Australian Government

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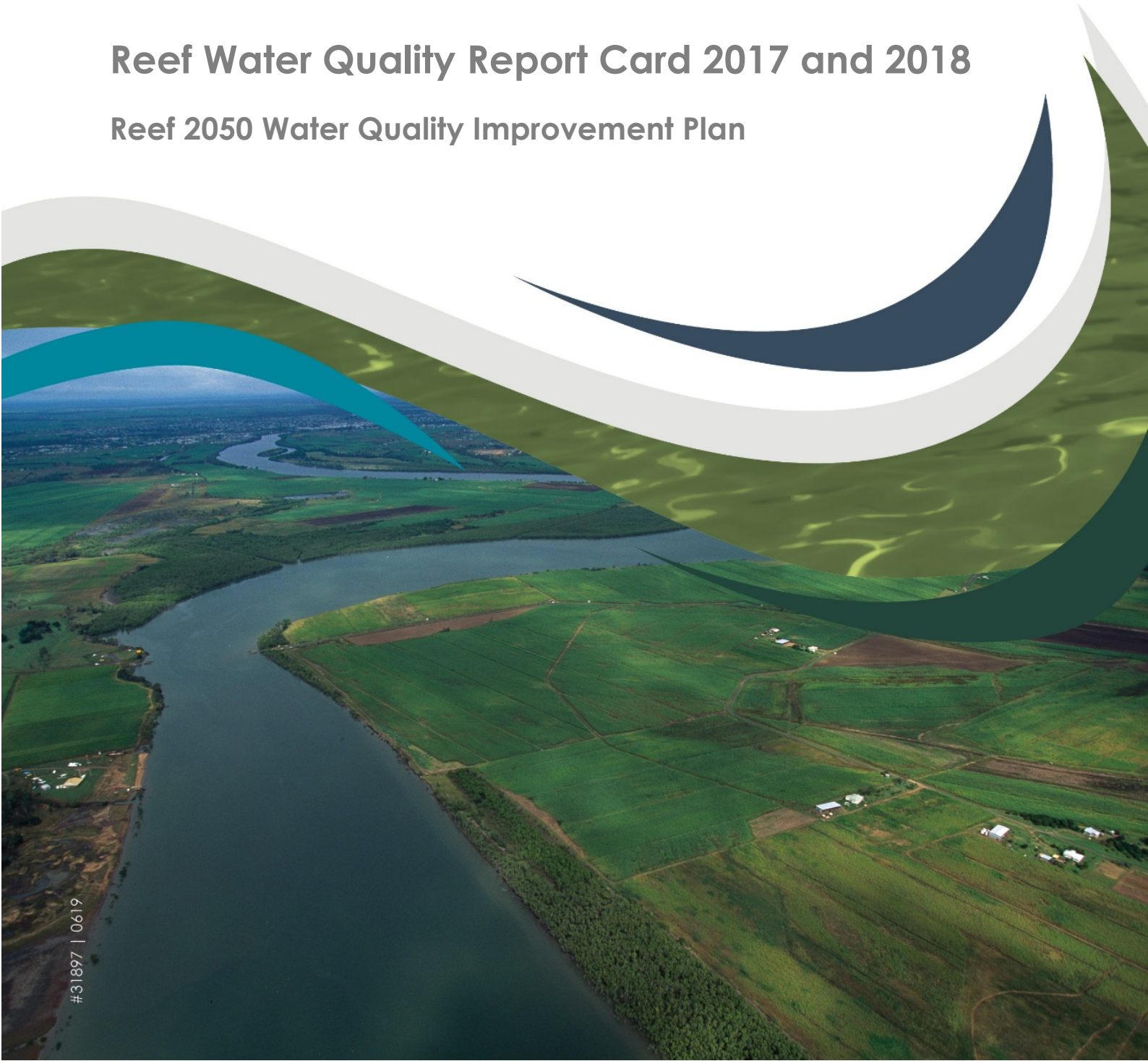
Pesticide Risk Baseline Results

Reef Water Quality Report Card 2017 and 2018

Reef 2050 Water Quality Improvement Plan



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CATCHMENT POLLUTANT DELIVERY – PESTICIDE RISK BASELINE RESULTS

This report presents the pesticide risk baselines developed for measuring progress towards the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP) 2025 water quality pesticide target (Australian Government and Queensland governments, 2018):

- to protect at least 99% of aquatic species at the end-of-catchments.

The pesticide target changed from a loads-based target in the previous Reef 2050 WQIP to a risk-based target based on the concentrations of pesticides required to protect 99% of species at the river mouth, applying across all catchments. For this reason a new pesticide baseline was established. This means that the results in the Reef Water Quality Report Card 2017 and 2018 are not directly comparable with previous Reef report card results.

The pesticide risk baselines for 35 major catchments and six natural resource management regions are presented in this report. The pesticide risk baselines are the estimates of the average per cent of aquatic species that should be protected during the wet season. Protected species should not experience adverse effects from the pesticides in the water they live in. In addition, the report presents the per cent contribution of various types of pesticides (photosystem II inhibiting (PSII) herbicides, other herbicides and insecticides) to the per cent of species that experience adverse effects (i.e. those not protected from pesticides).

A summary of the methods used to generate these results can be found in the accompanying Methods report (Australian and Queensland governments, 2019) or in the more detailed Tier 3 report (Warne et al., *in prep*).

Interpreting the pesticide risk baselines

As the new pesticide target is different to the previous loads-based target, the baselines and methods ued to measure progress towards the target are also different to those used previously. Therefore, it is helpful to provide some context on how to interpret the new results. The new reporting of pesticides is based on pesticide risk, which is an estimate of the proportion of the aquatic ecosystem that is protected from direct effects from pesticides. This is dependent on three factors: (i) the types of pesticides and the concentrations at which they are present in an ecosystem; (ii) the period of time the pesticides are present in the ecosystem; and (iii) the sensitivity of different species affected by the pesticides present. The first two factors are determined from water quality monitoring data that collects information on the types and concentrations of pesticides on a temporal scale. The third factor is described in more detail below.

The variation in the sensitivity of aquatic organisms to pesticides (sensitive species experience adverse effects at low pesticide concentrations and insensitive species experience adverse effects at high pesticide concentrations) can be summarised using species sensitivity distributions. Species sensitivity distributions were generated for the 22 pesticides included in the pesticide risk baselines. The vast majority of toxicity data used to generate species sensitivity distributions are the concentrations at which ecologically relevant sub-lethal[1] effects

[1] Ecologically relevant sub-lethal effects include reduction in population growth rate, reduction in individual growth, reduction in the ability to reproduce.

occur for a range of species after they have been exposed[2] to pesticides. So if a pesticide risk baseline value is 95% species protection, this means that 95% of aquatic species should not experience sub-lethal or lethal effects directly resulting from exposure to pesticides present in that waterbody. It also means that 5% of aquatic species would be expected to experience some effects, such as reduced population levels, reduced growth or reduced reproduction. Importantly, a value of 95% does not necessarily mean that 5% of species would experience deaths, rather, 5% of species could experience adverse sub-lethal effects.

In the above example it will be the most sensitive 5% of species that would experience adverse effects. What organisms are the most sensitive depends on the type of pesticides that they are exposed to. This occurs because pesticides are designed to kill or inhibit the growth, reproduction, photosynthesis or some other crucial biochemical pathway of 'pest' species. Ideally, they can kill the pest but have minimal effects on non-target species. Herbicides (including the PSII herbicides and other herbicide groups) are designed to kill plants and are therefore a risk to the most sensitive aquatic species are algae and aquatic plants (including seagrass and coral). In contrast, insecticides are designed to kill insects and are therefore a risk to the most sensitive aquatic species are aquatic insects and other arthropods (e.g. crabs, lobsters, prawns and copepods) which are closely related to insects.

Generally, as pesticide concentrations increase the per cent of species that experience adverse effects will increase and the type of adverse effects experienced will change from sub-lethal to lethal and effects will move from affecting individuals to populations to communities or ecosystems.

Fish are relatively insensitive to herbicides and insecticides as they do not have the biochemical pathways that these pesticides affect. Therefore, based on the types and concentrations of pesticides currently being detected in the lower reaches of Great Barrier Reef catchments and the inshore marine ecosystems, it is unlikely that fish mortality or population decline would occur as a direct result of exposure to those pesticides. Rather sub-lethal effects could occur. For example, Kroon et al. (2013) found that barramundi and coral trout collected along the east coast of Queensland exhibited sub-cellular signals of endocrine disruption and the extent of this was related to the concentration of a number of pesticides in the water where the fish were collected. In contrast, the effects on aquatic plants (such as algae) are expected to be greater, because they are more sensitive to herbicides, and this has been shown by Wood et al. (2018) who found that as herbicide concentrations increased the number of sensitive algal species present in waterways decreased.

Even though the concentrations of pesticides may not be sufficiently high to kill fish, they may experience a range of indirect effects from being exposed to pesticides. Indirect effects could occur as a result of more sensitive organisms being affected and this in turn affecting fish. For example, aquatic plants are at the bottom of foodwebs and provide shelter for many other organisms, if their growth or numbers were reduced this would decrease the amount of food and shelter available for organisms, including fish, further up foodwebs. Instability in a foodweb can lead to increased vulnerability of an ecosystem to other stressors (e.g. disease) and decrease ecosystem resilience.

Care needs to be taken in interpreting the pesticide risk baselines and risk categories for the whole of catchments, regions and Great Barrier Reef, as individual catchments within these areas may have different pesticide risks. This is because the predicted pesticide risk baselines were estimated as though all the land, at the whole-of-catchment, region or Great Barrer Reef

[2] The period of exposure is termed chronic which means the organism is exposed to the pesticide for at least 10% of their lifespan. Thus the length of chronic exposure is different for different organisms. Examples af chronic durations are provided in Warne et al. (2018).

level, was drained by a single waterway that discharged at a single point. Thus, a natural resource management region consisting of three major catchments that each discharge to the Great Barrer Reef, could have an overall moderate risk but the major catchments could have risks of very high, moderate and very low. An example of this is the Burdekin natural resource management region which protects approximately 98% of aquatic species (Table 1) but the Haughton major catchment protects only 86% of aquatic species, while the other major catchments in the region protect at least 97% of species.

Pesticide risk baseline values for natural resource management regions and major catchments

At the whole Great Barrier Reef level the baseline value is 97% meaning that 97% of aquatic species should be protected from experiencing harmful effects from pesticides (Table 1). At the region level only one region (i.e. Cape York) currently meets the pesticide target (i.e. to protect at least 99% of species). The Wet Tropics, Burdekin, Fitzroy and Burnett Mary regions all have baseline values of 95% to 99% and therefore face a low risk from pesticides (Table 1). The Mackay Whitsundays region has a baseline value of 81 and faces a high risk from pesticides. All regions that do not currently meet the pesticide target need to decrease pesticide concentrations in order to increase the per cent of species they protect and meet the target by 2025.

All the major catchments in the Cape York region meet the pesticide target (Table 1). Other major catchments that met the pesticide target are the Daintree, Barron, Black, Burdekin, Don, Shoalwater, Waterpark and the Boyne. This translates to approximately 43% of the major catchments already meeting the pesticide target. Approximately another 23% of major catchments currently face a low risk from pesticides – these are the Ross, Styx, Fitzroy, Calliope, Baffle, Kolan, Burnett and Mary. While approximately a further 23% of major catchments face a moderate risk from pesticides – these being the Mossman, Mulgrave-Russell, Johnstone, Tully, Murray, Herbert, Proserpine and Burrum. Only two major catchments (~ a further 6%) face a high risk from pesticides – the Haughton and the O'Connell and two major catchments (~6%) face a very high risk from pesticides – the Pioneer and Plane.

The relative contribution of PSII herbicides, other herbicides and insecticides to the risk baseline falls into four categories: those dominated by PSII herbicides; those dominated by other herbicides; equally dominated by PSIIs and other herbicides; and similar dominance by other herbicides and insecticides (Table 1). The below description of which major catchments belong to these four groups does not include the 43% of major catchments that already meet the pesticide target. The group dominated by PSII herbicides is the largest and it includes 11 major catchments – the Mossman, Mulgrave-Russell, Johnstone, Tully, Murray, Herbert, Haughton, Proserpine, O'Connell, Pioneer and Plane. The second largest group is dominated by other herbicides that includes seven major catchments – the Ross, Fitzroy, Calliope, Kolan, Burrum and Mary. The group dominated equally by PSII and other herbicides includes two major catchments – the Styx and Burnett. There is only one major catchment where other herbicides and insecticides equally dominate – the Baffle. The main pesticide or pesticides contributing to the baseline values should be the focus of improving land management practices. Thus, for example in the Mossman, Mulgrave-Russell, Johnstone, Tully, Murray, Herbert, Haughton, Proserpine, O'Connell, Pioneer and Plane major catchments the focus should be on improving land management practices that will reduce the concentration of PSII herbicides in the waterways.

Explaining the differences in baseline values

The pesticide risk baseline values and risk categories for each natural resource management region and major catchment along with the relative contribution of PSII herbicides, other herbicides and insecticides are presented in Table 1. The per cent of species predicted to be protected in the Cape York region and all of its major catchments is greater than 99% indicating they face a very low risk from pesticides and meet the pesticide target. This is consistent with the low per cent of land requiring pesticide application. Rather the dominant land uses were conservation, forested grazing and open grazing. While large quanties of tebuthiuron are used in open grazing and enters adjacent waterways, based on the available data, it has a very low toxicity to aquatic plants and algae.

The Burdekin region is predicted to protect approximately 98% of species, however the Haughton major catchment was expected to only protect approximately 86% of species. This relatively low level of protection offered in the Haughton is related to it having nearly 20% of land devoted to sugar cane. The lower protection offered in the Haughton was offset by the other major catchments which are all predicted to protect over 97% of species reflecting the dominance of low pesticide using land uses including conservation and forested grazing and the low toxicity land use of open grazing. The protection provided in the Burnett Mary and Fitzroy regions (97% and 96% of species, respectively) are essentially the same as the Burdekin and they have similar land-use patterns.

The Wet Tropics region provides marginally less protection (i.e. 95%) as it has six major catchments that protect between 91% and 94% of aquatic species. These major catchments all are dominated by conservation land use but all also contain 10% to 15% sugar cane, which is partly offset by reductions in the amount of open and forested grazing.

The Mackay Whitsunday region is predicted to protect only 81% of species. The per cent of species being protected in the major catchments of the Mackay Whitsundays ranges from 71% to 91% and this decreases as the per cent of land used for sugar cane increases. The per cent of land used for sugar cane explains approximately 99% of the decrease in predicted levels of protection in the Mackay Whitsundays and approximately 84% of the decrease in predicted protection in the Wet Tropics. Importantly, a similar relationship also applies to the pesticide risk measured in monitored catchments.

Table 1. The pesticide risk baseline values and the corresponding risk category for 35 major catchments, six regions and the Great Barrier Reef with the per cent contribution to the pesticide risk by PSII herbicides, other herbicides and insecticides for the major catchment. Major catchments are arranged from north to south.

Natural resource management region or major catchment	Pesticide risk baseline (% species protected)	Improvement needed to meet Pesticide target (% species protected)	Pesticide Risk category[1]	Per cent contribution of pesticide groups to the per cent of species that should experience adverse effects		
				PSII herbicides	Other herbicides	Insecticides
Great Barrier Reef	97	2	Low	-	-	-
Cape York region	100	0	Very low	-	-	-
Jacky Jacky	100	0	Very low	65	28	7
Olive-Pascoe	100	0	Very low	59	25	16
Lockhart	100	0	Very low	50	24	26
Stewart	100	0	Very low	45	22	33
Normanby	100	0	Very low	2	41	57
Jeannie	100	0	Very low	52	21	27
Endeavour	100	0	Very low	3	21	76
Wet Tropics region	95	4	Moderate	-	-	-
Daintree	100	0	Very low	2	0	98
Mossman	91	8	Moderate	53	36	11
Barron	100	0	Very low	14	69	17
Mulgrave-Russell	91	8	Moderate	47	26	27
Johnstone	92	7	Moderate	50	32	18
Tully	93	6	Moderate	59	20	21
Murray	91	8	Moderate	63	23	14
Herbert	94	5	Moderate	61	22	17
Burdekin region	98	1	Low	-	-	-
Black	99	0	Very Low	0	97	3
Ross	97	2	Low	1	79	20
Haughton	86	13	High	61	34	5
Burdekin	99	0	Very Low	42	54	4
Don	100	0	Very low	9	73	18
Mackay Whitsunday region	81	18	High	-	-	-
Proserpine	91	8	Moderate	48	28	24
O'Connell	84	15	High	60	27	13
Pioneer	76	23	Very high	59	24	17
Plane	71	28	Very high	62	26	12

Natural resource management region or major catchment	Pesticide risk baseline (% species protected)	Improvement needed to meet Pesticide target (% species protected)	Pesticide Risk category[1]	Per cent contribution of pesticide groups to the per cent of species that should experience adverse effects		
				PSII herbicides	Other herbicides	Insecticides
Fitzroy region	96	23	Low	-	-	-
Styx	99	0	Very Low	48	50	2
Shoalwater	99	0	Very low	0	5	95
Waterpark	100	0	Very low	48	35	17
Fitzroy	96	3	Low	35	65	0
Calliope	98	1	Low	24	70	6
Boyne	99	0	Very low	17	21	62
Burnett Mary region	97	3	Low	-	-	-
Baffle	99	0	Very Low	16	47	37
Kolan	96	3	Low	19	56	25
Burnett	97	2	Low	51	43	6
Burrum	92	7	Moderate	34	60	6
Mary	95	4	Moderate	23	69	8

- = not determined. [1]. Very low risk = ≤ 1% species affected or ≥ 99% protected, low risk = > 1% to < 5% affected or >95% to < 99% species protected, moderate risk = 5% to < 10% species affected or > 90% to 95% protected , high risk = %10 to < 20% species affected or >80% to 90% species protected, very high risk = ≥ 20% species affected or ≤ 80% species protected.

Glossary

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 that specifically kills or inhibits 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 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.

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

msPAF: The multi-substance potentially affected fraction (msPAF) 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, 2018) 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).

Natural resource management 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, basin, 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 basins 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. The pesticide risk metric is a combination of a number of different methods – the msPAF method, 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.

Reef 2050 Long-Term Sustainability Plan: The Reef 2050 Long-Term Sustainability Plan (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 until 2050. 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.

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.

References

ANZECC/ARMCANZ (Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand) 2000, National Water Quality Management Strategy, Paper No. 4. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Volume 2. Aquatic Ecosystems – Rationale and Background Information (Chapter 8). ANZECC and ARMCANZ, Canberra, Australia.

ANZG (Australian and New Zealand Governments) 2018, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand governments and

Australian state and territory governments, Canberra, ACT, Australia. <www.waterquality.gov.au/anz-guidelines>

Australian and Queensland governments 2018, Reef 2050 Water Quality Improvement Plan 2017–2022, State of Queensland, Brisbane, Australia, pp. 56, <www.reefplan.qld.gov.au/about/assets/reef-2050-water-quality-improvement-plan-2017-22.pdf>

Australian and Queensland governments 2019, 'Pesticide Risk Baseline Methods, Reef Water Quality Report Card 2017 and 2018, Reef 2050 Water Quality Improvement Plan', *Paddock to Reef Integrated Monitoring, Modelling and Reporting program*, State of Queensland, Brisbane, Australia.

Kroon, F, Hook, SE, Jones, D, Metcalfe, S, Henderson, B, Smith, R, Warne, MStJ, Turner, RD, McKeown, A, Westcott, DA 2015, 'Altered transcription levels of endocrine associated genes in two fisheries species collected from the Great Barrier Reef catchment and lagoon', *Ocean & Coastal Management*, vol.104, pp. 51-61.

Traas TP, Van de Meent D, Posthuma L, Hamers T, Kater BJ, De Zwart D, Aldenberg, T 2002, The potentially affected fraction as a measure of ecological risk. In: Posthuma L, Suter II GW, Traas TP, editors. Species Sensitivity Distributions in Ecotoxicology. Boca Raton (FL), USA: Lewis Publishers. p 315–344.

Warne, MStJ, Batley, GE, van Dam, RA, Chapman, JC, Fox, DR, Hickey, CW and Stauber, JL 2018, Revised method for deriving Australian and New Zealand water quality guideline values for toxicants – update of 2015 version', *Prepared for the revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand governments, and Australian state and territory governments, Canberra, Australia, pp. 48, <www.waterquality.gov.au/anz-guidelines/Documents/warne-wqg-derivation2018.pdf>

Warne, MStJ, Neelamraju, C, Strauss, J, Smith, RA, Turner, RDR, Mann, RM *in prep*, 'Development of a Pesticide Risk Baseline for the Reef 2050 Water Quality Improvement Plan', State of Queensland, Brisbane, Australia.

Wood, RJ, Mitrovic, SM, Lim, RP; Warne, MStJ; Dunlop, J; Kefford, BJ 2019, 'Benthic diatoms as indicators of herbicide toxicity in rivers - a new SPEcies At Risk (SPEARherbicides) index', *Ecological Indicators*, vol. 99, pp. 203-213.