Australian Government

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Pesticide Risk Baseline Methods

Reef Water Quality Report Card 2017 and 2018

Reef 2050 Water Quality Improvement Plan

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CONTENTS

CATCHMENT POLLUTANT DELIVERY – PESTICIDE RISK BASELINE METHODS

This report summarises the methods used to estimate the pesticide risk baseline in the 35 major catchments and six natural resource management regions of the Great Barrier Reef. The pesticide risk baseline is required to assess progress towards meeting the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP) 2025 water quality target for pesticides. Note that progress made towards meeting the pesticide target through improved land management practices will be reported in the Reef Water Quality Report Card 2019 to be released in 2020.

The water quality target for pesticides has changed from a loads-based target to a risk-based target that is:

- to protect at least 99% of aquatic species at the end-of-catchments (Australian Government and Queensland Government, 2018)

As a result of the change in the pesticide target and the methodology used to measure progress to the target, the results in the Reef Water Quality Report Card 2017 and 2018 will not be comparable with previous report cards[1].

Overview of the methods

We set a new baseline for pesticides based on monitoring data collected from 2015 – 2018. Progress to meeting the new pesticide target will be modelled and reported in future report cards from this baseline. The method to calculate the pesticide risk baseline is a newly developed method and as such, a detailed explanation of its development and validation is provided in the Pesticide Risk Baseline Tier 3 Report (Warne et al. in prep). A summary of the methods used to generate the pesticide risk baselines reported in the Pesticide Risk Basline Results report and the Reef Water Quality Report Card 2017 and 2018 is stated below.

The method to calculate the pesticide risk baselines for all GBR catchments and natural resource management regions relies on a combination of monitoring data with modelling to calculate a 'per cent of species protected' to all areas including those that are not routinely monitored. The 22 pesticides[2] that were included in the calculation of the Pesticide Risk Baseline (Warne et al. in prep) are herbicides and insecticides presented in Table 1– no fungicides were included. To assess which pesticides were having the greatest contribution to the total pesticide risk, the 22 pesticides were divided into three groups; (i) photosystem II (PSII) inhibiting herbicides, (ii) other herbicides (i.e. non-PSII herbicides), and (iii) insecticides.

The Catchment loads monitoring program (e.g. Huggins et al., 2017) collects monitoring data on pesticides for a portion of catchments (i.e. the monitored portion of a catchment that is upstream of the monitoring site), regions and the total Great Barrier Reef catchment area; i.e. 38 out of ~970 waterways that discharge to the Great Barrer Reef. As such, predictive relationships were required to estimate the pesticide risk for the whole of (major) catchment, region and Great Barrier Reef scales. The monitoring data are a reflection of the

[1] The previous pesticide target was a load reduction target (similar to the nutrient and sediment targets). Measuring progress towards that target involved modelling the annual loads of five photosystem II inhibiting herbicides discharging to the Great Barrier Reef.
[2] The 22 pesticides were selected based on how frequently they were detected in the monitored catchments, the availability of ecotoxicity data, and the ability to be modelled in Source Catchment models. For details refer to Warne et al. in prep).

concentrations and types of pesticides that result from the catchment-specific land and hydrological conditions upstream of the monitoring site. Using the relationships between the land-use, spatial and hydrological variables in a catchment and the pesticide monitoring data, we can predict what the pesticide risk would be for areas that aren't monitored, based on their specific land and hydrological conditions.

Table 1. The 22 pesticides that were included in the pesticide risk baseline. Pesticides are grouped according to their type; (PSII) indicates photosystem II inhibiting herbicides, (OH) indicates 'other' herbicides (i.e. non-PSII herbicides), and (I) indicates insecticides.

2,4-D (OH)	Ametryn (PSII)	Atrazine (PSII)
Chlorpyrifos (I)	Diuron (PSII)	Fipronil (I)
Fluroxypyr (OH)	Haloxyfop (OH)	Hexazinone (PSII)
Imazapic (OH)	Imidacloprid (I)	Isoxaflutole (OH)
MCPA (OH)	Metribuzin (PSII)	Metolachlor (OH)
Metsulfuron-methyl (OH)	Pendimethalin (OH)	Prometryn (PSII)
Simazine (PSII)	Tebuthiuron (PSII)	Terbuthyalzine (PSII)
Triclopyr (OH)		

The process of deriving the pesticide risk baseline for the whole-of-catchment, region and Great Barrier Reef scales, involves a number of key steps. The main types of data, the steps involved and the order in which the steps were conducted are presented in Figure 1. In summary:

1. aqueous pesticide concentration data was collected by the Great Barrier Reef Catchment loads monitoring program for 38 catchments or sub-catchments (Step 1, Figure 1).

2. the measured risk of pesticide mixtures (termed the pesticide risk from here on) to aquatic species at each monitoring site was then determined from the concentration data using the pesticide risk metric (Step 2, Figure 1). The risk is expressed as the average per cent of species affected during the wet season of 182 days for each of the monitored catchments (Step 3, Figure 1).

3. land-use and site-specific spatial and hydrological variables were calculated or collected for each catchment (Step 4, Figure 1)

4. the pesticide risk and catchment variables for all the monitored catchments were regressed against each other to develop predictive pesticide risk and catchment variable relationships (Step 5, Figure 1)

5. the pesticide risk and catchment variable relationships were used to predict the pesticide risk for each catchment (Step 6, Figure 1). The validity of relationships was tested by comparing the predicted pesticide risk with the pesticide risk measured at catchments not used to derive the relationships

6. the same land-use and site-specific spatial and hydrological variables were calculated for the 35 major catchments (Step 7, Figure 1), and the relationships were scaled-up and used (Step 8, Figure 1) to predict the pesticide risk for 35 major catchments (Step 9, Figure 1)

7. the same land-use and site-specific spatial and hydrological variables were then calculated for the natural resource management regions and the Great Barrier Reef catchment area and the relationships used (Step 10, Figure 1) to predict the pesticide risk for the six natural resource management regions and the Great Barrier Reef (Step 11, Figure 1)

8. the pesticide risk values, expressed as per cent of species affected, were converted to the per cent of species protected (per cent species protected = 100 minus per cent affected) and these form the pesticide risk baseline

9. this process was undertaken for 'total pesticides', i.e. all 22 pesticides together. Steps 2-6 were then repeated for the three pesticide groups; i.e. PSII herbicides, other herbicides and insecticides.

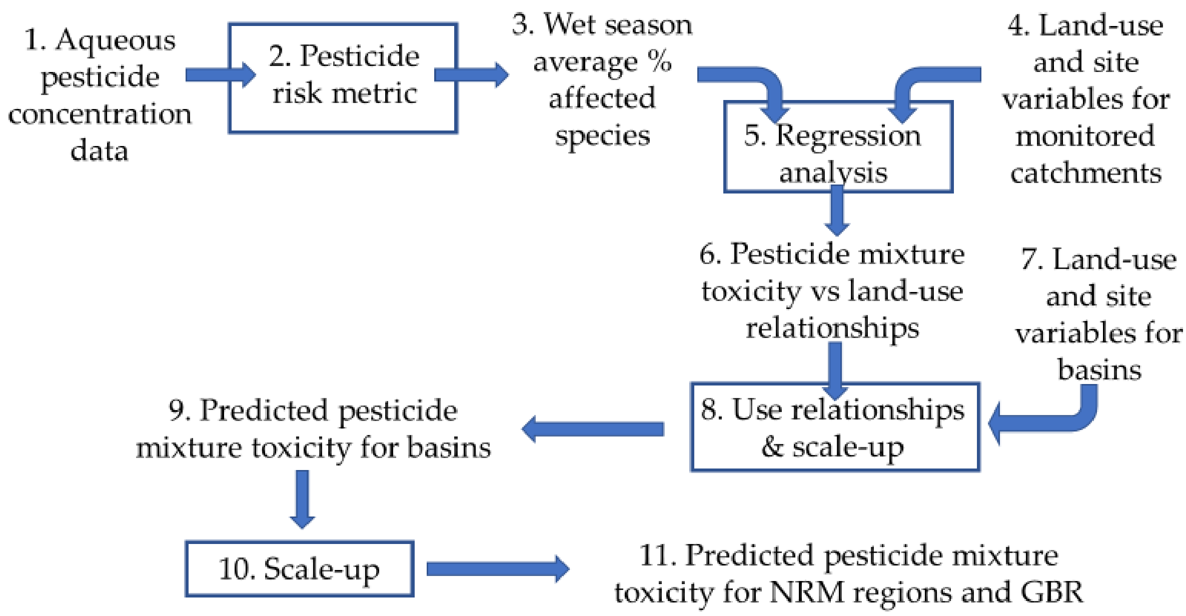

Figure 1. Schematic of the process of calculating the pesticide risk baseline at three different spatial scales: whole of catchment, region and Great Barrier Reef scales.

Constraints and assumptions in the pesticide risk baseline

In order to be transparent, the assumptions and constraints that were made in developing the pesticide risk baseline are presented below. The available information strongly indicates that the vast majority of the assumptions are valid and for the others the assumptions are reasonable. The assumptions of the project were:

- the measured pesticide concentrations collected through grab sampling are representative of the vertical and horizontal variation of pesticide concentrations in the water of the monitored catchments
- the quality assurance and quality control procedures implemented by the Catchment loads monitoring program are appropriate

- the measured pesticide concentrations are the dissolved and bioavailable concentration or a reasonable surrogate of the bioavailable concentration
- the sampling design (when monitoring is triggered, the frequency and duration of sampling) provides pesticide concentrations that are representative of the wet season
- the hydrological explanatory variables used in the relationships to predict pesticide risk, which are site specific, are representative of the catchment
- that land use will determine the pesticides detected in the monitored waterways, their concentation and combined toxicity
- the use of the independent action model, as described in the section pesticide risk metric, to estimate mixture toxicity is appropriate for the 22 selected pesticides
- the 68 unique combinations of site and year for which there are pesticide concentration data available are sufficient to develop high quality relationships to predict pesticide risk
- the dominance of pesticide data from 2017-2018 does not bias the pesticide risk baseline.

The constraints of the project were:

- pesticide data for the three most recent years (2015-2016, 2016-2017 and 2017-2018) were used in order to reflect current conditions but this meant that many sites only had one year of pesticide concentration data (see Table 2)
- there is no pesticide monitoring data available for any waterways in the Cape York region to use in developing or validating the relationships to predict pesticide risk (Table 2)
- the predictive relationships were independently derived for PSII herbicides, other herbicides, insecticides and total pesticides. Therefore the sum of the predicted pesticide risk values for PSII herbicides, other herbicides and insecticides will not necessarily equal the predicted total pesticide risk values. Therefore the predictive relationships for PSII herbicides, other herbicides and insecticides were only used to estimate the relative contribution of these groups of pesticides to the pesticide risk
- the data used was the best available at the time
- in order to protect freshwater, estuarine and marine organisms, ecotoxicity data for fresh and marine species were combined
- a risk based method (multiple-substance potentially affected fraction method) was used to be consistent with the Reef 2050 WQIP pesticide target and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality for toxicants <www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants>.

Pesticide concentration data

Aquatic pesticide concentration data for 2015-2016, 2016-2017 and 2017-2018 were obtained from the Catchment loads monitoring program. This program monitors 35 waterways, including catchments and sub-catchments, for the 22 pesticides listed in Table 1. Not all sites were sampled for pesticides for all three years (Table 2). All pesticide analyses were conducted by the Queensland Health Forensic and Scientific Services Organics Laboratory (Coopers Plains, Queensland), which is accredited for these analyses by the National Association of Testing Authorities. Pesticides were extracted from the water samples using solid phase extraction and then identified and quantified using liquid chromatography-mass spectrometry. The quality assurance and quality control procedures implemented by the Catchment loads monitoring program to determine the accuracy of pesticide concentrations (Huggins et al., 2017) were adopted.

Table 2. The waterways monitored for pesticides and used to derive the Pesticide Risk Baseline and the years for which pesticide data were available (indicated by an X). S-C indicates a site at a sub-catchment. No waterways in the Cape York region were monitored for pesticides.

Waterway	NRM Region	2015 – 2016	2016 – 2017	2017 – 2018
Baffle Creek	Burnett Mary	-	-	X
Barratta Creek	Burdekin	X	X	X
Barron River	Wet Tropics	-	-	X
Black River	Burdekin	-	-	X
Boyne River	Fitzroy	-	-	X
Burdekin River	Burdekin	X	X	X
Burnett River at Ben Anderson Barrage (S-C)	Burnett Mary	X	X	-
Burnett River at Quay St. Bridge	Burnett Mary	-	-	X
Burrum River	Burnett Mary	-	-	X
Calliope River	Fitzroy	-	-	X
Comet River (S-C)	Fitzroy	X	X	X
East Barratta Creek	Burdekin	-	-	X
Elliot River	Burnett Mary	-	-	X
Fitzroy River	Fitzroy	X	X	X
Gregory River	Burnett Mary	-	-	X
Haughton River at Powerline (S-C)	Burdekin	X	X	-
Haughton River at Giru weir	Burdekin	-	-	X
Herbert River	Wet Tropics	X	X	X
Johnstone River	Wet Tropics	X	X	X
Kolan River	Burnett Mary	-	-	X
Mary River at Homepark (S-C)	Burnett Mary	X	X	-
Mary River at Churchill St.	Burnett Mary	-	-	X
Mossman River	Wet Tropics	-	-	X
Mulgrave River (S-C)	Wet Tropics	X	X	X
North Johnstone River (S-C)	Wet Tropics	X	X	X

O'Connell River at Staffords Crossing (S-C)	Mackay Whitsunday	-		X
O'Connell at Caravan Park	Mackay Whitsunday	X	X	X
Pioneer River	Mackay Whitsunday	X	X	X
Proserpine River	Mackay Whitsunday	-		X
Russell River (S-C)	Wet Tropics	X	X	X
Sandy Creek	Mackay Whitsunday	X	X	X
Styx River	Fitzroy	-	-	X
Tinana Creek (S-C)	Burnett Mary	-	X	X
Tully River	Wet Tropics	X	X	X
Waterpark Creek	Fitzroy	-	-	X

Pesticide risk metric

The pesticide risk metric is a combination of three published methods (Figure 2). These are:

i. the **multiple-substance potentially affected fraction (ms-PAF)** method (Traas et al., 2002), which was used to convert the pesticide concentration data to per cent of aquatic species affected

ii. the **independent action model** of joint action (Bliss, 1939, Plackett and Hewlett, 1952), which was used to combine the per cent of species affected by multiple pesticides into one value representing the risk of the mixture of pesticides.

iii. and a **multiple Imputation method** (Donders et al., 2006), was used to estimate the pesticide risk for days without pesticide monitoring data and to determine the average per cent of species affected over the wet season.

The metric calculates the risk posed by mixtures of 22 selected pesticides and expresses it as the per cent of species affected for each water sample and then finally as the average per cent of species that should be affected during the wet season (a standardised 182 day period). Exposure was estimated during the wet season as this is when the majority of the rain falls and pesticides are transported to waterways and aquatic organisms are exposed. To determine the pesticide risk baseline and to report against the target, the per cent of species affected is converted to the per cent of species protected (i.e. per cent species protected = 100 minus per cent species affected).

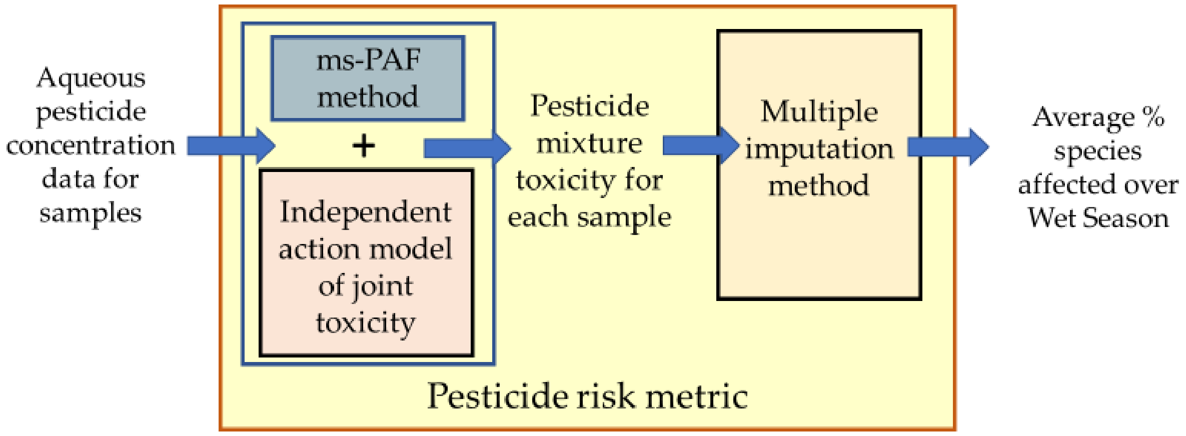

Figure 2. Schematic of the components of the pesticide risk metric that is used to estimate the pesticide risk of individual samples and all samples combined from a monitored catchment.

The multiple-substance potentially affected fraction (ms-PAF) method was selected because it can estimate the toxicity of mixtures of chemicals and express this as the per cent of species affected or protected, which is consistant with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

The pesticide reduction target (Australian and Queensland governments, 2018) applies at the mouth of catchments that discharge to the Great Barrier Reef and as such it needs to protect estuarine and marine species. Toxicity data for both fresh and marine species were therefore combined to estimate the pesticide risk, expressed as the per cent of species that should be affected when exposed to the selected pesticides. The per cent of species affected by an individual pesticide is estimated from its species sensitivity distribution, which is a representation of the varying sensitivities of aquatic species to the toxicity of a pesticide (Traas et al., 2002). The process uses statistical probability to estimate the per cent of species in an ecosystem likely to be affected by a given concentration of a pesticide. The toxicity data used to generate the species sensitivity distributions were obtained from a series of proposed default guideline values[3] (King et al., 2017) that have been generated as part of the current revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality <www.waterquality.gov.au/anz-guidelines/>. The species sensitivity distributions were generated using the nationally endorsed method for deriving species sensitivity distributions and default guideline values (Warne et al., 2018).

The independent action model was selected as the most appropriate model for determining the toxicity of mixtures of the selected pesticides (for details refer to Warne et al., in prep) as it provided closer estimates of the per cent of species affected compared to water quality guideline values for individual pesticides. In addition it permits the contribution of individual pesticides to the pesticide risk to be determined.

The pesticide risk metric calculates the per cent of species affected for each water sample. But for reporting in the Reef Water Quality Report Card 2017 and 2018 a single number is required to express the pesticide risk and it was determined that the baseline would be based on the average per cent of species protected over the wet season. There is not pesticide monitoring data at any site for each day of the wet season. Therefore, a multiple imputation method was adopted as it is a well-accepted method for dealing with missing data (Rubin,

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[3] Default guideline values is the new term for the limits set in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. This term replaced the term trigger values.

1996, Patrician, 2002; Donders et al., 2006,) that is widely used in the fields of statistics, epidemiology and social and political sciences. Multiple imputation methods fit a distribution to the existing data and then use re-sampling techniques to calculate estimates for the days missing data. Then the average per cent of species affected during the wet season was calculated for the pesticide data for each site and year (Table 2).

The pesticide risk was calculated for all 22 selected pesticides – termed the total pesticide risk. The pesticide risk was also separately calculated for the PSII herbicicdes, for other herbicides and for insecticides.

Developing relationships to predict pesticide risk at the whole of catchment, region and Great Barrier Reef scales

Relationships were developed between pesticide risk and land-use, spatial and hydrological variables. The pesticide risk data for this was generated as described in the section pesticide risk metric. The land-use, spatial and hydrological variables used to develop the relationships and how they were obtained is stated below. Relationships were developed separately for all pesticides, PSII herbicides, other herbicides and insecticides.

Land-use and site-specific spatial and hydrological variables

All the variables used to develop the relationships are presented in Table 3.

Spatial Variables

Latitude and longitude of the monitoring sites were obtained as well as the adopted middle thread distance, monitored surface area of each catchment expressed as a percentage of the all catchments that discharge to the Great Barrier Reef, and the natural resource management region in which each site was located.

Upstream catchment boundaries (shapefiles) were generated using topographical maps, watercourses, 1m contours and imagery from the SIR Geoportal then checked against local knowledge supplied by clients or subject matter experts. Shapefiles for the 35 major catchments were supplied by the Soil and Land Resources Unit within the Queensland Department of Environment and Science. These were the same as those developed for the Great Barrier Reef Source Catchment model (Australian and Queensland governments, 2019).

The natural resources management region boundary shapefiles were sourced from QSpatial <http://qldspatial.information.qld.gov.au/> and are consistent with those used in the Reef 2050 WQIP.

The surface area of each natural resource management region was extracted using the calculate geometry tool in ArcGIS Pro <www.esri.com/en-us/arcgis/products/arcgis-pro>, then summed to provide an area for all six natural resource management regions. The size of each monitored catchment relative to that the entire Great Barrier Reef catchment area was then determined by dividing each monitored catchment surface area by the summed area of all six natural resource management regions. This provided the explanatory variable relative monitored catchment size (m^2) for each of the sample sites.

Adopted middle thread distance is the length of a waterway, in kilometres, measured along the middle of the deepest section of a watercourse from the sample site to the river mouth. The adopted middle thread distance was included in the development of the pesticide risk versus land-use relationships to see if distance of the site from the river mouth affected pesticide risk. Most adopted middle thread distance data was extracted from the Queensland Department of Natural Resources, Mines and Energy Stream Gauging Station Index 2014 <https://water-monitoring.information.qld.gov.au>. Adopted middle thread distance was calculated by hand for sites that had no entry in the Gauging Station Index using a combination of ArcGIS Pro and Google Earth.

Land use variables

Land use types were grouped into thirteen categories that align with those used in the Great Barrier Reef Source Catchment model (i.e., bananas, conservation, dryland cropping, forestry, forested grazing, open grazing, horticulture, irrigated crops, sugarcane, urban, water, wetlands and other). Land-use was expressed as a per cent of total monitored catchment surface area.

The most recent Queensland Land Use Mapping Program dataset was extracted from QSpatial <www.qld.gov.au/environment/land/management/mapping/statewide-monitoring/qlump>.

Hydrological variables

Hydrological variables were included to capture the influence of precipitation, soil moisture and run-off on pesticide risk values. These included: average rainfall; maximum rainfall; total rainfall; average soil moisture; total soil moisture; maximum soil moisture; maximum and average relative run-off expressed as a percentage of the long-term average run-off; and maximum and average rainfall expressed as a percentage of the long-term average rainfall. These data were obtained from the Bureau of Meteorology (Frost et al., 2018).

Table 3. The spatial, land-use and hydrological variables used to derive the relationships to predict pesticide risk.

Spatial variables	Land-use variables (% of total monitored catchment surface area)	Hydrological variables
Natural resource management region	Banana	Average rainfall
Major catchment	Conservation	Average % rainfall
Catchment	Dryland Cropping	Maximum rainfall
Latitude	Forestry	Maximum % rainfall
Longitude	Grazing Forested	Total rainfall
AMTD[1]	Grazing Open	Average soil moisture
Monitored catchment surface area	Horticulture	Total soil moisture
	Irrigated Cropping	Maximum soil moisture
	Sugar	Average % runoff
	Urban	Maximum % runoff
	Water	
	Wetland	
	Other	

[1] Adopted middle thread distance

Statistical methods

There were 68 sets of pesticide risk, land-use, spatial and hydrological data for unique site and year combinations. These data were randomly allocated, on a 80:20 basis, to a training set and a validation set. The data in the training set were used to derive the relationships. The data in validation set were used to test how accurately the best relationships were able to predict the pesticide risk at other sites/year combinations.

Forward and backward step-wise regression was used to develop relationships between pesticide risk and land-use, spatial and hydrological variables from the training set.

Determining the best relationships

The best relationship for each of the following: all pesticides; PSII herbicides; other herbicides; and insecticides was determined based on the following:

- how well the statistical assumptions of regression analysis were met (indicated by the diagnostic figures)
- the quality of the fit of the relationships to the pesticide risk data in the training set (indicated by the adjusted coefficient of determination (R^2) values)
- how well the values predicted by the relationships agreed with the measured values for the sites in the validation set
- whether the predicted total pesticide risk values for whole-of-catchment, region and Great Barrier Reef scales were reasonable given the land-use and measured pesticide mixture toxicity values of the monitored catchments.

The variables used in the best relationships for each group of pesticides are presented in Table 4. The selected relationships were able to explain between 68% and 79% of the variation in pesticide risk values for all pesticides, PSII herbicides, other herbicides and insecticides.

Table 4. The predictive variables used to generate the pesticide risk baseline (total pesticides) and the contribution of the grouped pesticide types (PSII herbicides, other herbcides and insecticides) to the pesticide risk (per cent species affected).

Pesticide group	Predictive variables
Total pesticides (pesticide risk baseline)	Per cent dryland cropping, sugar cane, conservation, horticulture and urban
PSII herbicides	Adopted Middle Thread Distance and per cent conservation, horticulture, irrigated cropping and sugar cane
Other herbicides	Per cent urban, conservation, horticulture, dryland cropping and sugar cane
Insecticides	Average rainfall and per cent forestry, water, grazing forested, horticulture and sugar cane

Using the relationships to predict pesticide risk for whole-of-catchment, region and the Great Barrier Reef scales

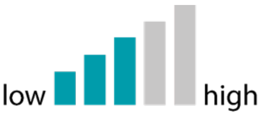
The relationships developed above between pesticide risk and land-use, spatial and hydrological variables were for monitored catchments. Appropriate land-use and site-specific spatial and hydrological variable values for the major catchments, regions and the Great Barrier Reef catchment area were then substituted into the best pesticide risk relationships to predict the pesticide risk at the whole-of-catchment, region and Great Barrier Reef scales.

For more detail on all aspects of the methods used to derive the pesticide risk baseline refer to the pesticide risk baseline Tier 3 Report (Warne et al., in prep).

Qualitative confidence rankings Pesticide Risk Baseline

A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the Reef Water Quality Report Card 2017 and 2018 from low to high. The approach combined expert opinion and direct measures of error for program components where available.

The methods used to calculate the pesticide risk baseline for measuring progress towards the pesticide target received a three-bar confidence ranking. The rationale for this confidence ranking is provided below.



Rationale for the Confidence Ranking

Maturity of methods

A score of one was awarded because not all individual methods used have been reviewed, the combination of methods used have not been reviewed, and the relationships used to predict pesticide risk have not been reviewed.

Validation

A score of two was awarded because the land use, spatial and hydrologic variables for predicting the pesticide risk (per cent of species affected), the pesticide monitoring (concentration) data, and the relationships used to predict pesticide risk were validated, but there is no validation of the per cent of species protected at the end of catchments.

Representativeness

A score of three was awarded because in 28 of the 35 basins that discharge to the Great Barrier Reef at least one catchment was monitored for pesticides. The seven basins without any pesticide monitoring are in Cape York, which should have a very low risk from pesticides (based on land use statistics).

Directness

A score of two was awarded because the assessment uses a mix of quantified assessments (i.e. catchment monitoring data, laboratory-based ecotoxicology data, remotely sensed land-use and spatial data, and modelled hydrological data) however, the per cent of species protected at the end of catchments is not directly measured.

Measurement error

A score of one was awarded because the error in the multiple data sources used and the multiple steps in the methodology is not able to be quantified at this point in time.

GLOSSARY

Adopted middle thread distance (AMTD): The distance between a monitoring site and the mouth of the waterway measured along the deepest part of the channel.

Australian and New Zealand Guidelines for Fresh and Marine Water Quality: The numerical and descriptive limits for pollutants and physico-chemical properties of water that are used in Australian and New Zealand to manage the quality of water for various purposes.

Bioavailable concentration: The concentration of a pollutant that is available (i.e., can be absorbed or cause harmful effects) to organisms. The bioavailable concentration is usually less than the total concentration or even the dissolved concentration. Bioavailability of a chemical is controlled by a variety of factors.

Catchment: The natural drainage area upstream of a point that is generally on the coast. It generally refers to the 'hydrological' boundary. There may be multiple catchments in a basin. Great Barrier Reef catchments are any terrestrial areas that drain into the Great Barrier Reef World Heritage Area.

Herbicides: A type of pesticide (see below) that specifically kill or inhibit plants. Herbicides usually inhibit a specific biochemical pathway that only occurs in plants and thus are far more toxic to plants than other organisms.

Insecticides: A type of pesticide (see below) that specifically kill or inhibit insects. Insecticides usually inhibit a specific biochemical pathway that only occurs in insects and thus are far more toxic to insects than other organisms. Insects are closely related to arthropods (e.g. crabs, prawns, lobsters) and these types of organisms are also affected by insecticides.

Independent action: A model for predicting the toxicity of mixtures of pollutants that do not interact but exert their toxicity in different ways (i.e. they have different modes of action).

Multi-substance Potentially Affected Fraction (msPAF): A method allows for the estimation of the effect of multiple pollutants on an ecosystem (originally described by Traas et al., 2002). Species sensitivity distributions form the basis of the method, similar to what is used to generate the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000; ANZG, 2019) for ecosystem protection. The msPAF risk metric estimates the fraction of species affected by the temporal exposure to mixtures of pesticides during the principal exposure period (i.e. the wet season).

Major catchment: There are 35 major catchments that drain into the Great Barrier Reef. A major catchment (basin) can be made up of a single or multiple river catchments (e.g. North and South Johnstone river catchments belong to one major catchment, the Johnstone catchment). Major catchments are primarily used here when discussing the relative delivery of a pollutant to the marine system.

Monitored catchment: The catchment area upstream of the monitoring site. Generally does not include the whole of catchment as the monitoring site is situated upstream of the mouth of the catchment.

Multiple imputation method: A statistical method used to estimate values from datasets that are missing. It does this based on the distribution of the data that is present.

Natural Resource Management (NRM) region: There are six natural resource management regions covering the Great Barrier Reef catchments. Each region groups and represents catchments with similar climate and bioregional setting, with boundaries extending into the adjacent marine area. The regions are Cape York, Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy and Burnett Mary.

Other herbicides: In this report this term refers to all herbicides included in the Pesticide Risk Baseline project that were not PSII herbicides.

Per cent land use: The surface area of land used for a particular purpose (e.g. conservation, forested grazing, horticulture) expressed as a per cent of the surface area of a catchment, region or the entire Great Barrier Reef catchment area.

Pesticides: Pesticides, including herbicides, insecticides and fungicides, are used for protecting agriculture against pest organisms (e.g. weeds and insects). Pesticides have been detected in sediments and waters of rivers, creeks, wetlands, estuaries, and the inshore parts of the Great Barrier Reef lagoon. The types and concentrations of pesticides in the fresh, estuarine and marine ecosystems vary between catchments and regions, reflecting the main land-use in each area.

Pesticide risk: The risk posed by mixtures of pesticides and expressed as the per cent of species likely to be adversely affected (i.e. per cent affected species). The pesticide risk was calculated for all 22 selected pesticides (the total pesticide risk), for the PSII herbicides, other herbicides and insecticides.

Pesticide risk baseline: The estimate of the per cent of species that were protected at the mouth of catchments that discharge to the Great Barrier Reef between 2015 and 2018. The per cent of species protected is calculated as 100 per cent minus the per cent of species affected.

Pesticide risk metric: This is the method used to calculate the toxicity of mixtures of the 22 selected pesticides that occur in waterways during the wet season (see glossary). The pesticide risk metric is a combination of a number of different methods: the multi-substance potentially affected fraction method, the independent action model and a multiple imputation method.

Photosystem II inhibiting herbicides (PSII herbicides): PSII herbicides bind to and block a specific binding site that is part of the photosystem II component of photosynthesis. Examples of PSII herbicides include atrazine, diuron, simazine and tebuthiuron.

Quality assurance and quality control: Processes used to ensure all aspects of a project are accurate and reliable and that the results and conclusions can therefore be trusted.

Reef 2050 Long-Term Sustainability Plan: The Reef 2050 Long-Term Sustainability Plan, or Reef 2050 Plan, is a joint commitment of the Australian and Queensland governments (released in March 2015) and is the overarching framework for protecting and managing the Great Barrier Reef. It defines actions, targets, objectives and outcomes to drive and guide the short, medium and long-term management of the Great Barrier Reef. The Reef 2050 Water Quality Improvement Plan (see below) aligns with and is nested within the Reef 2050 Plan.

Reef 2050 Water Quality Improvement Plan: The Reef 2050 Water Quality Improvement Plan 2017-2022 (Reef 2050 WQIP) is a joint commitment of the Australian and Queensland governments that seeks to improve the quality of water flowing from the catchments adjacent to the Great Barrier Reef. It defines actions, targets, objectives and a long-term outcome to drive and guide management of activities influencing water quality in the Great Barrier Reef.

Regression: A statistical method of determining if there is a relationship between one or more variables and then mathematically describing the relationship.

Relationship: This means that two or more variables affect another variable. For example, in a positive relationship increasing one variable will lead to the other variable increasing, while in a negative relationship increasing one variable will lead to the other decreasing.

Sensitive: The sensitivity of an organism is how susceptible it is to the harmful effects of pollutants (e.g. pesticides). A sensitive species is one that starts experiencing harmful effects at low concentrations of a pollutant. A non-sensitive (tolerant) species is one that starts experiencing harmful effects at high concentrations of a pollutant. A sensitive species is the opposite of a tolerant species.

Species sensitivity distribution (SSD): A SSD is a relationship between the concentration of a pollutant species that causes harmful effects and the per cent of species that are affected. It is a cumulative frequency distribution of the sensitivity of species to a pollutant. From a SSD the concentration that should protect any selected per cent of species can be calculated. It can also be used to predict the per cent of species that will be affected at any given pollutant concentration.

Source Catchments: The eWater CRC Source Catchments modelling framework simulates sediment, nutrient and pesticide loads entering the Great Barrier Reef lagoon including the pollutant loads at a sub-catchment scale. The framework allows specific customised models to be added as 'plug-ins' to meet a particular modelling objective.

Wet season: A period of 182 days that starts on the first day of the monitoring year (1 July to 30 June) when a rise in river water level and an increase in aqueous pesticide concentrations occurs.

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