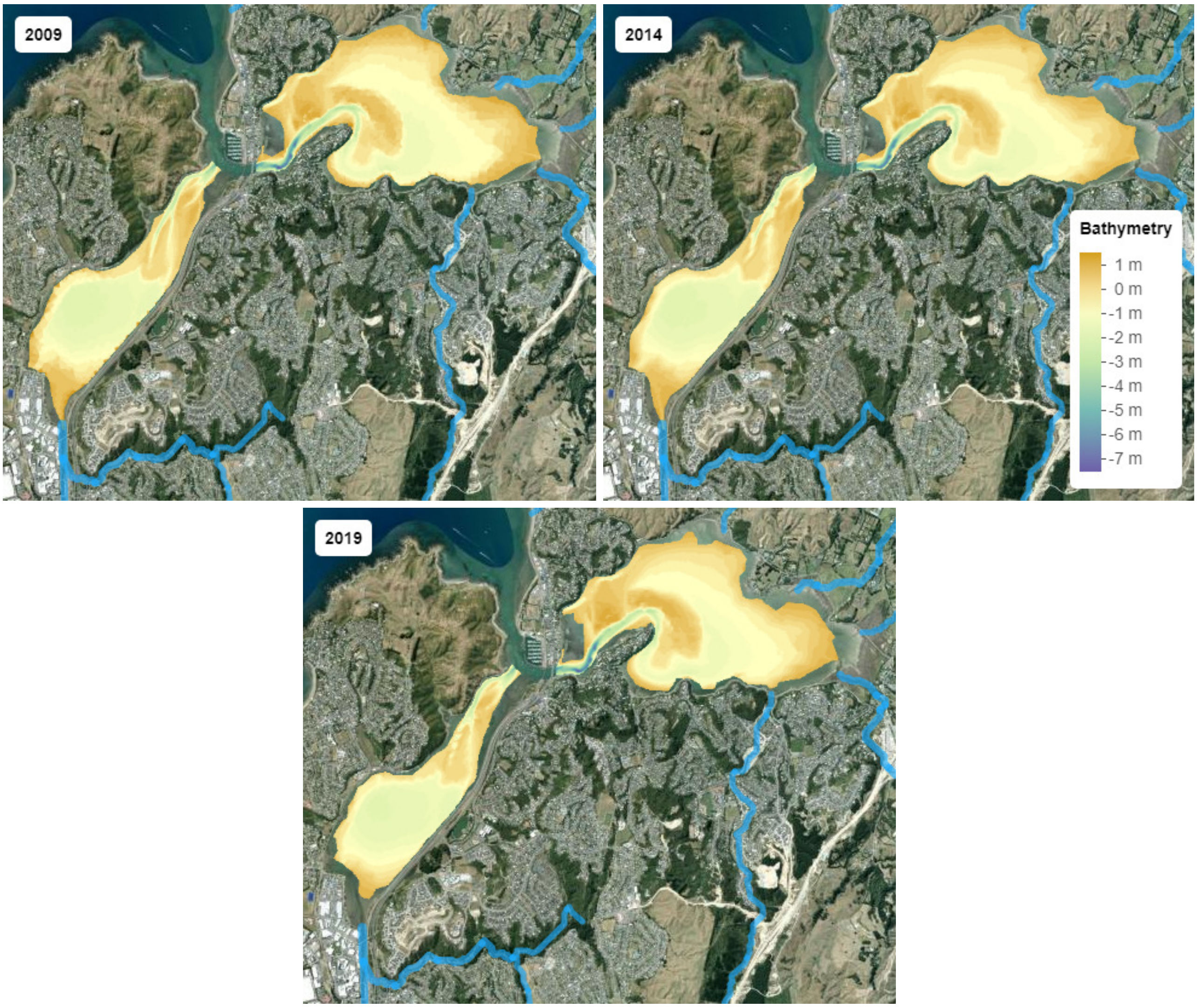

Figure 4: Bathymetry (m) survey results for 2009, 2014, and 2019.

Bathymetry change

Contours derived from differencing the 10 m resolution depth databases from each combination of surveys. Red areas indicate sedimentation, while blue areas indicate general harbour erosion. Bathymetry depths (m) are referenced to Porirua Sounding Datum (SD) which is linked to Porirua Chart Datum (CD), defined as 2.55 m below LINZ steel pin C1K1 at the Mana Cruising Clubrooms.

Results show shoaling across the main Onepoto Basin, but generally little change along the shallow banks at the northern entrance. The Pāuatahanui Inlet has likely experienced general shoaling at the southern side and some possible erosion or deepening on the northern side.

See Waller & Stubbing 2019 - Bathymetry for technical methods, data tables, and further information

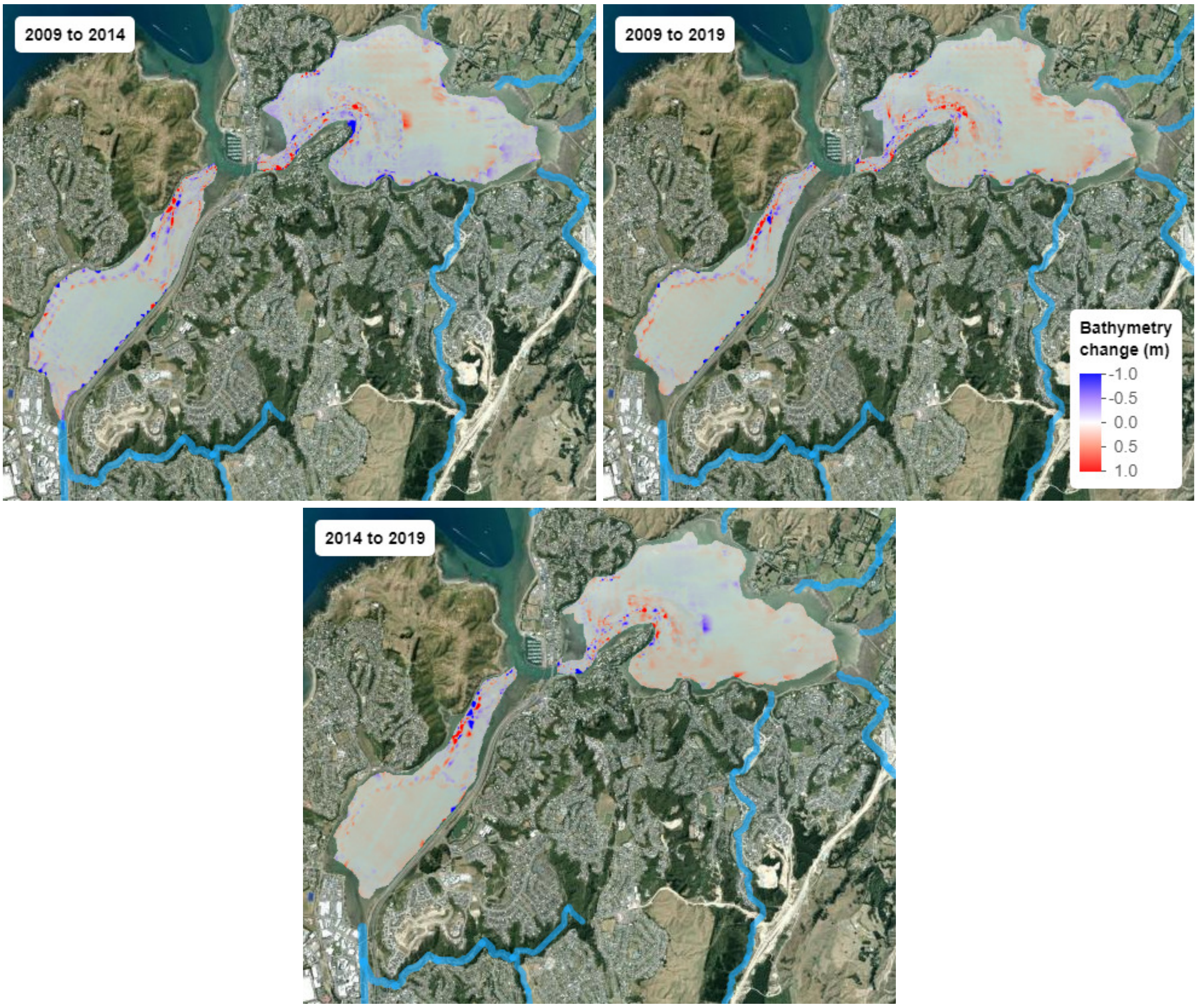

Figure 5: Bathymetry change (m) survey comparisons between 2009, 2014, and 2019.

Habitat

The main habitats monitored are unvegetated sediments (e.g. mud and sand areas) and areas vegetated with salt marsh and seagrass. Degraded habitat is a major contributor to reduced aquatic ecosystem health.

Substrates

In terms of estuarine health, a key broad scale focus is on understanding the spatial extent and temporal change in mud-dominated sediment (>50% mud content) across intertidal areas. See Stevens & Forrest 2020b - habitat mapping for technical methods, data tables, and further information

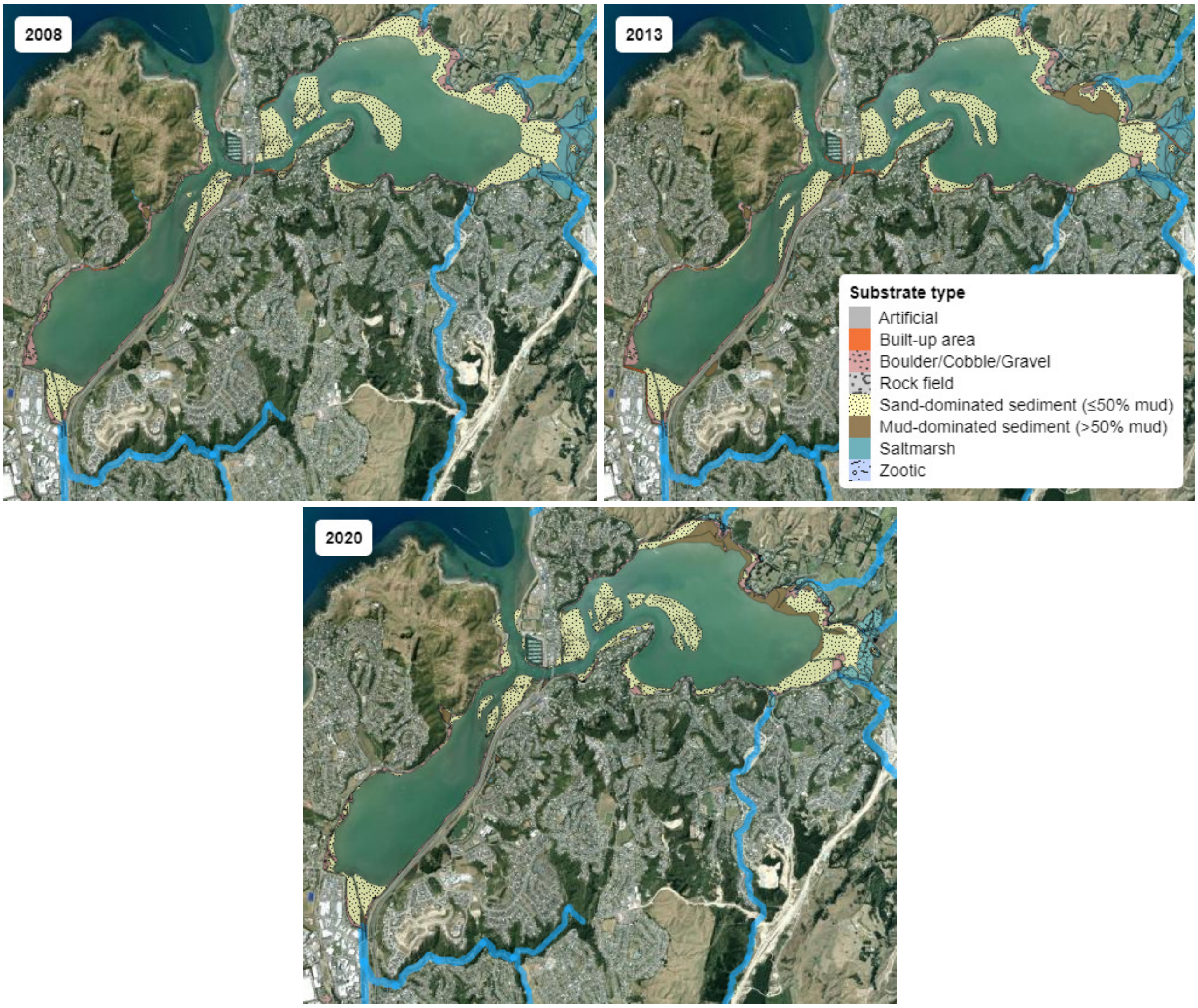

Figure 6: Broad scale substrate mapping results for 2008, 2013, and 2020.

Mud content

At discrete fine scale and sedimentation monitoring sites, mud content is determined from laboratory analysis of surface sediment samples, and results are rated against thresholds derived from the New Zealand Estuary Trophic Index. A sample mud content of 25% is considered the threshold above which significant ecological changes in associated macroinvertebrate communities can occur. See Cummings et al. 2022, Forrest et al. 2022 and Stevens et al. 2022 for technical methods, data tables, and further information

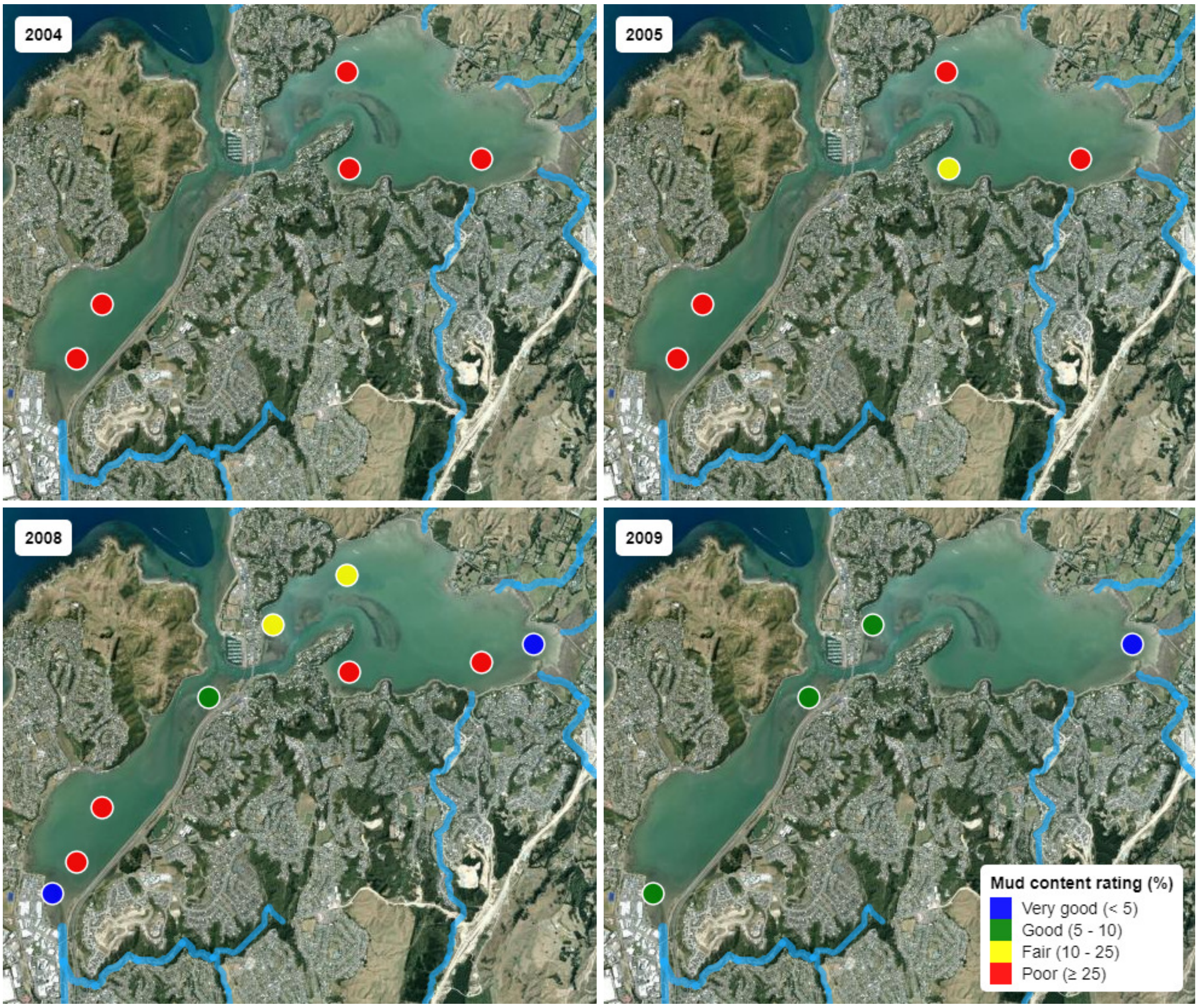

Figure 7: Mud content (%) ratings for 2004, 2005, 2008, and 2009.

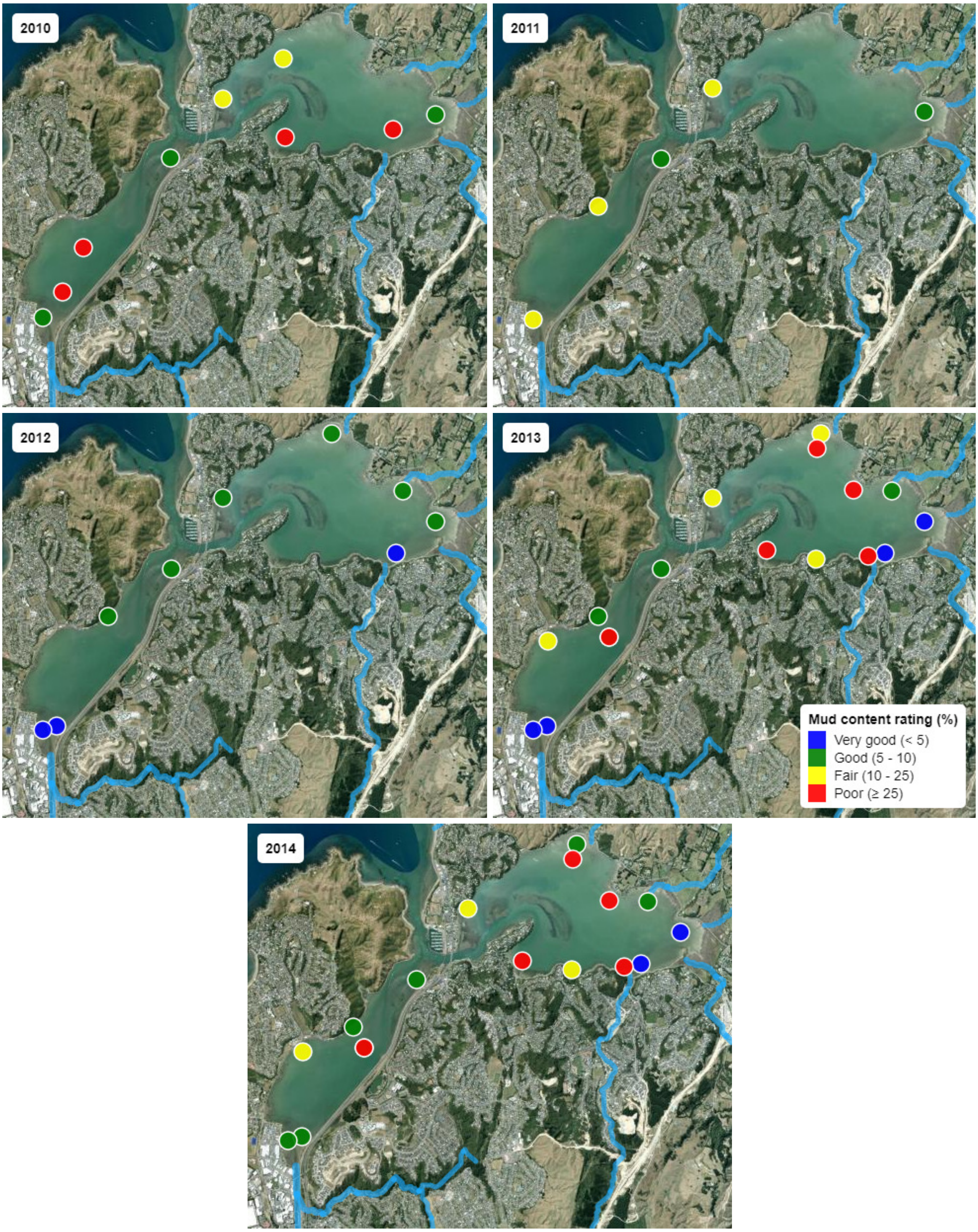

Figure 8: Mud content (%) ratings for 2010 to 2014.

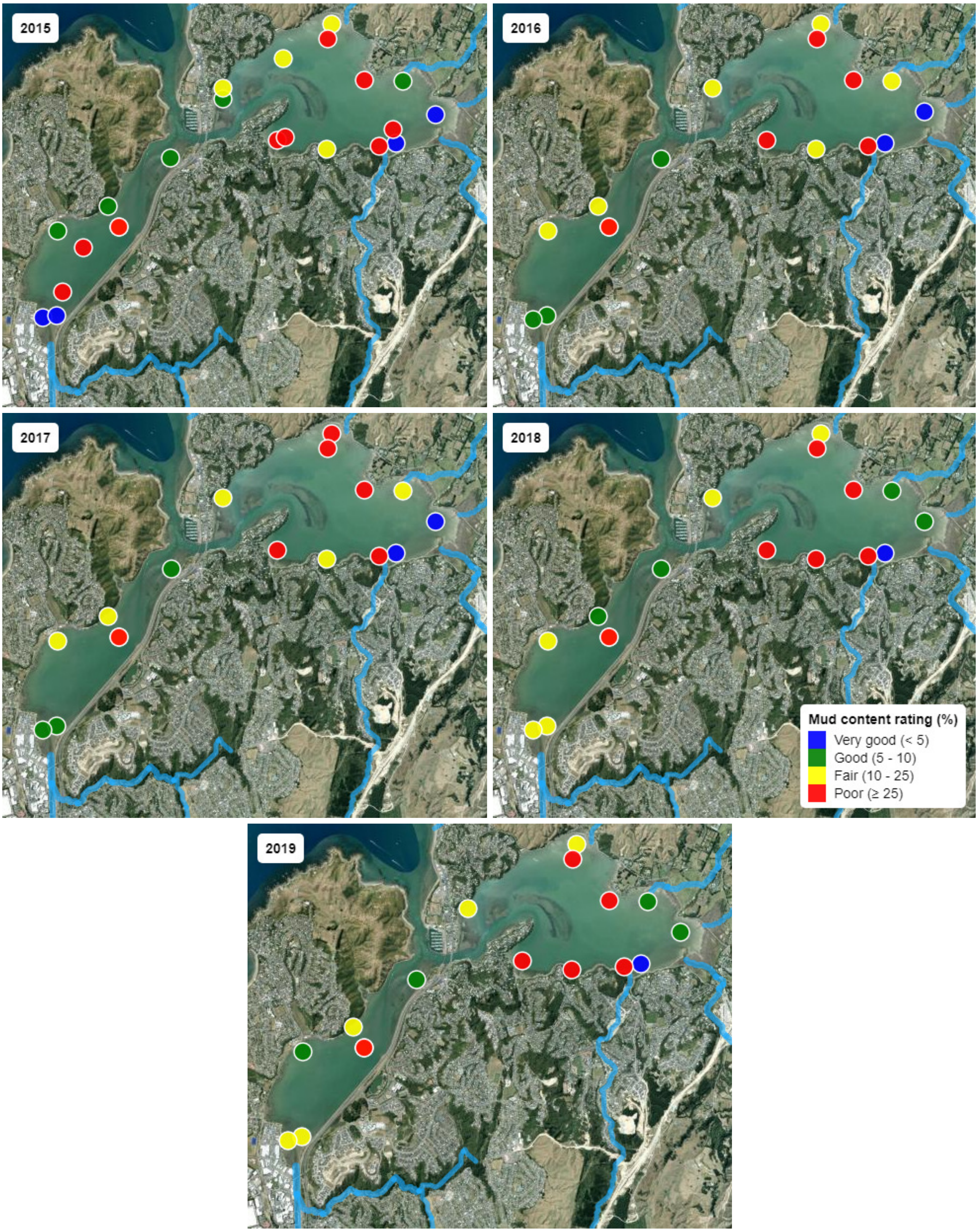

Figure 9: Mud content (%) ratings for 2015 to 2019.

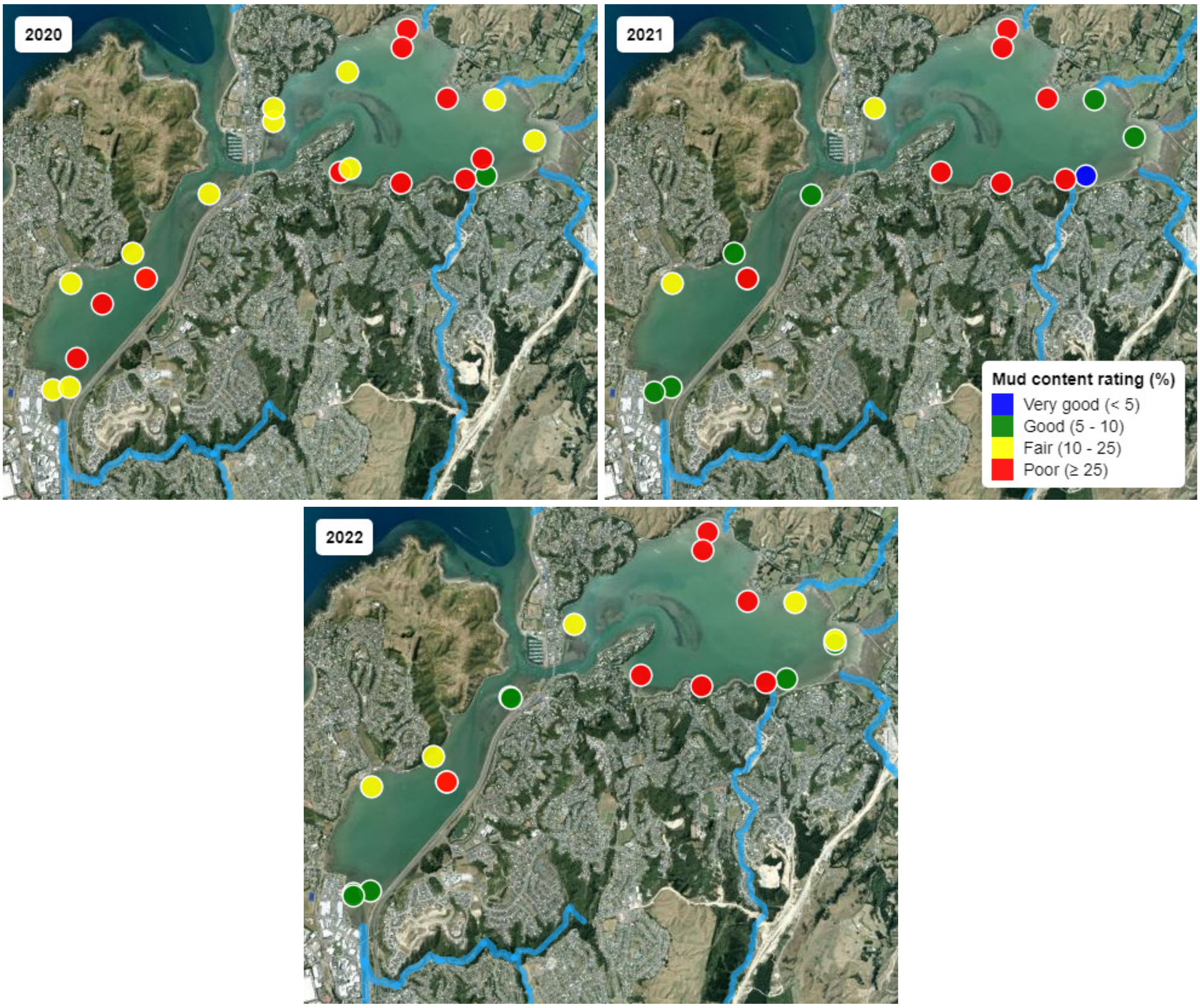

Figure 10: Mud content (%) ratings for 2020 to 2022.

Salt marsh

Salt marsh is upper tidal vegetation able to tolerate saline conditions where terrestrial plants are unable to survive. This habitat type is important in estuaries as it is highly productive, naturally filters and assimilates sediment and nutrients, acts as a buffer that protects against introduced grasses and weeds, and provides an important habitat for a variety of species including fish and birds. See Stevens & Forrest 2020b - habitat mapping for technical methods, data tables, and further information

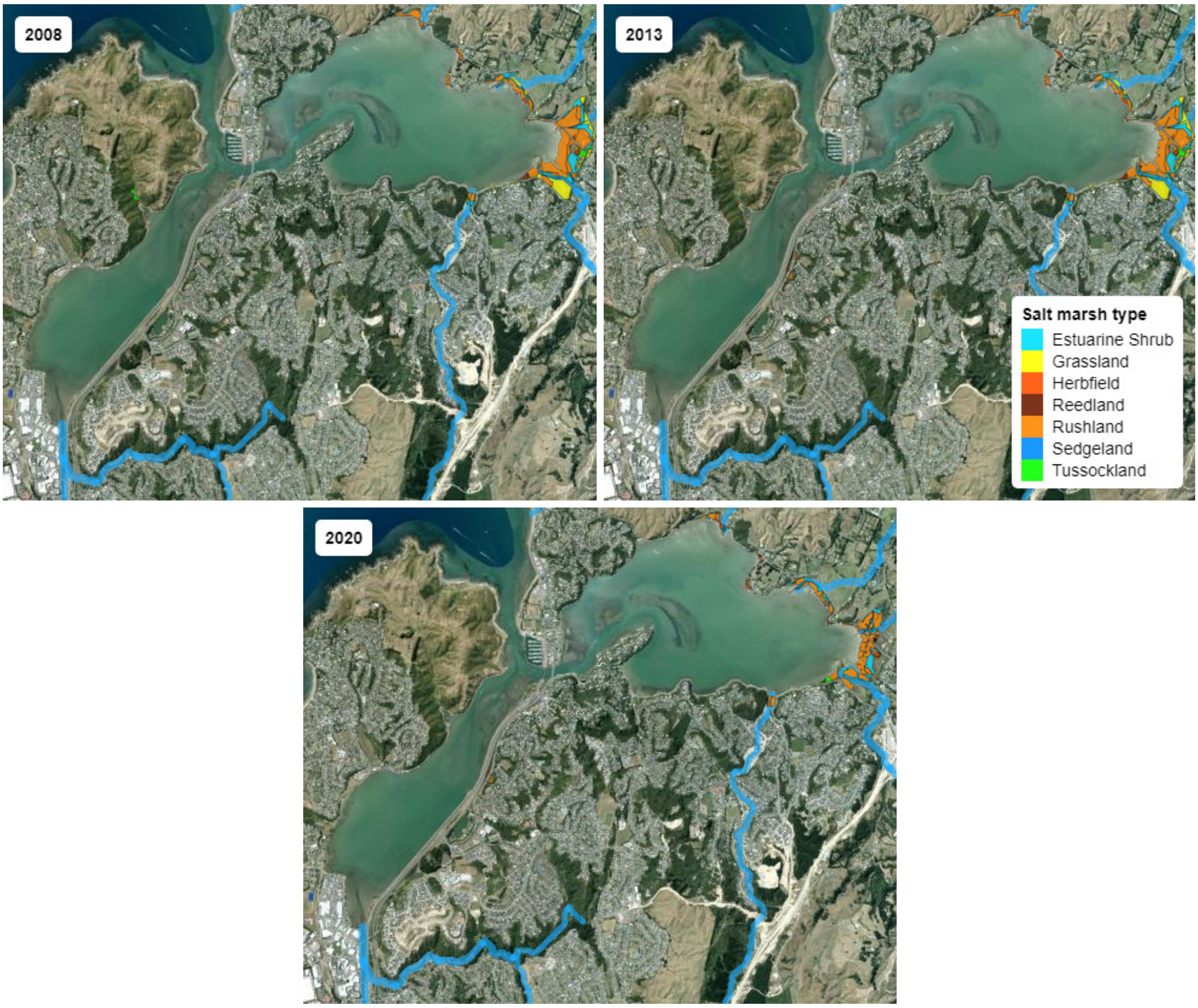

Figure 11: Broad scale salt marsh mapping results for 2008, 2013, and 2020.

Seagrass

Seagrass (*Zostera muelleri*) beds are important ecologically because they enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for a range of invertebrates and fish. Although tolerant of a wide range of conditions, seagrass is vulnerable to light reduction due to fine sediments in the water column, burial from sediment inundation, macroalgal overgrow where nutrient enrichment is excessive, and sediment oxygen reduction where macroalgal overgrowth or excessive organic enrichment occurs. Note that surveys prior to 2008 did not cover the whole harbour with areas not surveyed shaded in grey. Seagrass beds refer to areas with 30% coverage or greater. See Matheson & Wadhwa 2012 and Stevens & Forrest 2020b - habitat mapping for technical methods, data tables, and further information

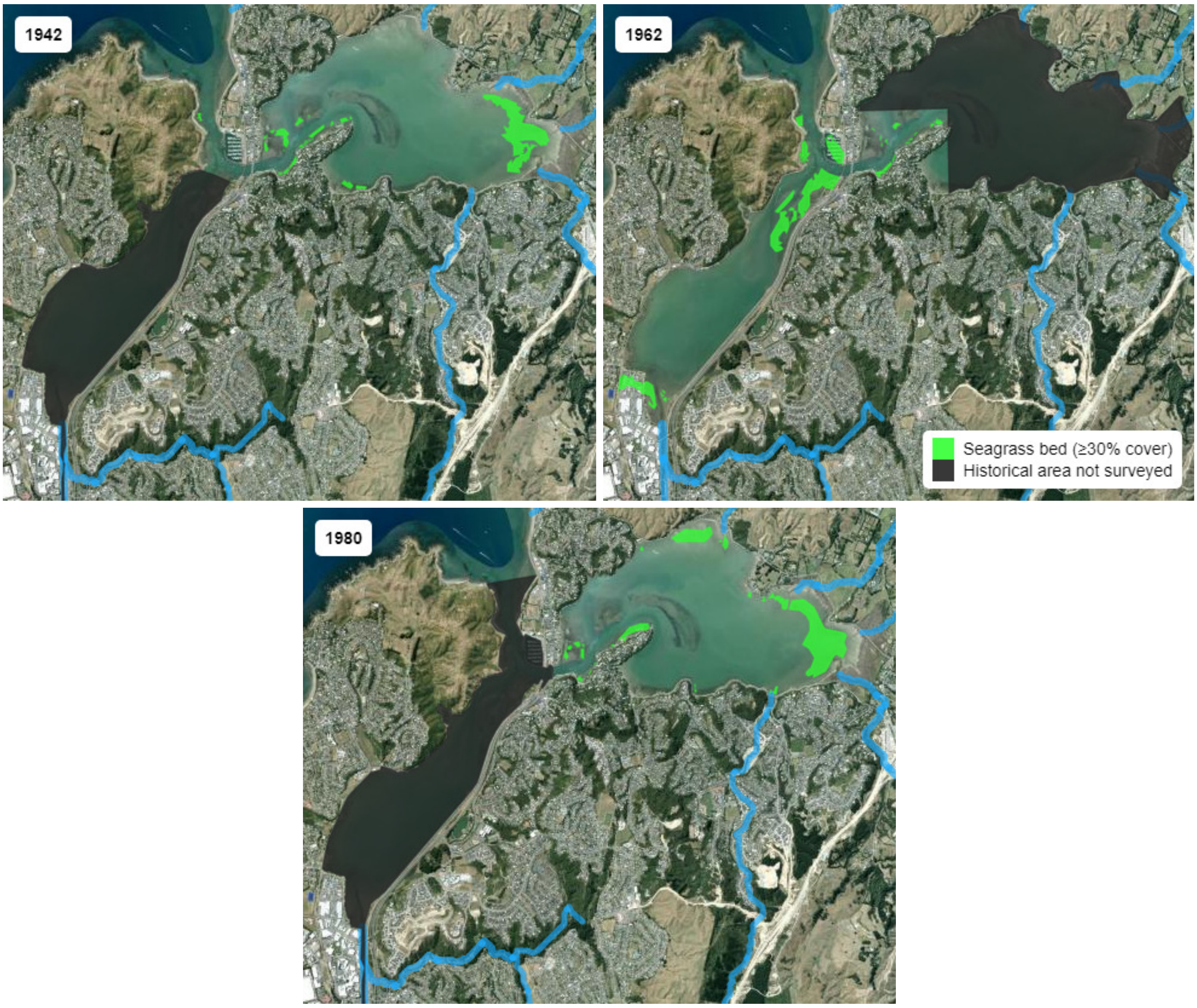

Figure 12: Seagrass mapping results for 1942, 1962, and 1980.

Figure 13: Seagrass mapping results for 2008, 2013, and 2020.

Macroinvertebrates

Macroinvertebrates, also known as macrofauna, are the animals living on top of or within the sediment. The abundance, composition and diversity of macrofauna are commonly-used indicators of estuarine health. The AZTI's Marine Biotic Index (AMBI) is one of several marine biotic indices that assesses estuarine health based on the types and numbers of macrofauna and their known tolerances to environmental stress. Lower AMBI values generally indicate better ecological conditions. Values are rated against thresholds derived from the New Zealand Estuary Trophic Index. See Oliver & Conwell 2014 and Forrest et al. 2022 for technical methods, data tables, and further information

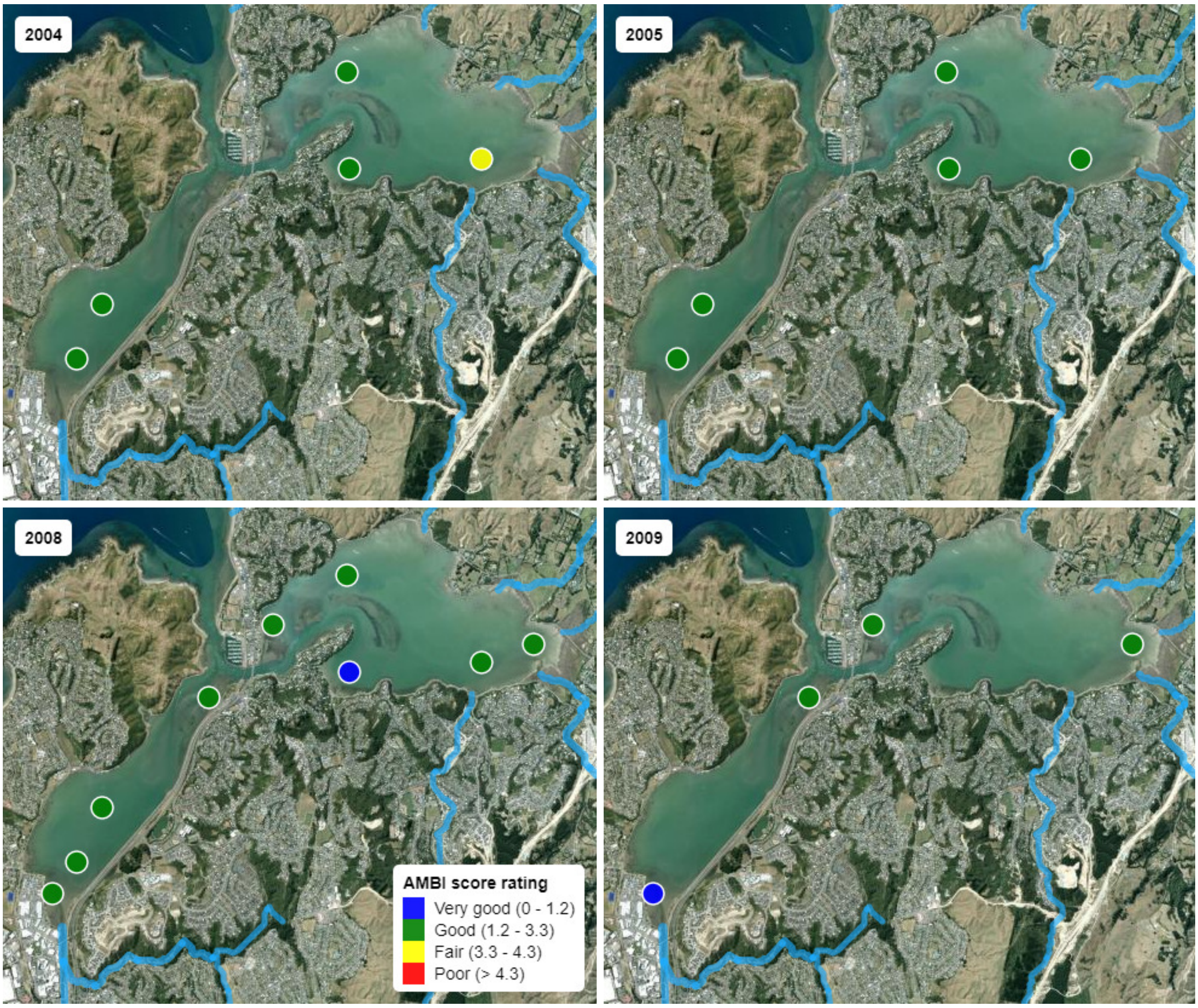

Figure 14: Macroinvertebrate AMBI ratings for 2004, 2005, 2008, and 2009.

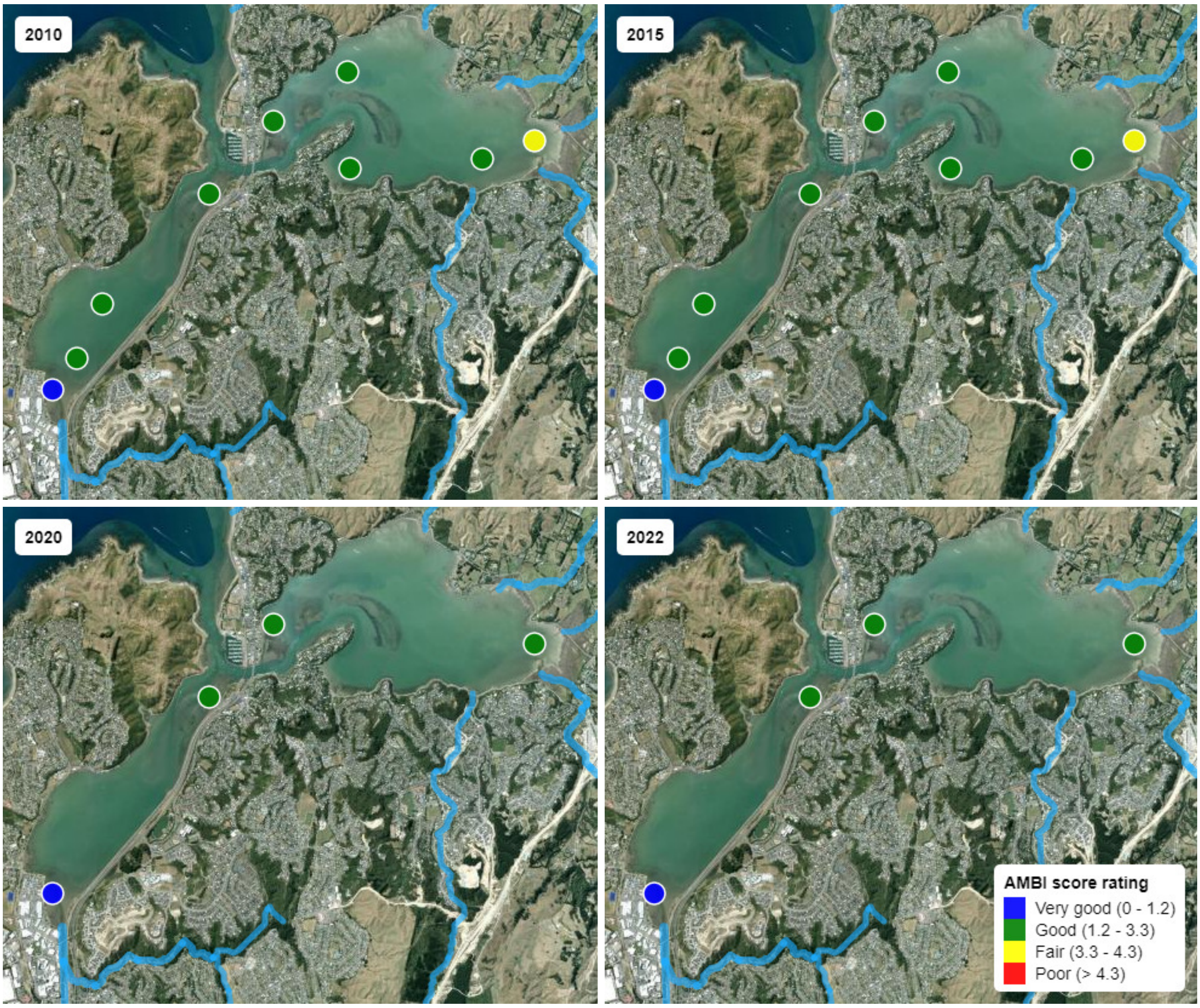

Figure 15: Macroinvertebrate AMBI ratings for 2010, 2015, 2020, and 2022.

Nutrient enrichment

When an estuary or coastal environment becomes over-enriched with nutrients excessive growths of algae can occur (eutrophication). These include growths of ‘opportunistic’ macroalgae such as the red seaweed *Gracilaria chilensis*, and blooms of potential harmful phytoplankton (microscopic algae that drift in water currents), which can include species that release biotoxins.

Macroalgae

Opportunistic macroalgal blooms are a primary consequence of estuary eutrophication (nutrient enrichment). Macroalgal blooms can deprive seagrass beds of light, causing their decline, while decaying macroalgae can accumulate subtidally and on shorelines causing oxygen depletion and associated nuisance odours in the sediments beneath. The main problem species in New Zealand are the red seaweed *Gracilaria chilensis* and the bright green *Ulva*. In Porirua Harbour over recent years, there has also been an increased prevalence of the filamentous green mat-forming species *Chaetomorpha ligustica*. See Stevens & Forrest 2020b - habitat mapping for technical methods, data tables, and further information

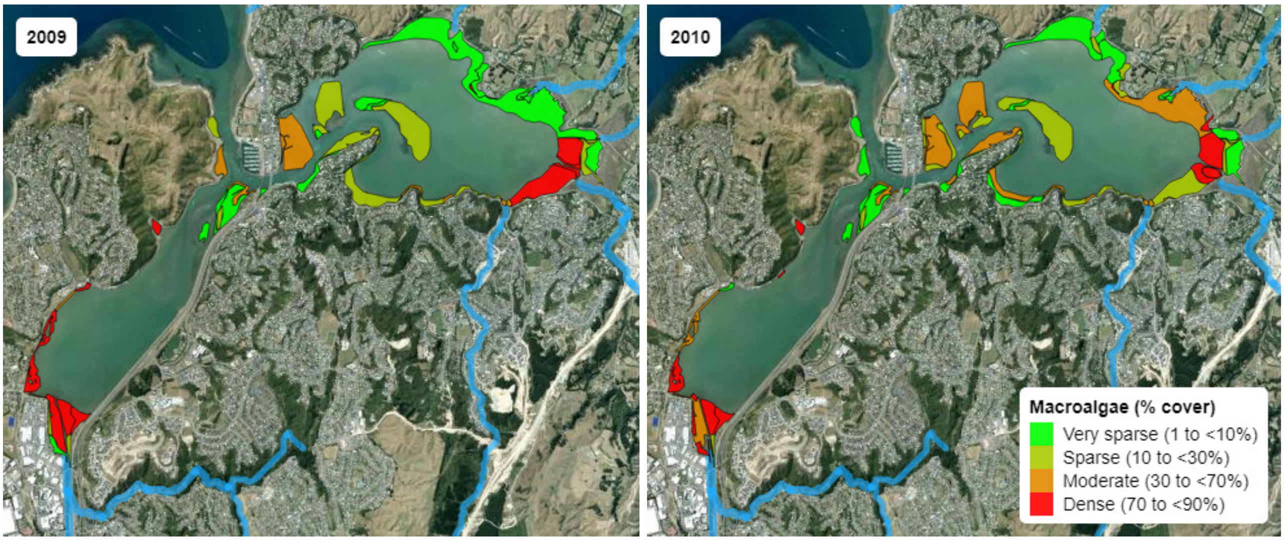

Figure 16: Broad scale macroalgal mapping results for 2009 and 2010.

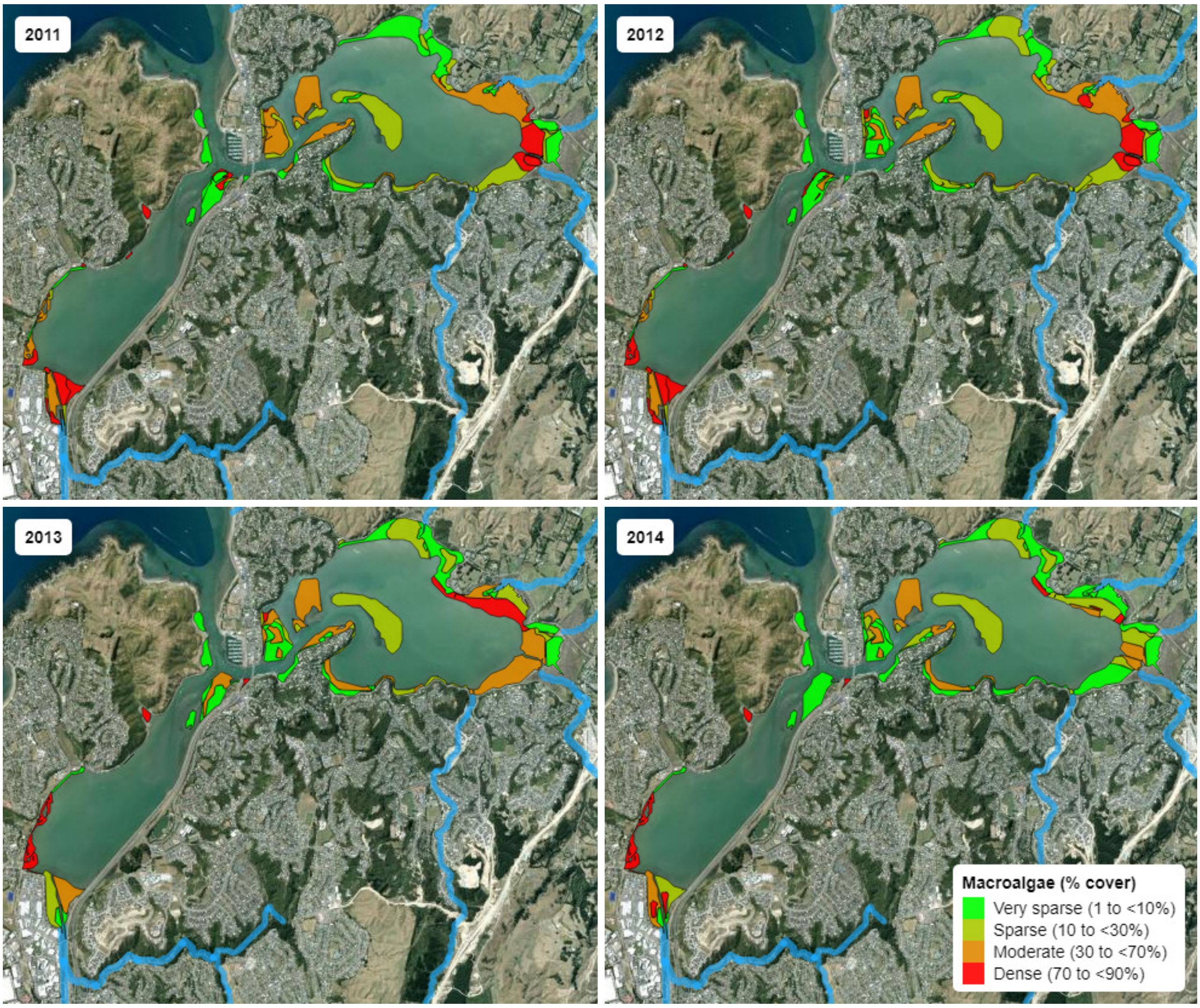

Figure 17: Broad scale macroalgal mapping results for 2011 to 2014.

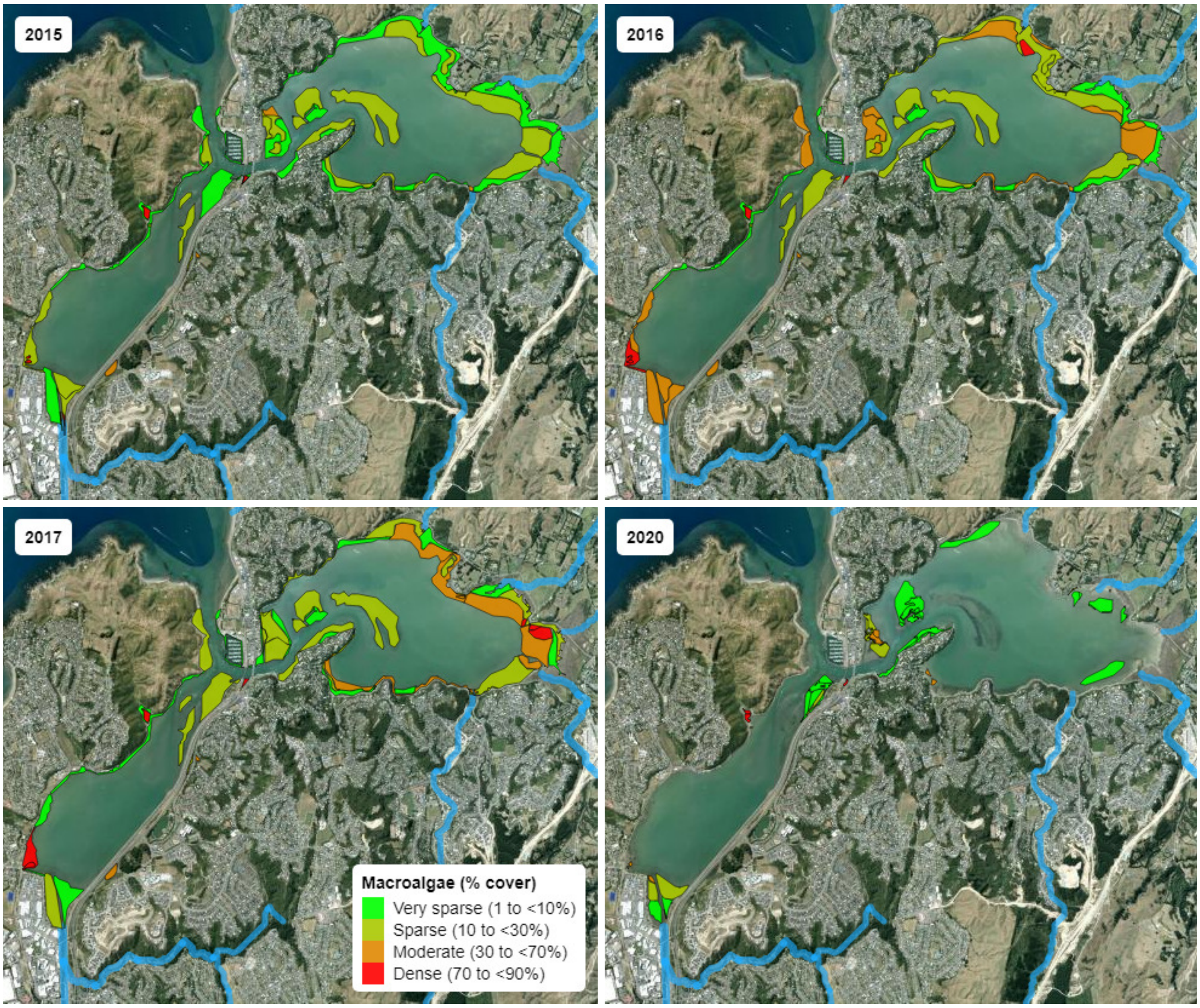

Figure 18: Broad scale macroalgal mapping results for 2015, 2016, 2017 and 2020.

Sediment oxygenation

The apparent Redox Potential Discontinuity (aRPD) is a time-integrated measure of the enrichment state of sediments according to the visual transition between brown oxygenated surface sediments and deeper less oxygenated grey/black sediments. The aRPD usually occurs closer to the sediment surface as organic matter loading increases. Values are rated against thresholds modified from those presented in the New Zealand Estuary Trophic Index. See Forrest et al. 2022 and Stevens et al. 2022 for technical methods, data tables, and further information

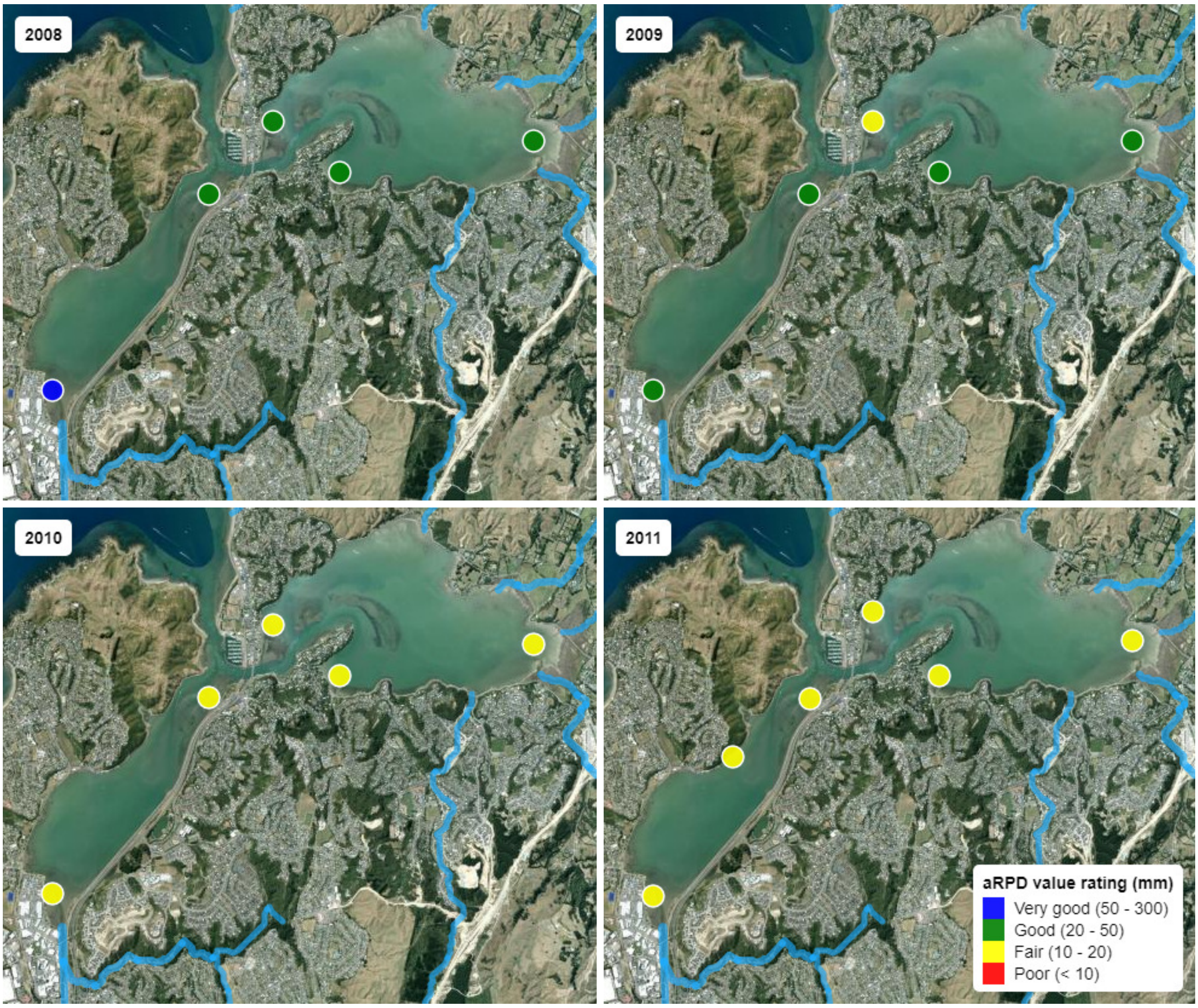

Figure 19: Sediment oxygenation aRPD (mm) condition rating results for 2008 to 2011.

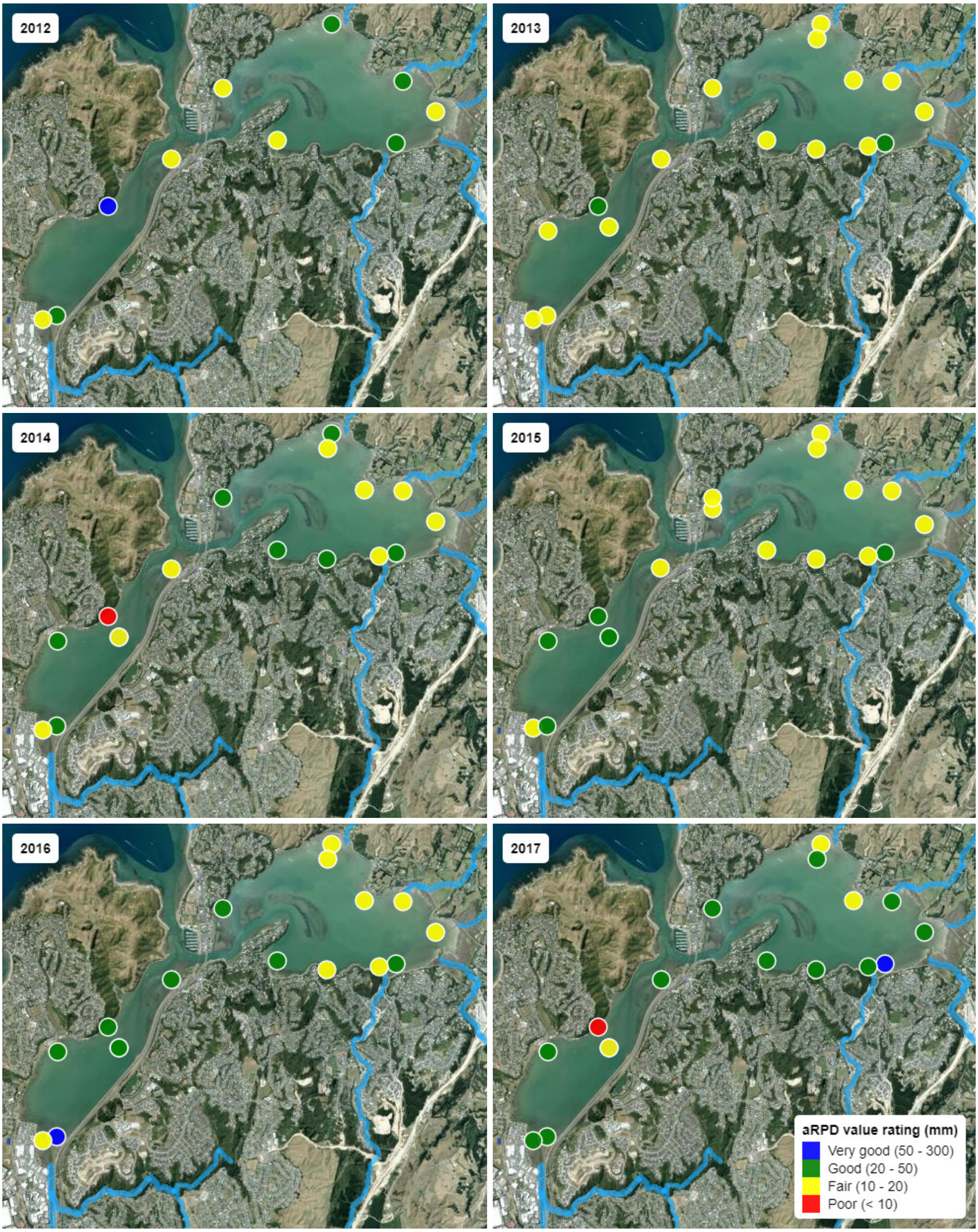

Figure 20: Sediment oxygenation aRPD (mm) condition rating results for 2012 to 2017.

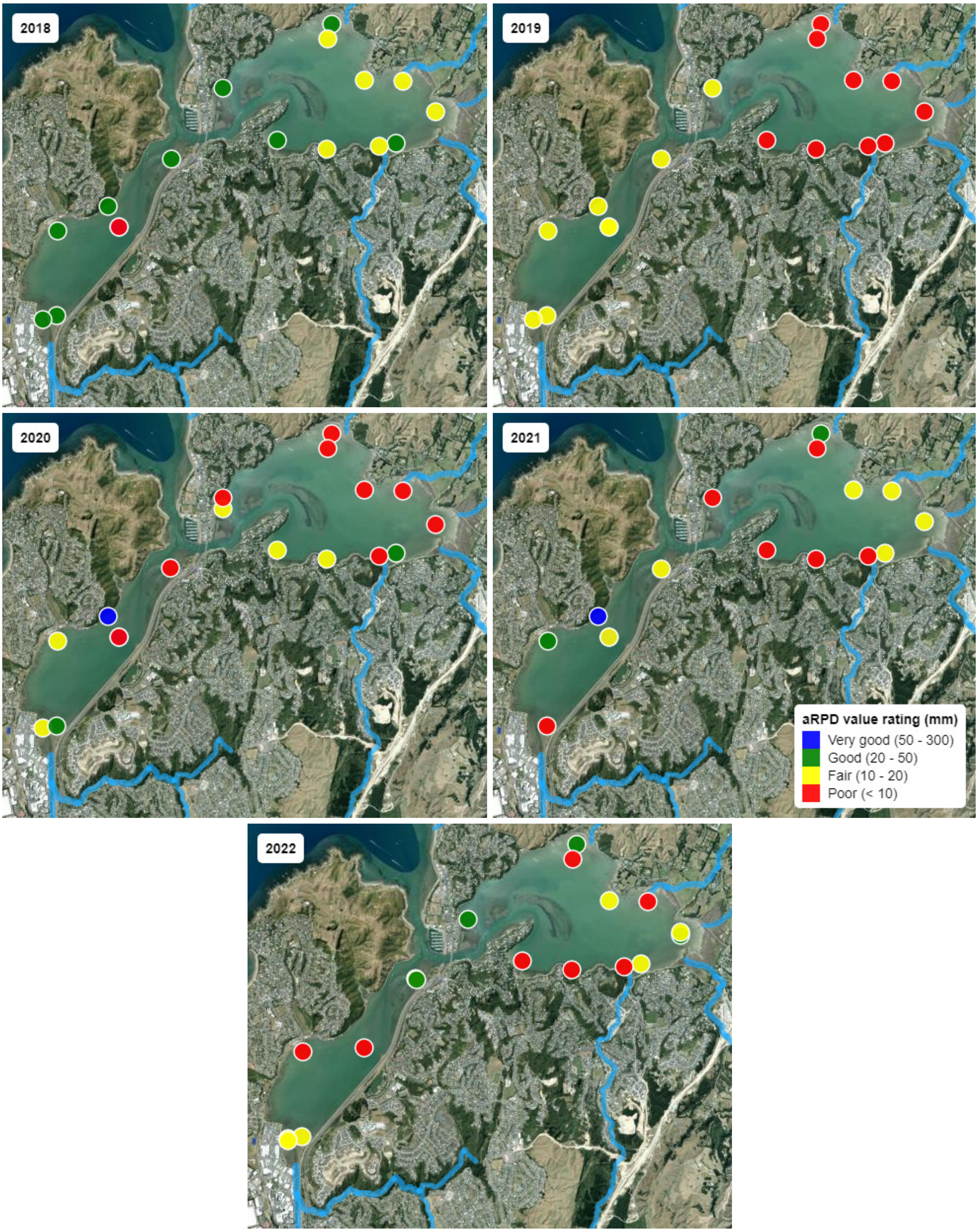

Figure 21: Sediment oxygenation aRPD (mm) condition rating results for 2018 to 2022.

Total Organic Carbon

Total Organic Carbon (TOC) is a measure of the organic content of sediments, which is associated with their enrichment status. Sediments with a high TOC (>1-2%) often display symptoms that indicate excessive enrichment, including reduced oxygenation. Values are rated against thresholds derived from the New Zealand Estuary Trophic Index (ETI). See Cummings et al. 2022 and Forrest et al. 2022 for technical methods, data tables, and further information

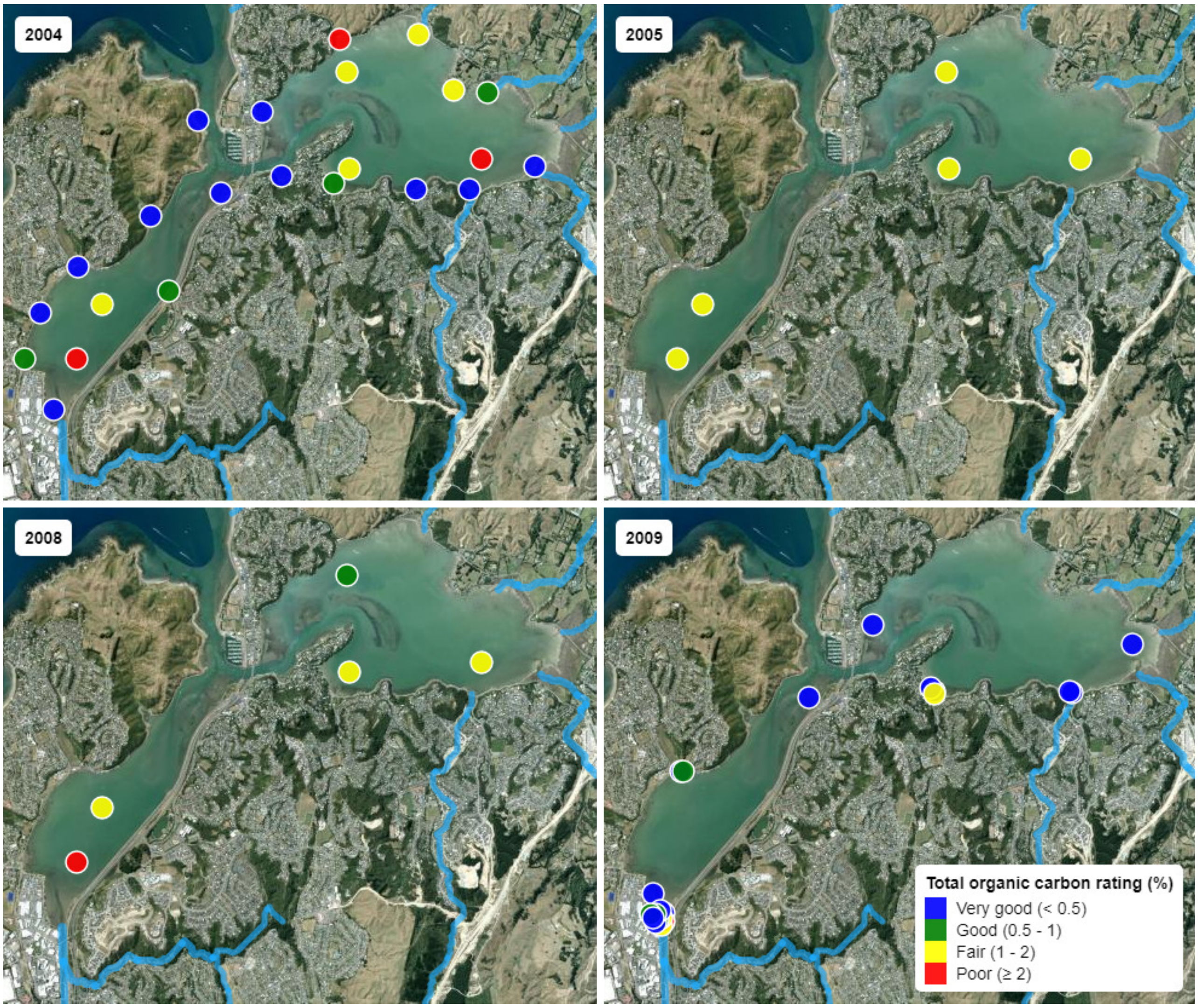

Figure 22: Total organic carbon (%) ratings for 2004, 2005, 2008, and 2009.

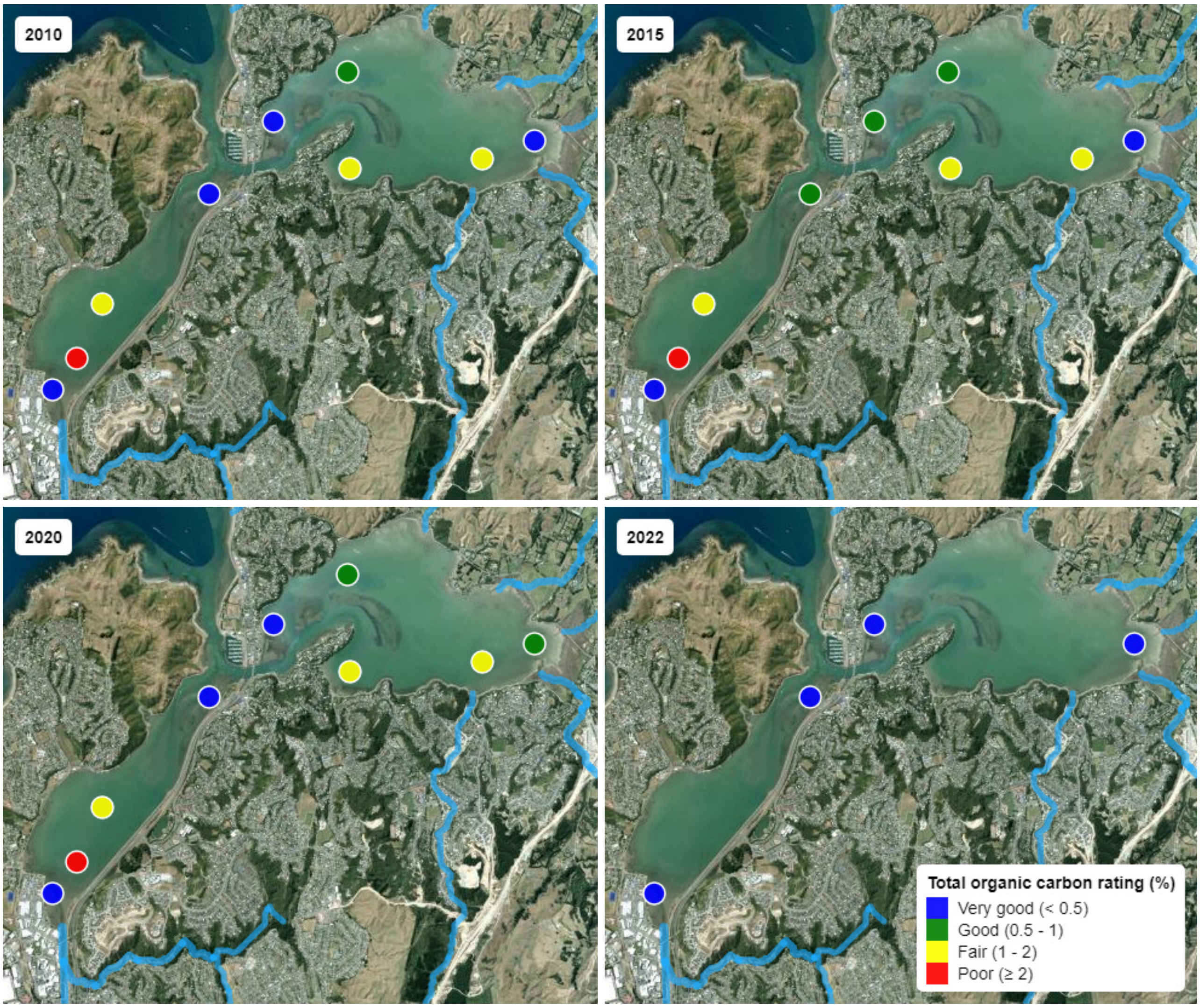

Figure 23: Total organic carbon (%) ratings for 2010, 2015, 2020, and 2022.

Total Nitrogen

Nitrogen is a key nutrient for plant and algae growth in estuarine and marine environments. Total nitrogen in sediments is an indicator of their trophic status and potential for algal blooms or other symptoms of excessive enrichment. Values are rated against thresholds derived from the New Zealand Estuarine Trophic Index (ETI). See Cummings et al. 2022 and Forrest et al. 2022 for technical methods, data tables, and further information

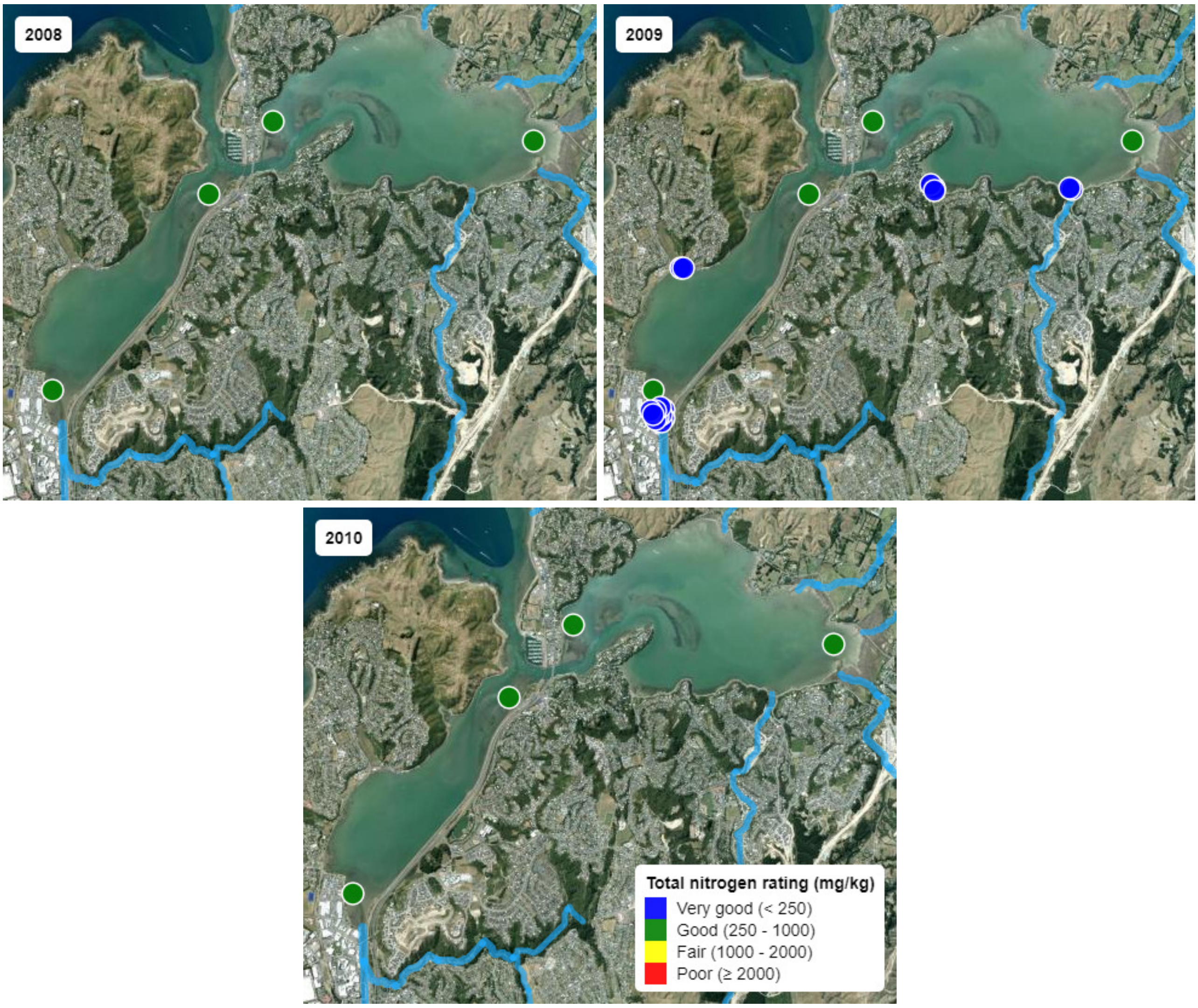

Figure 24: Total nitrogen (mg/kg) ratings for 2008, 2009, and 2010.

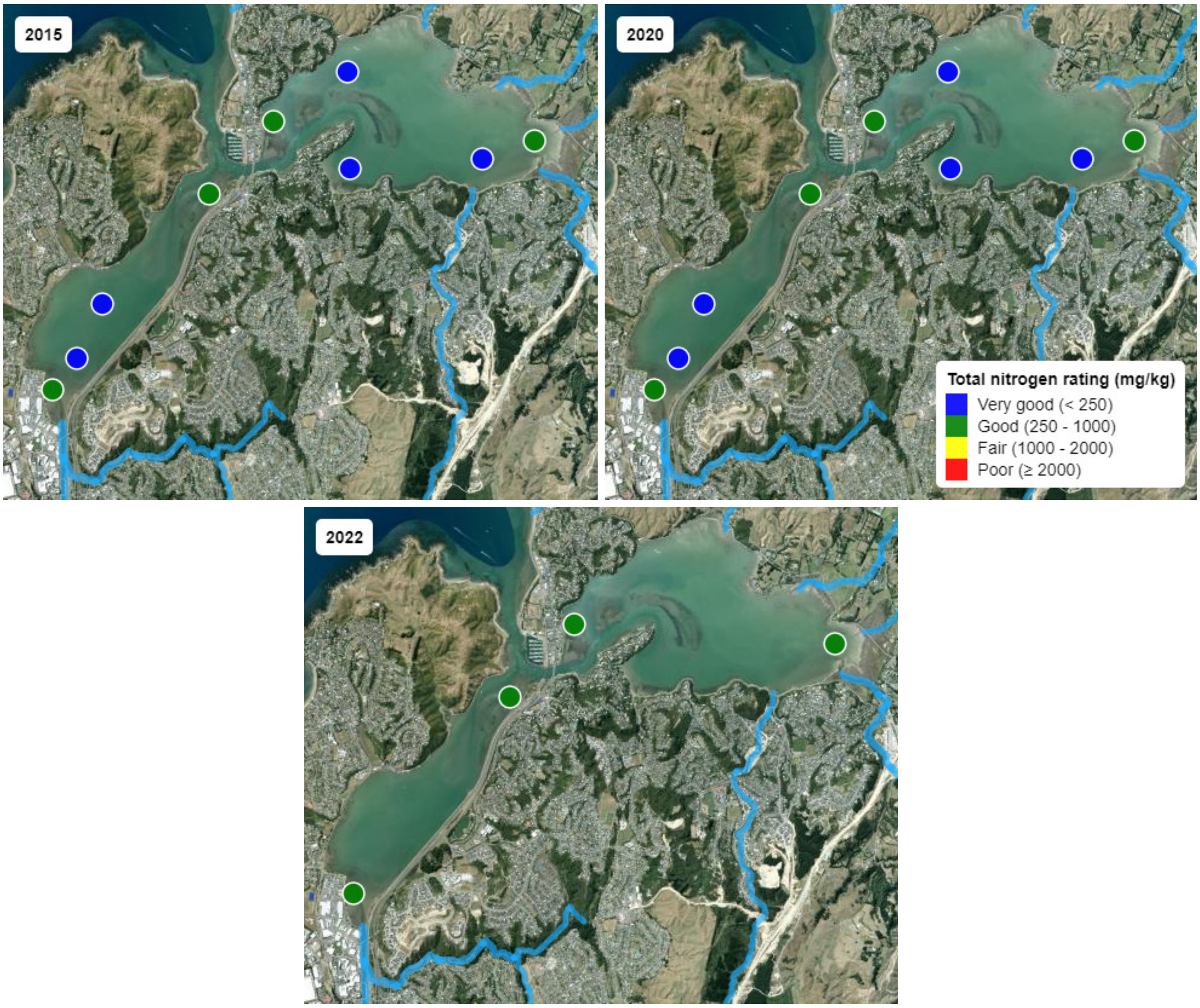

Figure 25: Total nitrogen (mg/kg) ratings for 2015, 2020, and 2022.

Metal contaminants

Some metals, when in high concentrations, can have toxic effects on aquatic life in both a dissolved state and when attached to sediment particles. Zinc and copper in particular are often used as proxies for the suite of other potential urban contaminants (e.g. polycyclic aromatic hydrocarbons, plasticisers) or legacy contaminants such as the historic pesticide DDT. These types of contaminants often end up in estuaries via stormwater runoff. Copper is approximately 5 to 10 times more toxic to aquatic life than zinc, but generally occurs in lower concentrations.

Values are rated against thresholds derived from the New Zealand Estuary Trophic Index (ETI), which in turn are scaled relative to 2018 Australia and New Zealand Guidelines (ANZG) for sediment quality. Ratings of “good” and “very good” correspond to ‘safe’ values that are less than ANZG (2018) default guidelines, while “fair” corresponds to values between the default and high-guideline values, reflecting “possible” ecological effects. “Poor” sites exceed the high-guideline value.

See Sorenson & Milne 2009, Cummings et al. 2022 and Forrest et al. 2022 for technical methods, data tables, and further information

Zinc

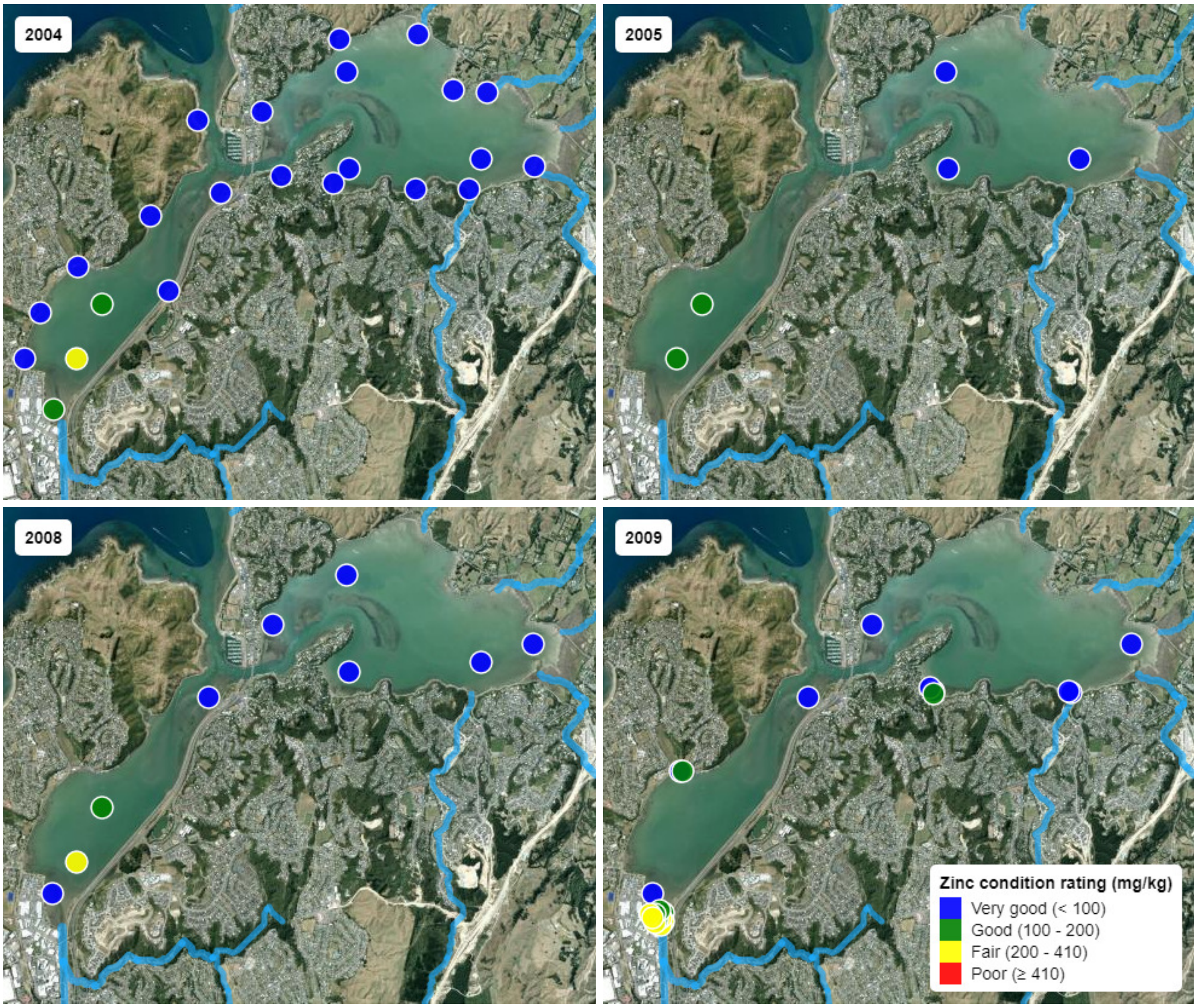

Figure 26: Zinc (mg/kg) ratings for 2004, 2005, 2008, and 2009.

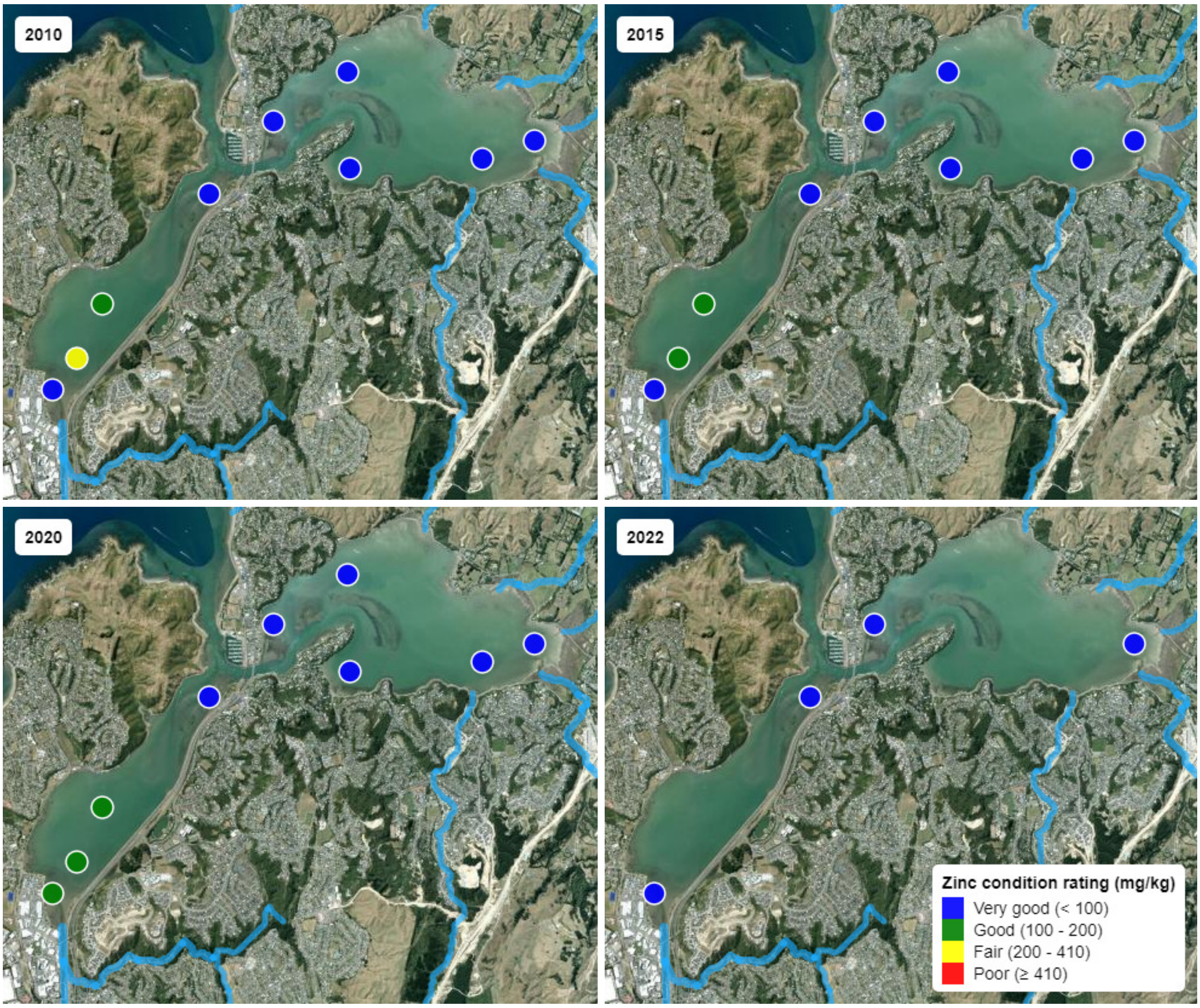

Figure 27: Zinc (mg/kg) ratings for 2010, 2015, 2020, and 2022.

Copper

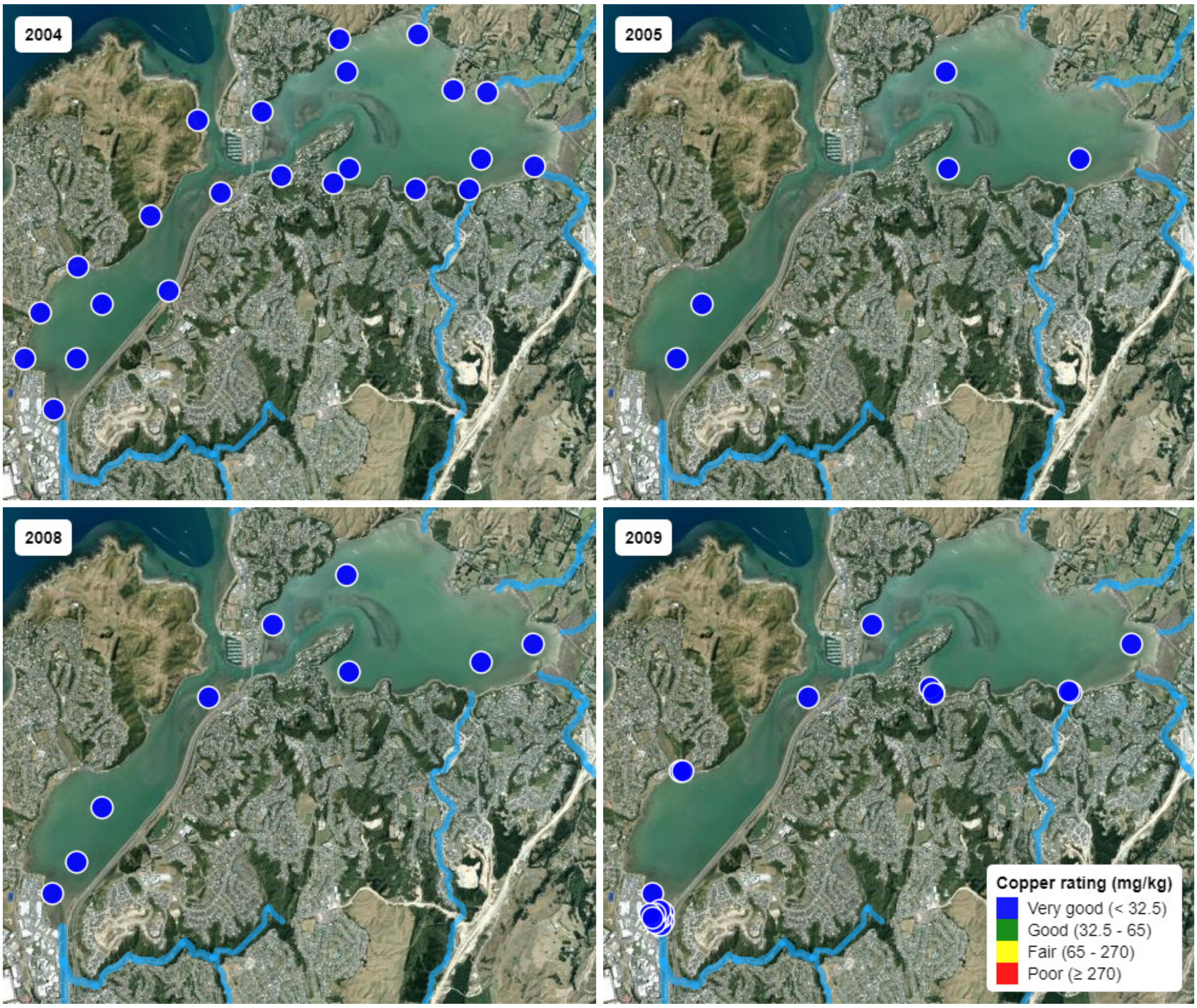

Figure 28: Copper (mg/kg) ratings for 2004, 2005, 2008, and 2009.

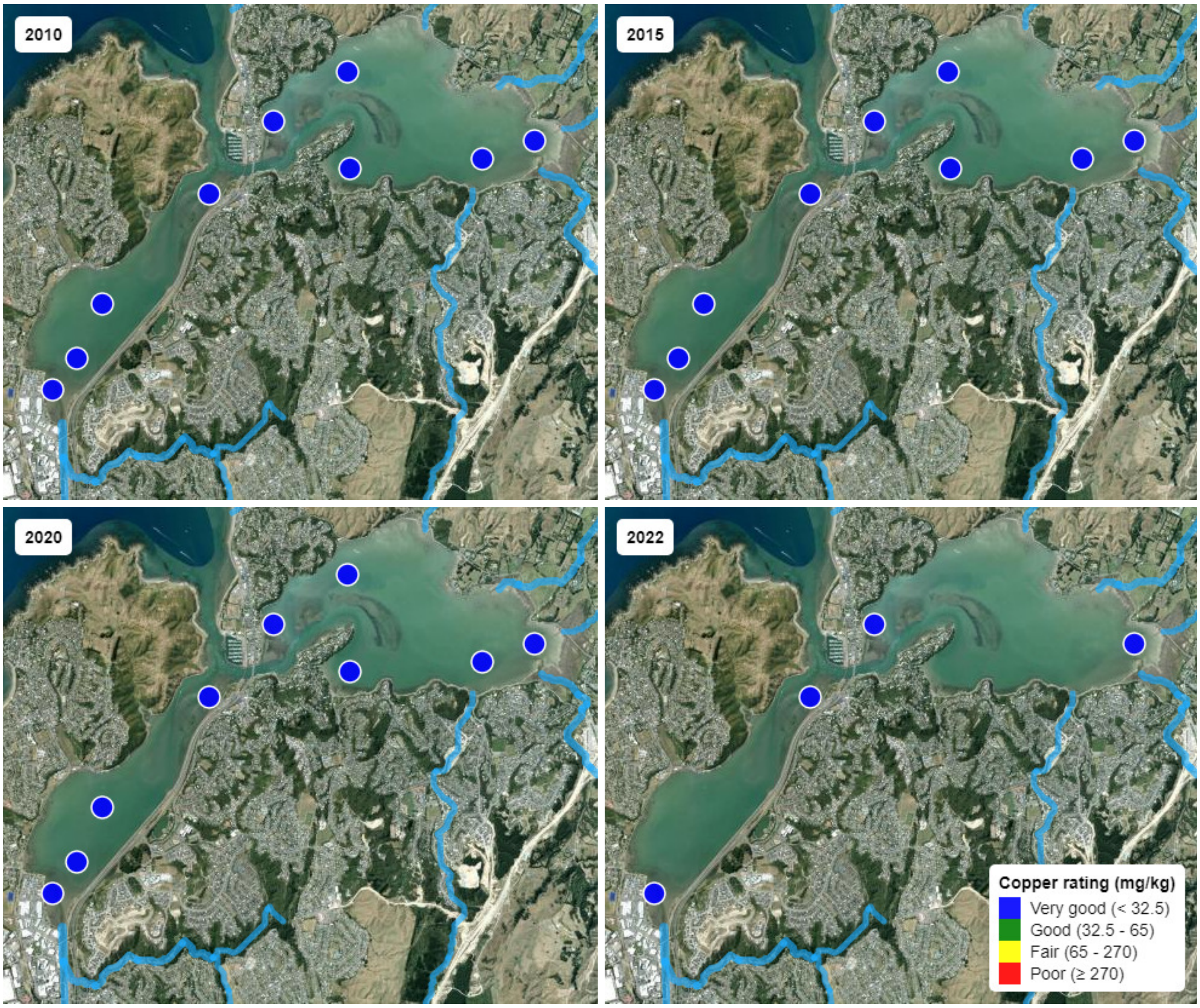

Figure 29: Copper (mg/kg) ratings for 2010, 2015, 2020, and 2022.

Resources

Sea Level Rise Mapping

Guardians of Pāuatahanui Inlet Cockle Survey

Land, Air, Water Aotearoa (LAWA) – Estuaries

Te Awarua-o-Porirua Harbour Catchment Sediment Monitoring Programme

Recreational Water Quality Monitoring Programme

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Appendix: Data tables

Check the methods and relevant mapped results section for links to references and more information on the data summaries presented below. Also, please note the disclaimer before using any of these data.

Sedimentation & bathymetry

Sedimentation rate

Table A1.1: Five year mean annual sedimentation rate (mm) results.

Location	Year period	Avg. sedimentation rate (mm)	No. sites
Onepoto Inlet	2007-2012	0.3	3
Onepoto Inlet	2008-2013	0.6	3
Onepoto Inlet	2009-2014	0.1	3
Onepoto Inlet	2010-2015	0.6	3
Onepoto Inlet	2011-2016	2.3	4
Onepoto Inlet	2012-2017	-2.7	7
Onepoto Inlet	2013-2018	-1.6	7
Onepoto Inlet	2014-2019	-1.0	7
Onepoto Inlet	2015-2020	4.7	7
Onepoto Inlet	2016-2021	4.7	7
Onepoto Inlet	2017-2022	4.4	6
Pāuatahanui Inlet	2007-2012	0.2	1
Pāuatahanui Inlet	2008-2013	0.4	2
Pāuatahanui Inlet	2009-2014	0.4	2
Pāuatahanui Inlet	2010-2015	-0.6	2
Pāuatahanui Inlet	2011-2016	-0.3	5
Pāuatahanui Inlet	2012-2017	6.1	10
Pāuatahanui Inlet	2013-2018	5.7	10
Pāuatahanui Inlet	2014-2019	3.8	10
Pāuatahanui Inlet	2015-2020	4.5	10
Pāuatahanui Inlet	2016-2021	5.1	10
Pāuatahanui Inlet	2017-2022	1.5	9
Whole estuary	2007-2012	0.3	4
Whole estuary	2008-2013	0.5	5
Whole estuary	2009-2014	0.2	5
Whole estuary	2010-2015	0.1	5
Whole estuary	2011-2016	0.9	9
Whole estuary	2012-2017	2.5	17
Whole estuary	2013-2018	2.7	17
Whole estuary	2014-2019	1.8	17
Whole estuary	2015-2020	4.6	17
Whole estuary	2016-2021	4.9	17
Whole estuary	2017-2022	2.6	15

Bathymetry change

Table A1.2: Sediment volume (m^3) comparisons between bathymetric surveys.

Sediment volume (m^3) change	**2009-2014**	**2014-2019**	**2009-2019**
Pāuatahanui Inlet	+ 7,131	+ 167,095	186,992
Onepoto Inlet	- 10,029	+ 92,636	81,011
Whole estuary	- 2898	+ 259,731	+ 268,003

Habitat

Substrates

Table A1.3: Substrate total area cover (ha).

Location	Substrate type	2008	2013	2020
Onepoto Inlet	Artificial	2.4		2.0
Onepoto Inlet	Built-up area	0.6	3.1	
Onepoto Inlet	Boulder/Cobble/Gravel	19.0	19.1	11.3
Onepoto Inlet	Rock field	0.7	0.7	0.9
Onepoto Inlet	Sand-dominated sediment (≤50% mud)	37.2	40.3	44.9
Onepoto Inlet	Mud-dominated sediment (>50% mud)	1.5	3.0	3.1
Onepoto Inlet	Saltmarsh	0.8	0.7	0.6
Onepoto Inlet	Zootic	0.4	0.2	0.3
Pāuatahanui Inlet	Artificial	1.6		0.8
Pāuatahanui Inlet	Built-up area	0.8	2.4	
Pāuatahanui Inlet	Boulder/Cobble/Gravel	13.8	15.8	18.0
Pāuatahanui Inlet	Rock field	3.4	3.4	4.0
Pāuatahanui Inlet	Sand-dominated sediment (≤50% mud)	149.9	127.7	149.1
Pāuatahanui Inlet	Mud-dominated sediment (>50% mud)	1.9	16.5	28.7
Pāuatahanui Inlet	Saltmarsh	48.6	47.9	28.7
Pāuatahanui Inlet	Zootic	1.2	1.2	2.0
Whole estuary	Artificial	4.0		2.7
Whole estuary	Built-up area	1.4	5.5	
Whole estuary	Boulder/Cobble/Gravel	32.7	34.9	29.4
Whole estuary	Rock field	4.1	4.1	4.9
Whole estuary	Sand-dominated sediment (≤50% mud)	187.1	168.0	194.1
Whole estuary	Mud-dominated sediment (>50% mud)	3.4	19.5	31.9
Whole estuary	Saltmarsh	49.4	48.6	29.3
Whole estuary	Zootic	1.6	1.4	2.3

Mud content

Table A1.4: Mud content (%) average rating results.

Location	Year	Rating	Avg. Mud (%)	No. sites
Onepoto Inlet	2004	Poor	78.7	2
Onepoto Inlet	2005	Poor	71.0	2
Onepoto Inlet	2008	Poor	40.0	4
Onepoto Inlet	2009	Good	7.5	2
Onepoto Inlet	2010	Poor	43.1	4
Onepoto Inlet	2011	Fair	10.1	3
Onepoto Inlet	2012	Good	5.3	4
Onepoto Inlet	2013	Fair	11.7	7
Onepoto Inlet	2014	Fair	13.9	7
Onepoto Inlet	2015	Fair	23.2	9
Onepoto Inlet	2016	Fair	15.3	7
Onepoto Inlet	2017	Fair	17.3	7
Onepoto Inlet	2018	Fair	16.4	7
Onepoto Inlet	2019	Fair	20.1	7
Onepoto Inlet	2020	Poor	32.1	9
Onepoto Inlet	2021	Fair	14.7	7
Onepoto Inlet	2022	Fair	18.6	9
Pāuatahanui Inlet	2004	Poor	38.4	3
Pāuatahanui Inlet	2005	Poor	31.2	3
Pāuatahanui Inlet	2008	Poor	25.4	5
Pāuatahanui Inlet	2009	Good	7.2	2
Pāuatahanui Inlet	2010	Poor	25.5	5
Pāuatahanui Inlet	2011	Good	8.0	2
Pāuatahanui Inlet	2012	Good	5.7	5
Pāuatahanui Inlet	2013	Fair	23.5	10
Pāuatahanui Inlet	2014	Poor	27.2	10
Pāuatahanui Inlet	2015	Poor	31.5	14
Pāuatahanui Inlet	2016	Poor	35.6	10
Pāuatahanui Inlet	2017	Poor	35.3	10
Pāuatahanui Inlet	2018	Poor	34.7	10
Pāuatahanui Inlet	2019	Poor	36.3	10
Pāuatahanui Inlet	2020	Poor	39.1	14
Pāuatahanui Inlet	2021	Poor	40.9	10
Pāuatahanui Inlet	2022	Poor	38.5	11
Whole estuary	2004	Poor	54.5	5
Whole estuary	2005	Poor	47.1	5
Whole estuary	2008	Poor	31.9	9
Whole estuary	2009	Good	7.3	4
Whole estuary	2010	Poor	33.3	9
Whole estuary	2011	Good	9.3	5
Whole estuary	2012	Good	5.5	9
Whole estuary	2013	Fair	18.6	17

Location	Year	Rating	Avg. Mud (%)	No. sites
Whole estuary	2015	Poor	28.2	23
Whole estuary	2016	Poor	27.2	17
Whole estuary	2017	Poor	27.9	17
Whole estuary	2018	Poor	27.2	17
Whole estuary	2019	Poor	29.6	17
Whole estuary	2020	Poor	36.4	23
Whole estuary	2021	Poor	30.1	17
Whole estuary	2022	Poor	29.5	20

Salt marsh

Table A1.5: Salt marsh total area cover (ha).

Location	Salt marsh type	2008	2013	2020
Onepoto Inlet	Herbfield	0.0	0.2	0.1
Onepoto Inlet	Reedland	0.0	0.0	
Onepoto Inlet	Rushland	0.2	0.5	0.5
Onepoto Inlet	Tussockland	0.5		
Pāuatahanui Inlet	Estuarine Shrub	9.3	9.3	5.9
Pāuatahanui Inlet	Grassland	7.9	7.7	0.0
Pāuatahanui Inlet	Herbfield	1.1	1.1	0.9
Pāuatahanui Inlet	Reedland	0.6	0.5	0.1
Pāuatahanui Inlet	Rushland	29.2	28.5	21.3
Pāuatahanui Inlet	Sedgeland			0.0
Pāuatahanui Inlet	Tussockland	0.7	0.7	0.5
Whole estuary	Estuarine Shrub	9.3	9.3	5.9
Whole estuary	Grassland	7.9	7.7	0.0
Whole estuary	Herbfield	1.1	1.3	1.0
Whole estuary	Reedland	0.6	0.5	0.1
Whole estuary	Rushland	29.4	29.1	21.8
Whole estuary	Sedgeland			0.0
Whole estuary	Tussockland	1.2	0.7	0.5

Seagrass

Table A1.6: Seagrass total area with beds ≥ 30% cover. NC denotes years/inlets where survey coverage was not complete.

Location	1942	1962	1980	2008	2013	2020
Onepoto Inlet	NC	25.0		20.3	18.3	15.9
Pāuatahanui Inlet	23.6	NC	36.8	36.9	35.3	32.2

Macroinvertebrates

Table A1.7: Macroinvertebrate AMBI average rating results.

Location	Year	Rating	Avg. AMBI	No. sites
Onepoto Inlet	2004	Good	3.1	2
Onepoto Inlet	2005	Good	3.1	2
Onepoto Inlet	2008	Good	2.4	4
Onepoto Inlet	2009	Good	1.9	2
Onepoto Inlet	2010	Good	2.1	4
Onepoto Inlet	2015	Good	2.3	4
Onepoto Inlet	2020	Good	1.3	2
Onepoto Inlet	2022	Good	1.3	2
Pāuatahanui Inlet	2004	Good	2.7	3
Pāuatahanui Inlet	2005	Good	2.8	3
Pāuatahanui Inlet	2008	Good	2.4	5
Pāuatahanui Inlet	2009	Good	2.7	2
Pāuatahanui Inlet	2010	Good	2.7	5
Pāuatahanui Inlet	2015	Good	3.1	5
Pāuatahanui Inlet	2020	Good	2.3	2
Pāuatahanui Inlet	2022	Good	2.5	2
Whole estuary	2004	Good	2.9	5
Whole estuary	2005	Good	2.9	5
Whole estuary	2008	Good	2.4	9
Whole estuary	2009	Good	2.3	4
Whole estuary	2010	Good	2.4	9
Whole estuary	2015	Good	2.7	9
Whole estuary	2020	Good	1.8	4
Whole estuary	2022	Good	1.9	4

Nutrient enrichment

Macroalgae

Table A1.8: Macroalgae total area (ha) by cover level.

Location	Year	Very sparse (1 to <10%)	Sparse (10 to <30%)	Moderate (30 to <70%)	Dense (70 to <90%)
Onepoto Inlet	2009	11.2	4.3	5.3	20.7
Onepoto Inlet	2010	15.3	1.6	9.7	14.3
Onepoto Inlet	2011	16.5	2.1	8.6	13.7
Onepoto Inlet	2012	16.2	1.8	7.7	15.2
Onepoto Inlet	2013	15.0	7.3	11.9	7.7
Onepoto Inlet	2014	19.8	5.9	6.3	9.9
Onepoto Inlet	2015	32.2	23.9	1.5	1.8
Onepoto Inlet	2016	8.8	16.6	28.4	4.9
Onepoto Inlet	2017	19.6	31.8	1.5	5.9
Onepoto Inlet	2020	11.4	8.9	0.6	1.0
Pāuatahanui Inlet	2009	66.9	49.8	18.1	22.8
Pāuatahanui Inlet	2010	41.6	45.4	59.2	14.8
Pāuatahanui Inlet	2011	41.7	50.0	54.4	14.9
Pāuatahanui Inlet	2012	37.0	60.9	43.9	17.3
Pāuatahanui Inlet	2013	41.7	49.7	54.6	15.3
Pāuatahanui Inlet	2014	67.2	59.6	32.1	2.5
Pāuatahanui Inlet	2015	65.5	93.2	1.7	
Pāuatahanui Inlet	2016	28.3	91.4	39.5	2.1
Pāuatahanui Inlet	2017	26.3	80.0	52.3	4.2
Pāuatahanui Inlet	2020	34.1	5.6	2.5	
Whole estuary	2009	78.1	54.2	23.3	43.5
Whole estuary	2010	56.9	47.0	69.0	29.1
Whole estuary	2011	58.3	52.1	63.0	28.6
Whole estuary	2012	53.2	62.6	51.5	32.6
Whole estuary	2013	56.7	57.0	66.5	23.1
Whole estuary	2014	87.0	65.5	38.4	12.5
Whole estuary	2015	97.7	117.1	3.2	1.8
Whole estuary	2016	37.1	108.0	68.0	7.0
Whole estuary	2017	45.8	111.8	53.8	10.1
Whole estuary	2020	45.5	14.5	3.1	1.0

Sediment oxygenation

Table A1.9: Sediment oxygenation aRPD (mm) condition average rating results.

Location	Year	Rating	Avg. aRPD (mm)	No. sites
Onepoto Inlet	2008	Good	39	2
Onepoto Inlet	2009	Good	25	2
Onepoto Inlet	2010	Fair	12	2
Onepoto Inlet	2011	Fair	12	3
Onepoto Inlet	2012	Good	26	4
Onepoto Inlet	2013	Fair	14	7
Onepoto Inlet	2014	Good	21	7
Onepoto Inlet	2015	Fair	19	7
Onepoto Inlet	2016	Good	26	7
Onepoto Inlet	2017	Good	24	7
Onepoto Inlet	2018	Good	29	7
Onepoto Inlet	2019	Fair	11	7
Onepoto Inlet	2020	Good	23	7
Onepoto Inlet	2021	Very good	62	6
Onepoto Inlet	2022	Fair	13	7
Pāuatahanui Inlet	2008	Good	36	3
Pāuatahanui Inlet	2009	Good	27	3
Pāuatahanui Inlet	2010	Fair	10	3
Pāuatahanui Inlet	2011	Fair	10	3
Pāuatahanui Inlet	2012	Fair	18	6
Pāuatahanui Inlet	2013	Fair	13	10
Pāuatahanui Inlet	2014	Fair	19	10
Pāuatahanui Inlet	2015	Fair	12	11
Pāuatahanui Inlet	2016	Fair	15	10
Pāuatahanui Inlet	2017	Good	21	10
Pāuatahanui Inlet	2018	Fair	15	10
Pāuatahanui Inlet	2019	Poor	7	10
Pāuatahanui Inlet	2020	Poor	10	11
Pāuatahanui Inlet	2021	Fair	10	10
Pāuatahanui Inlet	2022	Fair	12	11
Whole estuary	2008	Good	37	5
Whole estuary	2009	Good	26	5
Whole estuary	2010	Fair	11	5
Whole estuary	2011	Fair	11	6
Whole estuary	2012	Good	21	10
Whole estuary	2013	Fair	13	17
Whole estuary	2014	Good	20	17
Whole estuary	2015	Fair	14	18
Whole estuary	2016	Fair	19	17
Whole estuary	2017	Good	22	17
Whole estuary	2018	Good	21	17
Whole estuary	2019	Poor	9	17

Location	Year	Rating	Avg. aRPD (mm)	No. sites
Whole estuary	2021	Good	30	16
Whole estuary	2022	Fair	13	18

Total Organic Carbon

Table A1.10: Total organic carbon (%) average rating results.

Location	Year	Rating	Avg. TOC (%)	No. sites
Onepoto Inlet	2004	Good	0.70	10
Onepoto Inlet	2005	Fair	1.89	2
Onepoto Inlet	2008	Poor	2.09	2
Onepoto Inlet	2009	Good	0.66	14
Onepoto Inlet	2010	Fair	1.19	4
Onepoto Inlet	2015	Fair	1.26	4
Onepoto Inlet	2020	Fair	1.20	4
Onepoto Inlet	2022	Very good	0.27	2
Pāuatahanui Inlet	2004	Fair	1.01	13
Pāuatahanui Inlet	2005	Fair	1.30	3
Pāuatahanui Inlet	2008	Fair	1.41	3
Pāuatahanui Inlet	2009	Good	0.53	7
Pāuatahanui Inlet	2010	Good	0.96	5
Pāuatahanui Inlet	2015	Good	0.98	5
Pāuatahanui Inlet	2020	Good	0.97	5
Pāuatahanui Inlet	2022	Very good	0.39	2
Whole estuary	2004	Good	0.88	23
Whole estuary	2005	Fair	1.54	5
Whole estuary	2008	Fair	1.68	5
Whole estuary	2009	Good	0.62	21
Whole estuary	2010	Fair	1.06	9
Whole estuary	2015	Fair	1.10	9
Whole estuary	2020	Fair	1.07	9
Whole estuary	2022	Very good	0.33	4

Total Nitrogen

Table A1.11: Total nitrogen (mg/kg) average rating results.

Location	Year	Rating	Avg. TN (mg/kg)	No. sites
Onepoto Inlet	2008	Good	495	2
Onepoto Inlet	2009	Very good	64	14
Onepoto Inlet	2010	Good	353	2
Onepoto Inlet	2015	Very good	125	4
Onepoto Inlet	2020	Very good	125	4
Onepoto Inlet	2022	Good	250	2
Pāuatahanui Inlet	2008	Good	685	2
Pāuatahanui Inlet	2009	Very good	167	7
Pāuatahanui Inlet	2010	Good	635	2
Pāuatahanui Inlet	2015	Very good	170	5
Pāuatahanui Inlet	2020	Very good	133	5
Pāuatahanui Inlet	2022	Good	433	2
Whole estuary	2008	Good	590	4
Whole estuary	2009	Very good	98	21
Whole estuary	2010	Good	494	4
Whole estuary	2015	Very good	150	9
Whole estuary	2020	Very good	130	9
Whole estuary	2022	Good	342	4

Metal contaminants

Zinc

Table A1.12: Zinc (mg/kg) average rating results.

Location	Year	Rating	Avg. Zn (mg/kg)	No. sites
Onepoto Inlet	2004	Very good	92.8	10
Onepoto Inlet	2005	Good	148.0	2
Onepoto Inlet	2008	Good	112.3	4
Onepoto Inlet	2009	Good	168.6	14
Onepoto Inlet	2010	Good	112.8	4
Onepoto Inlet	2015	Good	108.4	4
Onepoto Inlet	2020	Good	131.7	4
Onepoto Inlet	2022	Very good	53.9	2
Pāuatahanui Inlet	2004	Very good	54.7	13
Pāuatahanui Inlet	2005	Very good	60.4	3
Pāuatahanui Inlet	2008	Very good	57.6	5
Pāuatahanui Inlet	2009	Very good	59.4	7
Pāuatahanui Inlet	2010	Very good	50.3	5
Pāuatahanui Inlet	2015	Very good	51.0	5
Pāuatahanui Inlet	2020	Very good	59.1	5
Pāuatahanui Inlet	2022	Very good	32.5	2
Whole estuary	2004	Very good	71.3	23
Whole estuary	2005	Very good	95.4	5
Whole estuary	2008	Very good	81.9	9
Whole estuary	2009	Good	132.2	21
Whole estuary	2010	Very good	78.1	9
Whole estuary	2015	Very good	76.5	9
Whole estuary	2020	Very good	91.4	9
Whole estuary	2022	Very good	43.2	4

Copper

Table A1.13: Copper (mg/kg) average rating results.

Location	Year	Rating	Avg. Cu (mg/kg)	No. sites
Onepoto Inlet	2004	Very good	11.5	10
Onepoto Inlet	2005	Very good	20.1	2
Onepoto Inlet	2008	Very good	13.2	4
Onepoto Inlet	2009	Very good	12.4	14
Onepoto Inlet	2010	Very good	12.4	4
Onepoto Inlet	2015	Very good	11.7	4
Onepoto Inlet	2020	Very good	12.7	4
Onepoto Inlet	2022	Very good	3.9	2
Pāuatahanui Inlet	2004	Very good	9.5	13
Pāuatahanui Inlet	2005	Very good	11.1	3
Pāuatahanui Inlet	2008	Very good	8.4	5
Pāuatahanui Inlet	2009	Very good	5.0	7
Pāuatahanui Inlet	2010	Very good	6.7	5
Pāuatahanui Inlet	2015	Very good	7.1	5
Pāuatahanui Inlet	2020	Very good	7.7	5
Pāuatahanui Inlet	2022	Very good	3.8	2
Whole estuary	2004	Very good	10.3	23
Whole estuary	2005	Very good	14.7	5
Whole estuary	2008	Very good	10.5	9
Whole estuary	2009	Very good	9.9	21
Whole estuary	2010	Very good	9.2	9
Whole estuary	2015	Very good	9.1	9
Whole estuary	2020	Very good	9.9	9
Whole estuary	2022	Very good	3.8	4