Australian Government

Queensland Government

# Wetland Condition Methods

## Reef Water Quality Report Card 2020

Reef 2050 Water Quality Improvement Plan

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# Contents

# Catchment condition – wetland condition monitoring methods

This report describes methods used to produce the Reef Water Quality Report Card 2020 wetland condition results. Within the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program, the Wetland condition monitoring program tracks progress towards the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP), improved wetland condition objective.

The program design is described in the Great Barrier Reef (GBR) catchments wetland monitoring pilot study: assessment methods and monitoring design (Tilden et al., 2015) and the proposed program analysis methods are set out in detail in the Great Barrier Reef catchments wetland monitoring program: analysis methods (Tilden and Vandergragt, 2017).

Between 2018 and 2020, the Program's assessment instrument, Wetland Tracker (WT), underwent a major method update, including:

- the development of a new set of pressure subindices, based on classes of pressure identified in a landscape-scale study of hazards to wetlands (DSITI 2015)
- changes to the scoring scales, reducing their complexity.

These methods changes are described in more detail in sections to follow.

## Methods

The analysis methods document (Tilden and Vandergragt, 2017) identified a number of activities to be carried out in 2020. The aims were to:

- Assess wetland condition, and change in wetland condition, in Great Barrier Reef freshwater floodplain wetlands[1].
- Test for any indication that multiple assessments of panel 1 wetlands are affecting the condition of the wetlands in that panel. A panel is a group of wetlands with the same schedule of repeat assessments across years. Potential effects of annual visits are that the wetlands of panel 1 are being degraded in some way (unlikely) or alternatively, that the average condition of panel 1 wetlands has improved because their landholders have managed aspects of wetland condition brought to their notice by the program (preferential management). In either case, the wetlands in panel 1 would then no longer be representative of the program subpopulation. The null hypothesis is that both panels (panel 1 and panel 4) still sample wetlands from the same subpopulation, despite panel 1 having been assessed five times and panel 4 just once.
- Test for trend in pressure and state, provided there is sufficient power to do so.

[1] In 2020, due to COVID-19 restrictions, field assessments could not be completed in Cape York wetlands. Instead, scores for field indicators in Cape York were imputed, based on data from previous years. Field assessments were able to be carried out as usual in all other regions.

Baseline data for pressure on wetland values and the state of wetland values were reported in 2016. Wetland condition was reported for 2018, along with an analysis of change between 2016 and 2018. Great Barrier Reef-wide analyses reported for 2020 are:

- Tests for change in wetland condition (**state** of environmental values and anthropogenic **pressure** on wetlands) between 2018 and 2020.
- Tests for change in wetland condition between the 2016 baseline study and 2020.
- Tests for differences between panel 1 and panel 4 data gathered in 2020 to look for effects associated with multiple assessments.

Trend assessment was not performed due to lack of power to detect trend after five years of repeat assessments on 19 wetlands (see White 2019, Starcevich et al, 2018).

## Progress with Great Barrier Reef-wide monitoring design

Table 1 shows the Great Barrier Reef wetland condition monitoring program sample design – an augmented serially alternating design comprising one panel[2] of 20 wetlands assessed every year, and four panels of 20 assessed in alternate years following a pattern that repeats every eight years. The total sample size is 100 wetlands, comprising a spatially balanced random sample of wetlands selected using the Generalised Randomised Tessellation Stratified[3] method. The sub-population sampled for the Great Barrier Reef-wide monitoring program is natural freshwater floodplain wetlands in high-density assemblages (see Figure 1).

**Table 1. Panel design for the GBR catchments wetland condition monitoring program*.**

| Panel | Year | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** |
| **1** | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| **2** | 20 | | 20 | | | | | | 20 | | 20 |
| **3** | | 20 | | 20 | | | | | | 20 | |
| **4** | | | | | 20 | | 20 | | | | |
| **5** | | | | | | 20 | | 20 | | | |
| **Year total** | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| **Total sample** | **40** | **60** | **60** | **60** | **80** | **100** | **100** | **100** | **100** | **100** | **100** |

*Some wetland sample sizes per panel differ from the planned n=20 due to factors such as attrition and replacement. For example, panel 1 originally comprised 21 wetlands, and 21 were assessed in both 2018 and 2020, but only 19 wetlands have been assessed five times. Two have dropped out and been replaced.

Testing for change between 2018 and 2020 is complex, due to the program's augmented serially alternating panel structure, designed to optimise both status and trend assessment in a long-term monitoring program (Tilden et al, 2015). The particular pattern of alternating panels was chosen so the 40 wetlands assessed in 2016 (baseline) would be reassessed in 2018. This made it possible to test for change, with the power to detect change in 2018 after the program had been running for just three years. Each year, with this design, ≈ 40 wetlands are assessed for status reporting but only one panel of ≈ 20 wetlands is repeated *every* year throughout the program.

[2] A panel is a group of wetlands with the same schedule of repeat assessments across years.
[3] Generalised Randomised Tessellation Stratified sampling

While it is possible to test for trend with only these 20 wetlands, the power and economy of the program design for trend detection is not fully realised until other panels have been repeatedly tested in order for their results to be included in the trend analysis.

For the years being compared in 2020, the design mixes dependent and independent sampling – all wetlands are from the same population. However, while panel 1 wetlands are assessed in all years, the 20 wetlands in panel 2 (assessed in 2016 and 2018) and the 19 in panel 4 (assessed in 2020) are independent samples. Consequently, for the 2020 wetland condition report card the analysis of change between 2018 and 2020 is based on panel 1 wetlands only (n=21). Likewise, the comparison between the baseline (2016) and the condition of wetlands in 2020 is based on the 19 panel 1 wetlands assessed in both years.

## Data collection

Wetland assessment data were collected in two ways:

- desktop analysis based on imagery and spatial data using a range of data sets for 14 indicators, primarily related to the pressure index
- field-based data collection methods for 10 indicators primarily related to state.

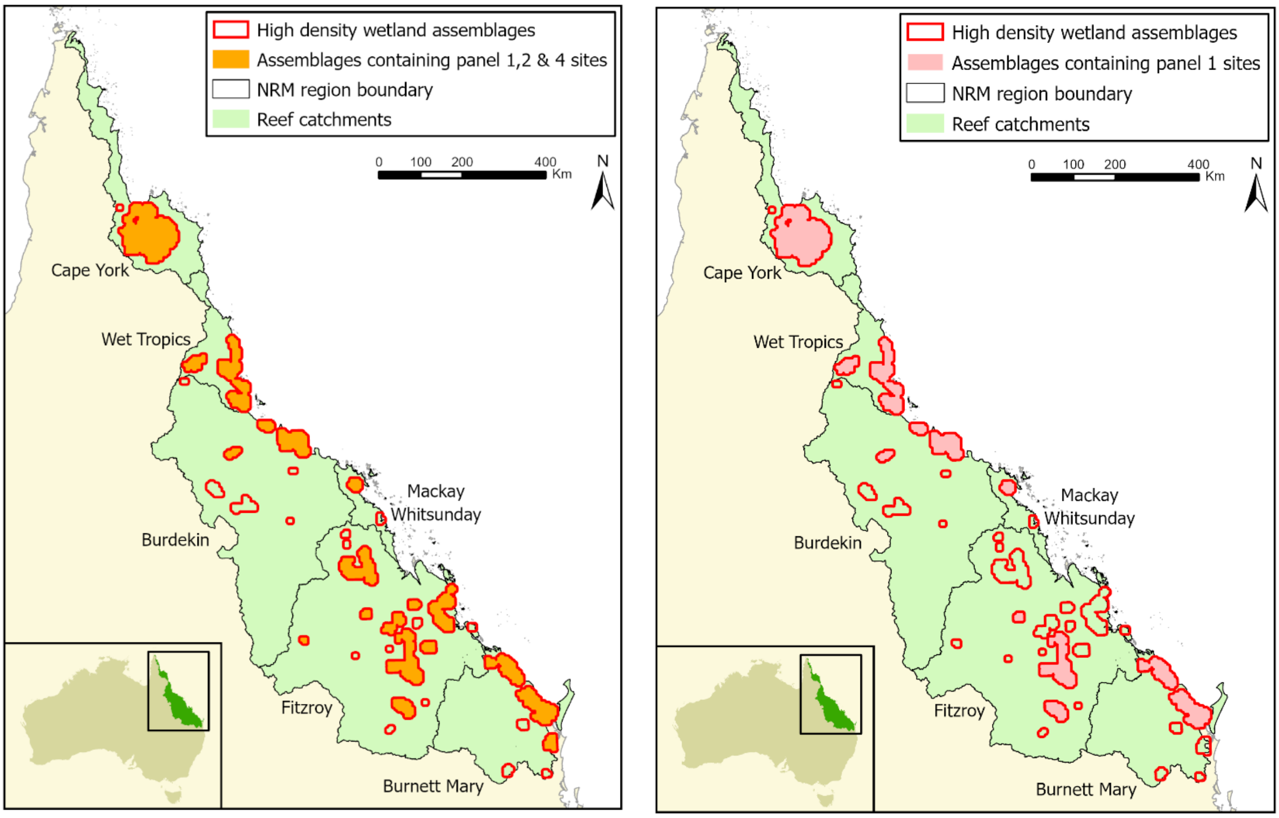


*Figure 1: High-density wetland assemblages containing panel 1, panel 2 and panel 4 wetlands assessed in 2018 and 2020 (left) and panel 1 wetlands assessed all years from 2016 to 2020 (right, n=19).*

## Calculating summary statistics – Wetland Tracker updated

A major update of Wetland Tracker brought changes to the structure of the instrument, with new sub-indices for assessing anthropogenic pressure on wetlands and new scoring scales for arriving at summary statistics and report card grades.

For each wetland, the condition assessment tool, Wetland Tracker (WT) produces overall scores for the **state** of wetland environmental values and for anthropogenic **pressure** on wetlands plus scores on four wetland environmental value (WEV) sub-indices of state, and four pressure class (PC) sub-indices.

The wetland environmental value sub-indices of state remain unchanged from the previous version of Wetland Tracker. They are:

- biotic integrity: the biological health and diversity of the wetland
- local physical integrity: the wetland's natural physical state and integrity
- local hydrology: the wetland's natural hydrological cycle
- connectivity: the natural interaction of the wetland with other ecosystems including other wetlands.

The new pressure sub-indices are based on pressure classes derived from a landscape-scale assessment of land-use hazard to freshwater wetlands in the Great Barrier Reef catchment area (Department of Science, Information Technology and Innovation, 2015):

- biological introduction pressure (e.g. plant pests and animals changing the wetland)
- habitat disturbance and alteration pressure (e.g. loss of natural vegetation around the wetland)
- pressure towards change to water regime (e.g. natural wetland water levels being altered by a dam or levee)
- pollutant input pressure (e.g. land use associated with the likelihood of chemicals and nutrients going into the wetland).

The structure of version 2 of Wetland Tracker with indices, sub-indices, indicators and their relationships is shown in Figure 2.

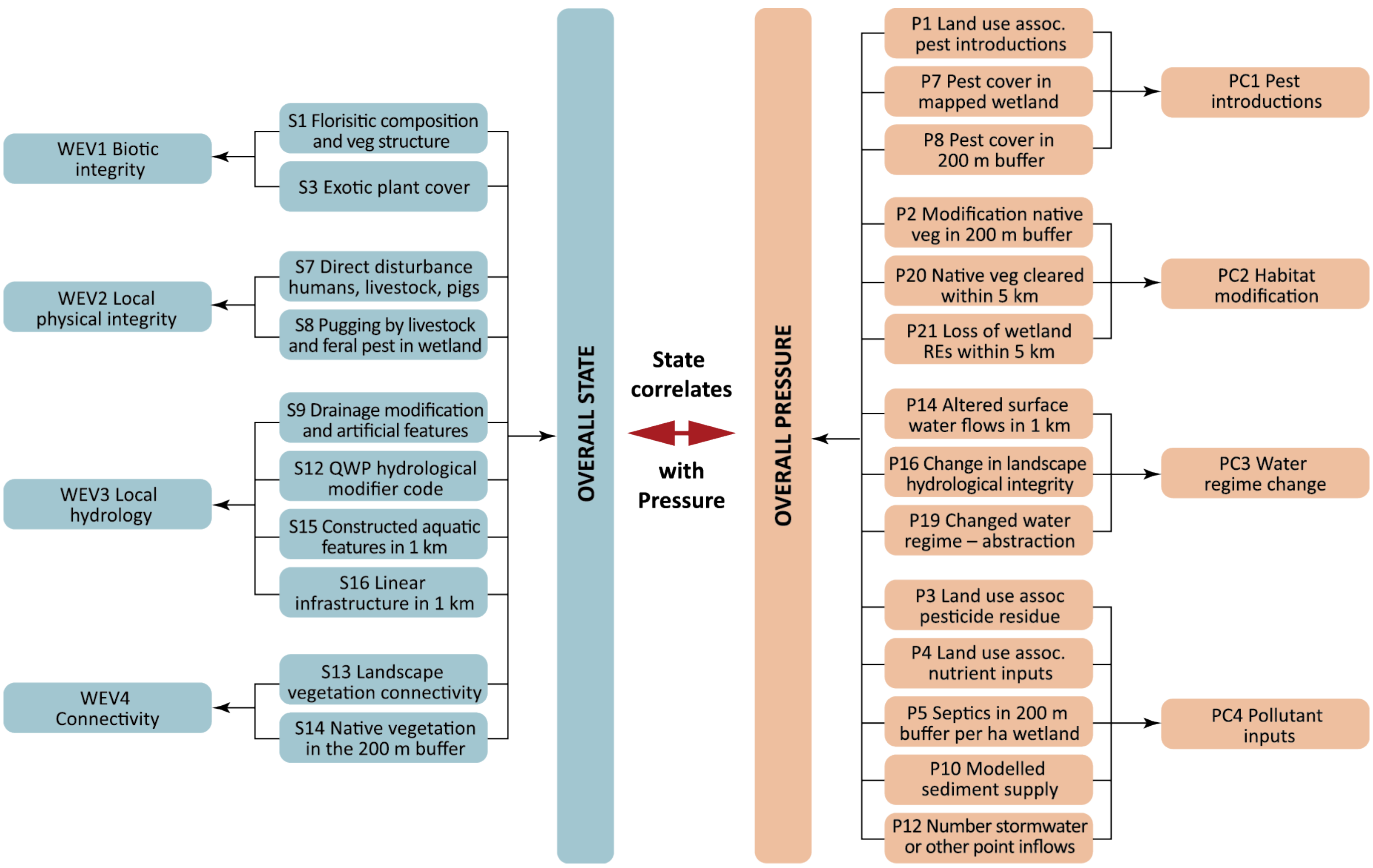


Figure 2: Structure of Wetland Tracker rapid assessment method, showing individual indicators (10 state, 14 pressure), sub-indices (4 state and 4 pressure) and overall index scores (state and pressure). Index and sub-index scores are calculated independently.

The status assessment for 2020 focuses on the 40 freshwater floodplain wetlands in the Great Barrier Reef catchments assessed that year (panels 1 and 4 in Table 1), while the assessment of change between 2018 and 2020, and between 2016 and 2020, includes solely wetlands assessed in both years (panel 1). Descriptive parametric and non-parametric statistics were calculated. Mean and variance of scores for overall wetland state and pressure were used to characterise the level of anthropogenic disturbance to Great Barrier Reef natural freshwater floodplain wetlands in 2020, along with the mean and variance per sub-index for state and pressure. Norman (2010) summarises work supporting the use of parametric statistics on aggregated ordinal data.

## Scoring scales for assessing, analysing and reporting wetland condition

Prior to the major update of Wetland Tracker, generating Great Barrier Reef scale wetland condition scores (pressure and state) was a five-step process. This process was not only complex, it also lost information from the data gathered because numeric scores were converted to integers before being analysed. The scoring process has since been simplified:

**Step 1. Scores per indicator:** Individual indicators (pressure and state) are assessed on ordinal scales with **integer** scores generally ranging from one to five.

| **Condition** | **Very low pressure/Very good state** | **Low pressure/ Good state** | **Moderate pressure/ Moderate state** | **High pressure/ Poor state** | **Very high pressure/ Very poor state** |
|---|---|---|---|---|---|
| Indicator scores (individual wetlands) | 1 | 2 | 3 | 4 | 5 |

**Step 2. Aggregation of indicator scores into sub-index scores:** The indicator scores are aggregated into sub-index **numeric scores** on a scale of one to five for each of the eight sub-indices per wetland: *biotic integrity*, *local physical integrity*, *local hydrology* and *connectivity* for state; *and biological introductions, habitat disturbance and alteration, changes to water regime and pollutant input* for pressure. Independently, the indicator scores are aggregated to generate an overall **numeric** pressure and state (OP and OS) score per wetland, also on a scale of one to five (not on a scale of one to 13, as previously recorded).

**Step 3. Great Barrier Reef wide scores**: At the Great Barrier Reef-wide scale individual sub-index pressure and state scores and overall pressure and state scores are calculated by averaging the **numeric** values obtained from the individual wetlands. All resulting average scores range from one to five.

**Step 4. Report card grades**: All variables are reported as raw score decimal values on a scale of one to five. Wherever report card grades are given, the cut-offs for grades are as follows:

| Wetland environmental value sub-index cut-offs (1–5 scale) | <1.50 | ≥1.50 to <2.50 | ≥2.50 to <3.50 | ≥3.50 to <4.50 | ≥4.50 |
|---|---|---|---|---|---|
| Report card grade | A | B | C | D | E |

As a result of changes in scoring scales, precision criteria set at the beginning of the program to determine the minimum sample size needed to detect a change between two assessment times have been recast. With the original 13-point scoring scale we aimed for an 80 percent likelihood that a change in score of less than one point meant there little to no change between two times (alpha = 0.05, power = 0.80). With the new five-point scoring scales for overall pressure and overall state, the equivalent change between two assessment times is 0.38 (alpha = 0.05, power = 0.80).

## Back scoring data to maintain comparability across five years of monitoring

The major upgrade of Wetland Tracker maintained, as far as possible, the continuity of year-on-year monitoring data. Improvements to individual indicators were made in such a way that back scores could be calculated for the program's previous years of data gathering (2016 to 2019). New indicators and the new pressure sub-indices were also able to be back scored. Back scores for all years to date are reported in the Reef Water Quality Report Card 2020 along with 2020 scores derived from 2020 wetland assessments using the new methods.

In 2020, all comparisons among summary statistics for different assessment years use back scored results for index and sub-index scores (state and pressure).

## Assessments of change between 2018 and 2020

Tests for change between 2018 and 2020 analysed aggregated wetland assessment scores.

Paired-sample t-tests were used to test for any statistically significant differences in aggregated state and pressure scores (index and subindex) between the 2018 and 2020 survey periods ($p \leq 0.05$). All assessments of change used back scored results. Paired-sample t-test results are for the n = 21 wetlands that were surveyed in both 2018 and 2020.

All paired-sample t-tests were two-tailed and were performed using the 't.test' function from the 'statsr' package in the R language and environment for statistical computing (R Core Team, 2018). 95% confidence intervals were computed for all t-tests. The hypothesis of 'no change' was accepted if the value of zero fell within the computed confidence interval. Narrower confidence intervals provide stronger confidence in accepting the null hypothesis of 'no change'.

## Assessments of change between baseline (2016) and 2020

Tests for change between 2016 and 2020 also analysed aggregated wetland assessment scores.

Paired-sample t-tests were used to test for any statistically significant differences in aggregated state and pressure scores (index and sub-index) between the 2016 and 2020 survey periods ($p \leq 0.05$). All assessments of change used back scored results. Paired-sample t-test results are for the n = 19 wetlands that were surveyed in both 2016 and 2020.

All paired-sample t-tests were two-tailed and were performed using the 't.test' function from the 'statsr' package in the R language and environment for statistical computing (R Core Team, 2018). 95% confidence intervals were computed for all t tests. The hypothesis of 'no change' was accepted if the value of zero fell within the computed confidence interval. Narrower confidence intervals provide stronger confidence in accepting the null hypothesis of 'no change'.

## Analysis by land use type

The aims of this analysis are to:

- Determine if, in 2020, there were any significant differences in state or in pressure scores between wetlands surrounded by conservation land uses and those surrounded by other land use categories.
- Determine if land use intensity (LUI) in the wetland and the surrounding area affects change in scores between 2018 and 2020.

Wetland condition scores – aggregated state and pressure scores for both indices and sub-indices as well as their corresponding report card grades – were calculated for all wetlands assessed in 2018 and 2020.

Students t-tests were used to test for any statistically significant differences in aggregated state and pressure scores (index and sub-index) between wetlands surrounded by conservation lands and those surrounded by other land uses.

To test the significance of changes in average scores by land use category between 2018 and 2020, we used paired-sample t-tests (two-tailed, $p \leq 0.05$) to analyse panel 1 data only ($n = 10$ for wetlands surrounded by conservation land use and $n = 11$ for wetlands surrounded by all other land uses). For each land use category, comparisons between 2018 and 2020 were made at the overall state or pressure score level, as well for individual sub-index state or pressure scores.

95% confidence intervals were computed for all t-tests. The hypothesis of 'no change' was accepted if the value of zero fell within the computed confidence interval. Narrower confidence intervals provide stronger confidence in accepting the null hypothesis of 'no change'.

## Comparing panels 1 and 4 for differences attributable to frequent testing

Students' t-test were used to compare the average condition of 21 wetlands in panel 1 with 19 in panel 4. By 2020, panel 1 wetlands had been assessed in five consecutive years, while panel 4 wetlands had had their first assessment. The null hypothesis under test was that the two panels of wetlands were independent samples from the same population. No indices or sub-indices had significantly different scores in the two years (alpha = 0.05).

For all variables tested, the computed 95% confidence intervals for the difference between panel 1 wetlands and panel 4 wetlands include the value of zero, however the confidence intervals are wide. Based on this test, there is no evidence that the two panels were not drawn from the same population, although confidence in this statement is reduced by the width of the confidence intervals around the mean differences between panels.

## Non-response bias

The 2016 Reef wetland condition report established that there was a non-response bias in the program's wetland assessment data related to the intensity of land use surrounding wetlands. Managers of wetlands surrounded by high-intensity land uses such as cropping and manufacturing were less likely to agree to monitoring than managers of wetlands surrounded by conservation land uses, with intermediate acceptance rates for wetlands surrounded by land use of intermediate intensity.

For wetlands assessed in 2020 (panels 1 and 4) this difference remains highly significant in a test for a trend in differences among acceptance rates by land use intensity (chi-square for trend in proportions = 11.57, $p < 0.001$, see Figure 3).

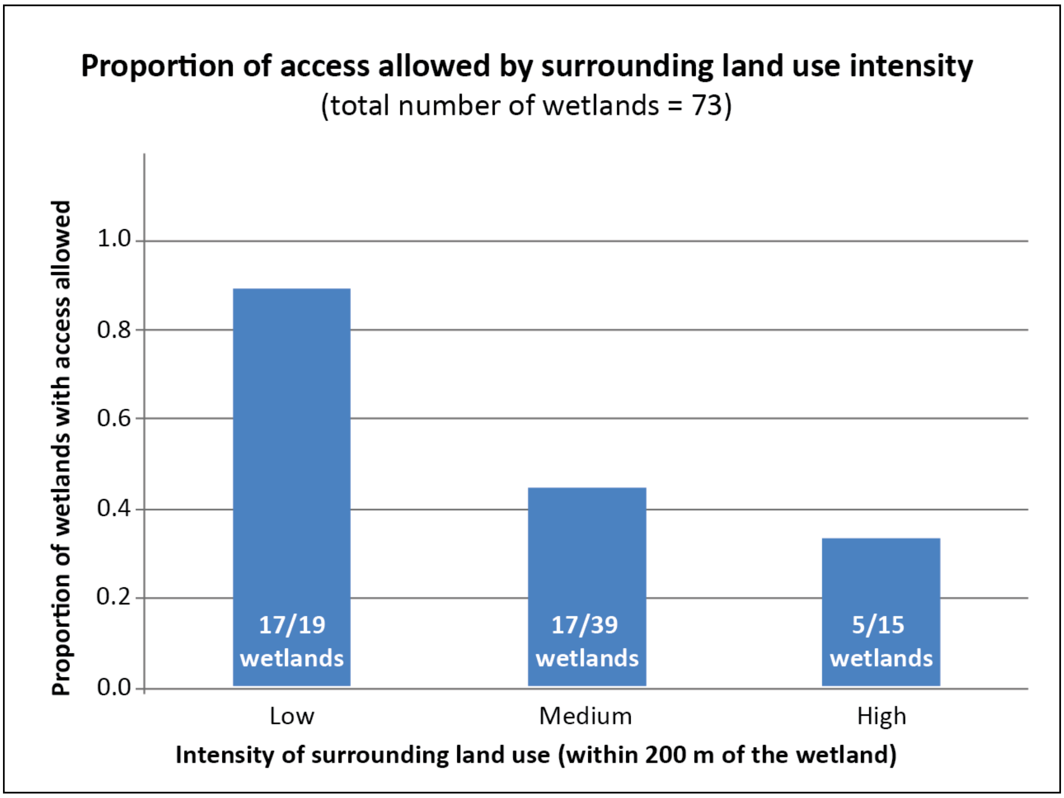


*Figure 3. Relationship between non-response rate and land use intensity, illustrating a non-response bias. The more intense the land use surrounding a wetland, the less likely land managers are to grant access.*

The effect of this bias would be to overestimate (towards the better end of the assessment scoring scale) the average condition of freshwater floodplain wetlands in the Great Barrier Reef catchment area.

To at least partially correct for this bias, adjustment weights were calculated by dividing the expected proportions of wetlands in each land use intensity class (high, moderate and low) by the observed proportions, and inverting the resulting values. All aggregated scores for the state of wetland environmental values and anthropogenic pressure on wetlands were adjusted using the resulting weights, and summary statistics were recalculated. Both adjusted and unadjusted results are given in the 2020 wetland condition results report. Only unadjusted scores were used in analyses of difference between times.

It is recognised that such adjustments are an approximation, and because the proposed source of the bias is correlated with the response variables measuring wetland condition, the adjustment weights calculated would only partially compensate for the effect of the bias. However, this is adjustment using weights based on observed non-response rates is preferable to no adjustment. For future reports, model-based methods of estimating non-response bias will be explored.

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## Glossary

**Aggregated wetland assessment scores:** The wetland assessment method uses scores at three levels – *indicators* are aggregated into four *subindices* based on wetland environmental values (WEVs). The WEV subindices are aggregated into two *indices*, overall pressure and overall state. The aggregation methods average the scores of indictors to derive subindex scores, which are in turn averaged to derive index scores.

**Augmented serially alternating design:** A monitoring design consisting of a number of panels of sites (wetlands), where one panel is assessed every year (the augmented section of the design) and the remaining panels are assessed in different years on a regular and repeating schedule.

**Baseline:** A baseline is the initial collection of data used for comparison with subsequently acquired data. In the case of the wetland condition monitoring component of the Reef Report, baseline data for the wetland results reported here were collected in 2015 and 2016 and reported in the Reef Water Quality Report Card 2016.

**DPSIR framework:** A causal framework for describing the interaction between society and the environment (Driver, Pressure, State, Impact, Response).

**Generalised Randomised Tessellation Stratified (GRTS) sampling**: A method for selecting a spatially balanced random sample of natural resources defined as areas, lines or points.

**Non-response bias:** A non-response bias occurs when randomly selected subjects (wetland managers) choose not to be involved in a study (wetland assessment), not at random, but in ways that are meaningful to the phenomenon under study.

**Panel:** A panel is a group of wetlands with the same schedule of repeat assessments across years.

**Power (to detect a change):** In statistical testing, Power = $(1 - \beta)$, where $\beta$ is the probability of making a Type II error, that is failing to detect an effect.

**Pressure:** Under the DPSIR framework, pressure refers to human activities directly affecting the environment.

**Spatially balanced random sample:** A random sample whose sample sites are more or less evenly dispersed over the extent of the population being studied.

**State:** Under the DPSIR framework, characteristics, at a particular time, of ecosystem processes and the organisms and habitats that define, support and/or adversely affect ecosystem environmental values.

**Index/indices/sub-index/sub-indices:** The Wetland Condition Monitoring Program assesses two indices of wetland condition, overall anthropogenic **pressure** and overall **state** of wetland environmental values. Sub-indices of pressure are classes of pressure on wetlands (PCs), defined as: biological introductions, habitat disturbance and alteration, changes to water regime and pollutant input pressures. State sub-indices are wetland environmental values (WEVs). Defined as: biotic integrity, local physical integrity, local hydrology and connectivity.

**Wetland condition:** Under the Great Barrier Reef Wetland Condition Monitoring Program, wetland condition refers to the pressure on wetlands' natural environmental values and the state of those values under a Driver, Pressure, State, Impact, Response (DPSIR) conceptual framework.