Australian Government

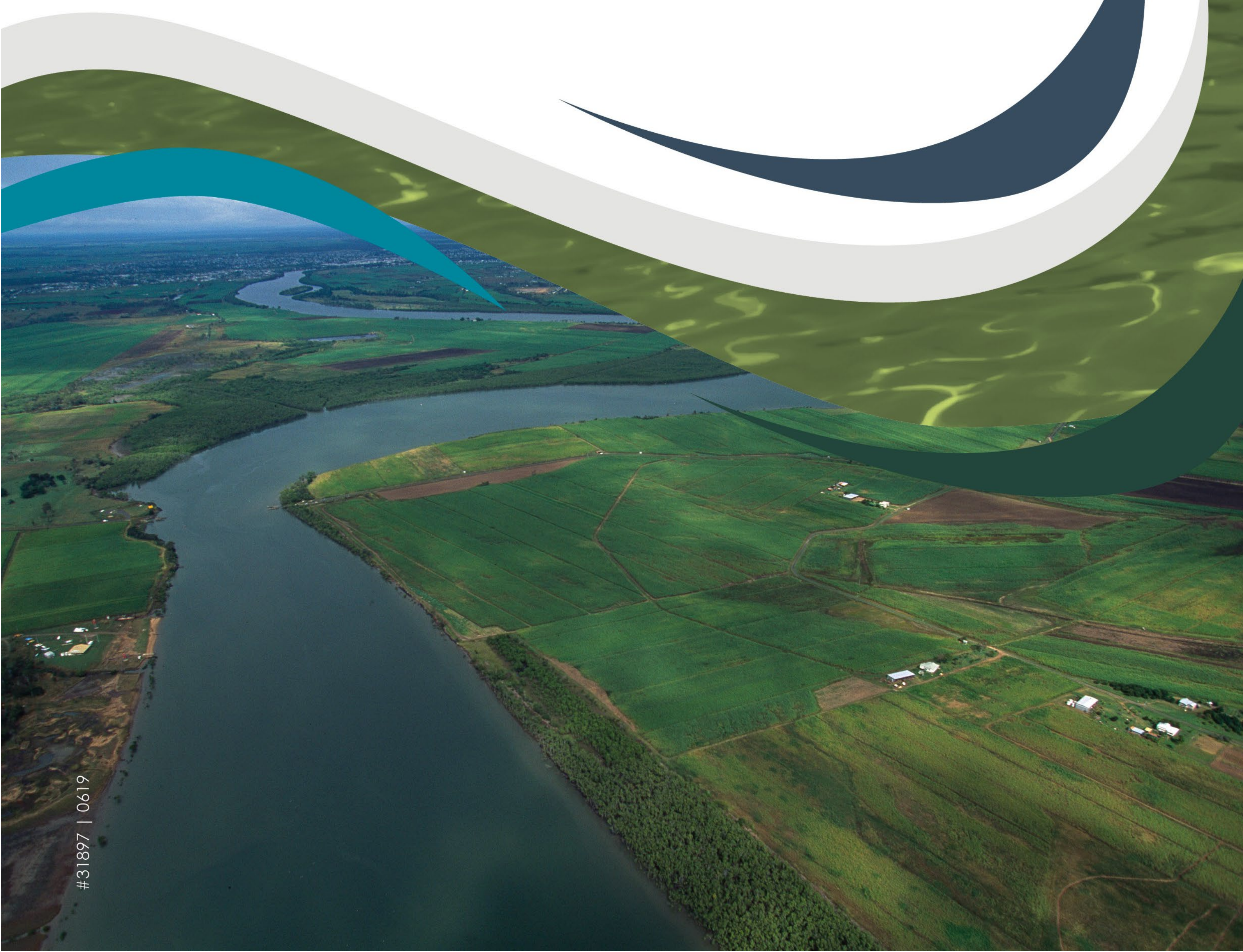
Queensland Government

Catchment Loads Monitoring

Methods

Reef Water Quality Report Card 2017 and 2018

Reef 2050 Water Quality Improvement Plan



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CATCHMENT LOADS MONITORING METHOD SUMMARY

This report summarises the methods undertaken by the Catchment pollutant delivery – Catchment loads monitoring program that reports the catchment loads monitoring results required for the delivery of the Reef Water Quality Report Card 2017 and 2018. The Catchment loads monitoring program provides data to the Catchment loads modelling program to validate progress towards achieving the Reef 2050 Water Quality Improvement Plan, 2025 water quality targets.

The targets for water quality that will contribute to ecosystem health and social resilience and benefits are as follows (Australian and Queensland governments, 2018):

- 60% reduction in anthropogenic end-of-catchment dissolved inorganic nitrogen loads.
- 20% reduction in anthropogenic end-of-catchment particulate nutrient loads.
- 25% reduction in anthropogenic end-of-catchment fine sediments loads.
- Pesticide target: To protect at least 99% of aquatic species at the ends-of-catchments.

Monitoring sites

Catchment water quality is currently measured at more than 43 sites across 20 major catchments that discharge to the Great Barrier Reef lagoon (Figure 1) as part of an ongoing, long-term monitoring program. Water quality monitoring site numbers and locations vary slightly from year to year, due to various logistical, climatic and operational reasons, the current monitoring site numbers can be found on the Reef Plan website.

During the 2016-2017 monitoring year, a total of 34 sites were monitored. Twenty end-of-catchment sites and 14 sub-catchment sites across 17 major catchments were monitored for total suspended solids and nutrients. Pesticides were monitored at a sub-set of 17 end-of-catchment sites and two sub-catchment sites across 14 major catchments (pesticides were not monitored in the Olive Pascoe, Normanby and Barron catchments).

During the 2017–2018 monitoring year, a total of 57 sites were monitored across 30 major catchments, consisting of 22 end-of-catchment sites and 18 sub-catchment sites for total suspended solids and nutrients. Pesticides were monitored at a sub-set of 32 end-of-catchment sites and three nested sub-catchment sites (pesticides were not monitored in the Cape York region).

Monitoring sites are classified as either end-of-catchment or sub-catchment sites. The end-of-catchment monitoring sites are located at the lowest point in a river or creek, where the discharge can be accurately measured, typically where gauging stations have been established and are being maintained by the Queensland Department of Natural Resources, Mines and Energy. Sub-catchment sites are located at the lowest point in a sub-catchment (tributary), mainly at existing gauging stations. Water quality samples collected at each monitoring site provide data related to land management activities in the catchment area upstream of the site. Both site types provide field data that are used to calibrate and validate catchment models.

Monitoring currently captures an estimated 92% of the total suspended solid load and 88% of the dissolved inorganic nitrogen load discharged to the Great Barrier Reef lagoon and pesticides are monitored in all priority locations.

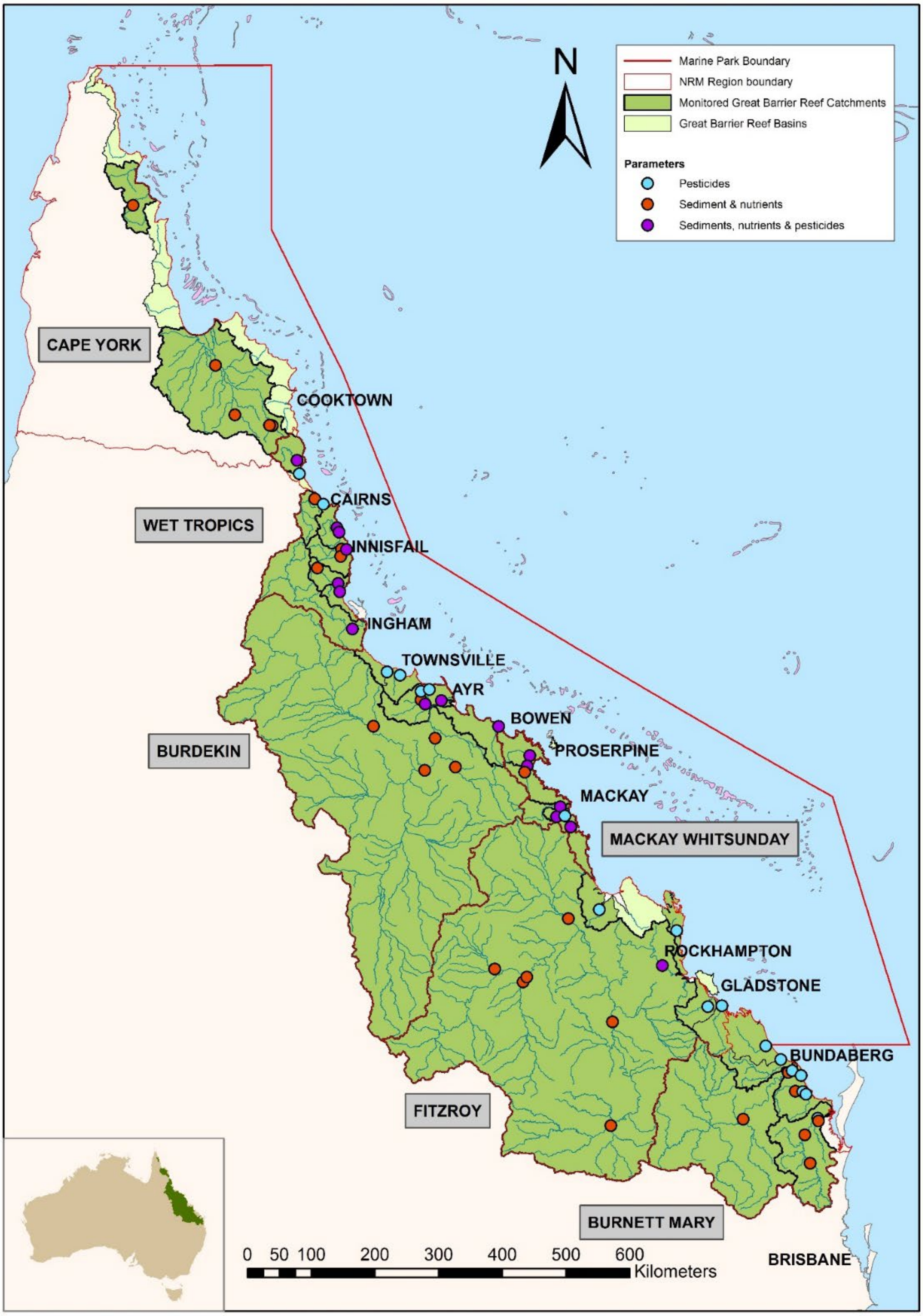

Figure 1. Map showing the location of catchment monitoring sites in the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program.

Rainfall data

Rainfall totals and rainfall decile data are currently obtained from the Bureau of Meteorology National Climate Centre. These data are synthesised using geographic information system tools to display total annual rainfall and annual rainfall deciles for Queensland during the period from 1 July to 30 June of each year (2016-2017 and 2017-2018). The total annual rainfall and annual rainfall deciles provide contextual information regarding the state of the climate during the reported monitoring year and is described in detail within the annual technical report.

Water quality sampling

Water samples are collected, stored, transported and quality assured and quality controlled in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual 2018 (www.ehp.qld.gov.au/water/monitoring/sampling-manual). Water quality samples are collected using two methods: manual grab sampling and automatic grab sampling using refrigerated pump samplers. Intensive sampling (daily or every few hours) is conducted during high flow events and monthly sampling is conducted during low or base-flow (ambient) conditions. For pesticides, intensive sampling (daily or every few hours) is similarly conducted during high flow events and weekly to monthly sampling is conducted during low or base-flow (ambient) conditions over the wet season. For the purpose of sampling pesticides, the standardised wet season (i.e. for assessing the main pesticide exposure period) commences with the first runoff event and continues for 182 days (6 months).

Where possible, total suspended solids, nutrients and pesticide samples were collected concurrently. Manual grab samples collected during low flow conditions, where sites are tidally influenced, were taken on the outgoing, low tide. Automatic grab samplers installed in tidal sites were activated during rainfall run-off events based on discharge measured with Horizontal Acoustic Doppler Current Profilers and conductivity and turbidity readings recorded *in situ*.

River discharge data

The volume of water flowing in the rivers is calculated using one of four methods, depending on the location and data availability:

- measured discharge from existing gauging station and extracted from Hydstra - the surface water database of the Department of Natural Resources, Mines and Energy (DNRME);
- 'time and flow factored' measured discharge from existing DNRME gauging station;
- modelled flows generated in the Source Catchments modelling platform using the Sacramento rainfall run-off model, where the Parameter Estimation Tool (PEST) was coupled with Source for the calibration process; or
- a combination of modelled flow and flow measured by Horizontal Acoustic Doppler Current Profiler.

The selected method for each site is reported annually in the technical report or ArcGIS dashboard.

Water quality sample analysis

The Science Division Chemistry Centre (Dutton Park, Queensland) analyses water samples for total suspended solids and nutrients (Table 1). The Queensland Health Forensic and Scientific Services Organics Laboratory (Coopers Plains, Queensland) analyses water samples for pesticides (Table 2). Both laboratories are accredited by the National Association of Testing Authorities for the analyses conducted.

Table 1. Summary information for each reported analyte in the catchment monitoring program.

Reported Pollutants	Abbreviation	Measured Analytes
Sediment (Total suspended solids)	TSS	Total suspended solids
Total nitrogen	TN	Total nitrogen as N
Particulate nitrogen	PN	Total nitrogen (suspended) as N
Dissolved organic nitrogen	DON	Organic nitrogen (dissolved) as N
Ammonium nitrogen as N	NH_4-N	Ammonium nitrogen as N
Oxidised nitrogen as N	NO_x-N	Oxidised nitrogen as N
Dissolved inorganic nitrogen	DIN	Ammonium nitrogen as N + Oxidised nitrogen as N
Total phosphorus	TP	Total phosphorus as P
Particulate phosphorus	PP	Total phosphorus (suspended) as P
Dissolved organic phosphorus	DOP	Organic phosphorus (dissolved) as P
Dissolved inorganic phosphorus	DIP	Phosphate phosphorus as P

Pesticide monitoring and reporting differs from nutrients and suspended solids due to the large range of pesticides used in agriculture and the variation in their use from one year to the next. For this reason, water samples are analysed for a general suite of pesticides. However, not all pesticides that are detected are reported each year. Other detected and non-detected pesticides will be reported via the pesticide exceedance dashboard. A sub-set of pesticides, referred to as the *reference pesticides*, are used to measure and model the progress towards the pesticide water quality target[1]. The reference pesticides (Table 2) have been selected based on the frequency of their detection in catchments, the availability of ecotoxicity data for individual pesticides, and their capacity to be modelled in Source Catchment models. The reference pesticides include herbicides and insecticides used in a range of agricultural land uses, including sugarcane, grazing, cropping and horticulture.

1 Note: The pesticide target encompasses all pesticides in GBR water bodies. All possible measures are taken to include as many pesticides in the metric to measure progress towards the target; however, measuring and modelling progress is reliant on other data (e.g. ecotoxicity and application data) not just concentration information, which is not available for all pesticides detected in catchments. For this reason, not all pesticides are included in the metric to measure progress towards the target. The number and types of pesticides included in the metric will expand over time as new data is collected.

Table 2. Pesticides included in pesticide risk metric. Not all of the listed pesticides were necessarily detected in collected water samples.

Reference pesticide	Pesticide type	Mode of Action
Chlorpyrifos	Insecticide	Acetylcholine esterase (AChE) inhibitor
Fipronil	Insecticide	Gamma-aminobutyric acid (GABA) gated chloride channel blocker
Imidacloprid	Insecticide	Nicotinic receptor agonist
Haloxyfop	Herbicide	Acetyl-coenzyme A carboxylase (ACCase) inhibitor
Imazapic	Herbicide	Acetolactate synthase (ALS) inhibitor
Metsulfuron-methyl	Herbicide	
Pendimethalin	Herbicide	Microtubule synthesis inhibitor
Metolachlor	Herbicide	Acetolactate synthase (ALS) inhibitor
Reference pesticide	**Pesticide type**	**Mode of Action**
Ametryn	Herbicide	PSII inhibitor
Atrazine	Herbicide	
Terbuthylazine	Herbicide	
Tebuthiuron	Herbicide	
Simazine	Herbicide	
Diuron	Herbicide	
Terbutryn	Herbicide	
Hexazinone	Herbicide	
Metribuzin	Herbicide	
2,4-D	Herbicide	Auxin mimic (Phenoxy-carboxylic acid auxins)
MCPA	Herbicide	
Fluroxypyr	Herbicide	Auxin mimic (Pyridine-carboxylic acid auxins)
Triclopyr	Herbicide	
Isoxaflutole	Herbicide	4-hydroxyphenylpyruvate dioxygenase (4-HPPD) inhibitor

Calculating nutrient and sediment loads

The suitability of the generated water quality monitoring data for use in load calculations was assessed using a sample representivity rating. The annual rating of sampling representivity was assessed against two criteria:

1. the number of samples collected in the top five per cent of annual monitored flow
2. the ratio between the highest flow rate at which a water sample was collected and the maximum flow rate recorded.

The representivity was determined for each monitoring year by assigning a score using the system presented in Table 3.

Table 2. Scores assigned to total suspended solids and nutrients data to determine their representivity.

Number of samples in top 5 per cent of flow	Score	Ratio of highest flow sampled to maximum flow recorded	Score
0 – 9	1	0.00 – 0.19	1
10 – 19	2	0.20 – 0.39	2
20 – 29	3	0.40 – 0.59	3
30 – 39	4	0.60 – 0.79	4
>40	5	>0.80	5

The rating of sample representivity for each analyte was the sum of the scores for the two criteria. Sample representivity for each analyte was rated as 'excellent' when the total score was greater than or equal to eight, 'good' when the total score was six or seven, 'moderate' for total scores of four or five or 'indicative' when the score was less than four. Furthermore, hydrographs were visually assessed to verify the representivity rating.

For nutrients and sediment, the concentration and flow data are used to determine the total load of each pollutant that is transported past the monitoring site in each catchment and sub-catchment. Annual and daily loads are calculated for total suspended solids and the nutrient analytes listed in Table 1, for the catchments and sub-catchments listed in Table 4, using the Loads Tool component of the software Water Quality Analyser 2.1.2.6 (eWater 2012). The total suspended solids and nutrient loads were calculated using concentrations reported in milligrams per litre (mg L^{-1}).

One of two methods was used to calculate loads: the average load (linear interpolation of concentration) or the Beale ratio. Average load (linear interpolation of concentration) is the most accurate and reliable method, provided events are adequately sampled, with a representivity rating of excellent. For complex events or events with a representivity rating of good, moderate and indicative, the Beale ratio is one of the recommended methods (Joo et al. 2012).

Calculating the Pesticide Risk Metric

The Pesticide Risk Metric estimates the percentage of species protected (reciprocal of percentage of species affected) by mixtures of pesticides detected during a standardised wet season of 182 days. The wet season was determined to be the only period of time when there was a significant risk of pesticide run-off. This metric, calculated from the monitored concentration data for the 22 reference pesticides, was used to estimate the percentage of species protected in each monitored catchment, which is also used to validate the Source Catchment modelled estimates of progress, from the Pesticide Risk Baseline[2], towards the end of catchment target. Note that modelled estimates of progress towards the pesticide target will be reported in future years.

In order to express the concentration data for all 22 reference pesticides as a single number that represents the overall risk to aquatic ecosystems, it was necessary to convert all the

2 The Pesticide Risk Baseline was generated using a suite of models that can predict the pesticide mixture toxicity from monitored sites to the whole catchment, region and GBR scales. The Baseline was developed using Catchment loads monitoring program data collected from monitoring sites across Queensland from 2015 to 2018. The model build, compared the monitored pesticide trends to spatial, climate and landuse characteristics at those sites. The Pesticide Risk Baseline then used the relationships developed to predict the current estimate of percent species protected from mixtures of 22 reference pesticides observed in major catchments discharging to the GBR (Warne et al. 2019).

pesticide concentration data into a term that represented the toxicity of the mixture of pesticides in each water sample. This was achieved using the multi-substance potentially affected fraction (ms-PAF) approach (Traas et al. 2002).

The 22 reference pesticides have multiple different modes of action (Table 2). The toxicity of pesticides with different modes of action was calculated using the independent action model of joint action (Plackett and Hewlett 1952) within the multiple-substance-potentially affected fraction (ms-PAF) method. Further details on how the pesticide risk metric calculations were made are provided in Warne et al. (2019). The pesticide mixture toxicity was calculated for all samples collected over the wet season. Where there was more than one sample per day a daily mean concentration was calculated.

The mixture toxicity data (i.e. ms-PAF values) for all water samples collected over the wet season were then summarised as a single value. In order to do this, it was necessary to estimate the daily average ms-PAF for days that weren't monitored during the wet season using a multiple imputation technique (Rubin 1996; Donders et al. 2006; Patrician 2002). This involved fitting a statistical distribution to the observed data for the wet season for the site. This distribution was then used to impute values to fill in the missing days in the 182-day period. The resultant 182 days of data were then divided by 182 to obtain the Pesticide Risk Metric and ranked into five risk categories (Table 4). These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters.

Calculating the contribution of pesticide sub-categories

The Pesticide Risk Metric method was used to obtain Pesticide Risk Metric values for four groups of pesticides - total pesticides, insecticides, PSII herbicides and non-PSII herbicides.

Table 4. Risk categories used to assess pesticide risk

Pesticide Risk Metric value		Risk Category	Ecological Condition (ANZWQG)
% species affected	% species protected		
≤1%	≥99%	Very low	High Ecological Value
>1 to <5%	>95 to <99%	Low	Slightly to Moderately Disturbed
5 to <10%	>90 to 95%	Moderate	Highly Disturbed
10 to <20%	>80 to 90%	High	
≥20%	≤80%	Very high	

Assessing progress towards the targets

The water quality targets for sediment and nutrients are based on annual average end of catchment load reductions and the pesticide target is based on the percent of species being protected - the progress of which is assessed through the Source Catchments model. This model is validated by the results of the catchment monitoring.

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