Australian Government

Queensland Government

# Wetland Condition Results

## Reef Water Quality Report Card 2017 and 2018

### Reef 2050 Water Quality Improvement Plan

#31897 | 0619

# CONTENTS

# CATCHMENT CONDITION – WETLAND CONDITION MONITORING RESULTS

This report describes progress towards the Reef 2050 Water Quality Improvement Plan 2017–2022 (Reef 2050 WQIP) objective of improved wetland condition (Australian and Queensland governments 2018). Improved condition of natural freshwater wetlands (palustrine and lacustrine), and management of the pressures on them, will support the long term outcome of sustaining the outstanding universal value of the Great Barrier Reef (GBR). This contributes to building the resilience and health of reef and coastal ecosytems, and benefits communities.

Following the 2016 report on the baseline condition of Great Barrier Reef freshwater floodplain wetlands, this report provides the GBR catchments wetland condition monitoring program with its first opportunity to report on *change* in wetland condition. Wetland condition is determined by assessing landuse-related pressure on wetlands' environmental values along with the state of their environmental values.

From a random sample of 41 natural freshwater wetlands in the GBR catchments,[1] pressure on freshwater wetland values and the state of freshwater wetland values were assessed for the 2016 baseline report using a wetland assessment tool developed for the program.[2] Thirty-nine of these wetlands have now been monitored at least twice (2016 and 2018), allowing change in the average condition of wetlands in the study population to be assessed.

Overall scores for **pressure** on wetland environmental values, and the **state** of wetland environmental values (WEVs), plus scores for WEV sub-indices of both pressure and state, were produced for each wetland. The WEV sub-indices are: *biotic integrity*, *local physical integrity*, *local hydrology* and *connectivity*. Here 2018 summary statistics are presented for these variables. As well, the differences between 2016 and 2018 are evaluated for each index and sub-index, to determine whether there has been any significant change in the condition of wetlands between the two times.

Two sets of wetland condition results are presented below, the results after adjustment for a non-response bias in the sample of wetlands assessed (discussed in more detail in a later section), followed by the results prior to adjustment for the bias. The non-response bias is related to the intensity of land use surrounding wetlands. The more intense the surrounding land use, the less likely land managers were to agree to wetland monitoring.

Non-response weights have been used to attempt to compensate for this bias, which would tend to underestimate the impact of land use intensity on the average condition of wetlands. However the use of non-response weights creates statistical issues in the analysis of differences between times (see for example Lynn, 1996, Höfler et al, 2005). It is therefore appropriate to report both adjusted and unadjusted scores, and to use unadjusted scores in statistical analyses.

[1] Comprising panels 1 and 2 of the program's augmented, serially alternating sampling design (see Reef report 2016: wetland condition methods p5)

[2] The Wetland Field Assessment Tool for Monitoring (WFAT–M), which used a 13 point scale for measuring overall wetland condition (pressure and state) and a 5 point scale for wetland environmental value sub-indices.

# Summary

## Wetland condition in 2018

Freshwater floodplain wetlands in the Great Barrier Reef catchments remain, on average, under moderate pressure (C) from catchment land use. The average overall state of these wetlands is moderate (C) after adjustment for non-response bias.

Pressure is significantly lower on wetlands surrounded by conservation land uses (B) than on those surrounded by all other land uses (D), and there is a corresponding difference in grades for the overall state of wetlands within conservation lands (B), compared with those surrounded by other land uses (C).

Overall pressure (OP) continues to be a strong predictor of a wetland's overall state (OS) score in 2018. The individual pressure indicators that best predicted overall state in 2018 were land use associated with nutrient inputs, land use associated with changes to natural surface water flow patterns, area of land cleared of native vegetation within 5 km of the wetland, and modification of native vegetation in the 200 m buffer and along the mapped wetland boundary. On average, wetlands tended to be in less disturbed states when they experienced lower levels of these pressures.

In terms of managing land use to improve the condition of wetlands, there is some evidence that protecting and/or rehabilitating the natural vegetation in a wetland's 200 m buffer would be a beneficial first response, *given the wetlands' current average state*.[3] Further monitoring and research is needed to confirm this observation.

## Change in wetland condition from 2016 to 2018

Figures 1 and 2 summarise report card grades for the average condition of GBR catchments' freshwater floodplain wetlands in 2016 and 2018, presenting results for pressure on wetland values and state of wetland values *after* adjustment for non-response bias. There were no changes in adjusted report card grades for average wetland condition between 2016 and 2018.

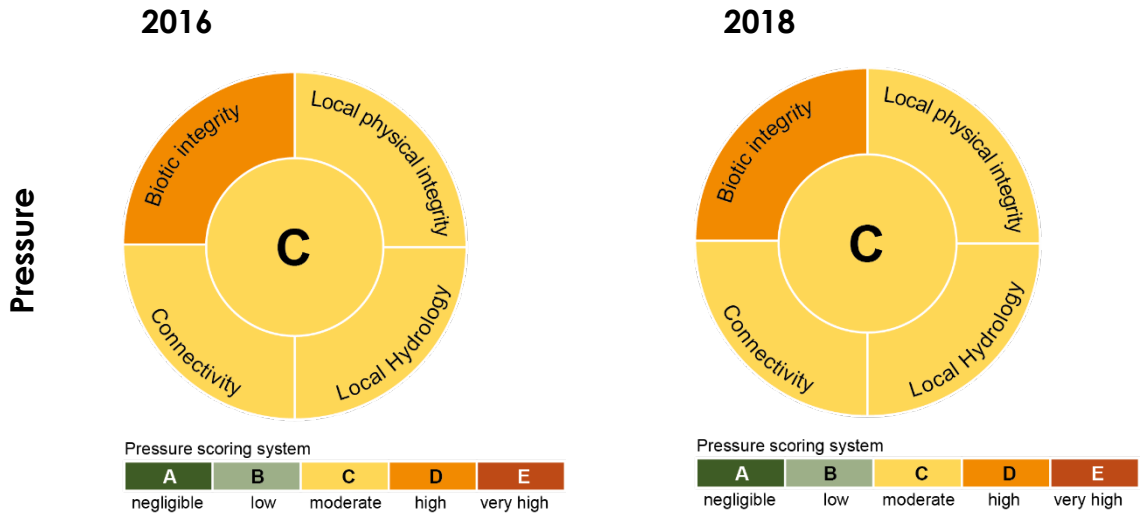



**Figure 1 Pressure grades for freshwater floodplain wetlands in GBR catchments, 2016 (backcast) and 2018 compared. Grades are adjusted for a non-response bias.**

[3] See the section on 'the relationship between pressure and state' for more information.

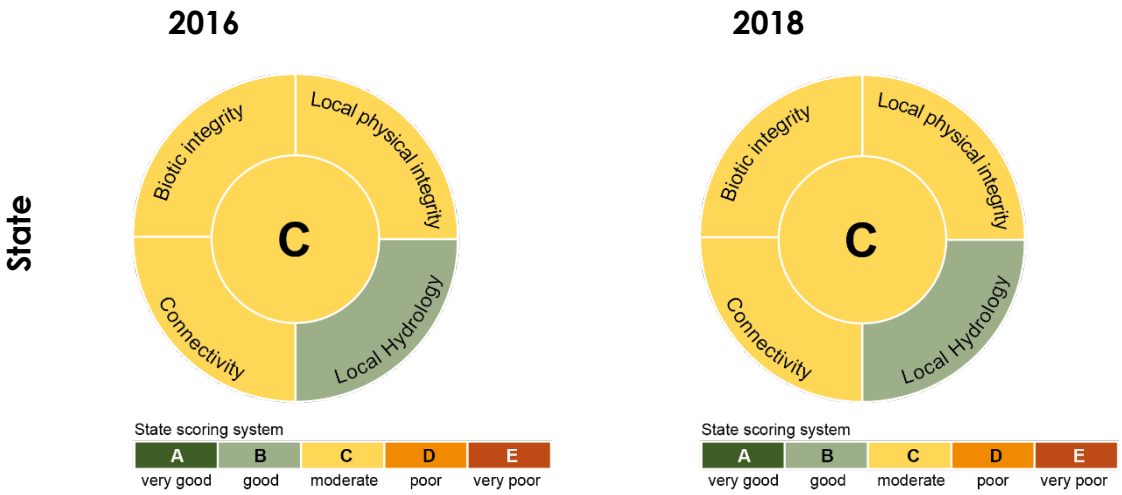



**Figure 2 State grades for freshwater floodplain wetlands in GBR catchments, 2016 (backcast) and 2018 compared. Grades are adjusted for a non-response bias.**

Table 2 provides the scores for the grades presented in Figures 1 and 2, as well as presenting the equivalent unadjusted (for non-response bias) results in the bottom half of the table. The unadjusted results show changes in report card grades for pressure on local physical integrity (WEV 2) and overall state of wetland environmental values but these changes were not statistically significant.

Conversely, there were statistically significant differences in the unadjusted scores for overall pressure and pressure on biotic integrity (WEV 1) for wetlands surrounded by land uses other than conservation (Table 16). This was largely due to differences, between 2016 and 2018, in pressure from plant pests in wetlands, pressure from landuse associated with the introduction of pest species and modification of native vegetation in the 200 m buffer of wetlands.

The state of local hydrology (WEV 3) in wetlands surrounded by conservation lands was also significantly different between 2016 and 2018 (Table 14), however the data shows this is likely an artefact of calibrating the scoring method for one indicator (abstraction) between the 2016 and 2018 data collection, rather than a real change in the state of wetand hydrology. This is discussed further in the summary statistics for state and change of state.

## Non-response bias

For each wetland assessed in 2016, the aggregated scores on overall pressure and state indices, along with scores on the WEV sub-indices, were weighted to adjust for a non-response bias related to the intensity of land use. The more intense the land use surrounding the wetland, the less likely land managers were to agree to have the wetland monitored. Weights were based on landholder acceptance rates for each land use intensity class (low, moderate and high). Table 1 summarises the land uses in each class.

**Table 1. Land use by intensity for calculating non-response bias**

| Land Use Intensity categories | Intensity |
|---|---|
| Intensive uses | High |
| Production from dryland agriculture and plantations | High |
| Production from irrigated agriculture and plantations | High |
| Conservation and natural environments | Low |
| Production from relatively natural environments | Moderate |
| Water – tertiary classification is conservation | Low |
| Water – tertiary classification is production, intensive use, aquaduct or stormwater | High |

Both unadjusted and adjusted results were reported in 2016. The same wetlands, subject to the same biases in their initial selection, were assessed in 2018, so the same adjustment weights have been applied to the 2018 assessment scores as to the 2016 (backcast baseline) scores.

Table 2 shows the effect of adjusting for the non-response bias. While all aggregated scores increase as a result of applying non-response weights, over half retain the report card grades of the unadjusted scores.

**Table 2. Comparing scores and grades for 2016 and 2018, both adjusted for non-response bias, and unadjusted.**

| Adjusted scores and grades | Overall pressure | WEV 1 | WEV2 | WEV 3 | WEV 4 | Overall state | WEV 1 | WEV 2 | WEV 3 | WEV 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016 | **7.04** | 3.58 | 2.56 | 2.60 | 3.37 | **6.08** | 2.80 | 2.91 | 2.15 | 3.25 |
| 2018 | **7.16** | 3.74 | 2.63 | 2.62 | 3.27 | **6.21** | 2.94 | 2.86 | 2.30 | 3.25 |
| 2016 | C | D | C | C | C | C | C | C | B | C |
| 2018 | C | D | C | C | C | C | C | C | B | C |

| Unadjusted scores and grades | Overall pressure | WEV 1 | WEV2 | WEV 3 | WEV 4 | Overall state | WEV 1 | WEV 2 | WEV 3 | WEV 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016 | **6.49** | 3.33 | 2.46 | 2.38 | 3.18 | **5.54** | 2.49 | 3.00 | 1.97 | 2.92 |
| 2018 | **6.62** | 3.49 | 2.54 | 2.41 | 3.18 | **5.41** | 2.49 | 2.85 | 2.15 | 2.92 |
| 2016 | C | C | B | B | C | C | B | C | B | C |
| 2018 | C | C | C | B | C | B | B | C | B | C |

As in 2016, both unadjusted and adjusted results are reported for overall index scores (pressure and state) and for sub-index scores. Adjusted scores are reported in the summary above. The analysis to follow, uses *unadjusted* scores.

## A note on scoring scales

Generating the GBR scale wetland condition Pressure and State scores is a five step process. It starts with indicator scoring at the individual wetland scale then steps through to calculating wetland scale WEV scores and overall Pressure and State grades. GBR-wide grades for the four WEVs (*biotic integrity*, *local physical integrity*, *local hydrology* and *connectivity for pressure and state respectively) and the overall* GBR-wide State and Pressure report card grading are then calculated. These steps, score classes and cut-off values are summarised in Tables 3 to 6.

**Table 3. Scores per indicator: Individual indicators (pressure and state) are assessed on ordinal scales with 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 |

**Table 4. Scores per WEV:** The indicator scores are aggregated and converted into sub-index numeric scores for each of the four WEVs per wetland : *biotic integrity*, *local physical integrity*, *local hydrology* and *connectivity for both pressure and state respectively*.

| | | | | | |
|---|---|---|---|---|---|
| WEV sub-index cutoff values | ≤1.53 | >1.53 to ≤2.33 | >2.33 to ≤3.13 | >3.1 to ≤3.93 | >3.93 |

**Table 5. Overall wetland pressure and state scores:** The four WEV pressure scores and the four WEV state scores are then aggregated to generate an overall numeric pressure and state (OP and OS) score per wetland corresponding to a 13 point grading scale as shown below.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aggregated overall pressure and state cut-off values | ≤1.27 | >1.27 to ≤1.53 | >1.53 to ≤1.8 | >1.8 to ≤2.07 | >2.07 to ≤2.33 | >2.33 to ≤2.6 | >2.6 to ≤2.87 | >2.87 to ≤3.13 | >3.13 to ≤3.4 | >3.4 to ≤3.67 | >3.67 to ≤3.93 | >3.93 to ≤4.2 | >4.2 |
| Pressure and state score classes (grades) | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |

**Table 6. GBR wide scores**: At the GBR-wide scale individual WEV pressure and states scores and overall pressure and state scores are calculated by averaging the numeric values obtained from the individual wetlands. The GBR-wide pressure and state scores are then converted to the report card grades as shown below.

**GBR scale WEV Sub-index Pressure and State report card grading**

| | | | | | |
|---|---|---|---|---|---|
| WEV subindex cutoffs (1–5 scale) | <1.5 | ≥1.5 to <2.5 | ≥2.5 to <3.5 | ≥3.5 to <4.5 | ≥4.5 |
| Report Card grade | A | B | C | D | E |

**GBR scale State and Pressure report card grading**

| | | | | | |
|---|---|---|---|---|---|
| Index cutoffs (1–13 scale) | <2.5 | ≥2.5 to <5.5 | ≥5.5 to <8.5 | ≥8.5 to <11.5 | ≥11.5 |
| Report Card grade | A | B | C | D | E |

## Wetland condition assessment and natural variability

The program's wetland assessment tool was designed to assess anthropogenic impacts while being unresponsive to natural variability. Sufficient data has not been collected as yet to test this proposition. Activities are planned to research the effects of rainfall, climate zone (tropical versus sub-tropical) and wetland habitat type on wetland assessment scores, to see if natural variability has been factored out to an acceptable degree.

For the 2016 assessment season, data were gathered between August and November 2015 as well as between March and September 2016, whereas the 2018 season extended from March to August 2018. The state-wide average monthly rainfall for the two seasons, including the three months prior to the beginning of each season, was approximately the same (44 mm for the 2016 season and 47 mm for the 2018 season, BoM, 2019). So unwanted effects of rainfall on GBR-wide wetland state are less likely to be a concern for this particular comparison period than for one comparing seasons with markedly different average rainfall across the region.

## Summary statistics

### Pressure and change in pressure

The 2016 Reef Report Card reported the mean pressure on 41 freshwater floodplain wetlands at 5.6 (on the 13 point scale), corresponding to a wetland assessment index score of 6 (when rounded) and a report card grade of C. For the 39 of these wetlands assessed in both 2016 and 2018, Table 7 summarises 'pressure' statistics for both periods.

The mean overall pressure score for 2016 reported here is higher than the mean overall pressure reported in the 2016 Wetland condition reef report card. Refinements of the wetland assessment tool since the previous report card have resulted in some score changes.[4]

**Table 7. Summary statistics for pressure on wetland values, 2016 and 2018 compared**

| VARIABLE | year | N | mean score | sd | median | min score | max score | IQR |
|---|---|---|---|---|---|---|---|---|
| **OVERALL PRESSURE** | 2016 | 39 | 6.49 | 2.98 | 7 | 2 | 11 | 5.5 |
| **OVERALL PRESSURE** | 2018 | 39 | 6.61 | 3.00 | 7 | 2 | 11 | 5 |
| **WEV1 Biotic integrity** | 2016 | 39 | 3.33 | 0.93 | 3 | 2 | 5 | 1 |
| **WEV1 Biotic integrity** | 2018 | 39 | 3.49 | 1.02 | 3 | 2 | 5 | 1 |
| **WEV2 Local physical integrity** | 2016 | 39 | 2.46 | 1.12 | 3 | 1 | 5 | 1.5 |
| **WEV2 Local physical integrity** | 2018 | 39 | 2.54 | 1.10 | 3 | 1 | 5 | 1.5 |
| **WEV3 Local hydrology** | 2016 | 39 | 2.38 | 1.14 | 3 | 1 | 5 | 2 |
| **WEV3 Local hydrology** | 2018 | 39 | 2.41 | 1.14 | 3 | 1 | 5 | 2 |
| **WEV4 Connectivity** | 2016 | 39 | 3.18 | 1.45 | 3 | 1 | 5 | 2.5 |
| **WEV4 Connectivity** | 2018 | 39 | 3.18 | 1.41 | 3 | 1 | 5 | 3 |

**N = number of wetlands in the sample; sd = standard deviation of scores; med = median; IQR = inter quartile range**

[4] Most of the differences in the results reported in 2016, compared with the 2016 backcast results used in this report, are due to an adjustment of the alignment between the scoring scales used for overall indices of pressure and state and those used for sub-indices. The general effect of this change has been to move sub-index grades towards the more disturbed end of their scoring scales. Some score changes have also been influenced by refinements to indicators.

Table 8 summarises the report card grades of 2018 as well as those of 2016, both as reported in 2016 and as backcast for the current report after refinements to the assessment instrument. For local physical integrity, the backcast score is B, while A was the calculated score in 2016. The difference is largely due to refinements to one indicator (modelled sediments). This sub-index was not reported in the 2016 report card due to the need to improve its indicators.

**Table 8. Report card grades for overall pressure and pressure sub-indices**

| Index | 2016 Grade N=41 | 2016 Grade N=39 (backcast data) | 2018 Grade N=39 |
|---|---|---|---|
| **Overall pressure score** | **C** | **C** | **C** |
| WEV1 Biotic integrity | C | C | C |
| WEV2 Local physical integrity | A | B | C |
| WEV3 Local hydrology | B | B | B |
| WEV4 Connectivity | C | C | C |

The overall report card grade for pressure on wetlands in 2018 remains at C. On the 13-point assessment index scoring scale, the score change between the two assessment periods translates to an increase in pressure of 1 point (6 to 7).

A report card grade of C for pressure means that, on average, the freshwater floodplain wetlands in the GBR catchments are under moderate pressure from surrounding land use. Of the four wetland environmental values that comprise the pressure index, biotic integrity, physical integrity and connectivity have higher pressure scores (at C or 'moderate') than hydrology (at B or 'good') in 2018.

Biotic integrity (WEV 1) is a measure of the biological health of wetlands. Its pressure indicators assess changes in the vegetation cover within 200 m of the wetland as well as changes in the extent of land use types that tend either to protect or to disturb a wetland's biological health (DSITIA 2014). Local physical integrity (WEV 2) measures naturalness of a wetlands' land form, depth and soil surface. Its pressure indicators assess processes that put pressure on the physical characteristics, the most influential in 2018 being sediment from the catchment. Indicators of pressure on *a wetland's natural interaction with other ecosystems* – connectivity (WEV 4), are loss of native vegetation within 5 km of the wetland and loss of wetland regional ecosystems within 5 km. Management actions to reduce pressure from these sources include protecting and/or re-establishing native vegetation, whether that vegetation is immediately surrounding the wetland, in the riparian zones of waterways or connecting wetlands in the landscape.

The differences between 2016 (backcast) and 2018, both in overall pressure and in pressure on individual environmental values of floodplain wetlands in the GBR catchments, were assessed using two-sided paired-sample t-tests. Table 9 shows the results.

**Table 9. Analysis of difference in pressure of wetland values between 2016 and 2018 (N=39)**

| Indicator | N | Mean_diff | sd_diff | t | p_value |
|---|---|---|---|---|---|
| **OVERALL PRESSURE GRADE (1–13)** | **39** | **0.13** | **0.52** | **1.53** | **0.13** |
| WEV1 Biotic integrity | 39 | 0.15 | 0.49 | 1.97 | 0.06 |
| WEV2 Local physical integrity | 39 | 0.08 | 0.48 | 1.00 | 0.32 |
| WEV3 Local hydrology | 39 | 0.03 | 0.16 | 1.00 | 0.32 |
| WEV4 Connectivity | 39 | 0.00 | 0.23 | 0.00 | 1.00 |

**N = number of wetlands in the sample; Mean_diff is the mean of differences between scores, sd_diff is the standard deviation of differences between scores; t is the value of the two-sided t-test of significance; p_value is probability value, used to determine if the difference between means is significant (values <0.05 are considered to be significant)**

All WEV mean pressure scores except WEV 4, connectivity, increased slightly from 2016 to 2018 for the 39 wetlands, although none of these individual changes in sub-index scores reached

significance. While the change in overall pressure grade also does not reach significance, these results will contribute to the assessment of trends as more data is gathered over time.

## State and change in state

In 2016 the mean state of wetland values of 41 freshwater floodplain wetlands was 5.18, corresponding to a wetland assessment index score of 5 and a report card grade of B (before adjustment for non-response). As noted above, 39 of these wetlands were reassessed in 2018. Table 10 reproduces the summary 'state' statistics for these 39 wetlands for both assessment periods.

**Table 10. Summary statistics for state of wetland values (condition), 2016 and 2018 compared**

| VARIABLE | Year | N | mean score | sd | median | min score | max score | IQR |
|---|---|---|---|---|---|---|---|---|
| **OVERALL STATE** | 2016 | 39 | 5.54 | 2.77 | 5 | 2 | 11 | 5 |
| **OVERALL STATE** | 2018 | 39 | 5.41 | 2.98 | 5 | 1 | 11 | 4 |
| **WEV1 Biotic integrity** | 2016 | 39 | 2.49 | 1.43 | 2 | 1 | 5 | 2.5 |
| **WEV1 Biotic integrity** | 2018 | 39 | 2.49 | 1.41 | 2 | 1 | 5 | 2 |
| **WEV2 Local physical integrity** | 2016 | 39 | 3.00 | 1.10 | 3 | 1 | 5 | 2 |
| **WEV2 Local physical integrity** | 2018 | 39 | 2.85 | 0.99 | 3 | 1 | 5 | 1.5 |
| **WEV3 Local hydrology** | 2016 | 39 | 1.97 | 0.70 | 2 | 1 | 4 | 0 |
| **WEV3 Local hydrology** | 2018 | 39 | 2.15 | 0.54 | 2 | 1 | 4 | 0 |
| **WEV4 Connectivity** | 2016 | 39 | 2.92 | 1.63 | 3 | 1 | 5 | 3 |
| **WEV4 Connectivity** | 2018 | 39 | 2.92 | 1.63 | 3 | 1 | 5 | 3 |

**N = number of wetlands in the sample; sd = standard deviation of scores; med = median; IQR = inter quartile range**

Table 11 summarises 2018 state report card grades as well as those of 2016, both as reported in 2016 and as backcast for the current report. Overall state and two of the four sub-indices have higher (more disturbed) report card grades in the backcast 2016 results than in those reported in 2016. This is due to the alignment adjustment of overall indices and sub-indices, as mentioned earlier.

**Table 11. Report card grades for overall state and state sub-indices**

| Index | 2016 Grade N=41 | 2016 Grade N=39 (backcast data) | 2018 Grade N=39 |
|---|---|---|---|
| **Overall state score (n = 39)** | **B** | **C** | **B** |
| WEV1 Biotic integrity | B | B | B |
| WEV2 Local physical integrity | C | C | C |
| WEV3 Local hydrology | A | B | B |
| WEV4 Connectivity | B | C | C |

The report card grade for average wetland state is B (before adjustment for non-response). On the 13-point numerical scoring scale of the wetland assessment tool, the score changes from 6 to 5, however, both scores are very close to the breakpoint between their score classes and the result is not significant ($p = 0.55$).

A report card grade of B would mean that, on average, the freshwater floodplain wetlands in the GBR catchments are in a good state. **Note** however that after adjustment for non-response the reported overall state of wetlands in 2018 is moderate (C), as it was in 2016 (backcast).

Of the four wetland environmental values that comprise the state index, the scores for local physical integrity and connectivity show greater impact from surrounding land use than those for the wetland's biotic integrity or hydrology.

State indicators of local physical integrity assess the naturalness of a wetland's landform as well as the extent and type of direct soil disturbance, whether caused by humans, livestock or feral animals. Managing livestock and feral animals around wetlands would improve the state score for this wetland environmental value. Indicators of the state of wetlands' connectivity relate to the state of native vegetation surrounding the wetland, both in the 200 m buffer and at the landscape scale. Management actions designed to protect or connect native vegetation around wetlands would help to maintain or improve this wetland value along with wetlands' overall state.

Table 12 displays the change analysis for the state of wetland values.

**Table 12. Analysis of difference in state of wetland values between 2016 and 2018 (N=39)**

| Indicator | N | Mean_diff | sdev_diff | t | p_value |
|---|---|---|---|---|---|
| **OVERALL STATE GRADE (1–13)** | **39** | -0.13 | 1.34 | -0.60 | 0.55 |
| WEV1 Biotic integrity | 39 | 0 | 0.56 | 0 | 1 |
| WEV2 Local physical integrity | 39 | -0.15 | 0.99 | -0.97 | 0.34 |
| WEV3 Local hydrology | 39 | 0.18 | 0.39 | 2.88 | 0.01** |
| WEV4 Connectivity | 39 | 0 | 0 | – | – |

**N = number of wetlands in the sample; Mean_diff is the mean of differences between scores, sd_diff is the standard deviation of differences between scores; t is the value of the two-sided t-test of significance; p_value is probability value, used to determine if the difference between means is significant (values <0.05 are considered to be significant)**

While there was no significant change in the overall state of wetland values between 2016 and 2018, the decrease in mean overall state score of 0.13 between survey periods (n = 39 wetlands) was large enough to result in a change in report card grade from C in 2016 to B in 2018, as seen in Table 11. When average wetland assessment scores are close to the breakpoint between two report card grades, it is possible for a grade change to occur without the change in score reaching significance.

The state of wetlands' biotic integrity, local physical integrity and connectivity also showed no significant difference between 2016 and 2018.

There was a significant difference in the state of wetland hydrology comparing 2016 unadjusted scores with those gathered in 2018. This difference is largely due to improved repeatability of field scoring for one indicator, abstraction of water from the wetland.[5] Before data was gathered in 2018, a calibration exercise clarified the assessment method to ensure that scoring for abstraction included drinking by cattle and feral animals. The effect of this was not random, resulting in a significant difference in the indicator score between the two years.

## The effect of land-use type on wetland pressure and state

Consistent with the results reported in 2016, the 2018 data show the impact of surrounding land use type on wetlands. There is a significant difference in overall pressure on wetland values and overall state of wetland values between wetlands surrounded by conservation uses such as national parks or water catchment protection reserves, and those surrounded by all other land uses (e.g. cropping, grazing, mining). Wetlands surrounded by non-conservation land uses suffer higher levels of pressure. This is reflected in higher pressure and state scores, indicating

[5] Abstraction is defined as water taken for use.

greater levels of disturbance to wetland environmental values. Table 13 illustrates the impact of these score changes on report card grades.

Overall pressure is two grades lower (less pressured) and overall state one grade lower (less disturbed) for wetlands surrounded by conservation lands compared with wetlands surrounded by other land use types, reflecting lower levels of human disturbance to wetland environmental values for conserved lands. All reported sub-index grades reflect these lower levels of disturbance for wetlands within conservation land uses. The 'natural interaction of the wetland with other ecosystems, including other wetlands' (connectivity) is most affected, with a difference of two grades for both pressure and state. The loss of connectivity refers either to the lack of linking vegetation corridors or to the historical loss of nearby wetlands.

**Table 13. Condition, in 2018, of GBR catchment freshwater floodplain wetlands surrounded by conservation compared with wetlands surrounded by all other land uses.**

| Index | Conservation lands | | All other land uses | |
|---|---|---|---|---|
| | *Mean score* | *Report grade* | *Mean score* | *Report grade* |
| **Overall pressure score (n = 39)** | **4.18** | **B** | **8.50** | **D** |
| WEV1 Biotic integrity | 2.76 | C | 4.04 | D |
| WEV2 Local physical integrity | 1.88 | B | 3.05 | C |
| WEV3 Local hydrology | 1.52 | B | 3.09 | C |
| WEV4 Connectivity | 2.17 | B | 3.95 | D |
| | | | | |
| **Overall state score (n = 39)** | **2.94** | **B** | **7.32** | **C** |
| WEV1 Biotic integrity | 1.35 | **A** | 3.36 | C |
| WEV2 Local physical integrity | 2.41 | B | 3.18 | C |
| WEV3 Local hydrology | 2.00 | B | 2.27 | B |
| WEV4 Connectivity | 1.71 | B | 3.86 | D |

## Change between times for different land use types

For wetlands surrounded by conservation land uses, only the state of local hydrology shows a significant change between 2016 and 2018. As explained in the previous section, this is an artefact of improved repeatability in field scoring methods between the two years, rather than a real change in the state of hydrology of wetlands surrounded by conservation land uses. For the remaining variables (overall pressure and state and their sub-indices) there are no significant changes in average scores between 2016 (backcast results) and 2018, as shown by two-sided paired sample t-tests of the average difference between times (Table 14). However, due to the relatively small size of the sample (N = 17) it is not possible to say with a high degree of certainty (i.e. greater than 80%) that there *is* no change between the two times.

**Table 14. Change between 2016 and 2018 for wetlands surrounded by conservation land uses**

| Indicator | N | Mean_diff | sd_diff | t | p_value |
|---|---|---|---|---|---|
| **OVERALL PRESSURE GRADE (1–13)** | 17 | 0.06 | 0.66 | 0.37 | 0.72 |
| WEV1 Biotic integrity | 17 | 0.00 | 0.50 | 0.00 | 1.00 |
| WEV2 Local physical integrity | 17 | 0.06 | 0.66 | 0.37 | 0.71 |
| WEV3 Local hydrology | 17 | 0 | 0 | – | – |
| WEV4 Connectivity | 17 | 0 | 0 | – | – |
| **OVERALL STATE GRADE (1–13)** | 17 | -0.29 | 1.40 | -0.86 | 0.40 |
| WEV1 Biotic integrity | 17 | 0.06 | 0.24 | 1.00 | 0.33 |
| WEV2 Local physical integrity | 17 | -0.18 | 0.95 | -0.77 | 0.46 |
| WEV3 Local hydrology | 17 | 0.24 | 0.44 | 2.22 | 0.04* |
| WEV4 Connectivity | 17 | 0 | 0 | – | – |

There was one non-significant change in report card grade (Table 15). As previously noted, this can happen when scores are close to the cutoffs for report card grades.

**Table 15. Report card grades (2016 and 2018) for wetlands surrounded by conservation uses**

| Conservation land uses | Mean score, 2016 | 2016 Grade, Backcast N=17 | Mean score, 2018 | 2018 Grade, N=17 |
|---|---|---|---|---|
| **Overall pressure score** | **4.12** | **B** | **4.18** | **B** |
| WEV1 Biotic integrity | 2.76 | C | 2.76 | C |
| WEV2 Local physical integrity | 1.82 | B | 1.88 | B |
| WEV3 Local hydrology | 1.53 | B | 1.53 | B |
| WEV4 Connectivity | 2.18 | B | 2.18 | B |
| **Overall state score** | **3.23** | **B** | **2.94** | **B** |
| WEV1 Biotic integrity | 1.29 | **A** | 1.35 | **A** |
| WEV2 Local physical integrity | 2.59 | C | 2.41 | B |
| WEV3 Local hydrology | 1.76 | B | 2.00 | B |
| WEV4 Connectivity | 1.71 | B | 1.71 | B |

As shown in Table 16, there *is* a significant difference in overall pressure on non-conservation wetlands between the 2016 backcast results and the 2018 data ($p = 0.04$, $N = 22$), and also a significant difference in the pressure on biotic integrity ($p = 0.01$, $N = 22$), although the difference in pressure on biotic integrity does not change the report card grades (Table 17). This finding is consistent with a near significant difference in pressure on a wetlands' biotic integrity across *all* land uses ($p=0.06$, see Table 9). Close examination of the data shows the pressure indicators contributing to the difference for wetlands surrounded by uses other than conservation are: pressure from plant pests in wetlands, pressure from landuse associated with the introduction of pest species and modification of native vegetation in the 200 m buffer of wetlands. Given the consistency in findings for pressure on the biotic integrity of wetlands, it is likely that this is a real change in pressure on wetlands between 2016 and 2018. Further research is needed to confirm this finding.

With 22 wetlands in the sample, the power of the t-test to detect a change in the remaining variables falls below the criterion value of 0.80. In other words, it cannot be reported with a high degree of certainty that there is no change in any of the other variables between 2016 and 2018.

**Table 16. Change between 2016 and 2018 for wetlands surrounded by non-conservation land uses (moderate to high land use intensity)**

| Indicator | N | Mean_diff | sdev_diff | t | p_value |
|---|---|---|---|---|---|
| **OVERALL PRESSURE GRADE (1–13)** | 22 | 0.18 | 0.4 | 2.16 | **0.04*** |
| WEV1 Biotic integrity | 22 | 0.27 | 0.46 | 2.81 | 0.01** |
| WEV2 Local physical integrity | 22 | 0.09 | 0.29 | 1.45 | 0.16 |
| WEV3 Local hydrology | 22 | 0.05 | 0.21 | 1.00 | 0.33 |
| WEV4 Connectivity | 22 | 0.00 | 0.31 | 0.00 | 1.00 |
| **OVERALL STATE GRADE (1–13)** | **22** | **0.00** | **1.31** | **0.00** | **1.00** |
| WEV1 Biotic integrity | 22 | -0.05 | 0.72 | -0.30 | 0.77 |
| WEV2 Local physical integrity | 22 | -0.14 | 1.04 | -0.62 | 0.54 |
| WEV3 Local hydrology | 22 | 0.14 | 0.35 | 1.82 | 0.08 |
| WEV4 Connectivity | 22 | 0 | 0 | – | – |

**N = number of wetlands in the sample; Mean_diff is the mean of differences between scores, sd_diff is the standard deviation of differences between scores; t is the value of the two-sided t-test of significance; p_value is probability value, used to determine if the difference between means is significant (values <0.05 are considered to be significant)**

**Table 17. Report card grades (2016 and 2018) for wetlands surrounded by non-conservation land uses.**

| Non-conservation land uses | Mean score, 2016 | 2016 Grade, backcast N=22 | Mean score, 2018 | 2018 Grade, N=22 |
|---|---|---|---|---|
| **Overall pressure score** | **8.32** | **C** | **8.50** | **D** |
| WEV1 Biotic integrity | 3.77 | D | 4.05 | D |
| WEV2 Local physical integrity | 2.95 | C | 3.05 | C |
| WEV3 Local hydrology | 3.05 | C | 3.09 | C |
| WEV4 Connectivity | 3.95 | D | 3.95 | D |
| **Overall state score** | **7.32** | **C** | **7.32** | **C** |
| WEV1 Biotic integrity | 3.41 | C | 3.36 | C |
| WEV2 Local physical integrity | 3.32 | C | 3.18 | C |
| WEV3 Local hydrology | 2.14 | B | 2.27 | B |
| WEV4 Connectivity | 3.86 | D | 3.86 | D |

## The relationship between pressure and state

As in 2016, overall pressure on a wetland is a strong predictor of its overall state score in 2018. The individual pressure indicators that best predicted overall state in 2018 were land use associated with nutrient inputs, land use associated with changes to natural surface water flow patterns, area cleared of native vegetation within 5 km of the wetland and modification of vegetation in the 200 m buffer and along the mapped wetland boundary. On average, wetlands were in better states when they experienced lower levels of these pressures.

There was a sharp transition in scores for the pressure indicator 'modification of vegetation in the 200 m buffer', between wetlands with an overall state grade of B, and those with grades C and D. No wetland scored better than C for overall state if it had more than 50 percent of its 200 m buffer cleared of native vegetation. Conversely, some wetlands experiencing moderate levels of pressure from land use associated with nutrient introduction and altered surface flows were in a good (= B) overall state when they also had intact vegetation in the 200 m buffer.

There is further work to be done to determine whether loss of a high proportion of the 200 m buffer is a genuine pressure threshold associated with a step change in wetland state from very good (A) or good (B), to moderate (C) or poor (D). Evidence collected to date suggests this could be the case. If so, protecting, rehabilitating and/or reinstating the natural vegetation

within 200 m of a wetland could be a management action that produces real improvement in support of the Reef 2050 objective of 'improving wetland condition'.

## Power to detect change

The 2016 baseline report on the condition of GBR freshwater floodplain wetlands theorised about the power of the wetland condition monitoring design to detect change and noted:

> By the end of 2018, 40 wetlands will have been assessed twice. This will allow us to measure the power of the [wetland assessment tool] to detect change between two times.

The GBR catchment wetland condition monitoring design (Tilden et al 2015) set precision criteria based on the outcome of a pilot study. These were: on the wetland assessment tool's 13 point scoring scales for pressure and state, a one point change should be detectable in the mean condition of wetlands assessed. The acceptable probability of false detection (Type I error) was set at less than 5 percent, along with an 80 percent chance that if *no change* is detected, then there really is no change (i.e. power is 0.80, equivalent to a probability of type II error equal to 0.20). A sample of 40 wetlands was conservatively estimated to be capable of delivering the required results.

A power analysis used two-sided paired t-tests to analyse the mean differences between 2016 and 2018 data. Based on data collected for the same 39 wetlands in 2016 and 2018, the minimum detectable differences for alpha <0.05 and power of 0.80 are given in the final column of Table 18.

**Table 18. Power analysis using data from all wetlands surveyed in both 2016 and 2018**

| VARIABLE | N | Mean difference | Sd of diff | power | sig.level | min.ES |
|---|---|---|---|---|---|---|
| **OVERALL PRESSURE GRADE (1–13)** | 39 | 0.13 | 0.52 | 0.8 | 0.05 | 0.24 |
| WEV1 Biotic integrity | 39 | 0.15 | 0.49 | 0.8 | 0.05 | 0.22 |
| WEV2 Local physical integrity | 39 | 0.08 | 0.48 | 0.8 | 0.05 | 0.22 |
| WEV3 Local hydrology | 39 | 0.03 | 0.16 | 0.8 | 0.05 | 0.07 |
| WEV4 Connectivity | 39 | 0.05 | 0.22 | 0.8 | 0.05 | 0.11 |
| **OVERALL STATE GRADE (1–13)** | 39 | -0.13 | 1.34 | 0.8 | 0.05 | 0.61 |
| WEV1 Biotic integrity | 39 | 0.00 | 0.56 | 0.8 | 0.05 | 0.26 |
| WEV2 Local physical integrity | 39 | -0.15 | 0.99 | 0.8 | 0.05 | 0.45 |
| WEV3 Local hydrology | 39 | 0.18 | 0.39 | 0.8 | 0.05 | 0.18 |
| WEV4 Connectivity | 39 | 0 | 0 | 0.8 | 0.05 | na |

**Min.ES = minimum detectable effect**

In all instances, the minimum detectable effect (min.ES) is below the criterion and in most cases, well below. That is, score differences of less than 1 are able to be detected (at alpha <0.05, power = 0.80). The overall state of wetland values and the sub-index WEV 2 state (local physical integrity) are closest to the criterion with minimum detectable differences of 0.61 and 0.45 respectively. The likely reason for their relatively lower precision compared with other variables is higher inter-operator variability in assessments for two of the WEV 2 state indicators. This is being addressed with a 2018–19 upgrade of the program's wetland assessment tool. Bearing in mind that the program's precision criteria have already been met with the current version of the instrument (for a sample of 40 wetlands), benefits of planned changes to reduce inter-operator variability will be that:

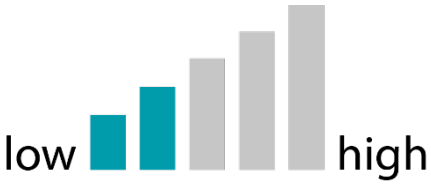
- Smaller sample sizes will be needed to meet the precision criteria, allowing us to scale up to regional level reporting in a cost efficient way.

- Greater precision in score estimates will allow us to detect changes with greater confidence, leading to more confident and timely management actions.

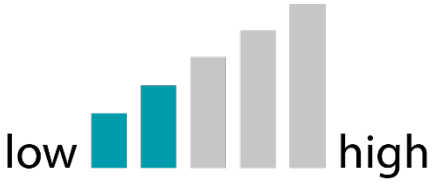
## Qualitative confidence rankings

A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the Reef report card, from low to high (Australian and Queensland Governments, 2016). The approach combined expert opinion and direct measures of error for program components where available.

Wetland condition received a two-bar confidence ranking.




**Overall pressure on wetland environmental values**




**Overall state of wetland environmental values**

### Representativeness

Score 3 out of 3

This year the score has been increased to 3 because the annual sample of ≈40 wetlands has now been shown to be capable of detecting change between times at the desired level of precision (mimimum difference between mean scores of ±1, power = 0.8, $\alpha$ = 0.05).

### Directness

Score 1 out of 3

For this confidence criterion the wetland condition score remains at 1 out of 3. The issues mentioned in 2016, namely, lack of calibration of the individual indicators, has been addressed by a major update of the instrument but this Version (2.0) will not be used to collect data until the 2019 field season (commencing in May).

### Maturity of methods

Score 2 out of 3

- The monitoring design and sampling plan have been peer reviewed and published.
- The wetland assessment tool is not published. After one more review and update, it should be publishable in about 12 months.

### Validation

Score 2 out of 3

- The assessment uses a mix of remotely sensed and field survey data.
- The field survey indicators provide directly measured data (score 3).
- The remotely sensed inputs are variable (score 2).

### Measurement error

Score 1 out of 3

- While it is still not possible to quantify the variance attributable to different sources of error in the data, a repeatability study has been completed (in 2017) to identify sources of inter-operator variance, especially in field methods.
- Versions 1.3 of the wetland assessment tool focussed on minimising this source of error variance.
- In relation to scoring wetland condition, it would be desirable to simplify the method of arriving at report card grades. The current process has several steps, one of which causes unnecessary loss of data precision. The issue of overly complex scoring scale methods will be dealt with as part of the overall upgrade of the wetland assessment instrument in 2019.
- On this basis, we have left the score for 'measurement error' at one.

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## Glossary

| | |
|---|---|
| Aggregated wetland assessment scores | The wetland assessment method uses scores at three levels – *indicators* are aggregated into four *sub-indices* based on wetland environmental values (WEVs). The WEV sub-indices are aggregated into two *indices*, overall pressure and overall state. The aggregation methods average the scores of indictors to derive sub-index scores, which are in turn averaged to derive index scores. |
| Alpha (α) | In statistical testing, the probability of making a Type I error, that is, falsely detecting an effect. (See Power) |
| 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 2018 wetland results reported here were collected in 2015 and 2016 and reported in the 2016 Reef Report. |
| DPSIR framework | A causal framework for describing the interaction between society and the environment. Driver, Presssure, State, Impact, Response. |
| Interoperator variability | Interoperator variability is the amount of variability between the results obtained by two or more observers examining the same material. |
| Lacustrine | Lake-like |
| Natural wetlands | Natural wetlands are areas that existed as wetlands before European settlement and that still meet the definition of wetlands (whether modified or not) in current state-wide wetland mapping. |
| 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. |
| Palustrine | Swamp-like |
| Panel | A panel is a group of wetlands with the same schedule of repeat assessments across years. |
| Power (to detect an change) | In statistical testing, Power = (1 – β), where β 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. |

| | |
|---|---|
| Repeatability | The closeness of agreement between results of successive measurements of the same subject (wetland) carried out under the same conditions of measurement. See interoperator variability. |
| 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. |
| 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. |
| Wetland environmental values | Wetland environmental values are individual physical and biological characteristics associated with a particular wetland that provide its ecological, social and economic benefits and are sometimes referred to as ecosystem services. The Wetland Condition Monitoring Program assesses wetland environmental values (WEVs), defined as:<br>• biotic integrity – the biological health and diversity of the wetland's ecosystems<br>• local physical integrity – the wetland's natural physical state and integrity<br>• local hydrology – the wetland's natural hydrological cycle<br>• connectivity – the natural interaction of the wetland with other ecosystems including other wetlands. |