Wetland condition results

Great Barrier Reef

Report Card 2016

Reef Water Quality Protection Plan

Australian Government

Queensland Government

Wetland condition results

1 Summary

The wetlands target in the Reef Water Quality Protection Plan 2013 (Australian and Queensland governments, 2013) is:

- *There is no net loss in extent, and an improvement in the ecological processes and environmental values, of natural wetlands.*

With the establishment of the Great Barrier Reef catchment wetland monitoring program, reporting on changes in wetland environmental values and, ultimately, ecological processes of natural freshwater wetlands is now included as part of the Paddock to Reef Monitoring, Modelling and Reporting Program. This allows wetland condition results to be reported in the 2016 Reef report card, for the first time.

This baseline report covers the component of the 2013 Great Barrier Reef Water Quality Protection Plan wetland target addressing wetland values and ecological processes. The baseline data for floodplain wetlands in the Reef catchments show that, overall, wetlands are in moderate condition and are under moderate exposure to pressures, putting them in the 'C' grade.

The overall scores on the two scoring indices—pressure on wetland values, and state of wetland values (condition)—were both 6 out of a possible 13[1] after correcting for a non-response bias in the data, related to land-use intensity. Managers of wetlands surrounded by intensive land uses such as cropping and mining were less likely to allow access to their wetlands than those whose wetlands were within conservation areas, with moderate land-use intensity producing an intermediate likelihood of a positive response from land managers. Correcting for this bias adjusts the average condition of freshwater floodplain wetlands in the Reef catchments one point towards the more disturbed end of the assessment spectrum.

However, this finding masks an important difference between wetlands surrounded by conservation land uses, such as national parks and water treatment reserves, and those surrounded by all other land uses, with condition scores for 'other uses' being four points towards the more disturbed end of the scale than those surrounded by conservation lands (uncorrected scores of 7 and 3 respectively). As well, wetlands surrounded by non-conservation land uses suffer higher levels of anthropogenic pressure (4 for conservation land uses and 7 for non-conservation uses). In wetlands surrounded by non-conservation land use, there is considerable opportunity for land managers to reduce pressure on wetland values, especially in intensive land-use areas, in order to bring about the improvement in wetland ecological processes and environmental values sought by the Reef Plan target.

The 2015–16 baseline study used a purpose-made rapid assessment tool, the Wetland Field Assessment Tool for Monitoring (WFAT–M)[2]. The capability of the tool to discriminate across the range of human disturbance to wetlands in the Reef catchment has been demonstrated. Using the results to date and the logic of statistics, it is reasonable to speculate that the tool has the level of precision needed to detect a change – or lack of change – between two assessment times i.e. a finding of 'no change' has an acceptable likelihood (>80%) of indicating that there really has been no change, rather than indicating a lack of precision in the tool. This level of precision will be empirically confirmed with a second round of assessments of the wetlands in this baseline study, due to be completed by the end of 2018.

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[1] The score of 6 on the 13 point WFAT–M scale corresponds to a score of 'C' on the 5 point report card scale. Lower scores on the WFAT–M scale indicate less disturbance to wetland environmental values. The report card score 'C' covers the WFAT–M score band from 6 to 8.

[2] An adaptation of the Wetland Field Assessment Toolkit (WFAT), under development by the Queensland Wetlands Program.

2 Results

2.1 Summary statistics

2.1.1 Pressure

The mean pressure for the 41[3] wetlands assessed was 5.6 (on a 13-point scale), corresponding to a WFAT–M score of 6 and a report card score of C. The median was 6. Standard deviation is 2.53 (variance 6.40) and interquartile range 5.

Figure 1 shows the distribution of overall pressure scores on the 13-point scale.

Figure 2 shows the distribution of pressure scores by wetland environmental value (WEV), on a scale of 1 to 5, where 1 represents the least pressure on wetland environmental values. The mean pressure scores for each of the WEVs were:

- WEV 1 (biotic integrity) = 3.0 (report card score C)
- WEV 2 (physical integrity) = 1.2 (A)
- WEV 3 (hydrology) = 2.0 (B)
- WEV 4 (connectivity) = 3.0 (C).

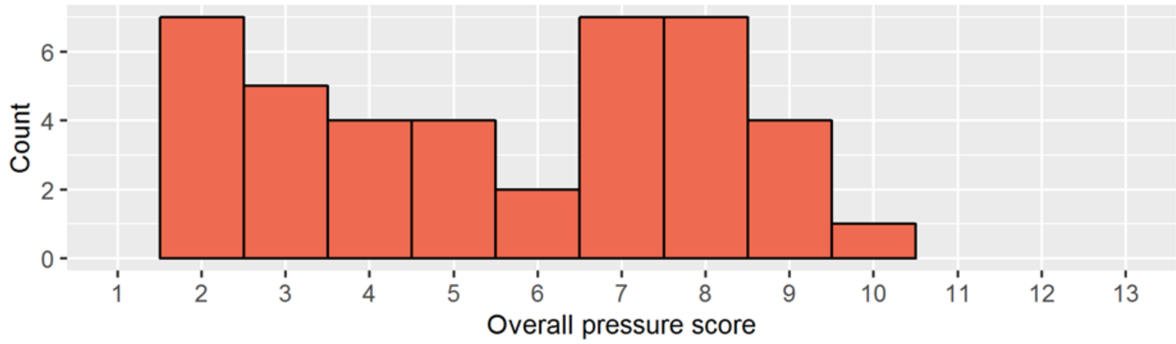

Figure 1: Scores for overall pressure on floodplain wetlands in the Reef catchment (N=41)

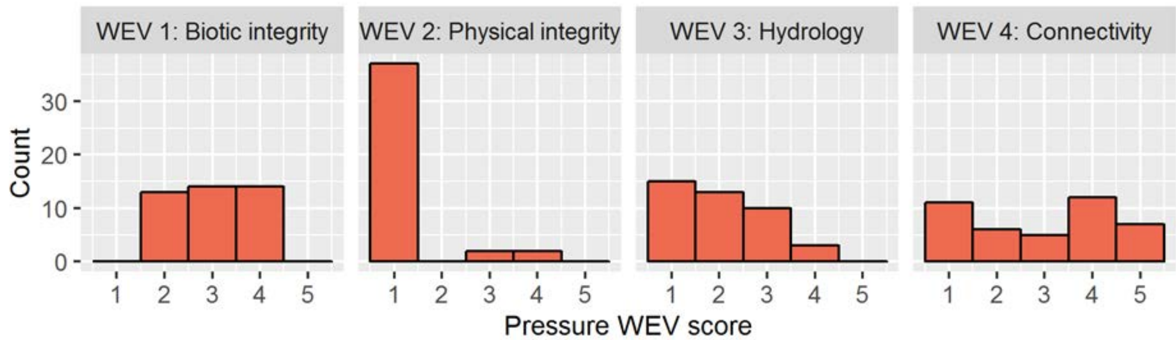

Figure 2: Scores for pressure on wetland environmental values (WEVs) for wetlands in the Reef catchment (N=41)

[3] A sample of 40 wetlands was planned for the baseline assessments (as per the Wetland Condition Methods report). An additional wetland was included in panel 1 to avoid having an entire region (Mackay Whitsunday) represented by just one wetland. This was done more for operational than scientific reasons, as one out of 40 wetlands is an accurate proportional representation of the number of floodplain wetlands in the Mackay Whitsunday region. The assessment results for this extra wetland were included in the baseline analysis but the wetland was excluded from the test for the effect of region on non-response. The technical reason for this is explained in footnote 6 of the methods report.

2.1.2 State

The mean state score for the 41 wetlands assessed was 5.2, corresponding to a WFAT–M score of 5 and a report card score of B. The median was 5. Standard deviation is 2.57 (variance 6.63) and interquartile range 4.

Figure 3 shows the distribution of overall state scores on the 13-point scale.

Figure 4 shows the distribution of state scores by wetland environmental value (WEV), on a scale of 1 to 5, where 1 represents the best state of wetland environmental values. The mean state scores for each of the WEVs were:

- WEV 1 (biotic integrity) = 2.0 (report card score B)
- WEV 2 (physical integrity) = 2.8 (C)
- WEV 3 (hydrology) = 1.3 (A)
- WEV 4 (connectivity) = 2.5 (B).

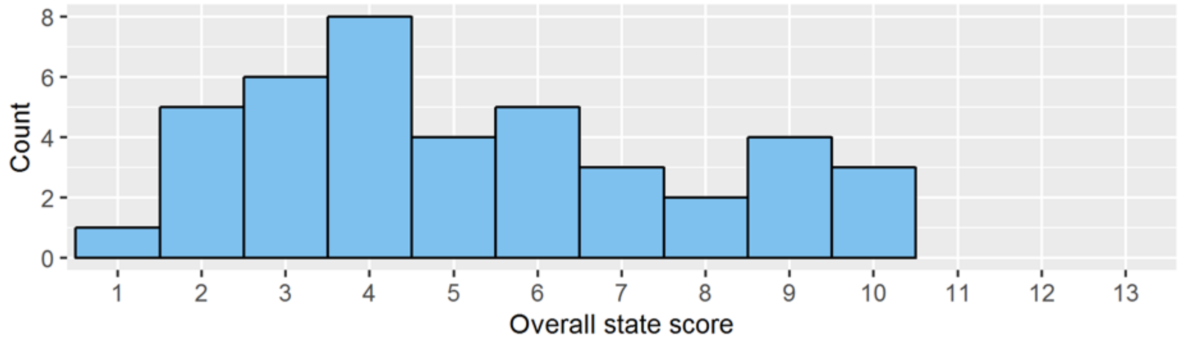

Figure 3: Scores for the overall state of floodplain wetlands in the Reef catchment (N=41)

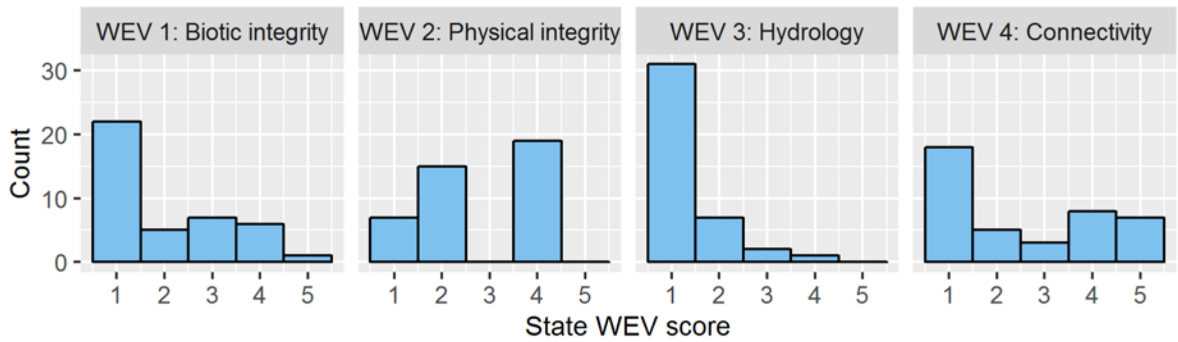

Figure 4: Scores for the state of wetland environmental values (WEVs) of floodplain wetlands in the Reef catchment (N=41)

2.1.3 Combined pressure and state results

Figure 5 plots the distributions for overall pressure and state scores for the 2015–16 baseline data. Pressure and state scores have similar ranges, means and variance, and are highly correlated (r = 0.72). These results differ from the pilot study in that the baseline pressure and state data have restricted ranges compared with the pilot results and there is no significant difference between mean pressure and state scores. For comparison, pilot study data are also plotted in Figure 5.

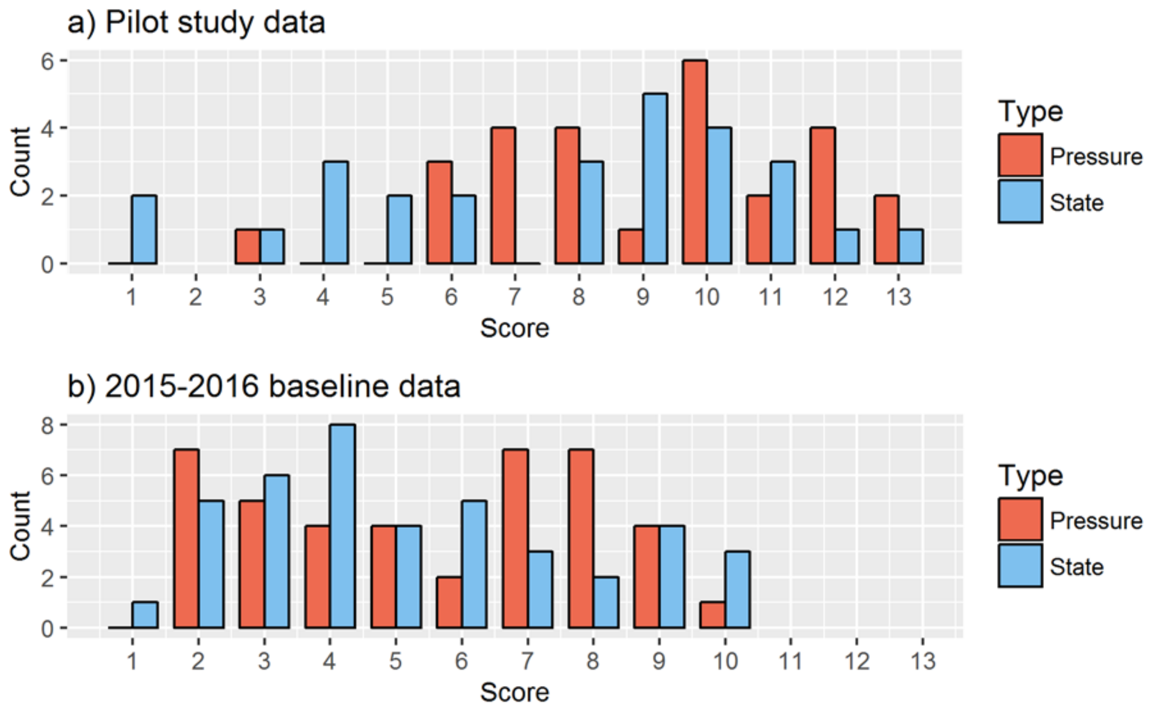

Figure 5: The distributions of overall scores for pressure (red) and state (blue) for the pilot study of 2014 (top) compared with those of the 2015–16 baseline study

These results were as expected. The pilot study was based on a purposive sample of wetlands designed to test the WFAT–M across the range of possible wetland states and pressures, whereas the baseline study is a random sample of wetlands drawn from the chosen sub-population of freshwater floodplain wetlands in dense aggregations in the Reef catchment. The explanation for the restricted score range of the baseline data is likely to involve some or all of the following:

- The pilot study wetlands were purposely chosen to test the full range of the WFAT–M without regard to the representativeness of the sample. Consequently, wetlands at the more disturbed end of the disturbance gradient were over-represented in the pilot sample.
- There is a non-response bias in the baseline data linked to land-use intensity and type, which would underestimate the average overall pressure on WEVs (producing a lower score) and also bias the estimated state of wetland values towards less disturbed levels.
- The WFAT–M was modified in response to the pilot study findings. The ability of the current version to yield scores at the higher end of the range needs further verification, especially in relation to the contribution of the pressure sub-index of physical integrity (WEV 2). This work is underway and will be reported in an upcoming evaluation of the performance of the WFAT–M.

Also in need of explanation is a difference between pressure and state means in the pilot data, which was not replicated in the baseline data (see Tilden et al., 2015). Several hypotheses were advanced to explain the difference between pressure and state means at the completion of the pilot study. One suggestion was that the pilot sample did not adequately represent wetlands at the less disturbed end of the disturbance gradient, so that the relationship between pressure and state found in that study was a distortion of their true relationship. Evidence noted in support of this conjecture was the fact that 'Dismal Swamp', the most pristine wetland ever assessed with the WFAT–M and one specifically included in the pilot study as an example of a wetland in the best possible condition, appeared as an outlier in the pilot scatterplot of pressure and state overall scores.

In Figure 6, Dismal Swamp, assessed in the pilot study, is represented by the red diamond at the bottom left of the graph. As can be seen, while this wetland is an outlier in its own (2014) pilot data set, represented by blue dots and trend line, it is close to the trend line for the 2015–16 baseline scatterplot (green dots). This supports the hypothesis put forward at the conclusion of the pilot study that the difference between mean overall pressure and mean overall state of wetlands in the pilot study was an artefact of the sampling design rather than a reflection of an underlying difference in the sub-population.

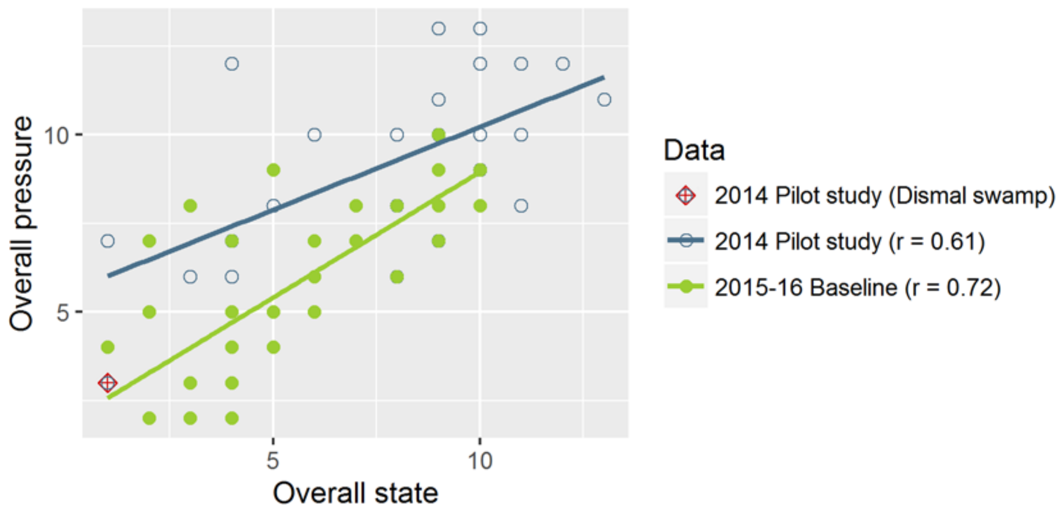

Figure 6: The relationship between pressure and state in the 2014 pilot data (blue dots and trend line) and in the 2015–16 baseline data (green dots and trend line). Dismal Swamp, a pristine wetland assessed in the pilot study is represented by the red diamond at the bottom left of the graph.

2.1.4 The effect of land-use type on pressure and state distributions

There was a suggestion of bimodality in some of the WFAT–M sub-indices (WEVs) for pressure and state (refer to figures 2 and 4) as well as in the distribution of overall pressure scores. It is hypothesised that there could, in effect, be two sub-populations associated with these distributions—those wetlands embedded in conserved areas and those in land managed for other purposes. Figure 7 shows the outcome of plotting these two groups separately. Exact Wilcoxon rank sum tests were performed on the score distributions of wetlands in conserved areas and ‘other use’ areas for pressure and state. For both tests, the likelihood of the conserved and ‘other use’ wetlands being drawn from the same distribution was extremely low. For pressure, $W = 326$ with $p = .001$ and for state $W = 374.5$ with $p < .0001$.

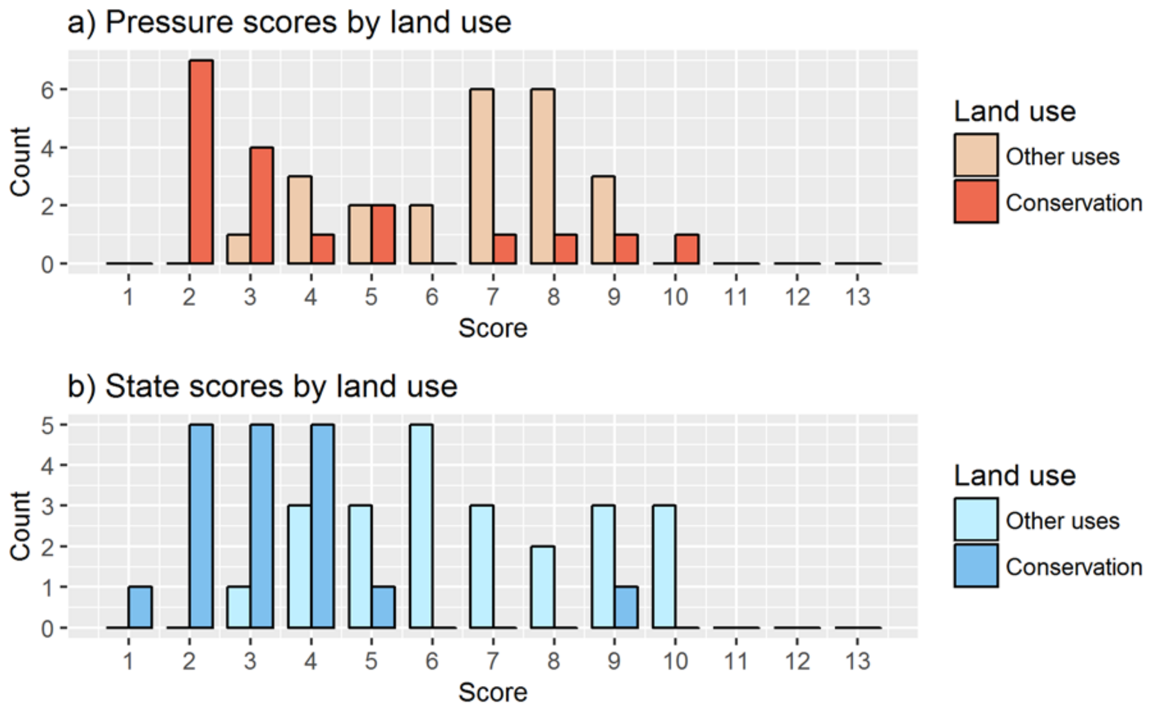

Figure 7: Overall pressure and state scores for Reef catchment wetlands in two land-use groups – conserved areas in dark red and dark blue (pressure and state, respectively) and all other land uses in the paler colours

2.2 The effects of the non-response bias

2.2.1 Testing for non-response bias

A chi-square test for linear trend in proportions was performed on the data displayed in Table 1 to determine whether there was a non-response bias in the baseline wetland sample due to different acceptance rates for three surrounding land-use intensity classes. The hypothesis that the surrounding land-use intensity had no effect on acceptance rate was rejected (chi square = 9.45, critical chi sq = 9.21 for $\alpha = .01$, df = 2). The effect of land-use intensity on acceptance rates is graphed in Figure 8.

Land managers of wetlands in areas of high land-use intensity were the least likely of the three groups to allow their wetlands to be assessed (29% acceptance) while access was granted to 86% of wetlands in areas of low land-use intensity. Moderate land use produced an intermediate rate of acceptance (52%).

Table 1: Landholder acceptance rates associated with intensity of land use surrounding the wetland

Land-use intensity	Approached (N)	Observed (N)	Acceptance rate (as a proportion)
Low	21	18	0.86
Moderate	38	20	0.52
High	7	2	0.29
Total	**66**	**40**	**0.61**

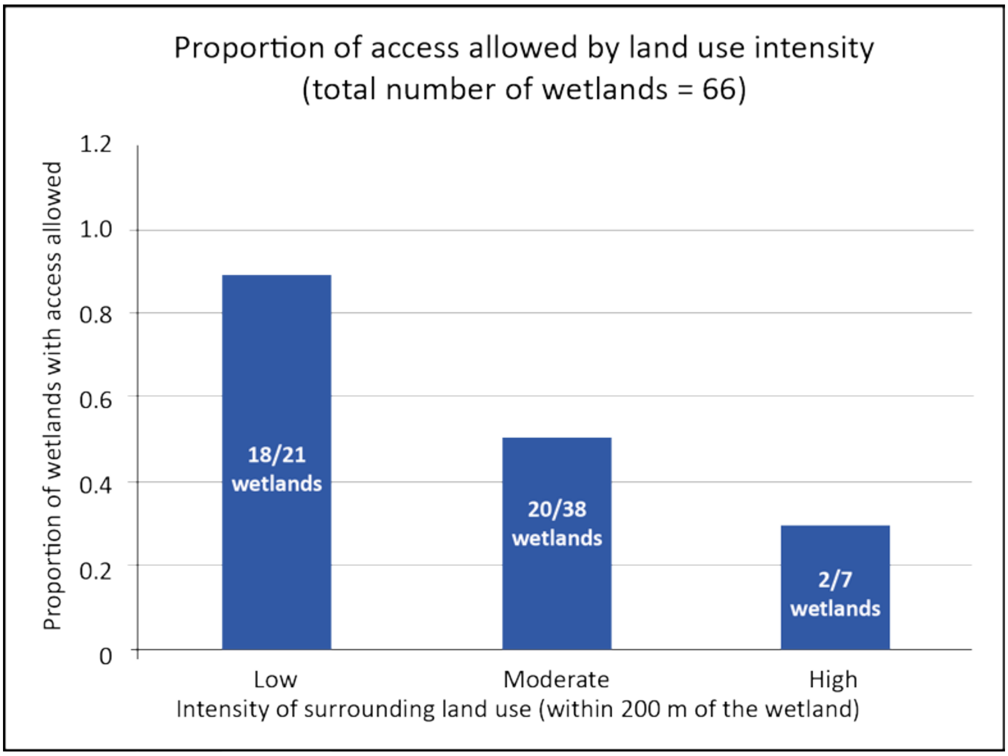

Figure 8: Proportion of wetlands accessed, by land-use intensity

2.2.2 Calculating non-response weights

It follows that the average scores for pressure and state of wetlands across the whole Reef catchment will be biased towards the less disturbed end of the scale unless individual wetland scores are weighted to correct for the non-response bias. Using the method of Johnson (2008), weights have been calculated by dividing the expected proportions of wetlands in each land-use intensity class (i.e. the sub-population proportions), by the observed proportions.

2.2.3 Effect of non-response bias on results

Correcting baseline pressure and state scores for the bias in rates of acceptance associated with land-use intensity moves the overall mean pressure score from 5.6 to 5.9 and the overall mean state score from 5.2 to 5.7. That is, the average condition of wetlands is assessed as more disturbed when the bias is taken into account. In the case of the state of wetland values, the increase in average score tips the score into the next report card grade, i.e. from a B to a C. Table 2 shows the impact of correcting for the bias on the overall scores, and on the WEV scores for pressure and state. Pressure WEV 2 (physical integrity) and State WEV 4 (connectivity) also change their report grades, in the direction of more disturbed, when the correction is applied.

Table 2: Mean overall WFAT–M scores and WEV scores, corrected and uncorrected for non-response bias

	Overall Pressure	WEV 1 Pressure	WEV 2 Pressure	WEV 3 Pressure	WEV 4 Pressure	Overall State	WEV 1 State	WEV 2 State	WEV 3 State	WEV 4 State
Uncorrected mean score	5.56	3.02	1.24	2.02	2.95	5.22	2.00	2.76	1.34	2.54
Corrected mean score	5.88	3.16	2.01	2.10	3.12	5.65	2.23	2.70	1.41	2.79
Uncorrected report card grade	C	C	A	B	C	B	B	C	A	B
Corrected report card grade	C	C	B	B	C	C	B	C	A	C

2.3 Relationship between baseline pressure and state and landscape hazard to wetlands

Land-use hazard assessment scores were attributed to wetlands based on land use in the 200-metre buffer zone of the wetland. Spearman's rho correlations were calculated for the relationships of these land-use hazard scores (on an ordinal scale of one to six) to overall pressure and overall state of the wetlands in the 2015–16 baseline sample.

Null hypotheses, that there are no relationships between land-use hazard score and either overall pressure score or overall state score, were tested and rejected. A significant correlation was found between land-use hazard score and both overall pressure score and overall state score, though not as high as the correlations in the pilot study. For pressure, the values were $\rho = 0.37$, $p < 0.05$, while for state the values were $\rho = 0.46$, $p < 0.01$. The mid-rank method was used to deal with tied ranks (Amerise and Tarsitano, 2014).

The significance of these findings for validation of the WFAT–M or, conversely, validation of the hazard assessment, is discussed below.

3 Discussion

3.1 Baseline status of freshwater floodplain wetlands in the Reef catchment

Figure 9 illustrates baseline pressure on wetland environmental values and the state of environmental values in floodplain wetlands of the Reef catchment. The overall scores have been corrected for a non-response bias that would have resulted in an underestimate of the average level of disturbance to the wetlands.

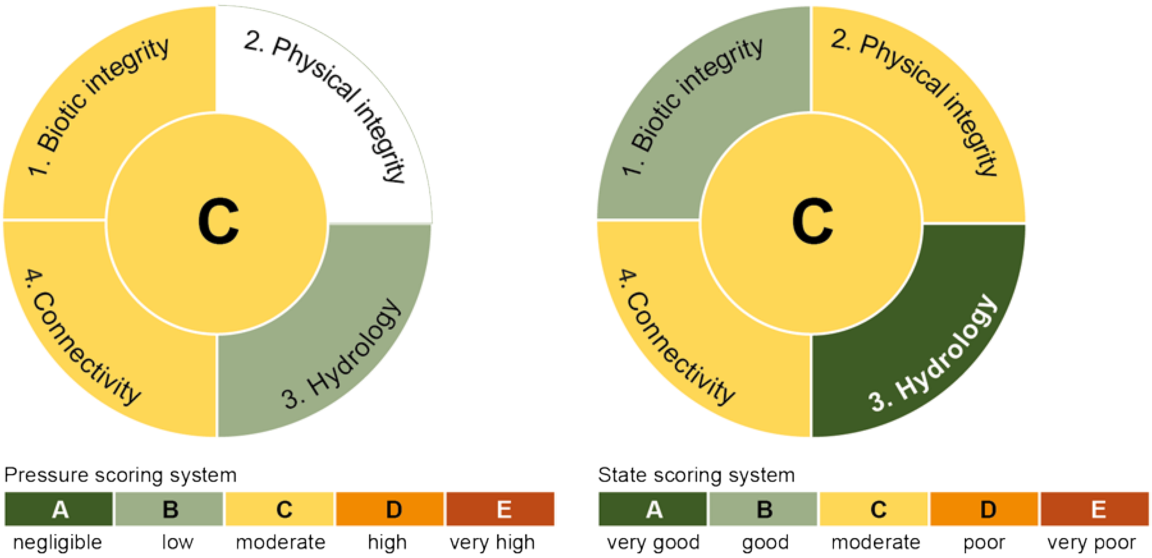

Figure 9: Corrected baseline pressure on wetland values (left) and state of wetland values (right) of floodplain wetlands in dense aggregations across the Reef catchment, as measured with the WFAT–M. Overall scores are in the centre of each circle with the four WEV scores arranged around the perimeter. There is no score for pressure on wetlands' physical integrity due to problems with the scaling of indicators for this sub-index.

The overall score on the pressure index was C before and after the correction was applied. For the state of wetland values, the score changed from B to C after correction, placing the average level of disturbance to freshwater floodplain wetlands in the Reef catchments at the midpoint of the reporting scale. As predicted, the overall scores achieved with a random sample of floodplain wetlands from dense wetland aggregations across the whole catchment showed less disturbance than those achieved with a purposive sample designed to test the WFAT–M across the full spectrum of wetland disturbance (Tilden et al., 2015). Overall scores in the 2014 pilot study were D for pressure and C for state.

These findings indicate that:

- overall, the WFAT–M is capable of discriminating across the spectrum of freshwater wetland disturbance
- wetland environmental values of freshwater floodplain wetlands in the Reef catchment are assessed as moderate in terms of both pressure and current state.

Across the four sub-indices, and with the exception of WEV 2 physical integrity, pressure scores tend to be higher (indicating more disturbance) than state scores. Hypothetically, this could signal lags between the application of anthropogenic pressures and their impacts on wetland condition. More work needs to be done on the WFAT–M index before any statement can be made with confidence about pressure on the physical integrity of wetlands. This issue is further discussed in the next section.

The 'Very good' state score for WEV 3, 'hydrology', representing the wetland's natural hydrological cycle, is notable. Possible reasons for this finding are also discussed in the next section.

The finding that the average pressure on WEVs and the average state of WEVs are both moderate masks an important difference between wetlands surrounded by conservation land uses, such as national parks or water treatment reserves, and those surrounded by all other land uses. Wetlands surrounded by non-conservation land uses suffer higher levels of anthropogenic pressure. This is reflected in higher pressure and state scores, indicating greater levels of disturbance to wetland environmental values. Figure 10 shows the difference in *uncorrected* scores[4] between wetlands in conservation areas and wetlands surrounded by more intensive land uses.

[4] The correction should not be applied in this case, as the non-response variable 'land-use intensity' and classification 'conservation land use' vs 'other land uses' are highly correlated. For this reason, applying the correction would erroneously inflate the difference between the two groups.

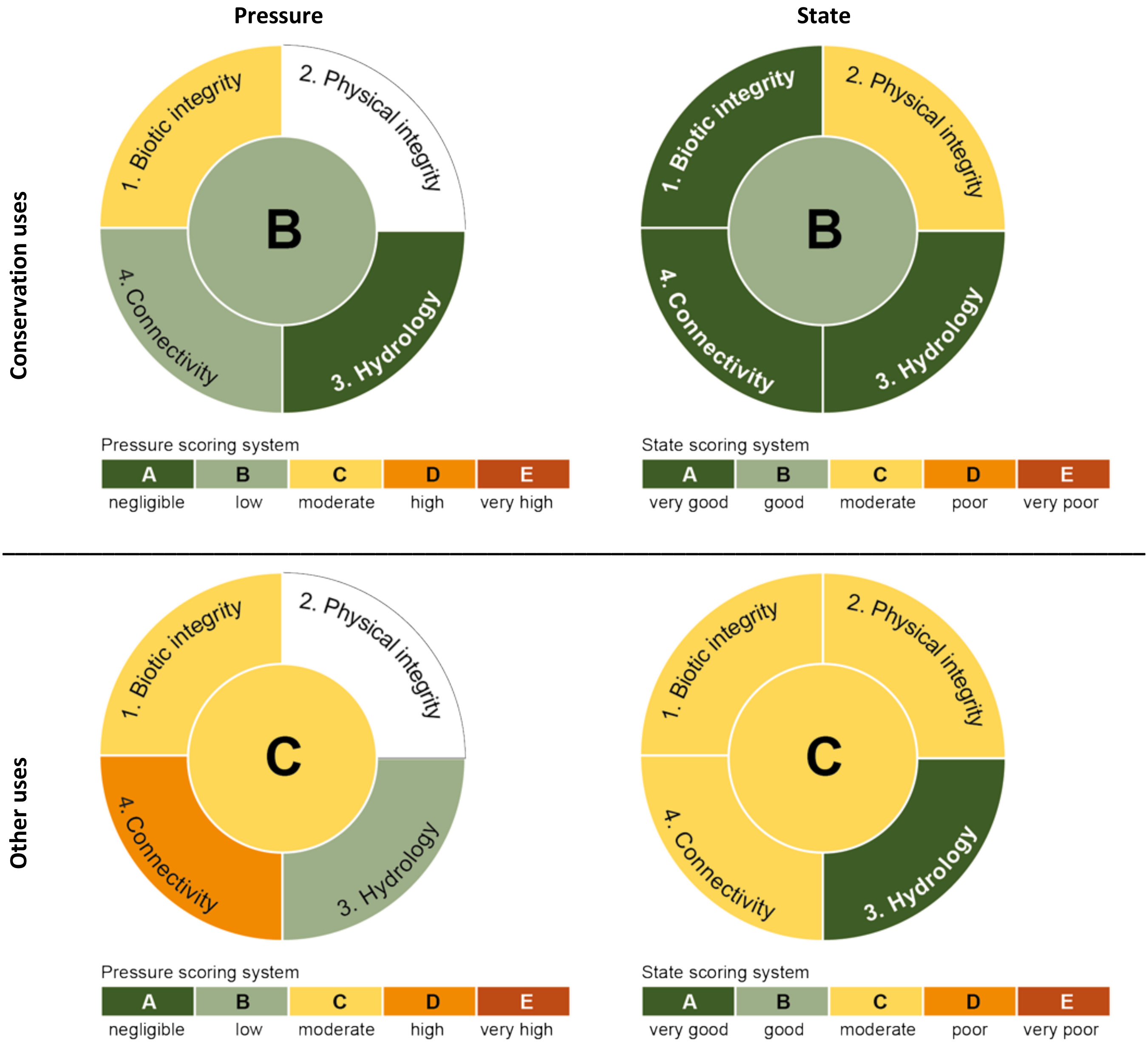

Figure 10: Baseline pressure on wetland values (left) and state of wetland values (right) of floodplain wetlands in the Reef catchment. The two top circles show pressure and state of wetlands surrounded by conservation areas, while the two at the bottom show pressure and state of wetlands surrounded by other land uses such as cropping, urban development, grazing and mining.

To make progress towards the target of improving 'the ecological processes and environmental values of natural wetlands', management actions could be applied in conserved areas to reduce pressure on the biotic integrity and connectivity of wetlands.

In wetlands surrounded by other (non-conservation) land use, there is considerable scope for reducing pressure on wetland values, especially on biotic integrity and connectivity but also on hydrology. Again, it is not possible to comment at this stage on the average level of pressures on the physical integrity of Reef wetlands.

3.2 Validity of WFAT–M conceptual modelling

There is a high overall correlation of 0.72 (Pearson's r) between the overall pressure and overall state scores. This validates the conceptual link between pressure and state illustrated in the wetland condition methods section of the Reef report card. While it cannot be said exactly what the causal links are between the two aggregate scores, it is clear that anthropogenic pressure on wetlands is strongly related to the overall condition of wetlands, as measured by the WFAT–M.

This relationship is upheld by three of the four sub-indices, with moderate to high Pearson's r correlations between pressure and state scores for WEV 1, 3 and 4 (r = 0.61, 0.51 and 0.82 respectively). There is no correlation between pressure and state for the measurements of disturbance to a wetland's physical integrity (r = 0.17). As Figure 2 shows, the sub-index measuring pressure on a wetland's physical integrity fails to discriminate across the range of disturbance to wetlands included in the 2015–16 baseline sample.

This sub-index comprises three indicators: P 10 – modelled sediment supply, P 12 – number of point inflows per hectare of wetland, and P 13 – recreational use (see Appendix 1 for the complete list of indicators). All three indicators lack sensitivity to discriminate at the less disturbed end of the score range, but for different reasons. It is proposed to address this problem in version 2 of the WFAT–M by recalibrating indicator scales for the field indicators and replacing P 10 with a better desktop indicator of sediment supply. It will be possible to hind-cast these changes so that the baseline assessments can still be compared with the results of future assessments, monitoring for change and trends in levels of disturbance to wetlands. For now, no average score is reported for pressure on the physical integrity of Reef wetlands.

Regarding the conceptual validity of WEV 3 'the wetland's natural hydrological cycle', there is a moderate positive correlation between the pressure and state scores for this sub-index; however, the finding of 'Very good' for the average hydrological condition of Reef floodplain wetlands is notable and bears examining.

In the context of a random sample of wetlands from the sub-population assessed, this result is expected to be an accurate reflection of the average hydrological condition of wetlands *at the wetland level*. About 85 per cent of wetlands in the baseline sample are H1 wetlands i.e. they have 'no modifications observed' that would affect their hydrology (at the 1:100,000 wetland mapping scale (EPA, 2005)). This is representative of the sub-population as a whole, as illustrated in Figure 11. The remainder are H2M2 wetlands—palustrine or lacustrine wetlands where size and/or hydrology has been changed by levee banks.

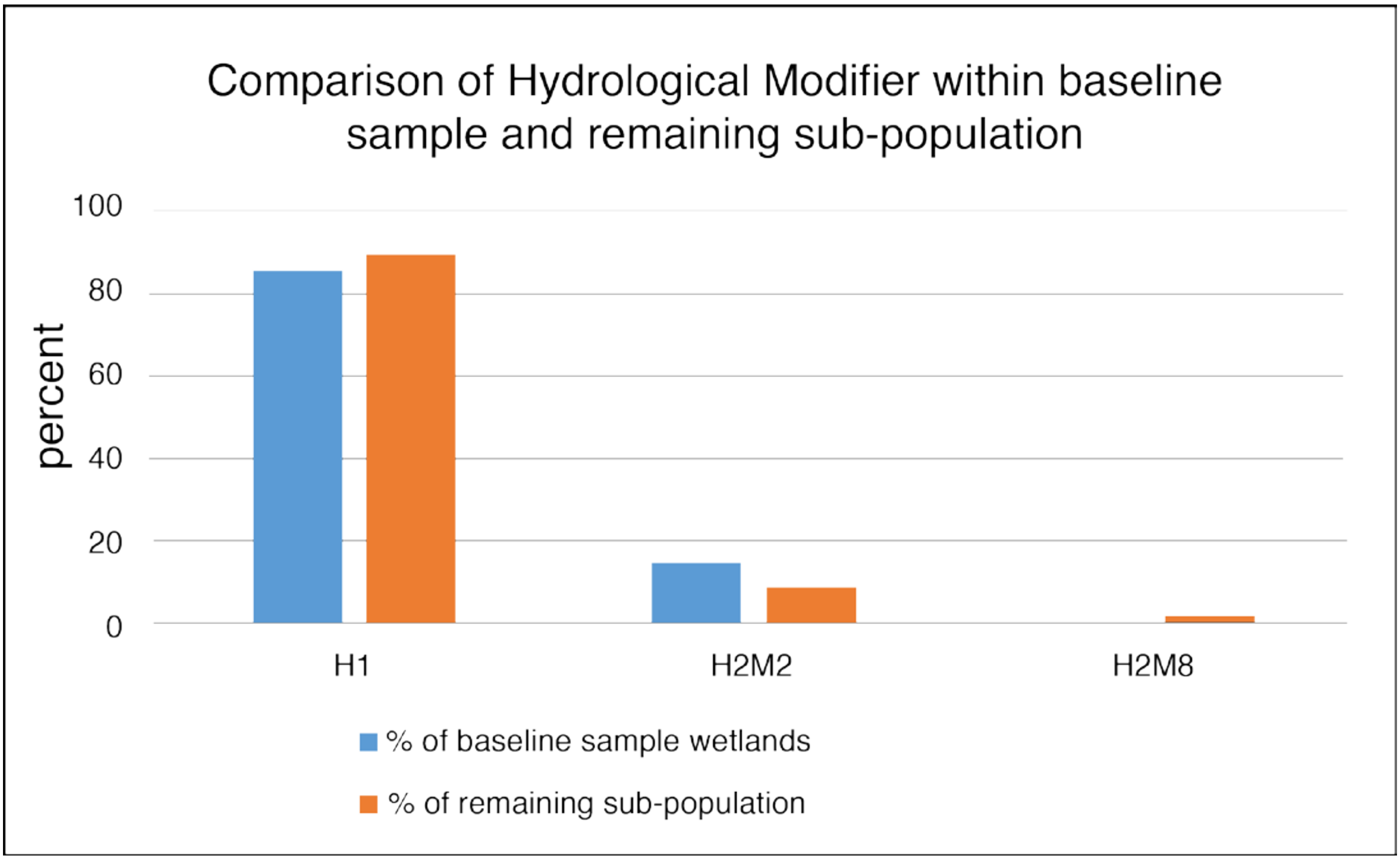

Figure 11: Representativeness of the 2015–16 baseline sample of Reef wetlands with respect to hydromodifier class

The state of wetland hydrology was assessed at the paddock scale to the wetland scale using indicators related to abstraction, additional water inputs, and physical barriers or drainage. While a wetland's hydrological state at this scale may appear to be very good, wetlands may be degraded by landscape scale alterations to hydrological processes which are difficult or impossible to assess *at the level of the individual wetland* with current levels of knowledge and research.

In this case, it would be possible to calibrate the WFAT–M hydrological state sub-index, moving the average state of the wetlands' hydrology towards the more disturbed end of the scale. This could compensate for the absence of wetland-level state indicators of landscape-scale degradation processes. However, any such change would need to be supported by empirical or modelled data, literature, and/or expert opinion that landscape-scale alterations to hydrology are ubiquitous across the Reef catchments, including in regions such as Cape York, which are relatively undisturbed.

It remains to be demonstrated whether or not the 'Very good' *average* state reported for wetland hydrology is an accurate reflection of the *average* sub-population condition across the whole Reef catchment. While the hydrology of wetlands in developed areas is known to be heavily impacted by human activity, most of the wetlands in our Reef-wide representative sample may indeed be in 'Very good' hydrological condition.

3.3 WFAT–M construct validity

As part of an ongoing internal review of the WFAT–M to inform the development of Version 2.0 in 2018, level 1 and level 3 data sets are being sought to test the tool's construct validity i.e. whether it measures what it purports to measure. One line of evidence, based on level 1 data that is both recent and Reef-wide, is the correlation between WFAT–M state scores and the magnitude of land-use hazard to wetlands, as assessed by the landscape hazard assessment (DSITI, 2015).

The correlation between WFAT–M overall pressure score and land-use hazard score was, in a sense, built in to the WFAT–M. Several of the pressure indicators were directly based on the relationships of particular types of land use to particular pressures on wetlands, as described in the landscape hazard assessment. On the other hand, the WFAT–M state indicators were adapted from other rapid assessment instruments or developed independently with expert advice not connected to the hazard assessment study.

In terms of the wetland monitoring program's Driver–Pressure–Impact–State–Response framework, pressure on wetland values is driven by land use. This conceptual link was operationalised in the land-use hazard assessment. The finding that WFAT–M overall pressure and state scores are highly correlated validates the conceptual link between WFAT–M pressure on wetland values and WFAT–M state of values (or condition). The correlation of land-use *hazard* to wetlands with the state of wetland values is an empirical link between two independent measures, both related to the level of disturbance to wetlands and with strong conceptual links to each other. This provides one valid line of evidence that the WFAT–M state index does indeed measure the condition of wetlands across a disturbance gradient i.e. it measures what it purports to measure.

Work is needed to find other lines of evidence to assess the construct validity of the WFAT–M; however, it is not necessary to benchmark the WFAT–M to independent indicators of wetland condition in order to measure changes and trends across time in pressure on wetland values and state of wetland values. What is needed is an instrument that (a) measures consistently across the range of possible pressures and states and (b) is capable of detecting the signal of anthropogenic disturbance within the considerable noise of natural wetland variability in space and time.

3.3.1 Baseline wetland condition and validation of the landscape hazard assessment for wetlands

As noted above, there is an empirical relationship between the state of wetland environmental values (i.e. wetland condition) as measured by the WFAT–M (a level 2 rapid assessment instrument), and the independently designed and conducted level 1 landscape-hazard assessment for wetlands. This relationship serves to validate the WFAT–M as a measure of disturbance to wetlands. It also offers some validation of the hazard assessment itself.

In effect, the correlation between the Reef-wide scores on both instruments is a triangulation on the variable that both sought to measure using very different methods but the same conceptual basis—anthropogenic disturbance to wetlands.

3.4 Power to detect change

By the end of 2018, 40 wetlands will have been assessed twice. This will allow us to measure the power of the WFAT–M to detect change between two times, at a level of sensitivity of ±1 point on the WFAT–M scale, with a sample of 40 wetlands.

What can be said about the power to detect change in 2017 when we have only the baseline data?

The 2014 pilot study measured the pressure on wetland values and the state of wetland values for 27 wetlands at a point in time. In order to estimate sample size, scenarios of likely and possible change between *two points in time* were generated. This exercise revealed that, for individual wetlands, incremental improvements or deteriorations were possible within one or two years, as were larger deteriorations (up to +4 points on the 13-point scale) due to 'catastrophic' events such as land clearing, development and drainage of wetlands. Large improvements were not likely to occur in such a short time.

The variance in overall *pressure* scores in the pilot study was 6.33, while the variance in overall *state* scores was 10.86. On the other hand, in the simulated scenarios of the difference of overall state between two points in time, the average variance was 3.88, while the most extreme variance was 5.29. A variance of 5.29 equates to a sample size of 42 (for a precision of ±1, power= .8, α= 05), while a variance of 3.88 equates to a sample size of 31. On this basis, a sample size of 40 was a conservatively high estimate of the number of wetlands that would be needed to achieve the desired precision for a difference between two points in time. For 40 wetlands, the critical level of variance is 4.85.

In the 2015–16 baseline assessment, the variances of the wetland WFAT–M scores were 6.40 for overall pressure and 6.63 for overall state. Because the same wetlands are being assessed twice, a strong correlation between the scores at time 1 and the scores at time 2 is expected and a considerably lower variance for the difference between scores would also be expected. This was borne out in the pilot study simulations; the variance in overall state score for the wetlands in the pilot study was 10.86, whereas the average variance of the difference between two assessment times generated by the scenarios was just 3.88.

It is, therefore, likely that the measured variance for the difference between wetlands in 2016 and the same wetlands measured in 2018 will be less than the critical value of 4.85, meaning the desired precision will have been achieved with a random sample of 40 wetlands. This would allow us to say with reasonable confidence by the end of 2018 whether or not there has been any change in the average level of anthropogenic disturbance to freshwater floodplain wetlands across the Reef catchment between 2015–16 and 2018.

There is one factor of potential concern in this speculative analysis of the power of the WFAT–M to detect change with a sample of 40 wetlands. The scenarios of possible and likely change between two times used to calculate the required sample size may have underestimated error variance associated with the reliability of the WFAT–M. Should the variance of the difference between times exceed the threshold value of 4.85, contingencies are in place to (a) improve the precision of the instrument and/or (b) increase the baseline sample size to 60 wetlands.

3.5 Methods development and research

As discussed above, refinements to the WFAT–M will ensure greater precision as well as confidence that what is being reported is as accurate as possible. Further developments will include:

- adjusting the WFAT–M, especially the physical integrity sub-index, by recalibrating indicator scales for some field indicators and replacing non-functioning indicators
- further validation of the WFAT–M using multiple lines of evidence.

A project involving more intense sampling of wetlands to assess their condition in basins with high exposure to water quality and ecosystem pressures will help direct management resources and ensure progress towards the wetland target.

Also, there is a need to understand better the relationship between intensity of land use and willingness to allow access for wetland assessment.

- What more can we discover about the barriers to access?
- Does the relationship between land-use intensity and willingness to allow access to wetlands affect the likelihood that land managers will adopt best practice for wetland and whole-of-property management?
- Are there implications for the uptake of water quality improvement practices in agriculture?

While best practice guidelines are available for managing wetlands (see, for example, DEEDI, 2011), little is known about land managers' attitudes and perceptions related to the management of wetlands. Qualitative surveys would help establish better understanding of the barriers and pathways to reducing pressures on wetlands and improving their condition through best management practice.

Presently, there is no baseline assessment of land managers' knowledge and application of wetland management practices. Monitoring of Reef-wide management practices would complement the wetland extent and condition monitoring programs.

Finally, there are significant opportunities to apply the WFAT–M to wetland rehabilitation case studies, demonstrating both the versatility of the assessment tool and the results of locally and regionally important wetland management projects.

4 Conclusion

With the assessment of 41 randomly selected wetlands across the Reef catchment, a baseline has been established for the anthropogenic pressure on wetland environmental values and the state of wetland environmental values of natural floodplain wetlands in the Reef catchment. For the first time, it is possible to report on the 2013 Reef Plan wetland target:

> 'There is … *an improvement in the ecological processes and environmental values*, of natural wetlands'.

Addressing this target is a primary objective of the wetland monitoring program.

The 2015–16 baseline study used a purpose-made rapid assessment instrument, the Wetland Field Assessment Tool for Monitoring (WFAT–M). The capability of the WFAT–M to discriminate across the range of human disturbance to wetlands in the Reef catchment has been demonstrated. Using the logic of statistics it is also reasonable to speculate that the WFAT–M has the level of precision needed to detect a change, or lack of change, between two assessment times i.e. that a finding of 'no change' has an acceptable likelihood (>80%) of indicating that there really has been no change, rather than indicating a lack of precision in the measuring instrument. This level of precision will be empirically confirmed with a second round of assessments of the 41 wetlands, due to be completed by the end of 2018.

The baseline scores reported for pressure on wetland environmental values and state of wetland environmental values were weighted before being aggregated into average catchment-wide scores. This step in the analysis addressed a non-response bias in the sample. Most wetlands in the Reef catchment are on private property, so land manager permission must be sought to assess them. We found that land manager acceptance rates decreased as the intensity of land use surrounding the wetlands increased. For example, managers of land surrounded by intensive cropping were less likely to allow access than those whose wetlands were surrounded by conservation lands. Intermediate levels of land-use intensity were associated with intermediate levels of acceptance. Both corrected and uncorrected overall scores are presented in this report.

5 References

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Appendix 1 WFAT–M indicators

PRESSURE INDICATORS		
WEV 1 Biological health and diversity of the wetland's ecosystems		**Indicator type**
P1	**Land use associated with the introduction or perpetuation of pest species**	**Desktop (field verified)**
P2	**Modification of vegetation in the 200 m buffer (excluding mapped wetland)**	**Desktop**
P3	**Land use associated with pesticide residue inputs**	**Desktop**
P4	**Land use associated with nutrient inputs**	**Desktop**
P5	**Number of septic systems within 200 m of the wetland per ha of mapped wetland**	**Desktop (field verified)**
P7	**Plant pest cover in the mapped wetland**	**Field**
P8	**Plant pest cover in the 200 m buffer**	**Field**
P9	**Fishing (or other fauna taking) within the mapped wetland**	**Field**
WEV 2 The wetland's natural physical state and integrity		
P10	**Sediment supply (modelled, GBR)**	**Desktop**
P12	**Number of stormwater or other point inflows per hectare of wetland**	**Field**
P13	**Recreational use**	**Field**
WEV 3 The wetland's natural hydrological cycle		
P15	**Floodplain hydrology**	**Desktop**
P16	**Land use associated with changes to natural water flow patterns**	**Desktop**
P17	**Area under constructed water storages**	**Desktop**
P18	**QWP hydrological modifier code for the mapped wetland**	**Desktop (field verified)**
WEV 4 The natural interaction of the wetland with other ecosystems, including other wetlands		
P20	**Native vegetation cleared within 5 km of the wetland**	**Desktop**
P21	**Loss of wetland regional ecosystems within 5 km of the wetland**	**Desktop**

STATE INDICATORS		
WEV 1 Biological health and diversity of the wetland's ecosystems		
S1	**Floristic composition and vegetation structure**	**Field (sampling site)**
S2	**Disturbance to native plant cover by people, pests (plant or animal), or livestock**	**Field (sampling site)**
S3	**Exotic plant cover**	**Field (sampling site)**
WEV 2 The wetland's natural physical state and integrity		
S5	**Integrity and stability of the upper water body margin**	**Field (traverse)**
S6	**Naturalness of landform**	**Field (sampling site)**
S7	**Direct disturbance by humans, livestock or pigs physically impacting soil**	**Field (sampling site)**
S8	**Pugging by livestock and feral pests in the mapped wetland**	**Field (traverse)**
WEV 3 The wetland's natural hydrological cycle		
S9	**Drainage modifications and artificial structures altering natural surface water flow patterns**	**Field (traverse)**
S10	**Wetland water regime – wetland water source**	**Field (traverse)**
S11	**Wetland water regime – abstraction (water taken out for use)**	**Field (traverse)**
WEV 4 The natural interaction of the wetland with other ecosystems, including other wetlands		
S13	**Connectivity of the wetland within a landscape context**	**Desktop (traverse)**
S14	**Native vegetation in the wetland's 200 m buffer zone (excluding the mapped wetland)**	**Desktop (field verified)**