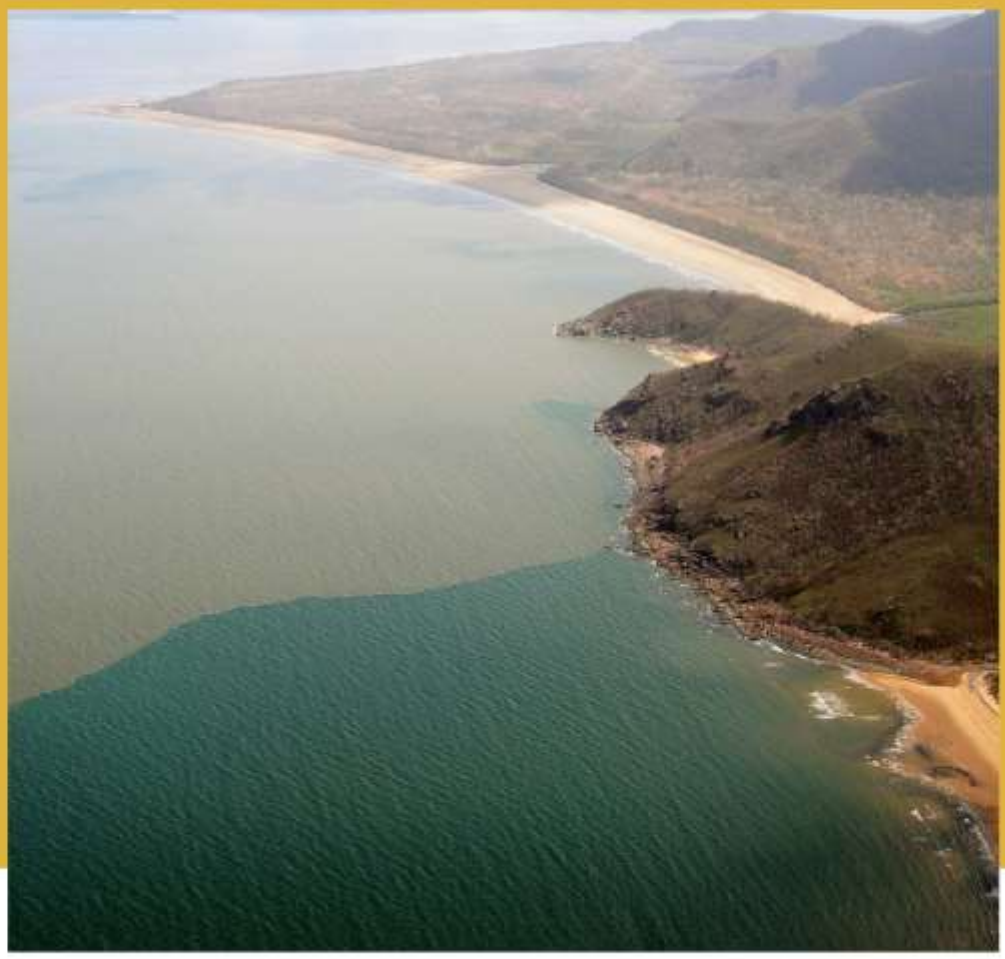
MARINE MONITORING PROGRAM



Annual Report for
INSHORE PESTICIDE MONITORING
2017-18

The University Of Queensland
AUSTRALIA

Queensland Alliance for
Environmental Health
Sciences

Australian Government
Great Barrier Reef
Marine Park Authority

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Front cover image Flood plume in Hinchinbrook Channel after Cyclone Yasi hit, on the 2nd February 2011. Photo by J Jones © Great Barrier Reef Marine Park Authority

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Comments and questions regarding this document are welcome and should be addressed to:

[1]Queensland Alliance for Environmental Health Sciences (QAEHS)
Incorporating the former National Research Centre for Environmental Toxicology (Entox)
The University of Queensland, 20 Cornwall St, Woolloongabba Qld 4102

[2] The Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER),
Catchment to Reef Processes Research Group, James Cook University, Townsville, Qld 4811

This project is supported by the Great Barrier Reef Marine Park Authority through funding from the Australian Government Reef Program, the Australian and Queensland governments Reef 2050 Integrated Monitoring and Reporting Program, the University of Queensland and James Cook University.

Project Team - Inshore Marine Water Quality Monitoring – Christie Gallen[1], Phong Thai[1], Chris Paxman[1], Pritesh Prasad[1], Gabriele Elisei[1], Tim Reeks[1], Geoff Eagleshamr[1], Ruby Yeh[1], Jochen Mueller[1]

Project Team - Assessment of Terrestrial Run-off Entering the Reef: Christie Gallen[1], Phong Thai[1], Chris Paxman[1], Gabriele Elisei[1], Pritesh Prasad[1], Tim Reeks[1], Geoff Eagleshamr[1], Ruby Yeh[1], Jochen Mueller[1], Jane Waterhouse[2], Stephen Lewis[2], Dieter Tracey[2], Caroline Petus[2]

Contents

List of figures and tables

Appendices: List of figures and tables

Common acronyms, abbreviations and units

Acronym	Detail
2,4-D	2,4-Dichlorophenoxyacetic acid
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG 2018	Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
Authority	Great Barrier Reef Marine Park Authority
%CV	per cent coefficient of variation
C_W	Concentration in water
DES	Department of Environment and Science (formerly DSITI)
DSITI	Department of Science, Information Technology and Innovation
EC_x	x per cent maximal effective concentration is observed
ED	Empore Disk^{TM} passive sampler
GBRCLMP	Great Barrier Reef Catchment Loads Monitoring Program
GBRMPA	Great Barrier Reef Marine Park Authority
GC-MS	Gas Chromatography-Mass Spectrometry
GPC	Gel Permeation Chromatography
GV	Guideline value
IC_x	x per cent of the maximal inhibitory concentration is observed
IWL	Interim working level
K_{OW}	Octanol-water partition coefficient
LC_x	x per cent of the lethal concentration is observed
LC-MS/MS	Liquid Chromatography-Tandem Mass Spectrometry
LOD	Limit of Detection
LOR	Limit of Reporting
MCPA	2-methyl-4-chlorophenoxyacetic acid
MMP	Marine Monitoring Program
ms-PAF	Multi-substance potentially affected fraction
NOEC	No Observed Effect Concentration
PDMS	Polydimethylsiloxane passive sampler
PFM	Passive/Plaster Flow Monitor
PSII-HEq	Photosystem II Herbicide Equivalent Concentration
PTFE	Polytetrafluoroethylene : Common brand name - Teflon
QAEHS	Queensland Alliance for Environmental Health Sciences (formerly Entox)
QA/QC	Quality Assurance/Quality Control
QHFSS	Queensland Health Forensic & Scientific Services
RPF	Relative Potency Factor
Reef 2050 WQIP	Reef 2050 Water Quality Improvement Plan
SOP	Standard Operation Procedure
SSD	Species sensitivity distribution

Note that the term pesticide is used to refer collectively to the group of insecticides, herbicides and fungicides.

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Executive Summary

This component of the Marine Monitoring Program provides an understanding of nearshore pesticide profiles and the exposure risk to marine organisms, as a part of water quality condition on the Great Barrier Reef.

Data are collected from eleven fixed monitoring sites located in four Natural Resource Management regions – the Wet Tropics (five sites at Low Isles, High Island, Normanby Island, Dunk Island and Lucinda), Burdekin (one site at Barratta Creek), Mackay Whitsundays (four sites at Repulse Bay, Round Top Island, Sandy Creek and Sarina Inlet) and Fitzroy (one site at North Keppel Island).

Sites are selected using several criteria, including being adjacent to areas of high pesticide usage on the catchment area, serviceability, likelihood of intercepting flood plumes during wet season river flow events and the safety of the site from public interference. The long-term monitoring data generated from these sites, aims to link changes in land-based agricultural activities (as a result of management initiatives) and how pressures such as catchment rainfall, river discharge and pesticide loads influence trends in marine pesticide concentrations.

Pesticide monitoring data is collected using two sampling techniques – passive and grab sampling. Two types of passive samplers are deployed at the fixed monitoring sites that allow the accumulation of pesticides from the water into the sampling device over a given deployment time. Using estimates of water flow at each site and uptake rates measured during laboratory calibration experiments, an average concentration in the water for accumulated pesticides are estimated for a deployment period (typically one month during the wet season, and two months during the dry season). Passive sampler extracts are analysed for a suite of thirty pesticides across two passive sampler types that target pesticides of varying water solubility:

- Empore Disks™ accumulate relatively water soluble pesticides
- Polydimethylsiloxane samplers accumulate less water soluble pesticides.

Grab samples are also taken during periods of high freshwater river discharge in the wet season to provide a single ‘point in time’ concentration of pesticides in water and capture potential peaks in pesticide concentration. This year sampling followed transects extending from the Russell-Mulgrave and Tully rivers (Wet Tropics region), and out from Barratta Creek in the Burdekin region.

The suite of pesticides monitored includes photosystem II (PSII) inhibiting herbicides (such as diuron, atrazine (and its metabolites), ametryn, hexazinone, tebuthiuron) which all affect photosynthesis, and are commonly detected due to their high usage in adjacent catchments. Other pesticides monitored include those that have non-photosynthetic effects (such as imidacloprid and metolachlor) and knockdown herbicides (such as 2,4-D) used increasingly as alternatives to the PSII herbicides.

Pesticide concentration data are evaluated in two ways:

- Individual estimates of concentration are checked against relevant water quality guidelines and exceedances noted;
- Measured concentrations in a given sample are assessed against a pesticide exposure risk metric which predicts the percentage of photosynthetic species that may be affected by mixtures of PSII herbicides detected. The risk metric used is the multi-substance potentially affected fraction.

A range of pesticides were detected at all monitoring sites in 2017–18. In line with previous monitoring years, diuron, atrazine and hexazinone were the most frequently detected and abundant of the pesticides at most sites, reflecting their high usage in sugar cane cultivation, which is located along much of the Great Barrier Reef coastline. Maximum concentrations of these three herbicides (778 ng L^{-1}, 405 ng L^{-1} and 134 ng L^{-1}) all occurred at Round Top Island (Mackay Whitsunday region), which typically experiences the highest pesticide concentrations of this monitoring program.

Region-specific differences in pesticide profiles have emerged over time. Diuron typically dominates the pesticide profile at sites located in the Wet Tropics and Mackay Whitsundays regions, atrazine (and its metabolites) dominates the profile at Barratta Creek (Burdekin region) and tebuthiuron is almost exclusively detected at North Keppel Island (Fitzroy region).

No individual exceedances of the current marine trigger values (i.e. water quality guideline values) were detected although these values are undergoing a review. Assessment against the proposed aquatic ecosystem protection guideline values (levels determined to protect 99 per cent of marine species) would however result in two instances of exceedance, both from passive samplers located at Round Top Island, in the Mackay Whitsunday region and both for diuron: 778 and 531 compared to the proposed value of 430 ng L^{-1}. If these values are adopted, the pesticide exposure risk at this site will be interpreted higher.

Also consistent with historical data, monitoring sites located in the Mackay Whitsunday region experienced the greatest risk of toxic effects due to pesticide exposure. Conversely, the Wet Tropics have consistently been at low risk, likely due to a number of factors such as higher average rainfall and river runoff (and greater dilution of pesticide concentrations) as well as the adjacent catchment area being less developed for agriculture. Grab sampling within both these regions indicated that elevated concentrations were localised near river mouths and, assuming conservative mixing processes, these concentrations decreased with increasing distance from the river mouth.

When pesticide mixture concentrations are assessed with the risk metric, all sites in the Wet Tropics (five sites) and at North Keppel Island (one site) met the desired very low risk: protective of 99 per cent of species (i.e. less than 1 per cent of species are affected) in 2016-17 and 2017-18. Remaining sites, other than Round Top Island (i.e. Barratta Creek, Repulse Bay, Sandy Creek, and Sarina Inlet) had a mix of very low risk: protective of 99 per cent of species (i.e. less than 1 per cent of species are affected) and low risk: protective of >95 per cent but <99 per cent of species (or 1 to <5 per cent of species affected). Although at Repulse Bay (2016–17) and Sandy Creek (2017–18) limited samples were obtained due to

sampler losses and deployment issues. No data is available for Normanby Island for 2016–17.

Round Top Island returned samples across all risk categories:

- Very low risk: protective of 99 per cent of species (i.e. less than 1 per cent of species are affected) – four samplers
- Low risk: protective of >95 per cent but <99 per cent of species (or 1 to <5 per cent of species affected) – one sampler
- Moderate risk: protective of >90 per cent but <95 per cent of species (or 5 to <10 per cent of species affected) – two samplers
- High risk: protective of >80 per cent but <90 per cent of species (or 10 to <20 per cent of species affected) – two samplers
- Very high risk: protective of ≤80 per cent of species (or ≥20 per cent of species potentially affected) – one sampler.

Pressures (i.e. rainfall and subsequent river discharge from rivers influencing passive sampler sites) affecting the release of pesticides into the Reef lagoon were highly localised this year. In the northern regions (Wet Tropics and Burdekin), rainfall was above average in the dry season, and the annual river discharge was high compared to the previous monitoring year (for the fourth consecutive year). Further south, the Mackay Whitsunday and Fitzroy regions experienced below-average wet season rainfall, and river discharge in both regions was also significantly lower than the previous year, which was influenced by high rainfall associated with cyclone Debbie.

Although no exceedances of current guidelines were detected, maximum pesticide concentrations at almost all fixed monitoring sites were higher than the previous monitoring year. At Round Top Island, the maximum pesticide concentration monitored this year was the highest recorded of any site since the Marine Monitoring Program commenced in 2005.

Given the high inter- and intra-annual climatic and other pressure variability, meaningful trend comparisons require a long term and complete monitoring dataset. Only five of the fixed monitoring sites have sampling records that predate 2009 and no trends have been detected yet. A statistical investigation of the data has commenced to assess the ability of the program to trace the effectiveness of the Reef 2050 Water Quality Improvement Plan.

1. Introduction

The Great Barrier Reef World Heritage covers an area of 348,000 km^2, extending 2000 kilometres along Queensland's coast and from the low water mark along the mainland coast up to 250 kilometres offshore (UNESCO, 1981). Thirty-five major rivers within a combined coastal catchment area of over 400,000 km^2 discharge into the Great Barrier Reef lagoon (Brodie et al., 2003). Poor quality water entering the Reef lagoon as run-off from adjacent catchments has, however, been identified as a key pressure on the Reef's long-term health and resilience (Reef Plan, 2013). Other key pressures include climate change, crown-of-thorns starfish, coastal development, shipping and fishing (GBRMPA, 2014a; Hairsine, 2017).

1.1 Pesticide monitoring in the Marine Monitoring Program

In response to concerns about the impact of land-based run-off on water quality, the 2003 Reef Water Quality Protection Plan (Reef Plan) was implemented by the Australian and Queensland governments and updated in 2009 and 2013 (Reef Plan, 2009, 2013). In response to unprecedented pressures such as the mass coral bleaching events in 2016 and 2017 and severe cyclone Debbie in 2017, the review of the Reef Plan was brought forward to 2017 to ensure its continued effectiveness, which culminated in the current version of Reef Plan, known as the Reef 2050 Water Quality Improvement Plan (Reef 2050 WQIP) (Australian and Queensland governments, 2018).

A key difference of the pesticide targets in the Reef 2050 WQIP is the move away from a target to reduce end-of-catchment pesticide loads, to a new target of protecting at least 99% of aquatic species at the end-of-catchments by 2025. The active engagement of communities and land owners to implement agricultural best management practices to reduce pesticide run-off from agricultural land use is expected to deliver this target and the larger objective of improved ecosystem health.

To monitor the progress towards Reef 2050 WQIP targets, the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef Program) collects and integrates data and information on the paddock-catchment-marine environments adjacent to and within the Marine Park (Paddock to Reef, 2013).

The Marine Monitoring Program (MMP) is the component of the Paddock to Reef Program that covers monitoring of the Reef's inshore environment, and is a collaborative effort between the Australian Government and several research groups. The program aims to assess long-term changes (trends) in the condition of inshore water quality, and link this to changes in the health of key inshore environments (coral reefs and seagrass) (GBRMPA, 2011).

The specific objectives of the 2017–18 pesticide monitoring component of the MMP were to:

- monitor and assess trends in inshore concentrations of pesticides against water quality guideline values relevant to the Marine Park
- link inshore concentrations of pesticides and their transport to end of catchment loads.

1.2 The structure of this Report

The next section presents a summary of the program's methods. Section 3 addresses the factors influencing pesticides delivered to marine waters, referred to as drivers and pressures in the Driver-Pressure-State-Impact-Response framework (Figure 1). The state, or condition and trend of pesticide contamination of marine waters is presented in Section 4, with historical monitoring data at selected sites since 2005. Results are described by Region in Section 0. Further details provided at the regional scales and in the supporting Appendices. The reports concludes with a discussion, including management relevance.

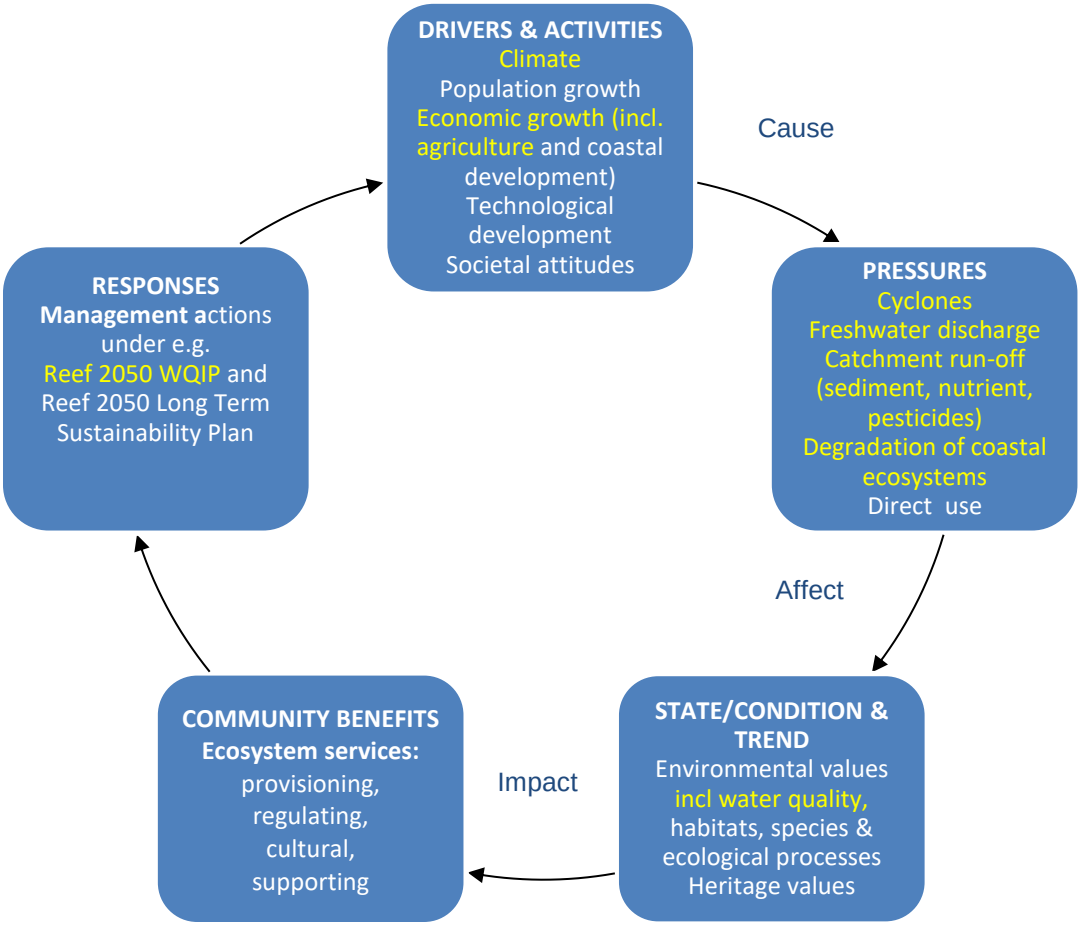


Figure 1: DPSIR framework used to guide the structure of the report, derived from the Great Barrier Reef Strategic Assessment (GBRMPA, 2014b). The aspects highlighted in yellow are included in this report.

2. Methods

2.1 Overview

Pesticide monitoring was conducted at fixed (long-term) monitoring sites using passive samplers: a time-integrated sampling technique that provides a time-averaged estimated concentration. The passive samplers accumulate chemicals into a sorbing material from water via passive diffusion over a month or more. The passive samplers used in this program include:

- SDB-RPS Empore^{TM} Disk (ED) polar passive samplers for relatively hydrophilic organic chemicals with relatively low octanol-water partition coefficients (log K_{OW}) such as the PSII herbicides (e.g. diuron).
- Polydimethylsiloxane (PDMS) non-polar passive samplers for organic chemicals that are relatively more hydrophobic (higher log K_{OW}) such as organophosphorus insecticides (e.g. chlorpyrifos).

In addition to the long-term pesticide levels assessment, flood plume monitoring was conducted during the wet season using both passive sampling (configured for deployments <7 days) and grab sampling. Full details regarding these methodologies have been described in the *Marine monitoring program quality assurance and quality control manual 2017–18* (GBRMPA, 2019) and in previous reports (Gallen et al., 2013; Gallen et al., 2014; Gallen et al., 2016; Grant et al., 2017; Kennedy et al., 2012).

2.2 Study area and sampling sites

2.2.1 Fixed monitoring sites (passive samplers)

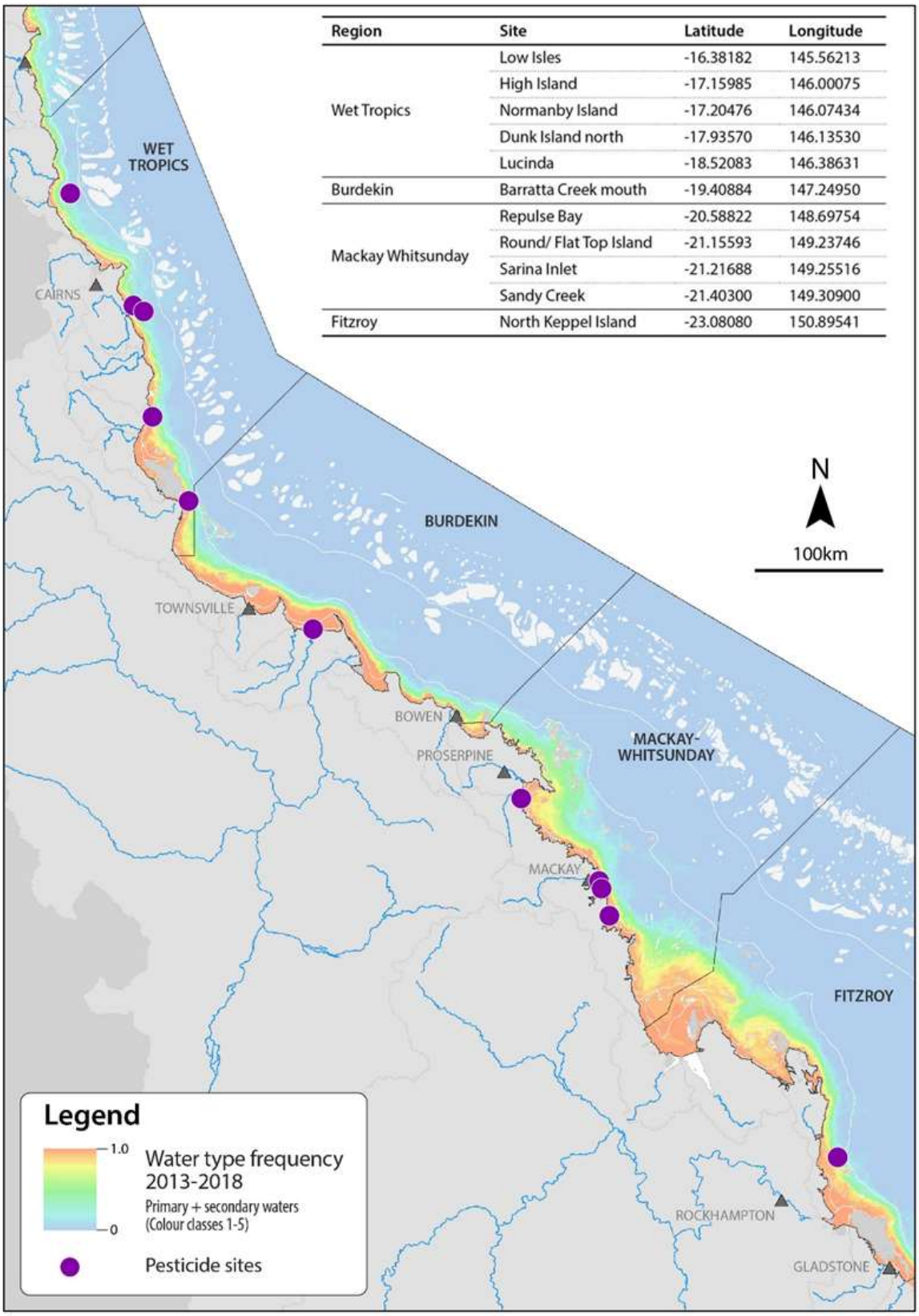
Based on criteria outlined in previous reports (Grant et al., 2017), eleven inshore Reef sites have been monitored since 2014-15, including five sites monitored since at least 2009 (Table 1). Sites are located within the expected extent of flood plumes from rivers that drain a variety of land uses on the adjacent catchment areas and discharge into the Reef lagoon (Table 1). Of the 11 sites monitored for pesticides, three (Low Isles, Dunk Island, and Sarina Inlet) are also seagrass monitoring sites under other elements of the MMP (McKenzie et al., 2017). Five sites (Low Isles, High Island, Normanby Island, Dunk Island and North Keppel Island) are nearby to monitored coral reefs (Thompson et al., 2017).

Fixed sampling sites in the Wet Tropics region in 2017-18 were at Low Isles, High Island, Normanby Island, Dunk Island and Lucinda (Figure 2).

There is one sampling site in the Burdekin region in 2017-18 at Barratta Creek mouth (Figure 2), which was established in 2014.

Sampling sites in the Mackay Whitsunday region in 2017-18 were Repulse Bay, Round Top Island, Sandy Creek and Sarina Inlet (Figure 2).

The one site in the Fitzroy region is at North Keppel Island (Figure 2).



Region	Site	Latitude	Longitude
Wet Tropics	Low Isles	-16.38182	145.56213
	High Island	-17.15985	146.00075
	Normanby Island	-17.20476	146.07434
	Dunk Island north	-17.93570	146.13530
	Lucinda	-18.52083	146.38631
Burdekin	Barratta Creek mouth	-19.40884	147.24950
Mackay Whitsunday	Repulse Bay	-20.58822	148.69754
	Round/ Flat Top Island	-21.15593	149.23746
	Sarina Inlet	-21.21688	149.25516
	Sandy Creek	-21.40300	149.30900
Fitzroy	North Keppel Island	-23.08080	150.89541

Figure 2: Locations of fixed monitoring sites where time-integrated passive sampling of pesticides occurred in 2017-18. Sites are overlaid on the 2003 – 2018 water type frequency map (for more information see Section 2.5.3). Grey triangles indicate towns. (Source – Dieter Tracy, James Cook University)

Table 1: Location of fixed passive sampling sites, closest influencing river and date that sampling first commenced

NRM region	Basin	Major River/ Creek	Fixed site name	Sampled since	Approx. distance from river mouth (km)
Wet Tropics	Mossman	Mossman River	Low Isles	Aug-2005	18
	Mulgrave-Russell	Mulgrave River/ Russell River	High Island	May-2015*	8.0
			Normanby Island	Jul-2005	11
	Tully	Tully River	Dunk Island	Sep-2008	13
	Herbert	Herbert River	Lucinda	Jul-2014	12
Burdekin	Burdekin	Barratta Creek	Barratta Creek mouth	Mar-2014	1.5
Mackay Whitsunday	Proserpine O'Connell	Proserpine River O'Connell River	Repulse Bay	Sep-2014	12 3.3
	Pioneer Plane	Pioneer River Sandy Creek	Round Top Island	Sep-2014	5 9
	Plane	Sandy Creek	Sandy Creek	Sep-2014	8.6
		Plane Creek	Sarina Inlet	May-2009	2.8
Fitzroy	Fitzroy	Fitzroy River	North Keppel Island	Aug-2005	50

* High Island was reintroduced to the sampling program in 2015–16 after its discontinuation in 2008.

2.2.2 Flood plume (transect) monitoring ('event' passive sampler and grab sampling)

Terrestrial run-off assessments, i.e. flood plume monitoring, have been conducted in past monitoring years along transects extending from river mouths during discharge events in two or three Natural Resource Management regions with a high risk from pesticide exposure. The locations and timing of the flood plume sampling changes annually, as it is event-driven and requires a rapid response.

In 2017–18, flood plume monitoring was undertaken along transects extending from the mouths of two rivers in the Wet Tropics region – the Tully and Russell-Mulgrave rivers (Figure 3, Appendix G Table G-1). Both transects have been sampled in previous monitoring years, with the Tully transect first sampled in 2010 and the Russell-Mulgrave transect first sampled in 2013.

Four event passive samplers were deployed at Dunk Island North in the Wet Tropics for between four and five days in an effort to capture short-term pulses in pesticide concentrations during periods of freshwater discharge.

Grab samples were collected at Barratta Creek mouth within the Burdekin focus area during early-season discharge events by the James Cook University (JCU) Inshore Marine Water Quality team (Figure 3).

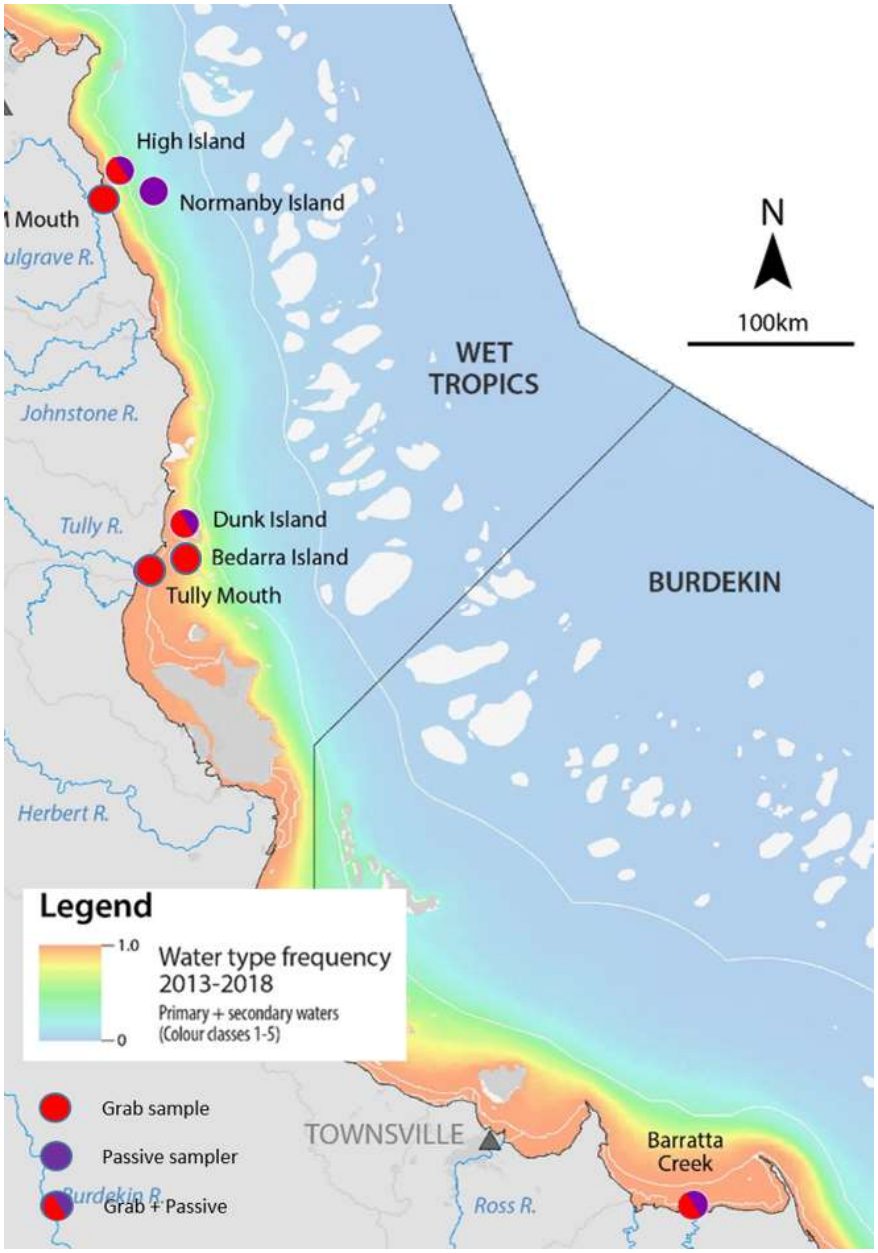


Figure 3: Locations of grab (flood plume monitoring) and passive samplers (fixed monitoring) collected on the Russell-Mulgrave River transect, and Tully River transect. Sampling sites are overlaid on a colour-scale representing the water type frequency of flood plumes for 2003-2018. Maps edited from those provided by Dieter Tracey, James Cook University (JCU).

2.3 Sampling approaches

Details of the techniques for passive and grab sampling are given in the *Marine Monitoring Program quality assurance and quality control manual 2017/2018 (GBRMPA, 2019)*. An overview of the sampling periods and types of samples collected is given below, with additional details in Appendix A.

2.3.1 Passive sampling (fixed monitoring sites) to establish long-term trends

Pesticide monitoring at fixed monitoring sites is reported for the year to 30 April 2018. The year is divided into "Dry 2017" (May 2017 to October 2017) and "Wet 2017-18" (November 2017 to April 2018) sampling periods for reporting purposes.

During dry sampling periods, passive samplers are typically deployed for two months at a time (maximum of three deployment periods each monitoring year), and for one month at a time during wet sampling periods (maximum of six deployment periods within each monitoring year). Time integrated concentrations are reported that reflect the average concentration over the actual period of deployment. The maximum number of samples obtained from each location in the monitoring year is nine.

Table 2: The types of passive samplers deployed at each fixed monitoring site in 2017-18.

Region	Site	EDs (polar)		PDMS (non-polar)	
		Dry	Wet	Dry	Wet
Wet Tropics	Low Isles	✓	✓	✗	✗
	High Island	✓	✓	✗	✗
	Normanby Island	✓	✓	✗	✗
	Dunk Island	✓	✓	✗	✗
	Lucinda	✓	✓	✗	✗
Burdekin	Barratta Creek Mouth	✓	✓	✗	✓
Mackay Whitsunday	Repulse Bay	✓	✓	✗	✓
	Round Top Island	✓	✓	✗	✓
	Sandy Creek	✓	✓	✗	✓
	Sarina Inlet	✓	✓	✗	✓
Fitzroy	North Keppel Island	✓	✓	✗	✗

All eleven fixed sites were monitored in both the Dry 2017 and Wet 2017-18 sampling periods using EDs (Table 2), targeting polar pesticides (see Table A-2 for a list of the polar pesticides in the passive sampler analysis suite). Due to losses of samplers, three sites (Normanby Island, Repulse Bay and Round Top Island) had only one successful dry season deployment. Five sites also had PDMS samplers deployed during the Wet 2017-18 sampling period (Table 2), targeting non-polar pesticides (see Table A-3 for a list of the non-polar pesticides in the passive sampler analysis suite).

PDMS samplers were co-deployed with the EDs in the Burdekin region (one site) and the Mackay Whitsunday region (four sites) (Table 2). These two regions were chosen for targeting non-polar pesticides based on their high proportions of sugar cane land use relative to other regions, and the high pesticide risk assigned to these regions (Brodie et al., 2013). The deployment dates and results for each fixed monitoring site are in Appendix F Table F-2 to Table F-12.

2.3.2 Grab sampling to assess flood plume (transect) profiles

Sampling activities targeting discharge events from major Reef basin rivers occurred during the Wet 2017-18 sampling period, and typically coincided with large rainfall events in the

adjacent basin area. Grab samples (250 mL) were collected along transects extending from river mouths to capture peak concentrations and establish the presence of any pesticides not adequately sampled by passive samplers (e.g. due to their high water solubility).

Forty-one grab samples were collected in 2017–18. Thirty-five were collected to monitor terrestrial run-off from the two river transects (the Tully and Russell-Mulgrave rivers) during flood plume events between January and March 2018 (Figure 3). A further six grab samples were collected from the Burdekin focus area at Barratta Creek mouth during major discharge events in both the dry and wet season. Further details for these samples including the date of collection and results for individual pesticides detected are provided in Appendix G Table G-1.

2.3.3 Sampler deployment and approaches for missing data

This monitoring year, 75 per cent of fixed site passive sampler sets sent to volunteers were successfully deployed, returned (undamaged) and analysed (Appendix F Table F-1). This return rate was comparable to the two previous years (75 and 73 per cent). The remainder of samplers were unsuccessful for several reasons but were typically because of a lost mooring following bad weather, human interference (e.g. theft of mooring) or *in situ* damage (e.g. membrane lost or fouled). Four sites (Dunk Island, High Island, Lucinda, and North Keppel Island) returned at least eight out of nine sampling kits. Once again, the sites located in the Mackay Whitsunday region experienced the highest sampler losses. Following a year of no sampling activity at Normanby Island in 2016-17, this site was successfully re-established, although only one dry season sampler was successfully returned this monitoring year.

For sites with lower successful deployment rates, trend comparisons with previous years are generally not possible, and care needs to be taken when comparing between the monitoring sites. Details on deployment procedures and approaches for data interpretation when samplers are not/ cannot be deployed or are lost are given in Appendix A: A-1.

2.4 Pesticide analyses and reporting QA/QC

2.4.1 Target pesticides

The list of target pesticides included in this report and their rationale for inclusion are given in Appendix A: A-2 and Table A-4.

2.4.2 Instrument analyses and quality assurance quality control (QA/QC)

Analysis of non-polar pesticides using Gas Chromatography-Mass Spectrometry (GC-MS) and polar pesticides using Liquid Chromatography-tandem Mass Spectrometry (LC-MS/MS) was conducted at Queensland Alliance for Environmental Health Sciences (formerly Entox) (QAEHS). Further analytical details are given in Appendix A.

Quality assurance quality control (QA/QC) includes the extraction and analysis of replicate ED samplers (i.e. to test the variability in the overall performance (chemical uptake) of the EDs). Duplicate analysis of 24 ED samplers and four grab samples resulted in mean coefficients of variation for replicates ranging from 3.3% to 55% Table A-1).

Blanks were extracted and analysed with every batch of samples. Most pesticides were below the limit of detection (LOD) in batch blanks. Where blank values were detected, sample concentrations in that batch that were less than 3 times the blank value were excluded from summary statistics and are shown with a "<" in the data tables in Appendix F .

The LOD for the LC-MS/MS instrument data are defined as follows: LODs are determined by adding a very low level of analyte to a matrix and injecting nine times into the instrument. The standard deviation of the resultant signals is obtained and a multiplication factor of three is applied to obtain the LOD. Values below the LOD are defined as non-detects (n.d.) in all tables in this report. The limit of reporting (LOR) is defined as three times the LOD. Values above LOD but below LOR are shown in the tables in this report in italics. Whilst there is some uncertainty regarding the accuracy of these relatively low concentrations, to be conservative, these values are included in summary statistics and multi-substance potentially affected fraction (ms-PAF) values and thus represent the worst-case scenario.

2.4.3 Calculating the pesticide concentrations

Once the concentrations of pesticides in the extract were measured, they are converted to a time-integrated concentration in water (ng L^{-1}) using an in-situ derived sampling rate R_S (L/day). In-situ sampling rates were derived using passive flow monitors (PFMs) deployed in duplicate alongside the passive samplers (O'Brien et al., 2011a). The R_S for atrazine and prometryn were directly predicted from the average in-situ flow velocity (m/s) estimated by the rate of loss of plaster from the PFMs during the deployment period based on data from previous calibration studies (O'Brien et al., 2011a; O'Brien et al., 2011b). The sampling rates of all other contaminants were either predicted from average ratios for the R_S of the target contaminant to that of atrazine based on a number of calibration studies (including for analogous contaminants for which no calibration data exist) or the sampling rate of atrazine was assumed (when no calibration data were available for analogous contaminants).

At present, there are limited passive sampler calibration data available for many of the other pesticides now in use in Reef basins. Some pesticides (e.g. the herbicide asulam) are highly water soluble and unlikely to accumulate in passive samplers, and therefore grab sampling may increase the probability of detecting them in the marine environment. Calibration studies in the field are labour intensive; however, they may need to be considered in the future to better understand the uptake of these chemicals into passive samplers, and more accurately estimate water concentrations.

2.5 Data analyses and reporting metrics

2.5.1 Water quality guideline values (GVs)

A key aim of this program is to compare measured concentrations of pesticides to current guideline values for chemicals in marine waters.

The Australian and New Zealand water quality guidelines (see Appendix B for more details) for freshwater and marine ecosystems are recently revised (DoE, 2016; Warne et al., 2015; Warne et al., 2018). For the purposes of this report, monitoring data are compared against the ANZECC and ARMCANZ guidelines however, pesticide concentrations that exceed the

proposed aquatic ecosystem protection guideline values (PGV), which are still undergoing endorsement, are highlighted.

PGVs for 28 pesticides for freshwater and marine ecosystems have been determined using species sensitivity distributions (SSD) by the Department of Environment and Science (DES). All these guidelines will be submitted for consideration for national endorsement and inclusion into the Australian and New Zealand Water Quality Guidelines (King et al., 2017b; King et al., 2017c). If endorsed, they will supersede the current Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA, 2010) In advance of endorsed PGVs being released, ecotoxicity threshold (ET) values for diuron, ametryn, hexazinone and simazine in marine waters (PC99, 95, 90, 80) have recently been published (King et al., 2017a; King et al., 2017c; Warne et al., 2018).

Due to the high ecological value of the Reef, PC99 values are relevant to this ecosystem, and are required by Great Barrier Reef Marine Park Authority water quality guidelines (GBRMPA, 2010). The published ETs and the PGVs for 24 other pesticides submitted for endorsement and relevant to the current monitoring period, are detailed in Appendix B (Table B-1).

2.5.2 Risk assessment metric

Up until the 2016–2017 monitoring year, the Photosystem II Herbicide Equivalent Concentration (PSII-HEq) Index (based on diuron equivalent concentrations) has been used to assess ecological risk of mixtures of 13 PSII herbicides & metabolites for MMP reporting (for detailed information about this method see (Grant et al., 2018). This index defines ranges of PSII-HEq that equate with different levels of effect (based on published toxicity data using Reef relevant species). The index included only the five priority PSII herbicides – ametryn, atrazine, diuron, hexazinone and tebuthiuron.

In this current report, an alternative risk assessment metric, the ms-PAF method has been proposed as a more relevant approach to quantify the overall ecological risk of mixtures of pollutants for ecological communities. The ms-PAF method allows the effect of multiple pesticides on an ecosystem to be estimated by determining the potentially affected fraction of species (i.e. percentage of species that will theoretically be affected when exposed to a given mixture). The ultimate aim is to report a single assessment end point (PAF) for all monitored pesticides detected in the MMP program (further information on the ms-PAF metric and its application for this report is in Appendix C).

Marine results are not directly comparable with the end-of-catchment results primarily due to differences in sampling. However, they provide insight into the transport and fate of pesticides, from the end of rivers to marine sites, and the risk to marine ecosystems from the mixture of pesticides. The key differences are:

- three of the pesticides are not analysed for in the marine samples (i.e. 19 of the 22 pesticides analysed at the end of catchment are analysed for in marine samples)
- passive sampler results are reported here and grab samples are used at end of catchment
- an area under the curve mathematical calculation is used to extrapolate end of catchment mixtures to a wet season single outcome and is not applied here for the marine samples.

The missing pesticides may mean that the mixture toxicity would be higher. The three pesticides not currently analysed for are fipronil, isoxaflutole, and triclopyr. Of these three pesticides, only isoxaflutole will regularly occur in freshwater catchments (i.e. in Mackay Whitsunday catchments) at concentrations that exceed draft ecosystem protection guidelines for protection of 99% species (0.33 µg L^{-1}) (King et al. 2017a). Even so, the highest concentration recorded during 2017–18 was 1.7 µg L^{-1} (in water collected from Sandy Creek in Mackay Whitsunday) and is unlikely to contribute significantly to overall pesticide toxicity in inshore marine waters (Great Barrier Reef Catchment Loads Monitoring Program, pers comm). Fipronil has a very low draft ecosystem protection guidelines for protection of 99% species (0.0034 µg L^{-1}) (King et al. 2017b), and is below the limit of reporting for samples collected as part of routine analyses by Great Barrier Reef Catchment Loads Monitoring Program (0.02 µg L^{-1}). However, where more sensitive analysis methods are used the concentrations detected (if detected at all) were very low and again unlikely to contribute significantly to overall pesticide toxicity in inshore marine waters.

Passive samplers integrate pesticide concentrations over the time of their deployment so they represent a portion of the wet season, not the full season. Given there is a range of risk reported across the deployments, averaging for the season would likely result in a reduced overall score. In the coming years we will explore methods to increase the comparability. In the interim, we are reporting the ms-PAF value for the deployment with the highest concentrations (and highest ms-PAF scores).

2.5.3 Mapping the frequency and extent of flood plumes (water type frequency maps)

River flood plumes are the primary vehicles that deliver basin-derived pollutants to the Reef lagoon. The Marine Water Quality component of the MMP maps the frequency and extent of (surface) ‘water types’ associated with flood plumes (Waterhouse et al., 2017b; Waterhouse et al., 2018). Weekly water type colour class data were recorded for each of the fixed monitoring sites for the wet season (details provided in 0Table E2). Site maps presented in this report overlay the water type frequency maps to indicate sampling site positions relative to primary and secondary flood plume occurrences. The information on colour classes inform the likelihood of a passive sampling site to encounter a flood plume and how often and for how long it may be impacted by plume waters.

Further information on how plumes are characterised is given in Appendix E, Section E.1.

2.5.4 Other data sources (weather, rainfall)

This report utilises supporting data including:

- Land use
- Hydrological data

Those data were sources from GBRMPA (2014a), DNRM http://watermonitoring.dnrm.qld.gov.au/host.htm, and DNRM Stream Gauging Network.

3. Drivers and pressures influencing pesticide concentrations during 2017–18

Agricultural land use, as well as multiple paddock-scale pressures relating to pesticide usage, together with cyclones, rainfall and freshwater river discharge, collectively influence the end-of-catchment pesticide loads discharged to the Reef lagoon. Other sources of pesticide are the result of urban and industrial activities (GBRMPA, 2014b), although the relative contribution of these sources is not known.

3.1 Land use

A wide range of land uses occur in the Reef basins, with great diversity between Natural Resource Management regions (Figure 4).

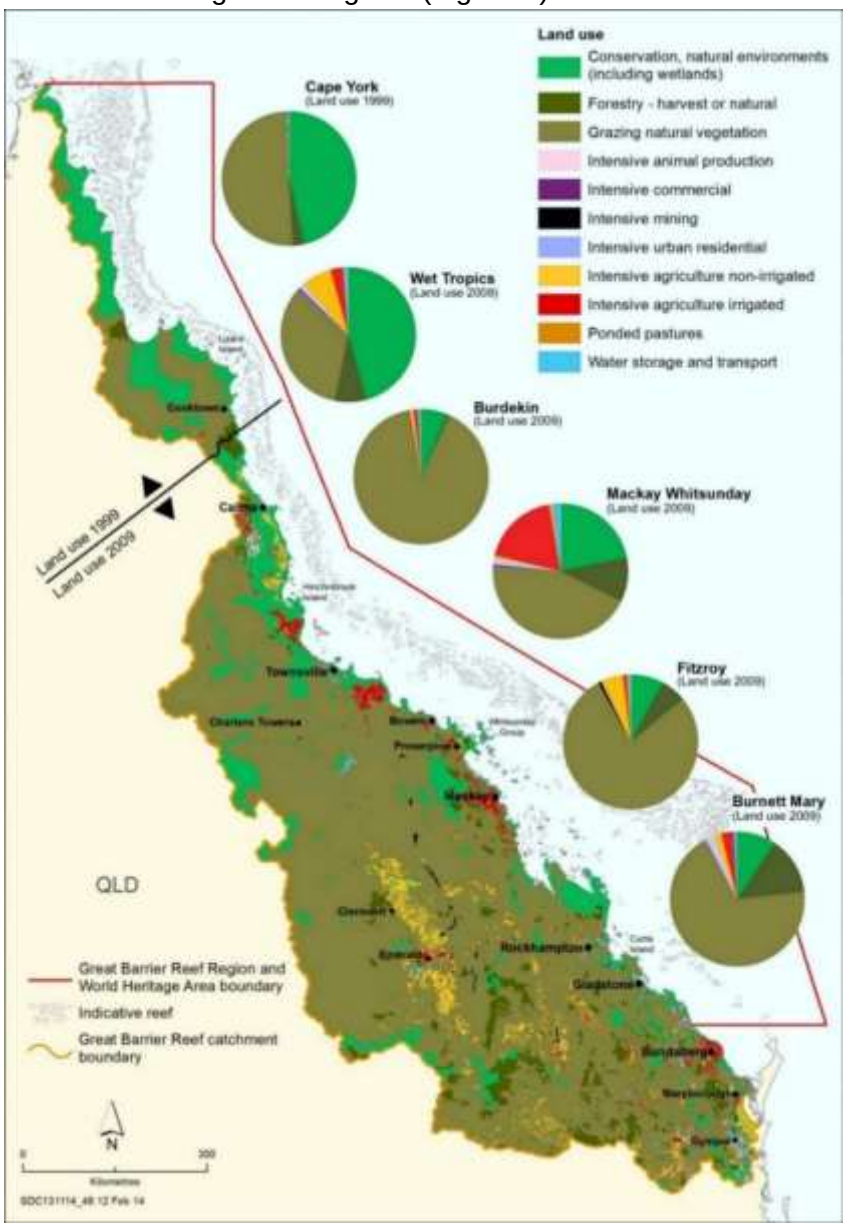


Figure 4: Land use in the Reef basins. Sourced from GBRMPA (2014a)

Land use in the Reef's basins varies from being largely undeveloped in the far north, to agriculture, mining, and urban uses in the central and southern regions. In total, 80 per cent of the Reef basins support agricultural activities with cattle grazing the most extensive land use, particularly in the drier Burdekin and Fitzroy regions where 90 per cent and 77 per cent, respectively, are grazed (DSITIA, 2012a, b).

- The Wet Tropics region encompasses eight basin areas, covering approximately 2.2 million hectares (ABS, 2010).
- The Burdekin region spans five basins and covers 14 million hectares, of which 90 per cent is used for agricultural purposes, with grazing primarily inland and some sugar cane and horticulture along the coast (ABS, 2010; DSITIA, 2012b).
- The Mackay Whitsunday region is the smallest Natural Resource Management region, spanning four basins with an area of approximately 900,000 hectares (ABS, 2010). This region is dominated by grazing, which comprises 30 – 60 per cent of the region's land use depending on the basin basin, and the sugar cane industry, which comprises 6 – 50 per cent of the region's land use (DSITIA, 2012d).
- The Fitzroy region spans six basins and covers an area of 15.6 million hectares (ABS, 2010). Cattle grazing is the most prevalent industry (78 per cent of the land use), with broad acre cropping (five per cent of the land use) and cotton farming also present (DSITIA, 2012a).

The Wet Tropics and Mackay Whitsunday regions also have grazing activities (31 per cent and 42 per cent, respectively); however other uses such as nature conservation (49 per cent of land use in the Wet Tropics) and irrigated cropping (sugarcane) (18 per cent of land use in the Mackay Whitsunday) are also significant (DSITI, 2016; DSITIA, 2012d).

The range of land uses results in point and diffuse sources of pesticides from a variety of human activities. Certain regions and/or smaller coastal basins may represent areas of higher localised risk of pesticide run-off due to the intensity and nature of agricultural activities (such as sugar cane cropping) occurring in coastal areas (Brodie et al., 2013).

Although land-use is well characterised in the Reef basins, limited data on pesticide usage are available and models are used to extrapolate for estimates of run-off of pesticides from the different land use areas to a wider range of basin conditions and to also investigate the impact of management options (Shaw et al., 2011).

3.2 Hydrological conditions in the Reef basins

The magnitude of releases is also highly influenced by weather conditions and most run-off is delivered in short-lived flood events during the wet season, forming distinct flood plumes that sometimes disperse far into the lagoon (Devlin and Schaffelke, 2009). An overview of the rainfall and cyclonic activity, and associated river discharge, for the Reef region is given in the following three sections. These data provide a general understanding of the climatic and flow conditions experienced in Reef basins in 2017-18 and allow broad comparisons with previous years. Regional monitoring data are presented in the context of individual rivers' hydrographs (river flow rates over time).

3.2.1 Cyclones

No cyclones influenced the Reef in 2017-18 and only one cyclone occurred in 2016–17 (cyclone Debbie), which passed through the Mackay Whitsunday region.

In the 11 years since the MMP began in 2006–07, ten cyclones have been Category 3 or above and have affected the health of the Reef.

3.2.2 Rainfall

Annual rainfall across the central and southern Reef basins and Cape York was at or below the wet season averages in 2017–18 (Figure 5), whilst the Wet Tropics basins (Mossman to Herbert) recorded above average rainfall. This is in contrast to the previous monitoring year when the central and southern basins experienced higher than average rainfall, largely due to cyclone Debbie. The first significant rainfall event (i.e. weekly rainfall >100mm) occurred in the Wet Tropics in early January 2018 and continued until late March (Table 4). Rainfall events did not occur until late February in the Mackay Whitsundays region, which experienced a second significant rainfall event in late March. Neither the Burdekin or Fitzroy regions recorded weekly rainfall >100mm for the entire wet season but recorded moderate rainfall events over the month of February (see 0for more details).

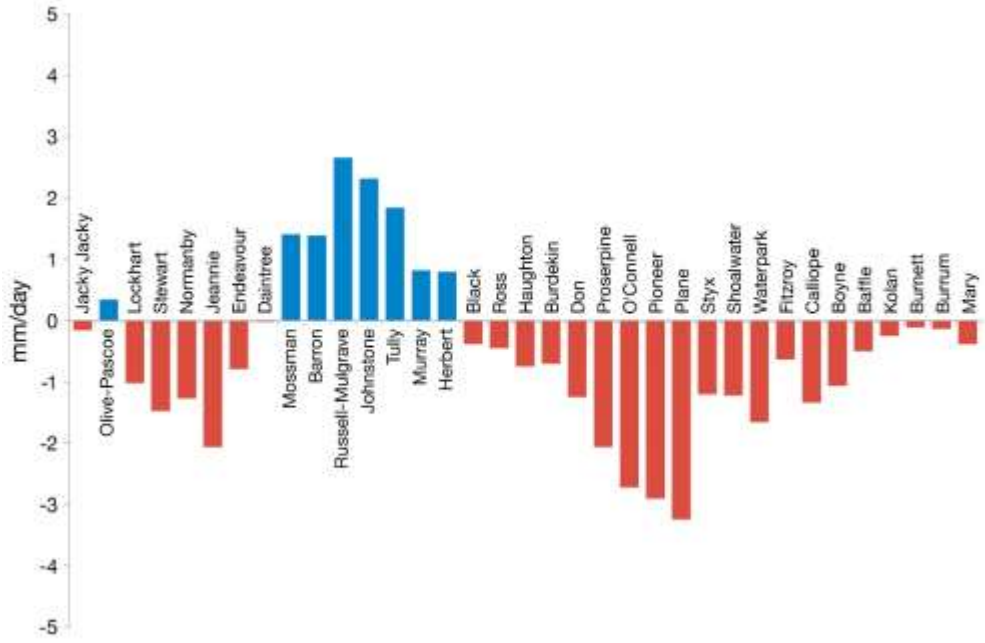


Figure 5: Annual average wet season rainfall (December 2017 - April 2018), as compared to the long-term wet season rainfall average (1961 – 1990). Red and blue bars denote basins with rainfall below and above the long-term average, respectively. Basins are ordered from north to south (left to right). Figure is extracted from Gruber et al 2019.

Table 3: Weekly mean basin rainfall (mm) in basins adjacent to fixed passive sampler sites during the 2017-18 wet season (beginning 1 December 2017). Data provided by Dieter Tracey, JCU

		w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12	w13	w14	w15	w16	w17	w18	w19	w20	w21	w22
Region	**Catchment**	01-Dec-17	08-Dec-17	15-Dec-17	22-Dec-17	29-Dec-17	05-Jan-18	12-Jan-18	19-Jan-18	26-Jan-18	02-Feb-18	09-Feb-18	16-Feb-18	23-Feb-18	02-Mar-18	09-Mar-18	16-Mar-18	23-Mar-18	30-Mar-18	06-Apr-18	13-Apr-18	20-Apr-18	27-Apr-18
Wet Tropics	Mossman	27.5	0.8	3	10	1	53	70	125	47	225	6	52	76	244	247	14	554	6	7	38	1	11.3
	Mulgrave-Russell	26.5	1.5	6.7	1.2	1	112	233	198.7	112	366	24	60	92	296	410	89	505	24	10	71	5	39.0
	Tully	30.3	3.6	3	0	14	56	127	111.4	84	298	17	107	109	354	309	87	410	21	18	79	5	54.0
	Herbert	29.4	4.6	0.4	1	22	24	39	40	44	115	4	78	128	172	181	32	180	12	3	9	1	12.6
Burdekin	Burdekin	21.8	5.4	0	3.2	15	12	11	2.2	18	41.5	1.0	52	88.1	37	17	7	30	9	4.8	4.5	0.4	0.8
Mackay Whitsunday	Proserpine	67.4	0.9	0	0	7	8	13	17.8	22	58	2.6	60	197	20	21	35	125	111	16.2	45.4	1	3.7
	O'Connell	92.1	1.8	0	1	6	16	7	28.8	61	66.6	3	56	138	38	18	22	94	132	20.2	32.2	1	6.0
	Pioneer	90.6	3.7	0	0	6	13	2	19	37	68.7	2	52	83.5	42	11	8	74	124	25	25.5	1	7.3
	Plane	68.9	3.9	0.5	0	20	7	1	15.4	35	53.0	3	92	106	19	16	11	102	91	19	14.1	1	9.3
Fitzroy	Fitzroy	38.7	6.0	0.0	8	33	12.0	1	0.4	5	68.8	2.5	69	41.7	22	1	1	9	5	1.1	5.4	2.3	0.8

Low 0.0 mm — 50th percentile — **High** >400 mm

Colour gradient: Red indicates the highest value, yellow represents the 50th percentile and green represents the lowest value.

3.2.3 River discharge

Rivers located in the northern basins typically flow year-round, whereas rivers located in the drier southern basins only flood periodically following large rain events during summer (Larson et al., 2013; Lewis et al., 2006). The differences in the timing, duration and intensity of rainfall between the northern and southern Reef basins contribute to the pattern of pesticide discharge to the marine environment.

Total annual discharge of freshwater (based on corrected gauge values for the hydrological year) into the Reef lagoon in 2017-18 was equal to the long term median discharge over the last 15 years (Figure 6). Despite this close to median discharge, total discharge from rivers located in the Wet Tropics and Burdekin were the highest recorded in the previous three years (Figure 7).

With the exception of the Herbert River, all regions where passive or grab sampling sites were located in 2017-18 had annual discharge close to or less than the long term median (an average of 0.76 times the median) (Table 4).

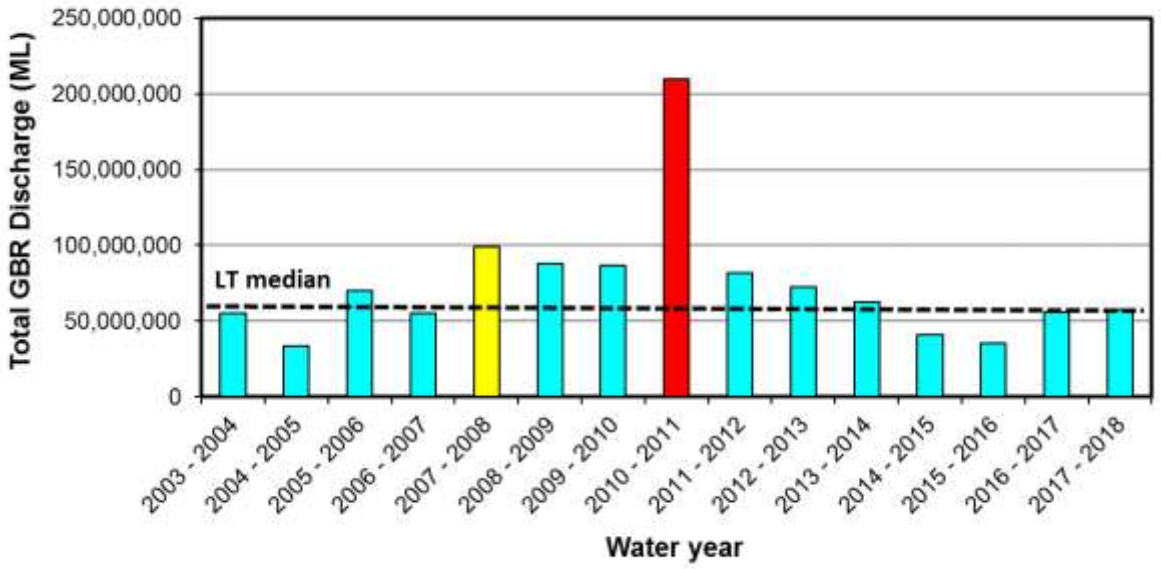


Figure 6: Long-term total annual discharge (ML) (hydrological year: 1 October to 30 September) for the 35 main Reef river basins. Blue indicates <1.5 times the median, orange indicates 1.5 to 2 times the median and red indicates >2 times the median Data derived from DNRM http://watermonitoring.dnrm.qld.gov.au/host.htm. Figure is extracted from Gruber et al 2019.

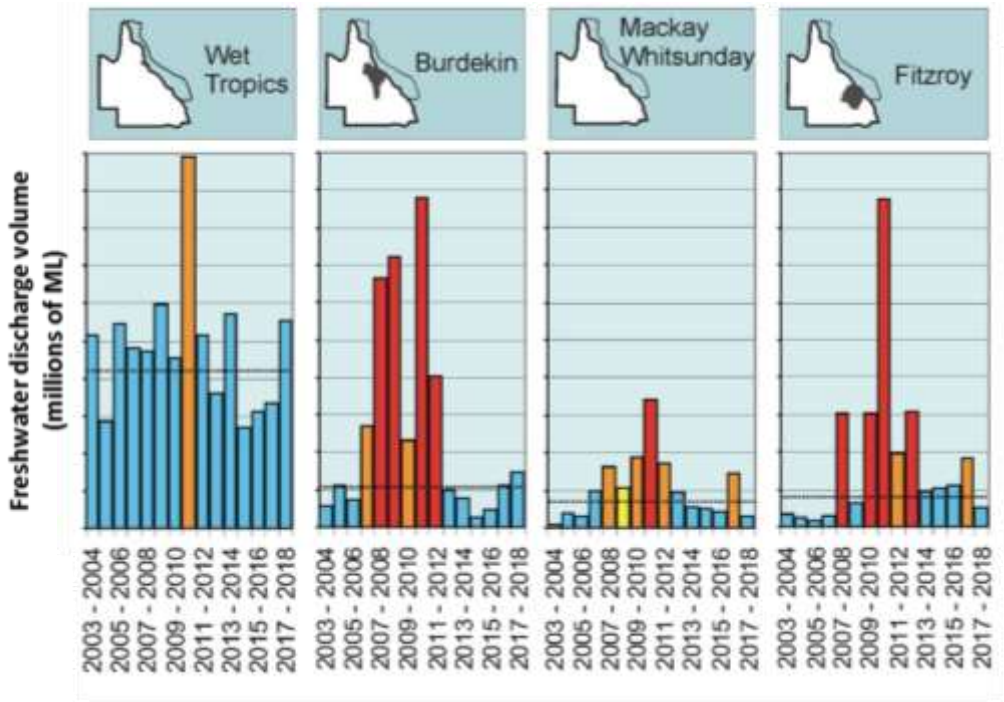


Figure 7: Corrected annual hydrological/water year (1 October to 30 September) discharge from each NRM region (using the correction factors in Table 2-2 (Waterhouse et al., 2018)) for 2002–03 to 2017–18 in millions of megalitres per year. Dot line is the long-term median discharge for each NRM; blue indicates <1.5 times the median, orange indicates 1.5 to 2 times the median and red indicates >2 times the median. Data derived from DNRM http://watermonitoring.dnrm.qld.gov.au/host.htm and figure provided by Steve Lewis, JCU.

Table 4: 2017-18 annual discharge (ML) of the major Reef basin rivers adjacent to passive sampling sites (1 October to 30 September 2018, inclusive) compared to the long term (LT) median discharge. Relative discharge (fraction of long-term median) are shown

Region	Site	2017–18 annual discharge (ML)	LT median annual discharge (ML)	Relative discharge (fraction of long-term median)					
				2012 - 2013	2013 - 2014	2014 - 2015	2015 - 2016	2016 - 2017	2017 - 2018
Wet Tropics	Mossman	1,503,754	1,207,012	1.0	1.6	0.7	1.0	0.9	1.2
	Mulgrave-Russell	5,759,716	4,457,940	0.8	1.2	0.7	0.7	0.7	1.3
	Tully	4,237,041	3,536,054	0.9	1.2	0.8	0.8	0.9	1.2
	Herbert	6,385,655	3,556,376	0.9	1.2	0.3	0.5	0.6	1.8
Burdekin	Burdekin	5,542,306	4,406,780	0.8	0.3	0.2	0.4	0.9	1.3
Mackay Whitsunday	Proserpine	543,452	887,771	1.0	0.8	0.2	0.4	1.9	0.6
	O'Connell	487,713	796,718	1.0	0.8	0.2	0.4	1.9	0.6
	Pioneer	249,530	776,984	1.5	0.8	2.6	0.8	1.8	0.3
	Plane	273,639	1,052,831	1.9	0.7	0.2	0.8	2.5	0.3
Fitzroy	Fitzroy	954,533	2,852,307	3.0	0.6	0.9	1.3	2.2	0.3

Colours highlight years for which river flow exceeded the median annual flow as estimated from available long-term time series for each river: yellow = 1.5 to 2-times LT median, orange = 2 to 3-times LT median, red= >3-times LT median. Discharge data were supplied by DNRM and corrected by Waterhouse et al. (2018) for different placements of gauges within each basin. The full dataset from which these data were derived is given in 0

3.2.4 End-of-basin pesticide monitoring

Systematic monitoring has identified that pesticide contamination in the rivers, streams and estuaries that drain into the Reef marine environment is widespread (Brodie et al., 2012), with the highest levels around Mackay (Brodie et al., 2013). In some cases, pesticide concentrations have been elevated above Australian and New Zealand Water Quality Guideline (2000) trigger values in basins adjacent to intensive agricultural activity (DSITI, 2015; O'Brien et al., 2016; Smith et al., 2012).

Forty-three pesticides and metabolites were monitored in 34 basins (comprising both end-of-basin and sub-basin sites) under GBRCLMP (Huggins et al., *in prep*). Samples were collected at regular intervals throughout the year (typically monthly) during low-flow (ambient) conditions and higher frequency sampling during high-flow (event) conditions.

4. Pesticides detected in marine waters

4.1 Frequency of pesticide detections

Thirteen PSII herbicides (including terbuthylazine for the first time this monitoring year) and two metabolites of atrazine (DE atrazine and DI atrazine) were included in the sample analysis suite of the polar passive sampler extracts. Of these fifteen compounds, thirteen were detected at one or more of the marine monitoring sites (Figure 8).

Consistent with previous years, the most commonly detected PSII herbicides (indicated in blue) were diuron, atrazine, and hexazinone (each detected in 88% of samplers). Conversely, prometryn and terbutryn were not detected at any site (LOD = 0.54 and 0.55 μg L^{-1}, respectively).

Of the eleven other pesticides (non-PSII) in the ED analysis suite (indicated in green in Figure 8), all were detected at measurable levels, with detection frequencies ranging between 3% (fluroxypyr) and 88% (metoloachlor) of samplers.

All five non-polar pesticides (indicated in yellow) were detected in the PDMS samplers, with detection frequencies ranging between 33% (trifluralin) and 100% (propazine) of samplers (Figure 8).

It is noted that the detection frequency information should be considered together with the return rate of the passive samplers. In this monitoring year, 75% of fixed site passive sampler sets sent to volunteers were successfully deployed, returned (undamaged) and analysed (Appendix F, Table F-1).

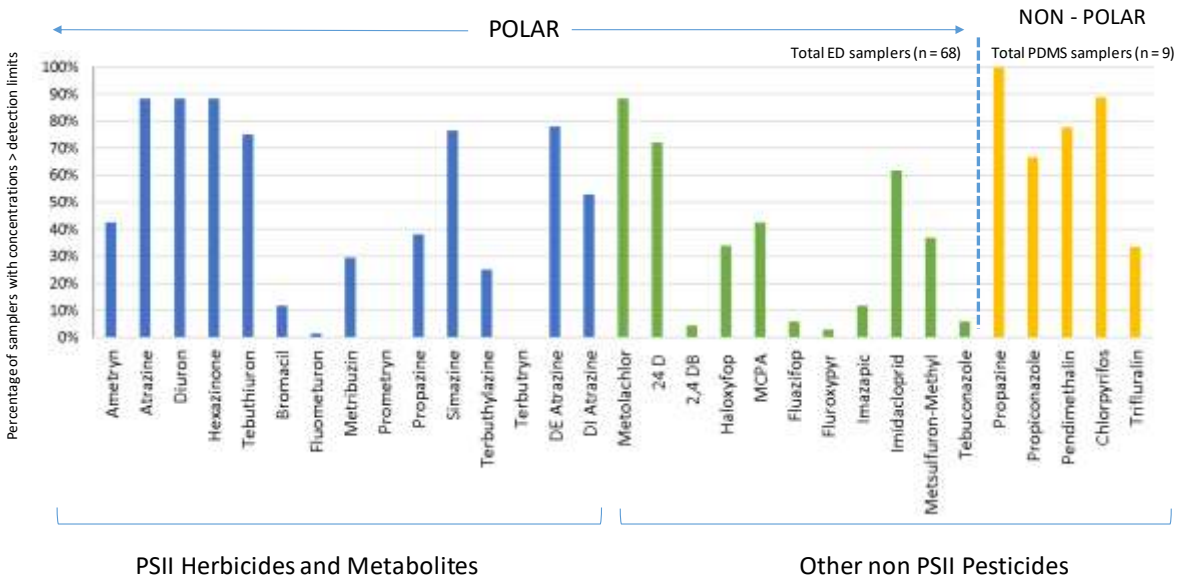


Figure 8: Percentage of ED and PDMS samplers that had measurable pesticide levels (i.e. above the limit of detection, LOD) for each pesticide included in this study, out of a total of 68 ED samplers and 9 PDMS samplers returned in 2017-18 (Table F-1, Appendix F). Blue: PSII herbicides; Green: Other pesticides; Yellow: non-polar pesticides

4.2 Summary of pesticide concentrations in 2017–18

The PSII herbicides detected at the highest concentrations in 2017–18 were also the most frequently detected, with maximum concentrations (C_{max}) of:

- diuron 778 ng L^{-1}
- atrazine 405 ng L^{-1}
- hexazinone 134 ng L^{-1}.

All of these were detected at Round Top Island (Table 5), approximately five and nine km from the Pioneer River and Sandy Creek mouths respectively, in the Mackay Whitsunday region. This site also experienced the highest concentrations of these same PSII herbicides in the previous monitoring year (Grant et al., 2018).

Other PSII herbicides, including DE atrazine, tebuthiuron and simazine were also frequently detected (>70% of samplers), although most often at much lower concentrations (typically <5 ng L^{-1}), with the highest concentration being 32 ng L^{-1} of DE atrazine (also at Round Top Island).

Similar to the previous monitoring year, the non-PSII pesticides 2,4-D, imidacloprid and metolachlor were consistently detected across the sampling sites (>60% of samplers), although at lower concentrations compared to the PSII herbicides with the maximum concentrations (C_{max}) of:

- 2,4-D 8.1 ng L^{-1}
- imidacloprid 42 ng L^{-1}
- metolachlor 28 ng L^{-1}.

When pesticide mixture concentrations are assessed with the risk metric results are variable. All sites in the Wet Tropics and at North Keppel Island met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected). Remaining sites, other than Round Top Island (i.e. Barratta Creek, Repulse Bay, Sandy Creek, and Sarina Inlet) had a mix of very low risk: protective of 99% of species (i.e. less than 1% of species are affected) and low risk: protective of >95% but <99% of species (or 1 to <5% of species affected). At Repulse Bay (2016–17) and Sandy Creek (2017–18) only one and zero wet season samples were obtained, respectively due to sampler losses and deployment issues. No data is available for Normanby Island for 2016–17.
Round Top Island had samples returned across all categories (Appendix F):

- Very low risk: protective of 99% of species (i.e. less than 1% of species are affected) - four
- Low risk: protective of >95% but <99% of species (or 1 to <5% of species affected) – one deployment from 6/12/2017 to 22/1/2018
- Moderate risk: protective of >90% but <95% of species (or 5 to <10% of species affected) – two deployment from 15/2/2018 to 15/3/2018 and 15/3/2018 to 12/4/2018
- High risk: protective of >80% but <90% of species (or 10 to <20% of species affected) – one deployment from 22/1/2018 to 15/2/2018
- Very high risk: protective of ≤80% of species (or ≥20% of species potentially affected) – one deployment from 7/11/2017 to 6/12/2017

The PSII-HEq Max was also calculated for all sites (ranging from 6.4 – 901 ng L^{-1}) of which the highest concentration also corresponded to the highest risk Category 1 on the Index:

- Category 1 (published demonstrated effects on the growth and death of aquatic plants and animals exposed): one site
- Category 2 (published scientific observations of reduced photosynthesis for three coral species): no sites
- Category 3 (published scientific observations of reduced photosynthesis for two seagrass species and three diatoms): two sites
- Category 4 (published scientific observations of reduced photosynthesis for two diatoms): four sites
- Category 5 (no published demonstrated ecosystem effects): four sites.

Both risk metrics indicate that the Round Top island site located in the Mackay Whitsunday region is exposed to elevated risk of pesticide exposure, compared to other sites.

4.3 Comparison to guideline values

No individual exceedances of the current marine trigger values (i.e. water quality guideline values) were detected but it is noted these values are undergoing a review. The current ANZECC and ARMCANZ trigger value for diuron is 1800 ng L^{-1} (a low reliability interim working value) and the Authority's PC99 (protective concentration values that will protect 99% of the species) is 900 ng L^{-1} (Table B-1). Under both these guidelines, the Round Top Island diuron values are not an exceedance. Note that there are no existing PC99 or trigger values for imidacloprid.

Applying the proposed values under review (levels determined to protect 99% of marine species), there would be two instances of exceedance, both from passive samplers located at Round Top Island, in the Mackay Whitsunday region and both for diuron: 778 and 531 compared to 430 ng L^{-1}.(King et al., 2017a). Until endorsed, comparisons with this proposed value are provided only for consideration.

4.4 Comparison to previous years: trends in pesticide concentrations

The 2017–18 Cmax values for diuron and imidacloprid were in a similar range to those detected in 2016–17 (580 and 53 ng L^{-1}, respectively) when PGV exceedances also occurred. With the exception of Normanby Island (no sampling in 2016-17) and Sandy Creek (unreliable sampling in 2017–18), the 2017–18 C_{max} were generally similar to or higher than results from 2016–2017 (Grant et al., 2017).

The ms-PAF and PSII-HEq Max values assessments both find Round Top Island is the highest risk site (Figure 10 and Figure 11). Barratta Creek, Sandy Creek and Sarina Inlet return lower risk categories with the new mixture assessment. (Note that trend comparisons for sites most recently introduced to the program as well as sites that experience higher than average sampler losses should be interpreted with particular caution due to limited data).

Table 5: Maximum detected time integrated (or chronic) pesticide concentrations at each fixed passive sampling site. % of species affected values are colour-coded according to their risk category. Shaded pesticides indicate that no calibration data is available and the sampling rate of atrazine was assumed.

		Concentration PSII herbicides (ng/L)													Concentration other herbicides/ pesticides (ng/L)												
Region	Passive sampling site	Ametryn*	Atrazine*	Diuron*	Hexazinone*	Tebuthiuron*	Bromacil*	Fluometuron*	Metribuzin*	Prometryn*	Propazine*	Simazine*	Terbuthylazine	Terbutryn*	% Species Affected	DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
Wet Tropics	Low Isles	n.d.	1.9	6.7	1.8	0.24	n.d.	n.d.	n.d.	n.d.	n.d.	0.46	n.d.	n.d.	3.81	0.43	0.07	0.13	0.21	n.d.	0.03	n.d.	n.d.	n.d.	n.d.	1.0	n.d.	n.d.
	High Island	n.d.	2.8	24	6.8	0.03	n.d.	n.d.	0.06	n.d.	n.d.	n.d.	n.d.	n.d.	7.75	0.11	n.d.	0.51	1.1	n.d.	0.10	0.09	n.d.	n.d.	n.d.	2.5	n.d.	n.d.
	Normanby Island	n.d.	1.8	6.3	1.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	n.d.	n.d.	3.62	0.14	n.d.	0.12	0.09	n.d.	0.03	n.d.	n.d.	n.d.	n.d.	0.30	n.d.	n.d.
	Dunk Island	n.d.	5.2	28	7.4	0.20	n.d.	n.d.	0.20	n.d.	0.03	3.0	n.d.	n.d.	8.36	0.35	n.d.	0.26	1.4	n.d.	0.10	0.03	n.d.	n.d.	n.d.	2.43	n.d.	n.d.
	Lucinda	n.d.	9.4	7.9	2.3	0.06	n.d.	n.d.	n.d.	n.d.	0.05	0.51	n.d.	n.d.	4.15	0.46	0.11	0.51	0.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.22	n.d.	n.d.
Burdekin	Barratta Creek	7.9	309	10	0.98	0.95	0.60	n.d.	1.03	n.d.	1.9	0.83	n.d.	n.d.	6.03	16	1.8	28	4.6	n.d.	0.60	1.8	n.d.	n.d.	n.d.	0.38	0.50	0.01
Mackay Whitsundays	Repulse Bay	0.20	9.6	22	11	2.6	0.47	n.d.	0.09	n.d.	0.12	0.19	0.10	n.d.	9.00	3.7	1.1	1.9	2.2	n.d.	0.06	0.19	n.d.	n.d.	0.39	8.5	0.07	n.d.
	Round Top Island	3.8	405	778	134	1.1	n.d.	n.d.	42	n.d.	2.3	2.1	0.68	n.d.	34	32	6.2	16	8.1	n.d.	n.d.	3.9	n.d.	n.d.	3.9	41.95	0.72	n.d.
	Sandy Creek^	n.d.	3.0	10	3.8	0.55	n.d.	n.d.	n.d.	n.d.	0.04	1.9	n.d.	n.d.	4.50	0.62	0.16	0.50	0.22	n.d.	n.d.	n.d.	n.d.	n.d.	0.00	<0.17	0.05	n.d.
	Sarina Inlet	0.46	27	60	27	1.8	n.d.	n.d.	0.07	n.d.	0.18	0.37	0.47	n.d.	10.0	0.81	n.d.	1.8	0.52	n.d.	n.d.	0.09	n.d.	n.d.	n.d.	0.62	n.d.	n.d.
Fitzroy	North Keppel Island	n.d.	0.56	6.1	0.45	0.20	n.d.	n.d.	n.d.	n.d.	n.d.	0.23	n.d.	n.d.	4.21	n.d.	n.d.	0.24	0.26	n.d.	n.d.	0.19	n.d.	n.d.	n.d.	0.21	n.d.	n.d.

n.d. = maximum concentration did not esceed the limit of detection

^Note only 2 successful sampling periods

Concentration range: Lowest — 50th percentile — Highest

Risk category: Very High | High | Moderate | Low | Very Low

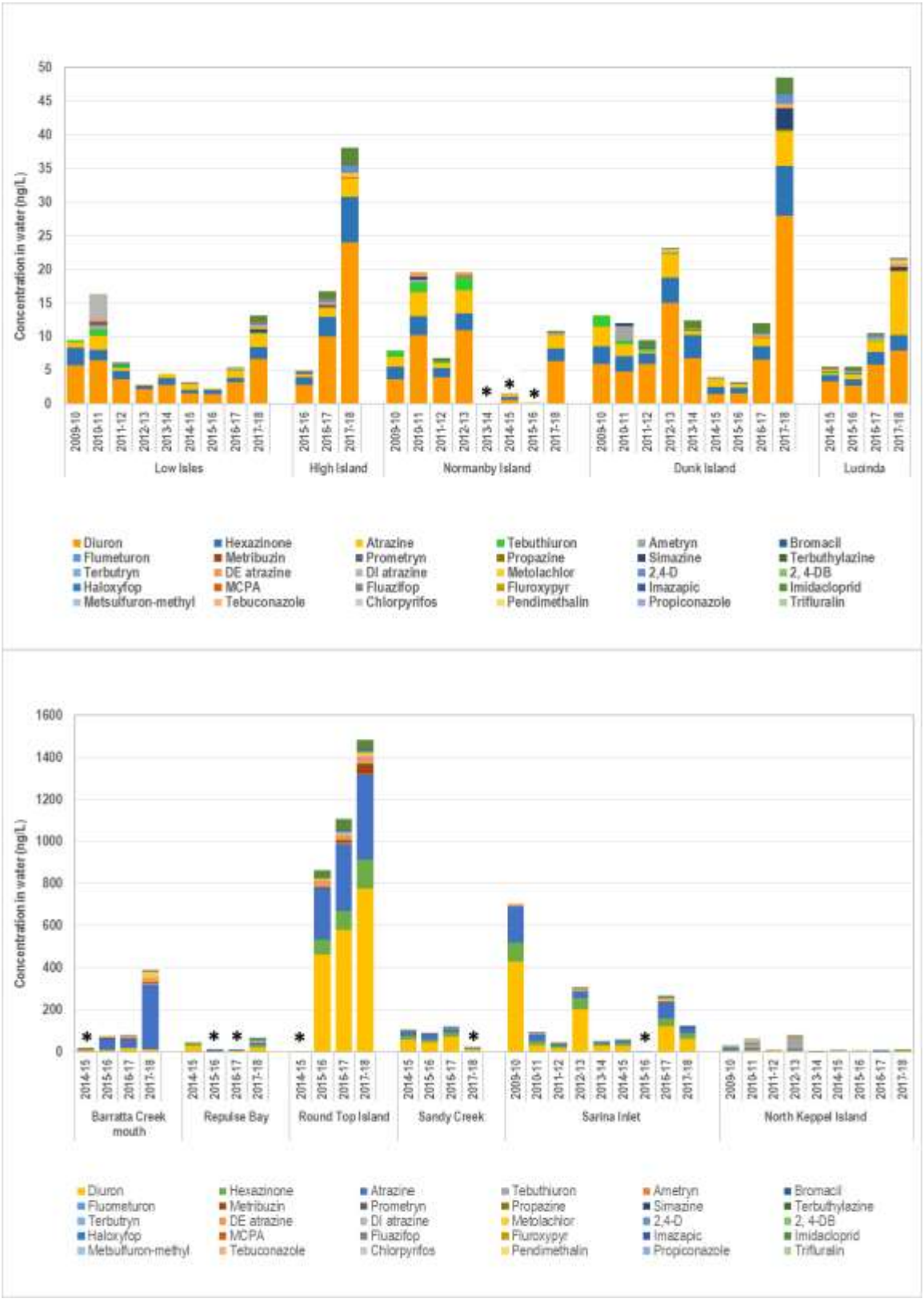


Figure 9: Maximum concentrations of individual pesticides at all sites monitored in 2017–18 compared to previous years (2009–10 onwards) in the Wet Tropics (upper panel) and the Burdekin, Mackay-Whitsunday and Fitzroy (lower panel). Note that the scale of the vertical axis differs between the panels. Several pesticides were recently added to the analysis suite and are only included in the relevant years (2014-15 onwards). 2,4-DB and fluometuron are not shown as values were <LOD for all sites and all years. * Dates with an asterisk are not representative values due to incomplete wet season sampling and should be interpreted with caution.

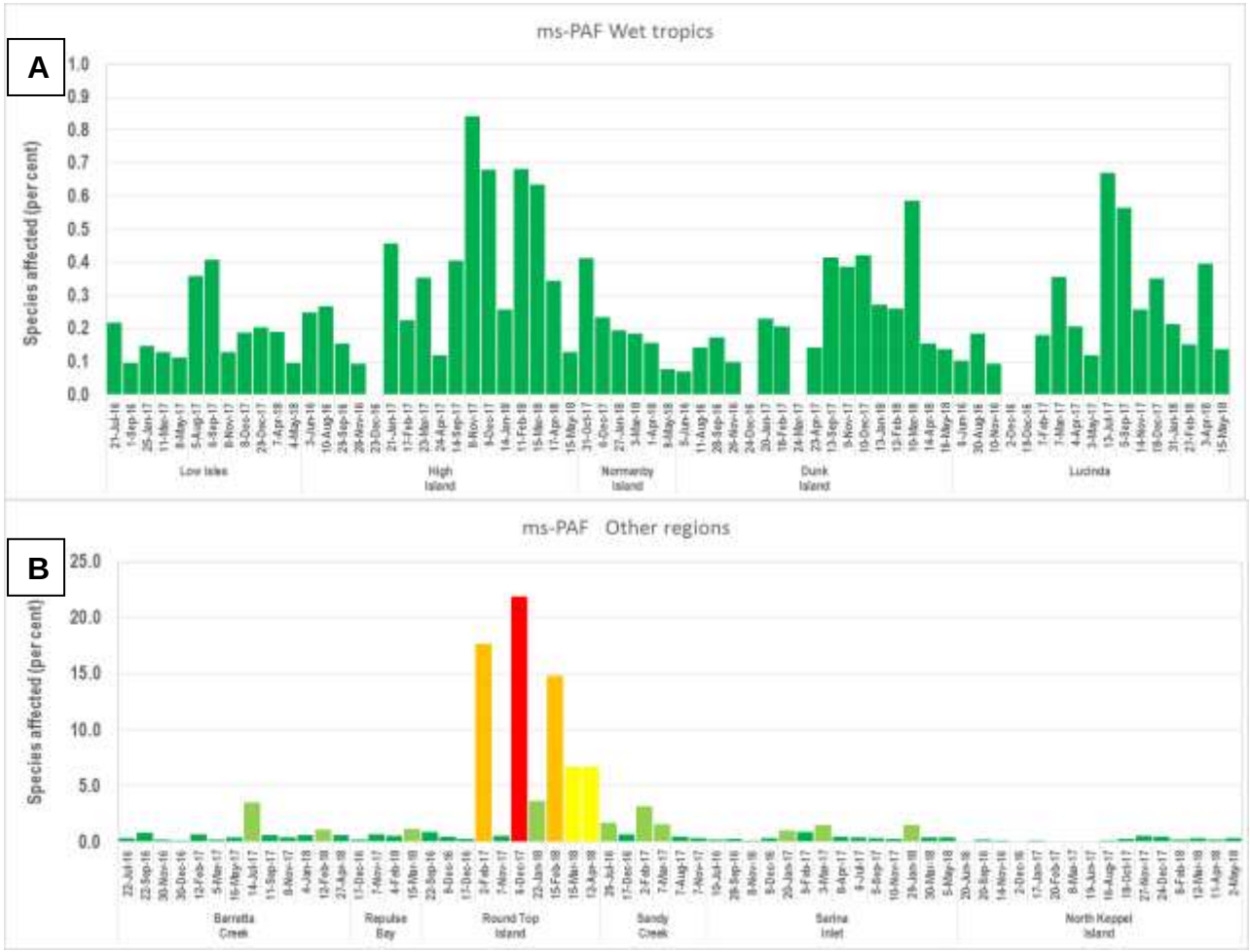


Figure 10: (A) Maximum % of species affected calculated using the ms-PAF method for all Wet Tropic sites and (B) Maximum % of species affected calculated using the ms-PAF method for all other sites. Dates are when passive samplers were collected. Color scale: ■ = very low risk (>99% species protected). ■ = low risk (>95% but <99% of species protected), ■ = moderate risk (>90% but <95% of species protected), ■ = high risk (>80% but <90% of species protected), ■ = very high risk (≤80% of species protected). Note the difference in y-axis scale between panels A and B. Note the difference in y-axis scale.

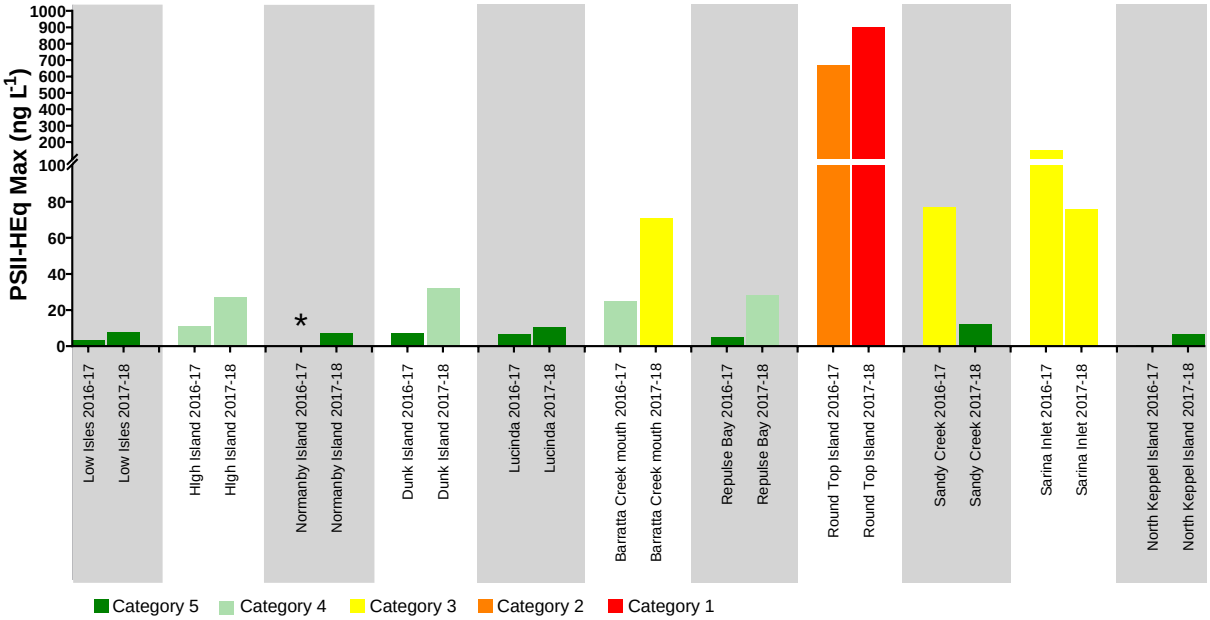


Figure 11: Maximum PSII herbicide equivalent concentrations at all sites compared to previous years (2016-18 shown). The risk categories are described in Appendix C, Table C-1. Asterisk indicates no data. Previous data is published in earlier reports.

5. Regional results

5.1 Wet Tropics Region

No exceedances of guideline values were detected in this monitoring year. Continuing the trend of previous monitoring years, the predominant pesticides detected using EDs in the Wet Tropics region in 2017–18 were atrazine, diuron and hexazinone. All three were detected in all wet season samplers returned from monitoring sites (Appendix F Table F2 to Table F-6). Simazine, tebuthiuron and DE atrazine (metabolite) were PSII herbicides that were also frequently detected in at least 50% of samplers at all sites as were the other non-PSII pesticides 2,4-D, imidacloprid and metolachlor. Ms-PAF values were calculated and no sites in the region are above Category 4. Note that the concentrations of non-PSII pesticides are yet to be integrated into this risk metric and thus the potential risk from all pesticides could be higher than what is reported here.

5.1.1 Low Isles

In 2017–18, there is no exceedances of guideline values at the Low Isles site.

Maximum concentration of PSII herbicides during the 2017–18 monitoring year was 6.7 ng L^{-1} of diuron during the wet season of February/March 2018. Diuron is usually the pesticide with the highest concentration among the 26 chemicals analysed for at this site.

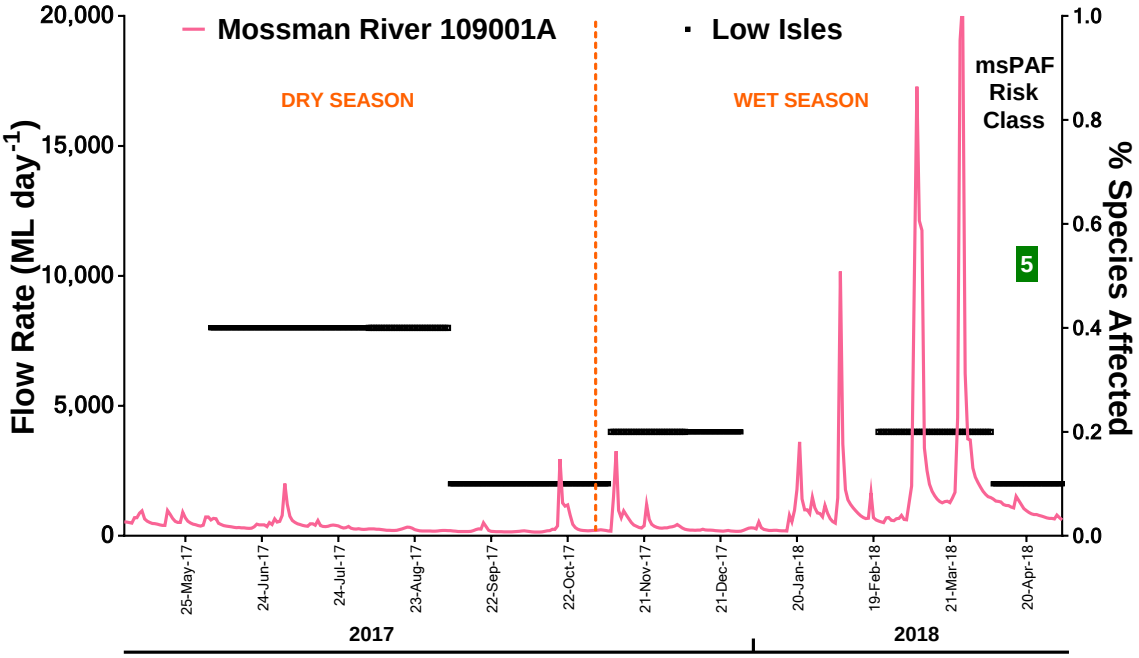


Figure 12: Temporal trends in % of species affected by pesticides (indicated by the black bars) in Low Isles in 2017-18, together with the flow rate of Mossman river. Flow data from DNRM Stream Gauging Network.

The maximum concentrations of pesticides monitored in 2017–18 were higher than in the previous two monitoring years (Table 5; for historical data, see Figure H-1). The ms-PAF values in 2017–18 at this site met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all deployments.

5.1.2 High Island

There is no exceedances of guideline values at the High Island site in 2017–18.

i) For passive samplers

The maximum concentration of PSII herbicides at High Island in this monitoring year was 38.5 ng L^{-1} of diuron at the start of the wet season in November 2017. Similar to Low Isles, diuron is usually the pesticide with the highest concentration among the pesticides monitored in this site.

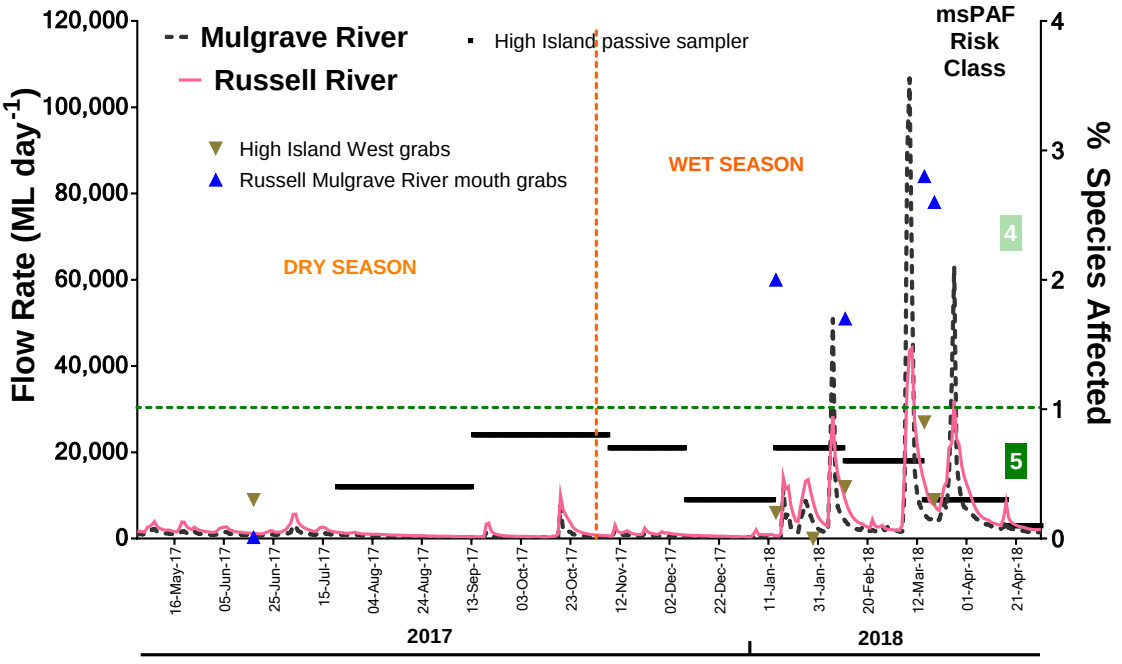


Figure 13: Temporal trends in % of species affected by pesticides by passive (indicated by the black bars) and grab samples (indicated by the spots) in High Island in 2017-18, together with the flow rate of Mulgrave and Russell rivers. Flow data from DNRM Stream Gauging Network.

At High Island, the maximum concentrations of pesticides monitored in 2017–18 were also higher than in the previous two monitoring years (Table 5; for historical data, see Figure H-1). It is noted that there was a high concentration detected early in the wet season when the flow is still low.

The ms-PAF values in 2017–18 at this site met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all deployments.

ii) For grab samples along the transect

Grab samples were collected from the Russell/Mulgrave River mouth and High Island (fixed monitoring site) on four occasions (one ambient and three during flow events throughout the wet season). Wet season sampling coincided with the first flow event of the wet season in January 2018, with a subsequent flow in February, followed by the major flow event in March 2018. The Russell Mulgrave river mouth site was impacted more strongly by primary flood plume water than the High Island site returning a mix of low risk (category 4: protective of >95% but <99% of species (with a highest return of 3% of species affected) and the desired

very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected).

Pesticide concentrations in grab samples collected at the river mouth were all below guideline values. Concentrations were higher during the wet season (diuron concentrations between 22 and 35 ng L^{-1}) than the dry season, before a decrease was observed in a sample collected on 19 March 2018. This final sample collection closely followed the major flow event of the season, and the additional volume of water may have served to further dilute pesticide loads already delivered by the initial flows of the season. For comparison, concentrations of pesticides in grab samples collected at the river mouth in the previous monitoring year (2016–2017) were significantly higher (C_{max} diuron of 299 ng L^{-1}).

Concentrations in grab samples collected at High Island gradually increased over the same time period (January to March 2018), reaching a peak diuron concentration, although of only 14 ng L^{-1}, on 15 March 2019. Concentrations of pesticides at this site were also lower than those in the previous monitoring year. The per cent of species affected in the grab samples at the river mouth compared to the High Island site once again demonstrating the effects of dilution and degradation in the flood plumes with increasing distance from their source.

The profile of the major pesticides in the grab samples was largely consistent with previous years, with dominant contributions of atrazine, diuron, hexazinone, imazapic and imidacloprid (Appendix G Table G-1). Other pesticides haloxyfop, MCPA, 2,4-D and metsulfuron methyl were frequently detected at the river mouth, but were less frequently detected at further distance from the river mouth at High Island.

A similar pesticide profile was observed between the grab and passive samplers at High Island (atrazine, diuron, hexazinone and imidacloprid dominance). The other pesticides, haloxyfop, MCPA and 2,4-D that were less frequently detected in grabs collected at High Island, were found during in many deployment period in the passive samplers, but at very low concentrations (~1 ng L^{-1}).

5.1.3 Normanby Island

There was no exceedance of guideline values in Normanby Island site in 2017–18.

The maximum concentration of PSII herbicides at Normanby Island in this monitoring year was 6.4 ng L^{-1} of diuron in March 2018 during the wet season. Again, the pesticide with the highest concentration at this site is diuron.

At Normanby Island, the maximum concentrations of pesticides monitored in 2017–18 were higher than in 2015–2016 and 2014–2015, the two recent monitoring years where the data are available. In 2016-2017, there was no data (Table 5; for historical data, see Figure H-1).

The ms-PAF values in 2017–18 at this site met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all deployments.

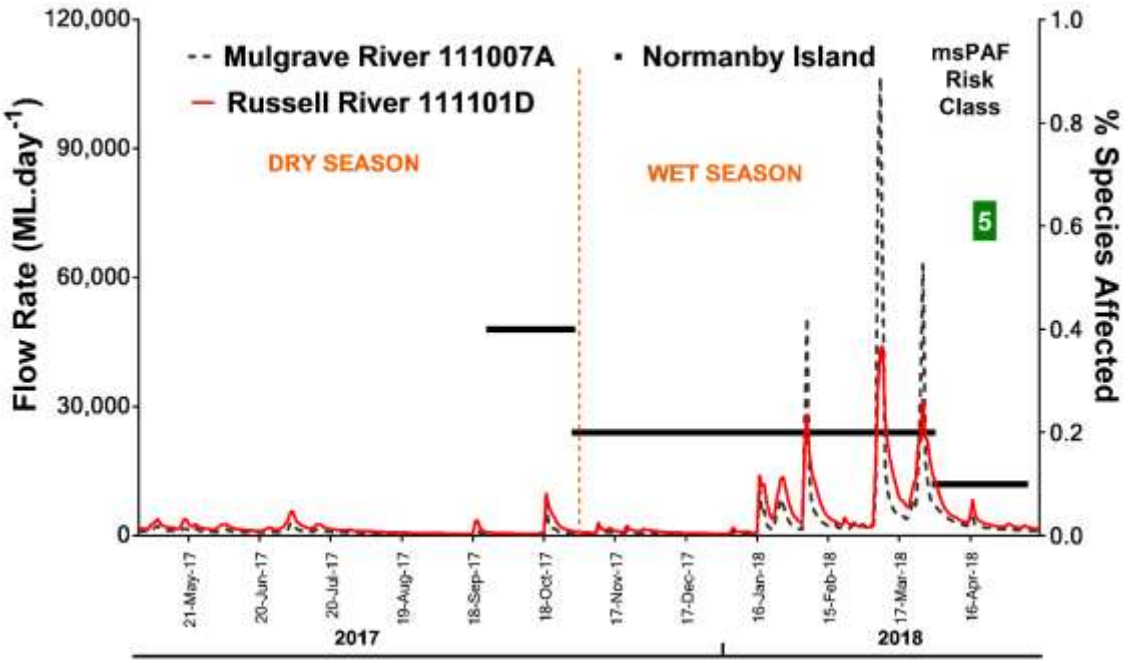


Figure 14: Temporal trends in % of species affected by pesticides (indicated by the black bars) in Normanby Island in 2017-18, together with the flow rate of Mulgrave and Russell rivers. Flow data from DNRM Stream Gauging Network.

5.1.4 Dunk Island

There is no exceedances of guideline values at the Dunk Island site in 2017–18.

i) For passive samplers

The maximum concentration of PSII herbicides at Dunk Island in this monitoring year was 27.9 ng L^{-1} of diuron in February 2018 during the wet season. Diuron is still the pesticide with the highest concentration in this site.

At Dunk Island, the maximum concentrations of pesticides monitored in 2017–18 were higher than in the previous two years. The concentrations in 2015–2016 and 2014–2015 were the lowest on record since 2009–2010 (Table 5; for historical data, see Figure H-1).

The ms-PAF values in 2017–18 at this site met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all passive sampler deployments.

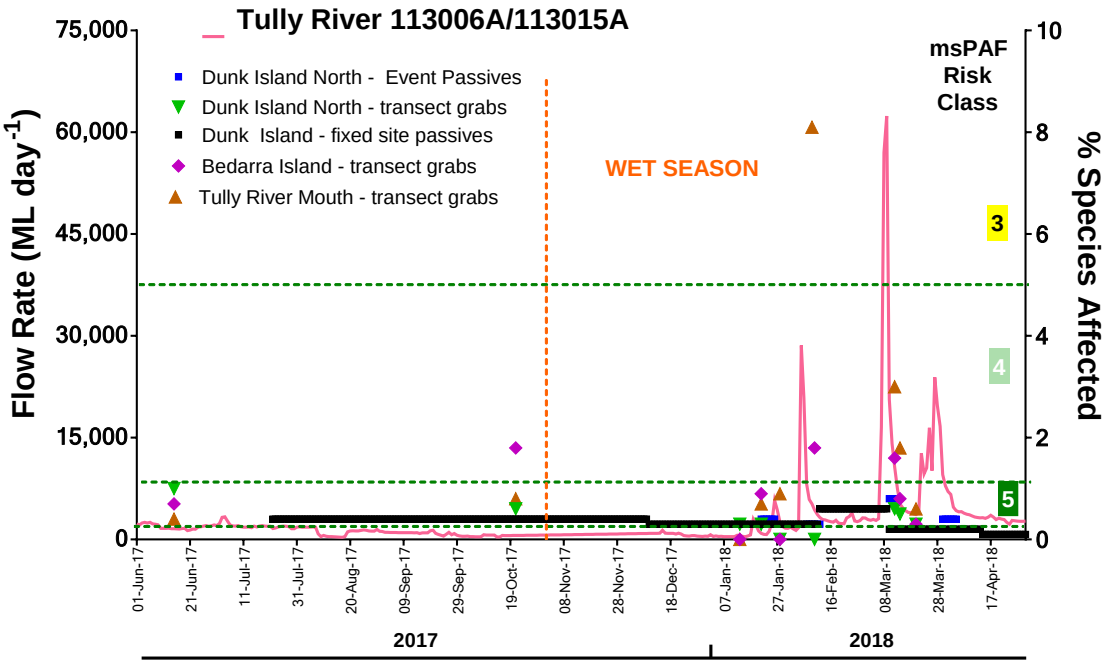


Figure 15: Temporal trends in % of species affected by pesticides (indicated by the black bars) in Dunk Island in 2017–18, together with the flow rate of Tully river. Flow data from DNRM Stream Gauging Network.

iii) For grab samples along the transect

In the Tully region, a grab sampling campaign was undertaken during the wet season, with samples collected from three sites,Tully River mouth, Bedarra Island directly offshore from the Tully River and Dunk Island, which lies to the north of the Tully (Figure 3).

The samples were collected on three main occasions, during base flow in June and October 2017 and during the major flow events in January/February 2018 and March 2018. Additionally, four 'event' passive samplers to capture shorter-term peaks in flood plume pesticide concentrations, were deployed at Dunk Island over the same time period.

The highest concentrations were detected in the grab sample collected at the Tully River mouth following the early-February 2018 flow (Table G-1). Similarly to the Russell Mulgrave transect, the pesticide profile at the river mouth site was dominated by (C_{max}):

- diuron 198 ng L^{-1}
- atrazine 154 ng L^{-1}
- hexazinone 159 ng L^{-1}
- imidacloprid 83 ng L^{-1}
- imazapic C_{max} 15 ng L^{-1}
- metolachlor, 2,4-D and haloxyfop were also frequently detected.

The mixture ms-PAF assessment returned a moderate risk of exposure for the sample following the flood with 8% of species affected at the Tully River mouth (category 3: protective of >90% but <95% of species (or 5 to <10% of species affected) (Table G-1). Follow-up samples on 12 and 14 March returned low risk assessments with 3 and 2% of species continuing to be affected, respectively (category 4: protective of >95% but <99% of

species (or 1 to <5% of species affected). The 20 March sample saw pesticide risk returned to meeting the very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected). This shows that species were potentially affected for over a month in these waters.

The highest ms-PAF value observed at Bedarra Island also followed the early-February flow event with 2% of species affected (category 4: protective of >95% but <99% of species) Dunk Island met the very low risk category for all grab samples (further away). Both the Bedarra and Dunk Islands grab samples had a very similar pesticide profile but lower concentrations and frequencies of detections than at the river mouth (Table G-1).

Concentrations and pesticide profiles in both the event and fixed passive samplers overall closely reflected one another. But as expected, grab sampling during major flow events provided the opportunity to catch the peak concentrations of pesticides while passive sampling provided the average concentrations during the sampling period.

Water type frequency data collected at each of the transect sites indicated the Tully River mouth site was almost continually impacted by primary plume water types (colour class 4 and above) for the entire wet season, with the month of March experiencing the greatest impacts of colour class 1 and 2. Water type frequencies at the Bedarra Island and Dunk Island locations indicated these sites were less impacted by primary plumes over the wet season, with primary plume water types encountered over the month of March only, coinciding with the major rainfall on the basin and the largest river flow event of the season.

5.1.5 Lucinda

There was no exceedance of guideline values at the Lucinda site in 2017–18.

The maximum concentration of PSII herbicides at Lucinda in this monitoring year was 9.4 ng L^{-1} of atrazine in November 2017 at the start of the wet season. At this site, atrazine and diuron are the two pesticides with the highest concentrations.

At Lucinda, the maximum concentrations of pesticides monitored in 2017–18 were higher than in the previous years, hence the highest since the monitoring started in 2014–2015 (Table 5; for historical data, see Figure H-1).

The ms-PAF values met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all passive sampler deployments.

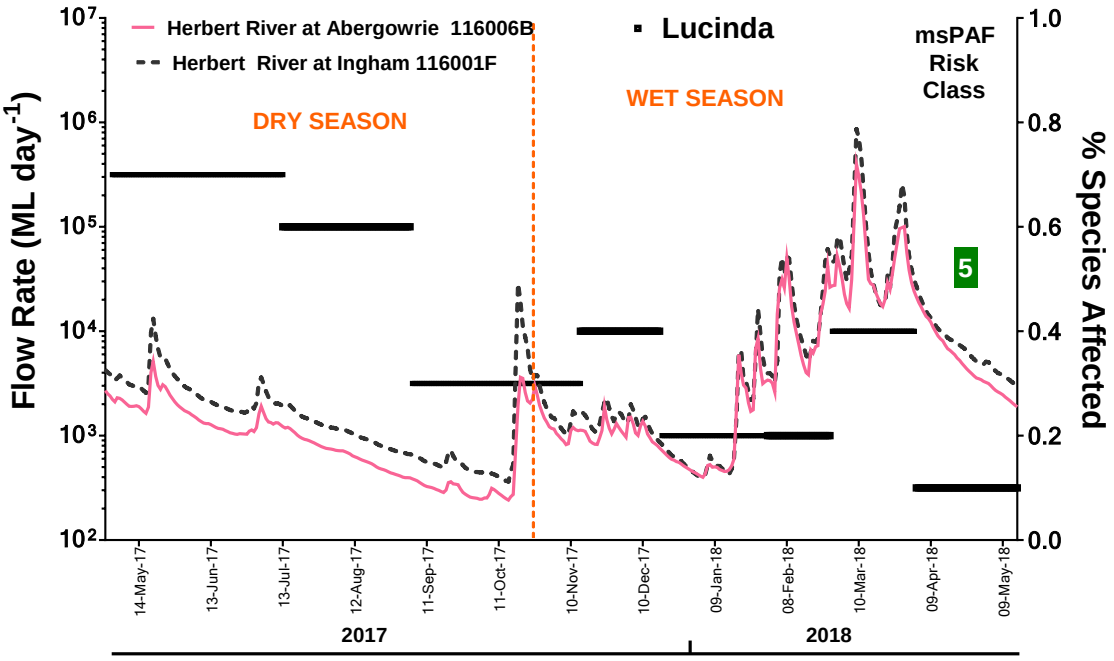


Figure 16: Temporal trends in % of species affected by pesticides (indicated by the black bars) in Lucinda in 2017-18, together with the flow rate of Herbert River. Flow data provided by DNRM Stream Gauging Network.

5.1.6 Factors influencing the pesticide concentrations in the Wet Tropics

Wet season rainfall in the Wet Tropics in 2017–18 typically met the long term wet season average, and increased in comparison to rainfall in the 2016–2017 wet season. Rainfall in the dry season was considered very much above average. Consequently, the annual regional river discharge was increased by 1.7 times when compared with the previous monitoring year, continuing a trend of increase since the 2013–2014 monitoring year (Figure 7). Overall total discharge from the entire region was only marginally higher than the long term median (by 1.3 times).

The rivers in the Wet Tropics generally flowed year-round with small flow events occurring regularly throughout the dry season. In the wet season, a relatively small first flush event occurred in most Wet Tropics rivers in October, followed by the first wet season rainfall event in January 2018 that resulted in flow events in the rivers (Mossman, Russell, Mulgrave, Tully and Herbert Rivers). Subsequent widespread high rainfall events in March triggered the largest flow events of the season in all rivers.

Rainfall in the adjacent basins likely contributed to an increase in the frequency of colour class 4 and above water types impacting passive sampling sites at High Island, Dunk Island and Lucinda. Despite this brief increase, overall the Wet Tropics sites experienced the lowest water type frequencies of all regions (0.19–1.0), with three sites encountering only tertiary water types for at least half of the wet season.

Land use in the Wet Tropics differs between its northern and southern basins with the northern Daintree and Mossman River basins largely comprised of national parks and state

forests. Large areas of land are used for sugarcane growing in the southern basins clustered around Cairns, Innisfail, Tully and Ingham (ABS, 2013). This regional variation in land use may lead to the difference in pesticide concentrations measured in each site although the PSII herbicide profiles (Figure H-1 to Figure H-5) remained very similar (dominated by diuron, atrazine and hexazinone) across all sites. The actual amount of pesticide uses and the level of river mixing may influence the actual pesticide concentrations measured.

There appears to be a seasonal change in herbicide profile across the sites within the region. In the wet season, diuron contributes approximately 50% and atrazine approximately 20% to the total pesticide concentration whereas in the dry season, the contribution of diuron drops to between 30 and 40%, and atrazine increases to an average contribution of 35%. Such change could be due to the difference between the half-lives of the two herbicides in the marine environment (Mercurio et al., 2015).

5.2 Burdekin Region

5.2.1 Barratta Creek passive sampling

No exceedances of pesticide concentration were detected at Barratta Creek in 2017–18.

Similarly to the previous monitoring year, most of the PSII herbicides (and metabolites) monitored in this program (with the exception of fluometuron, prometryn and terbutryn) were detected (Appendix F).

Historically, atrazine and atrazine metabolites have typically dominated the pesticide profile at Burdekin sites, including those sites monitored in previous years but no longer in the current program (e.g. Cape Cleveland; (Gallen et al., 2016)). The same atrazine-dominated profile was observed at Barratta Creek in 2017-18. In contrast to the pesticide profiles of the other regions, atrazine levels were higher than diuron in all sampling periods. Atrazine can contribute up to 80% of the total pesticide concentration (Figure H-6), and contributed an average of 45% in all sampling periods.

Of the other pesticides, metolachlor and 2,4-D were also detected, with maximum concentrations of 28 and 4.6 ng L^{-1} respectively in May 2017. Unlike samplers from the Wet Tropics region, ametryn was consistently detected, albeit at low levels (1-10 ng L^{-1}), throughout the year. Using PDMS samplers, propazine, chlorpyrifos and pendimethalin were detected in the two samplers that were successfully returned but at very low concentrations (Appendix F). Total pesticide concentrations in the current year were comparable with the previous two monitoring years (Table 5; for historical data, see Figure H-1).

The ms-PAF values in 2017–18 at this site had a mix of very low risk: protective of 99% of species (i.e. less than 1% of species are affected) and low risk: protective of >95% but <99% of species (or 1 to <5% of species affected). The ms-PAF level was highest in May 2017 correlating with an out of season flow, although the risk level remained low.

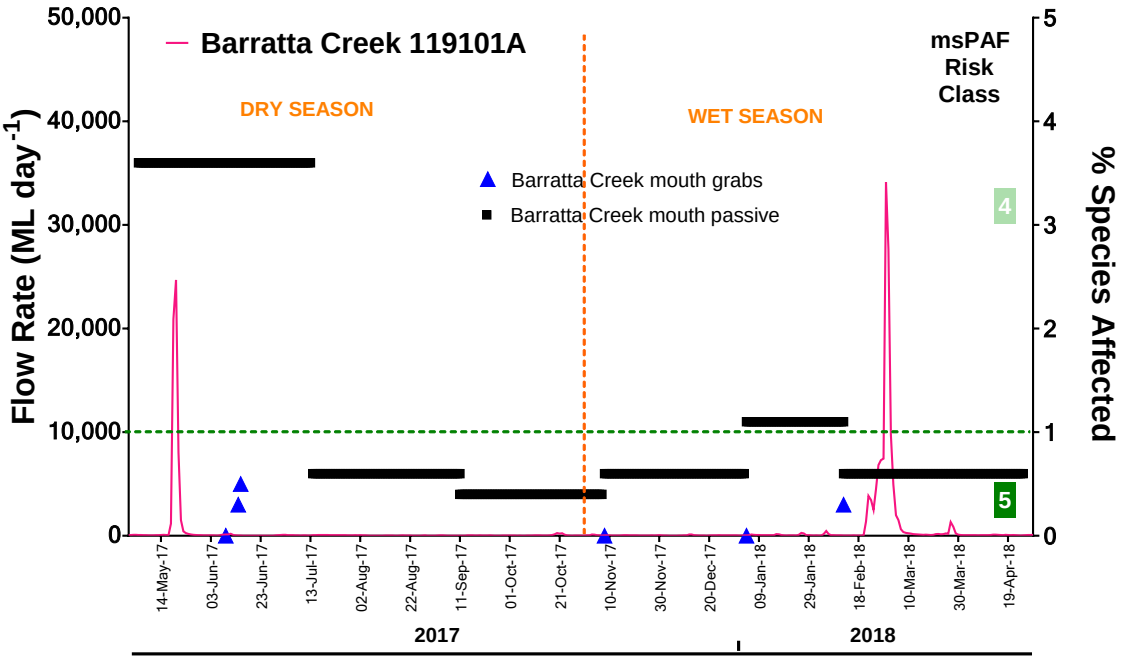


Figure 17: Temporal trends in ms-PAF values at Barratta Creek mouth fixed passive sampling (black bar) and grab samples (blue triangles) relative to the flow rate of the rivers influencing the sampling sites. Flow data from DNRM Stream Gauging Network.

The Burdekin River is historically the river with the highest long-term median discharge volume; however, above median discharge is intermittent and highly reliant on large rainfall events in the basin. In 2017–18, after several low discharge years, discharge from the Burdekin basin to the Reef lagoon increased for a third consecutive year. Unusually high rainfall during the dry season (May 2017), contributed to the highest concentrations in passive samplers detected (1.5% species affected) of this monitoring year, which was dominated by very high levels of atrazine (309 ng L^{-1}). The first notable rain of the wet season fell in early December 2017 with low rainfall over January, increasing in late January/ early February 2018 but did not result in significant flow. The major rainfall occurred in late February subsequently resulting in the flow event.

The Barratta Creek mouth fixed passive sampler site was highly impacted by primary water types (colour class 4 and above) for almost the entire wet season, particularly throughout February and March with several consecutive weeks of colour class 2 and 1. Unfortunately no data are available for a two week period starting in late February that coincided with the major flow event of the season.

A review of the extent of the Burdekin flood plume indicated that average flood events could reach a northward distance of approximately 200 km, and the maximum for extreme large flood events could be approximately 500 km (Lewis et al., 2006). Retrospective calculation of the ms-PAF metric, for the previous dry year of 2016–2017, showed this site met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all deployments.

5.2.2 Burdekin Focus Region flood plume sampling

In addition to deploying passive samplers at the Barratta Creek mouth, grab samples were collected from this location throughout the year. Concentrations in grab samples were low, likely due to the timing of their collection during periods of relatively low flow, and therefore, it is likely that the concentrations of pesticides at this site were underestimated (Figure **17**).

Despite the low flows recorded over the majority of the wet season, the water types recorded at this location indicated primary plume waters were impacting the site across the wet season. Two grab samples were taken during periods when colour class 2 waters were prevalent; however, these grab samples did not reflect the relatively high pesticide concentrations indicated by the passive samplers deployed over that period of time (Table E-2; Appendix E). All of the grab samples met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected). Atrazine and its metabolite DE atrazine were dominant in the pesticide profile although at very low concentration (Atrazine C_{max} 12 ng L^{-1}). Many of the PSII herbicides and other pesticides that were detected in passive samplers at this site were below detection limits in the grab samples.

5.3 Mackay Whitsunday Region

In 2017–18, in most sites of this region, there is no exceedance except on two occasions at the Round Top Island site where the PGVs of diuron was exceeded. This is the third consecutive year that wet season levels have exceeded proposed guideline values in a deployment period at this site. Round Top Island had the highest concentration of most pesticides monitored, compared to any other sites.

Despite breaks in the deployment record at several of these sites, overall the profiles of PSII herbicides (and metabolites) detected are comparable to previous monitoring years with diuron, hexazinone and atrazine being the most frequent (Table F-8 to Table F-11). Terbuthylazine (included in reporting for the first time this year) as well propazine were detected in almost every sampler deployed at Round Top Island and Sarina Inlet although at very low concentrations (<2 ng L^{-1}). Other pesticides, imidacloprid, 2,4-D, MCPA and metolachlor, were regularly detected in at least one sampler at all sites.

Despite being deployed at all four sites in the region, PDMS samplers were only successfully returned from Repulse Bay and Round Top Island and the sampling record is incomplete for both sites due to losses. At Repulse Bay, propazine propiconazole and chlorpyrifos were detected at low concentrations (<1 ng L^{-1}), whilst at Round Top Island trifluralin and pendimethalin were additionally detected in multiple samplers, again at concentrations typically less than 1 ng L^{-1}.

5.3.1 Repulse Bay

There is no exceedances of guideline values in the Repulse Bay site.

Maximum concentration of PSII herbicides during the 2017–18 monitoring year was 22.7 ng L^{-1} of diuron during the wet season of February 2018. Diuron is usually the pesticide with the highest concentration, followed by hexazinone in this site.

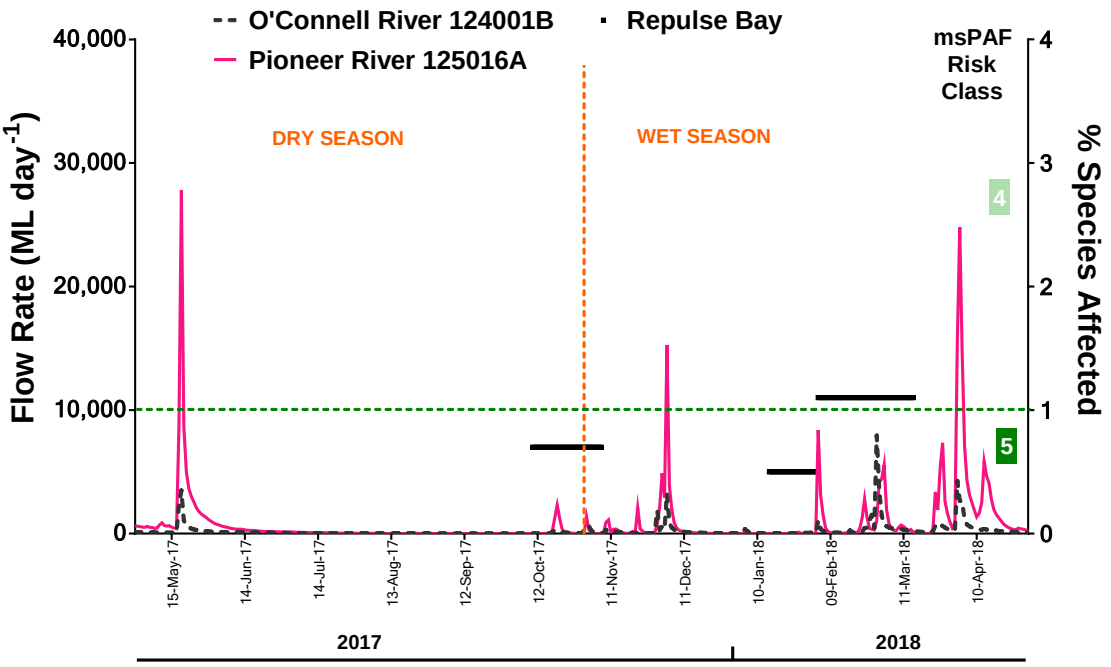


Figure 18: Temporal trends in % of species affected by pesticides (indicated by the black bars) in Repulse Bay in 2017-18, together with the flow rates of adjacent rivers. Flow data provided by DNRM Stream Gauging Network.

The maximum concentrations of pesticides monitored in 2017–18 were higher than in the previous two monitoring years (Table 5; for historical data, see Figure H-1).

The ms-PAF values in 2017–18 in this site met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all except one deployment which returned a low risk, category 4 assessment at 1.1% of species affected: protective of >95% but <99% of species (or 1 to <5% of species affected).

5.3.2 Round Top Island

No individual exceedances of the current marine trigger values (i.e. water quality guideline values) were detected although some of these values are undergoing a review. Assessment against the PGVs for diuron (levels determined to protect 99% of marine species) would however result in two instances of exceedance, both from passive samplers located at Round Top Island, in the Mackay Whitsunday region: 778 and 531 compared to the proposed value of 430 ng L^{-1}. There was also a near-exceedance for imidacloprid.

The first exceedance occurred during the early wet season of November 2017 when diuron had its maximum concentration of the 2017–18 monitoring year (778 ng L^{-1}). The second exceedance happened in January/February 2018 with diuron concentration of 531 ng L^{-1} (Appendix B, Table B-1). At this site, atrazine and hexazinone are also usually found at high concentrations.

Concentrations of imidaclopid were not as high as the PSII herbicides but in November 2017 reached the highest concentration of 42 ng L^{-1} (the PGV for imidacloprid is 57 ng L^{-1}).

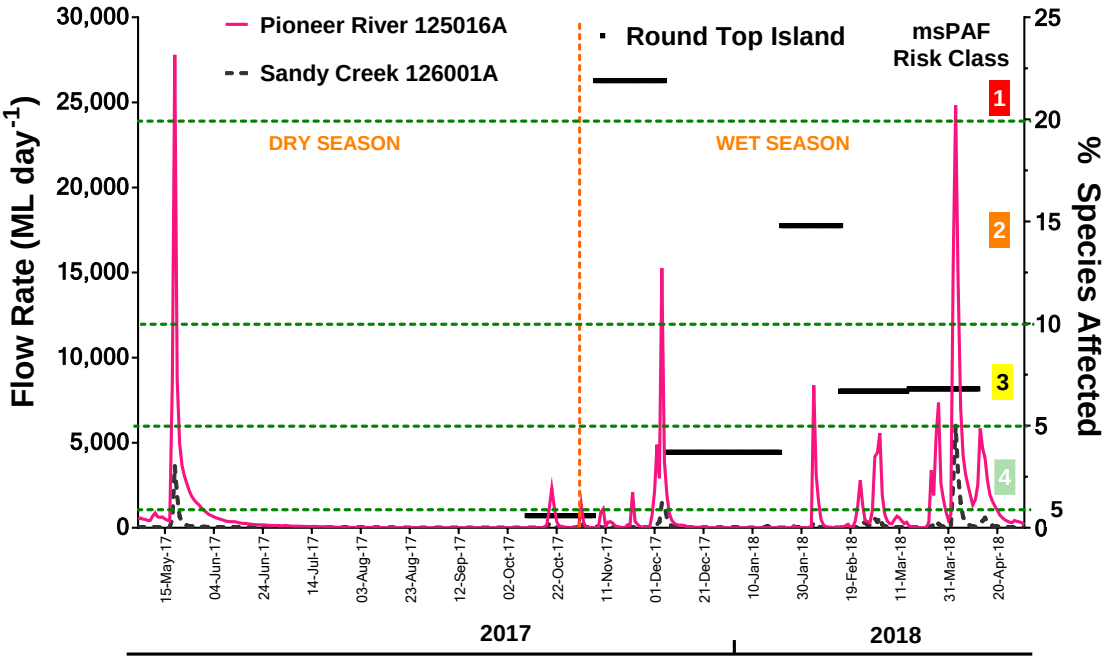


Figure 19: Temporal trends in % of species affected by pesticides (indicated by the black bars) in Round Top Island in 2017-18, together with the flow rates of adjacent rivers. Flow data from DNRM Stream Gauging Network.

The total concentrations of pesticides monitored in 2017–18 were similar to those of the previous two monitoring years (Table 5; for historical data, see Figure H-1). Although at Repulse Bay in 2016–17 limited samples were obtained due to sampler losses and deployment issues.

Round Top Island returned samples across all risk categories, and is our highest risk monitored site:

- Very low risk: protective of 99% of species (i.e. less than 1% of species are affected) - four
- Low risk: protective of >95% but <99% of species (or 1 to <5% of species affected) - one
- Moderate risk: protective of >90% but <95% of species (or 5 to <10% of species affected) - two
- High risk: protective of >80% but <90% of species (or 10 to <20% of species affected) – two
- Very high risk: protective of ≤80% of species (or ≥20% of species potentially affected) - one

5.3.3 Sandy Creek

The number of samplers recovered for this monitoring period is low with only two retrieved in the dry season. There is no exceedances of guideline values from these two returns.

Maximum concentration of PSII herbicides during the monitoring year was 13 ng L^{-1} for diuron in October 2017 at the end of the dry season. Diuron is the pesticide with the highest concentration, followed by atrazine and hexazinone.

The level of total concentrations of pesticides monitored in the dry season of 2017 were lower than the previous monitoring year 2016, with data not available in 2014 and 2015 (Table 5; for historical data, see Figure H-1).

Both of the dry season deployments returned ms-PAF values that met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected).

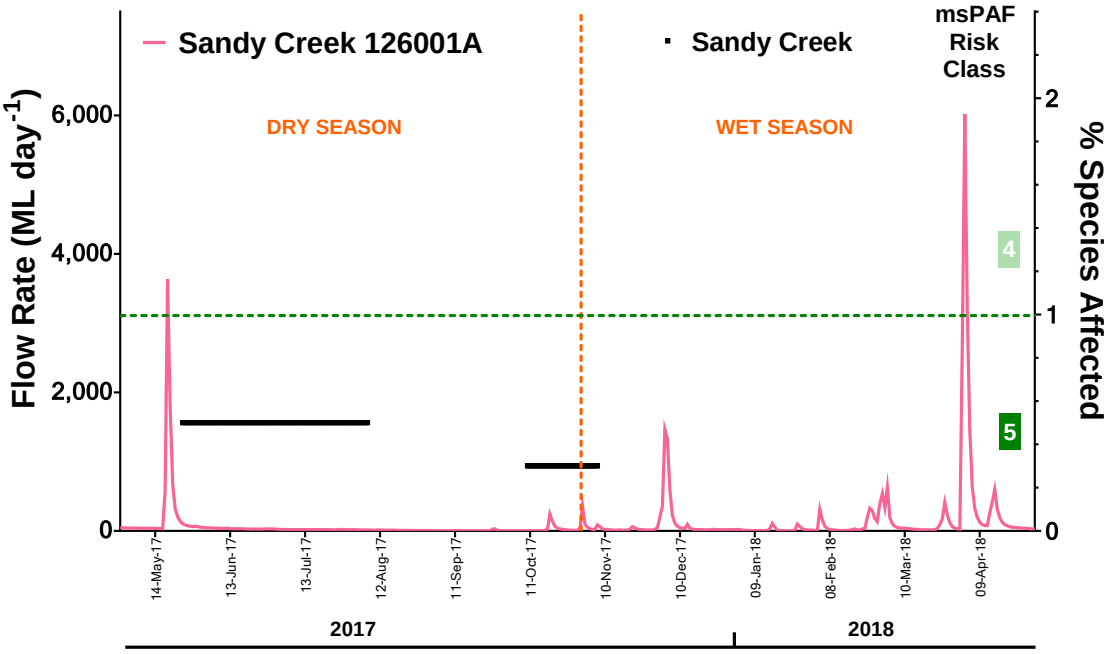


Figure 20: Temporal trends in % of species affected by pesticides (indicated by the black bars) in Sandy Creek in 2017–18, together with the flow rates of adjacent rivers. Flow data from DNRM Stream Gauging Network.

5.3.4 Sarina Inlet

There was no exceedances of guideline values at the Sarina Inlet site.

The maximum concentration of PSII herbicides during the monitoring year was 60 ng L^{-1} for diuron in November/January 2017 at the beginning of the wet season. Similar to the close-by site of Sandy Creek, in Sarina Inlet, diuron is the pesticide with the highest concentration, followed by atrazine and hexazinone.

The total concentrations of pesticides monitored in 2017–18 were similar to the previous monitoring year of 2016–2017 and higher than 2015–2016 (Table 5; for historical data, see Figure H-1).

The ms-PAF values in 2017–18 at this site met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all except one deployment which returned a low risk, category 4 assessment at 1.5% of species affected: protective of >95% but <99% of species (or 1 to <5% of species affected).

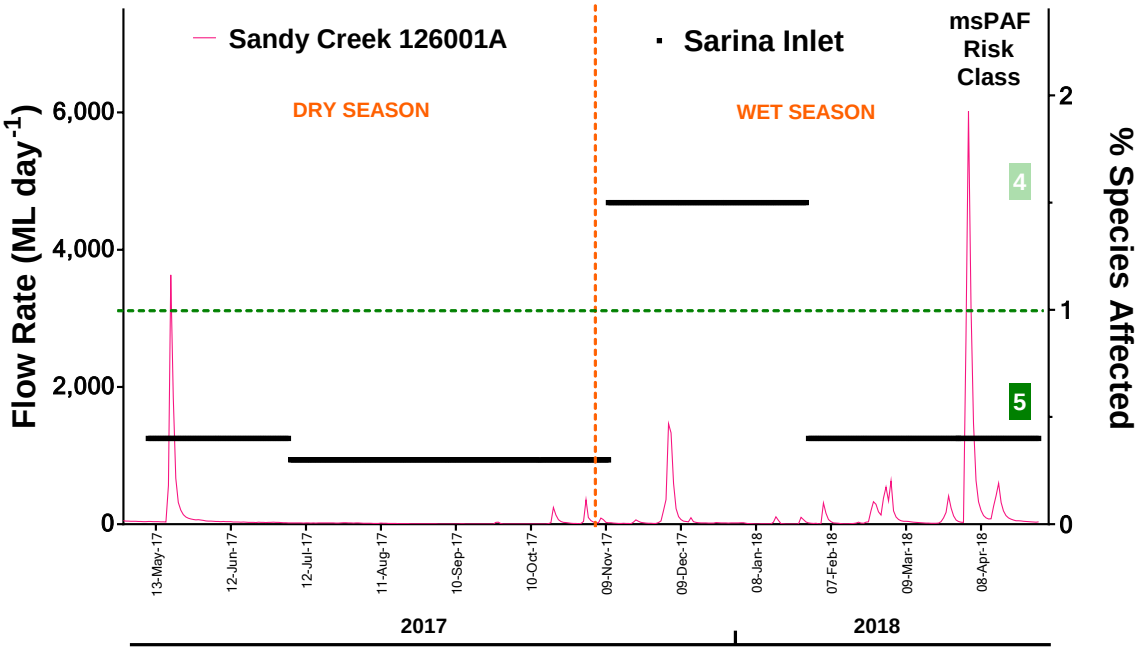


Figure 21: Temporal trends in % of species affected by PSII pesticides (as indicated by the black bars) in Sarina Inlet in 2017–18, together with the flow rates of adjacent rivers. Flow data from DNRM Stream Gauging Network.

5.3.5 Factors influencing the pesticide concentrations in the Whitsunday region

The rivers influencing passive sampling sites in the Mackay Whitsunday region discharged below median volumes (0.3 – 0.6 times the long-term median) this monitoring year. This is in contrast to the previous year, when rainfall in excess of 500 mm associated with cyclone Debbie contributed to above median discharge in all relevant rivers.

There were three wet season rainfall events in the basins this year occurring in late January, late February and late March 2018. This resulted in numerous flow events across the region during this period, with the highest flow event occurring following the late March rainfall event. Similarly to the Burdekin region, one large dry season flow event (similar in magnitude to the highest flow event in the wet season) occurred in May 2017.

The incomplete sampling records particularly at Repulse Bay and Sandy Creek (no successful wet season sampling) mean the maximum concentrations may be underestimated for this monitoring year at those sites. The pesticide levels and risk of pesticide exposure recorded at Round Top Island were also the highest reported in ED samplers across all the sites currently being monitored, compared to both the current year and all historically reported levels and is the first instance of a Risk Category 1 using the ms-PAF risk metric. These high levels may be a result of the small first flush events coinciding with pesticide applications in the basin and therefore dilution effects were minimal.

PSII-HEq Max values and the retrospective calculation of ms-PAF for 2016–2017 at sites located in this region have been consistently higher than sites in other Natural Resource

Management regions. According to HEq Max data, this is the ninth consecutive year that a site in the Mackay Whitsunday region had the highest risk of exposure to pesticides using either risk metric. These comparatively higher concentrations may reflect the land use, pesticide usage and land management practices of the adjacent basin, but also the ideal positioning of the monitoring sites to intercept flood plumes from nearby rivers. Unfortunately, these sites experience some of the highest sampler losses due to possible human interference and lost moorings associated with poor weather, and sampling records are often incomplete. Efforts to improve the sampler return rate are ongoing.

Historical data from all MMP monitoring sites indicates that high pesticide concentrations (and guideline exceedances) are not necessarily correlated with large flow events possibly due to dilution effects associated with the high volume of water discharged during these events. Pesticide concentrations in river discharges may therefore be higher in drier years because there is less of a dilution effect. However, in dry years, a sufficiently large discharge volume is required for pesticides to reach monitoring sites that are not located directly at the river mouth.

Water type frequencies recorded at the sites in this region indicated both Repulse Bay and Sarina Inlet were frequently impacted by primary flood plume water types for at least half the wet season (Table E-2; Appendix E). Round Top Island and Sandy Creek did not experience water types with colour classes above 4. Despite the apparent low influence of flood plumes on the Round Top site, the highest pesticide concentrations for all sites was detected here.

5.4 Fitzroy Region

5.4.1 North Keppel Island

There was no exceedances at North Keppel Island in the Fitzroy region during the 2017–18 monitoring year.

PSII herbicides detected at North Keppel Island in 2017–18 included atrazine, diuron, hexazinone, simazine and tebuthiuron (Table F-12). Metolachlor, terbuthylazine, 2,4-D and MCPA were also detected, at relatively low concentrations. Diuron typically dominates the PSII herbicide profile at North Keppel Island with the maximum concentration of 6.1 ng L^{-1} at the beginning of the wet season.

The ms-PAF values met the desired very low risk category 5: protective of 99% of species (i.e. less than 1% of species are affected) for all passive sampler deployments.

Tebuthiuron is only discharged at trace levels from basins other than the Fitzroy but is consistently detected up and down the Reef coastline at low levels. This suggests tebuthiuron has long-range transport potential reaching as far as the Wet Tropics region, which is consistent with its long half-life (under Reef relevant conditions) of over 900 days (Negri et al., 2014). Despite its widespread usage in grazing areas, there is little data relating to tebuthiuron application in Reef basins and its movement in basin run-off (Devlin et al., 2015). Tebuthiuron also has a relatively high PGV (4700 ng L^{-1}), much higher than the levels typically found in Reef samples.

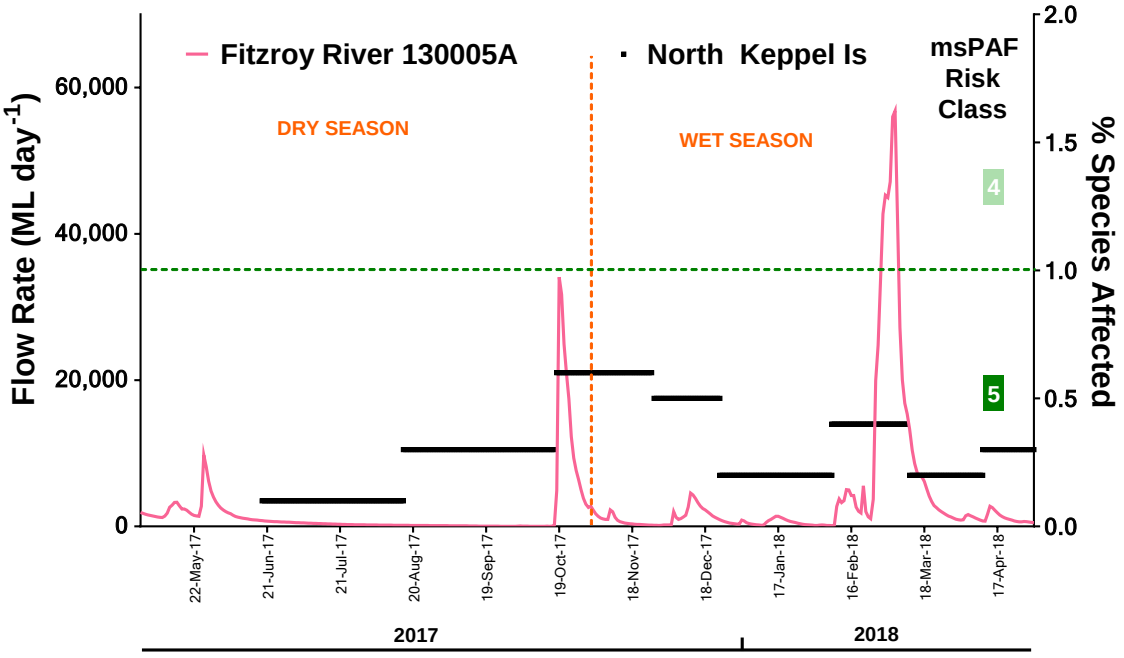


Figure 22. Temporal trends in ms-PAF values in 2017-18, relative to the flow rate of the Fitzroy River influencing North Keppel Island's fixed passive sampler site. Flow data from DNRM Stream Gauging Network.

5.4.2 Factors influencing the pesticide concentrations in the Fitzroy region

The rivers influencing passive site, the Fitzroy River, had significantly lower discharge in 2017–18 (0.3 times the long-term median) than in the previous monitoring year (2.2 times the long-term median). An initial peak in river flow occurred in the dry season in October 2017. Only two moderate rainfall periods occurred throughout February (both <100 mm) which resulted in one main river flow event in late February/ early March 2018 (Figure 22).

Water type at the passive sampler site at North Keppel Island remained colour class 5 (indicative of secondary flood plumes) for the entirety of the wet season. Historically, this site is the one of the least impacted by primary plume water types, which is unsurprising, given its relatively distant location (50 km) from the Fitzroy River mouth. Despite the relatively low discharge, concentrations of pesticides detected during the wet season at North Keppel Island were the highest detected since 2012–13 at this site (for historical data see Figure H-11), albeit still at relatively low concentrations.

6. Discussion

Pressures and overall trends in pesticide levels at fixed monitoring sites.

In 2017–18, trends in the pesticide concentrations could be broadly interpreted with respect to hydrological conditions (river discharge and rainfall on adjacent basins). The pressures governing the release of pesticides into the Reef lagoon were highly localised in the current monitoring year, and were somewhat inversely related to the previous monitoring year.

- This year, river discharge in the northern NRM basins (Wet Tropics and Burdekin) was slightly above the long-term median and for the Wet Tropics region, several basins experienced weekly rainfall during the wet season exceeding 500 mm and above average rainfall during the dry season across the entire region. For both regions, it was the fourth consecutive year of increase in regional river discharge.
- Further south in the Mackay Whitsunday and Fitzroy regions, regional river discharge was below the long term median, and significantly lower than the previous year which was impacted by high rainfall and above median river discharge associated with cyclone Debbie in late March 2017.

Pesticide concentrations at fixed monitoring sites were, in most cases, higher than the previous monitoring year. Three currently monitored sites (Low Isles, Normanby Island and North Keppel Island) have long term (relatively) continuous monitoring data that extends to the ‘very wet’ La Niña years (2007– 2012) when rainfall, river discharge and cyclonic activity were considerably above long-term averages.

No individual exceedances of the current marine trigger values (i.e. water quality guideline values) were detected although some of these values are undergoing a review. Assessment against the proposed PGVs for diuron (levels determined to protect 99 % of marine species) would however result in two instances of exceedance, both from passive samplers located at Round Top Island, in the Mackay Whitsunday region: 778 and 531 compared to the proposed value of 430 ng L^{-1}. If these values are adopted, the pesticide exposure risk at this site will be interpreted higher.

This is the third year running that proposed guideline exceedances have occurred at the Round Top Island site (incomplete data from 2014–2015 does not allow comparison with the first year of sampling), suggesting this may be a higher risk site. The end-of-basin loads, ideal location of the monitoring site within the flood plumes, seasonal pulses of river flow patterns, discharge volumes and other factors (such as timing of pesticide application) affecting the transport of pesticides from the river mouth to the site all likely contribute to the higher concentrations at this site. Historically, the highest pesticide concentrations have been detected at the Mackay Whitsunday sites, which correlates with the dominant land-use in the adjacent basins.

The observed increase in pesticide levels was highest for the northern Reef basins, which may be the result of the moderately increased river discharge delivering pesticide-rich water following three ‘dry’ years (Wet Tropics) and five ‘dry’ years (Burdekin). Nevertheless, risk assessment of mixtures at these sites returned only low or very low risks.

In the southern Reef basins, the incomplete sampling records at the sites located in the Mackay Whitsundays (particularly at Repulse Bay, Round Top Island and Sandy Creek) makes comparison with the previous year wet season less meaningful. Nonetheless, despite below average rainfall across much of the Mackay Whitsunday region during the wet season, the observed integrated maximum levels of pesticides remained high at Round Top Island, continuing from the previous three monitoring years. The below median river discharge during this 'dry' year in these southern basins, likely resulted in a reduction in the dilution effects commonly associated with the large volumes of water during 'wet' years and may have contributed to the observed increase in pesticide levels at these sites.

As suggested by the current year's data, even when complete monitoring data sets are available, it can still be challenging to elucidate the reasons behind observed trends in monitored offshore pesticide data, especially when changes to multiple pressures occur simultaneously. Whether a reduction in pesticide detections at offshore monitoring sites is due to, for example, climatic variabilities influencing pesticide transport potential from basin to Reef or better land management practices reducing pesticide usage and runoff, or both, requires a detailed understanding of all the factors driving these changes. Quite often, the necessary data needed to interpret these changes (particularly pesticide usage and application rates) are either not available or only updated periodically. All these factors, as well as the overall small number of fixed passive sampling sites, make it difficult to quantitatively assess the link between improved land management practices as a direct result of Reef 2050 WQIP initiatives and changes in nearshore marine water quality.

Since pesticides are principally exported during runoff events in the wet season, river discharge is expected to be a key driver of pesticide concentrations reaching offshore monitoring sites. To assess the ability of the monitoring program to trace the effectiveness of Reef 2050 WQIP, a statistical investigation of the data is proposed.

PSII herbicide profiles

Similar to previous monitoring years, diuron, atrazine and hexazinone were the most consistently detected and abundant PSII herbicides at most sites (Bentley et al., 2012; Gallen et al., 2013; Gallen et al., 2014; Gallen et al., 2016; Grant et al., 2017; Kennedy et al., 2010; Kennedy et al., 2012). These herbicide residues reflect land-use applications primarily in the sugar cane, horticulture and grain cropping industries (Bainbridge et al., 2009; Devlin et al., 2015; Kroon et al., 2013; Lewis et al., 2009).

Diuron is typically associated with the intensive sugar cane farming in the coastal area of the Tully River, Herbert River, Pioneer River and Sandy Creek basins, and high concentrations of diuron have been typically measured in sites of these basins since monitoring commenced in 2010.

Atrazine (also registered for use in sugarcane) has historically been used extensively in the Barratta and Burdekin basins, and has been found during recent passive sampling activities in these basins (O'Brien et al., 2016), and previous monitoring years by this MMP (in both passive and grab samples). This herbicide continues to represent the highest proportion of PSII herbicides at the monitoring sites in this region.

Tebuthiuron has been, and continue to be, associated almost exclusively with the Burdekin and Fitzroy River basins where land use is predominantly grazing. The North Keppel Island site in the Fitzroy region has in the past been characterised by relatively high concentrations of tebuthiuron, including an exceedance of the Authority guidelines in 2013 (Gallen et al., 2013). However, notably in the current monitoring year, the pesticide profile was characterised by only low levels of tebuthiuron and was dominated by diuron.

Other pesticide profile

Farming best management practice of Reef-catchment based agricultural industries (particularly sugar cane cultivation) endorses the use of alternative knock-down herbicides (such as 2,4-D, glyphosate) (Reef Plan, 2013; Smith et al., 2015). In addition, a large number of other pesticides are also now known to be used and transported in basins discharging to the Reef (Devlin et al., 2015), including insecticides, fungicides and other herbicides (i.e. herbicides that are not used as a PSII herbicide alternative weed control, e.g. metsulfuron-methyl).

The prevalence of other pesticides are now being monitored as part of GBRCLMP in addition to the PSII herbicides targeted as a priority for reduction in Reef Plan (2009 and 2013). Routine analysis of other pesticides in both passive and grab samples was initiated in 2014–2015, and many have been detected since then in both sampler types at most sites. Metolachlor, 2,4-D, MCPA, and imidacloprid were consistently detected in passive samplers in the current monitoring year. Other pesticides are also detected at low levels. Compared to PSII herbicides, detected concentrations of other pesticides at the fixed passive sites were generally very low (i.e. typically <1 ng L^{-1}) with the exception of isolated samples from Round Top Island where the maximum concentrations of metolachlor and 2,4-D were 16 and 8 ng L^{-1}, respectively.

The discharge of diverse mixtures of pesticides with multiple modes of action into the marine environment presents a combined toxicity risk to aquatic life, which is assessed by the ms-PAF matrix.

The end-of-basin pesticide monitoring under the GBRCLMP reflects the entirety of paddock-scale drivers and pressures resulting in pesticide losses into waterways and subsequent detection in marine environments. Overall, compared to rivers and estuarine waters in the catchment, concentrations of pesticides in the marine environment are low (Devlin et al., 2015), due to processes such as dilution and degradation (Lewis et al., 2009). Nevertheless, the chronic effects of low level pesticide exposure to corals and seagrass, especially in combination with other local and global pressures, remain a concern (Brodie et al., 2013; Wilkinson et al., 2017).

Pesticide metric for risk categorisation

The PSII-HEq index was identified as a suitable indicator of exposure risk to inshore pesticide levels over time based on a review by Kuhnert et al. (2015) and has been applied to MMP pesticide data since monitoring began. Presently, the index only includes 11 PSII herbicides and 2 metabolites; however, monitoring data in recent years confirms the extensive use of a number of non-PSII inhibiting pesticides in Reef basins, through loads delivered in runoff and detections in both passive and grab samples in the nearshore marine

environment. It is therefore becoming ever more important to determine the increased risks (if any) they may have on the health and resilience of the Reef.

A desktop assessment of the relative risk of alternative herbicides (considering the risks of off-site run-off and toxicity across a range of indicative trophic levels) found that several of the proposed alternatives presented a risk comparable to those of the priority PSII herbicides they were replacing (Davis et al., 2014).

Given the uncertainty over the risk profile of this complex mixture of pesticides (i.e. the priority PSIIs, the alternative 'knockdown' herbicides and the non-PSII inhibiting pesticides), an alternative method of exposure risk assessment that can assess the cumulative risk for a suite of pesticides that have different modes of action is being adopted.

The multisubstance – potentially affected fraction (ms-PAF) approach to assess mixture toxicity of pesticides (Traas et al., 2002) is an alternative approach has been reported for the first time in this program for this monitoring year. For this report, pesticide condition was based on concentrations of 19 pesticides including 9 PSII herbicides from passive sampler devices and grab samples over the year. This differs from pesticide condition in the catchments, which is based on multiple grab samples over the wet season. Passive samplers provide a single time integrated concentration for each sampler representing the entire deployment time (typically four weeks). Passive samplers allow for a longer-term 'average' concentration to be identified, which suits annual condition reporting. While grab samples have the potential to identify acute, rapid, irregular peaks in pesticide concentration, this is only the case if taken at the opportune time.

Marine results are not directly comparable with the end-of-catchment results primarily due to differences in sampling. However, they provide insight into the transport and fate of pesticides, from the end of rivers to marine sites, and the risk to marine ecosystems from the mixture of pesticides. The key differences are:

- three of the pesticides, fipronil, isoxaflutole and triclopyr, are not included in the analysis suite for the marine samples (i.e. 19 of the 22 pesticides analysed at the end-of-catchment are analysed for in marine samples). This may mean that the mixture toxicity is underestimated (relative to the catchment monitoring results). However, it is likely at worst a minor underestimation as only isoxaflutole is regularly detected at the end-of-catchment (i.e. in Mackay Whitsunday catchments) at concentrations that exceed draft ecosystem protection guidelines for protection of 99% species (0.33 µg L^{-1}) and is unlikely to contribute significantly to overall pesticide toxicity in inshore marine waters (Great Barrier Reef Catchment Loads Monitoring Program, *pers comm*).
- passive samplers are deployed throughout the year providing an ~monthly average concentration of pesticides during both wet and dry seasons. In contrast, end-of-catchment pesticide results are based on high frequency, point in time, grab samples primarily targeting the wet season. Given there is a range of risk reported across the deployments, averages based on passive sampling would likely result in a reduced overall risk.

- the end of catchment pesticide data is converted to a single value representing the time-averaged[1] per cent of species protected during a standardised wet season period (182 days = 6 months). Passive sampler concentrations are converted to a per cent of species protected during each passive sampler deployment.

In the coming years we will explore methods to increase the comparability of the marine and end of catchment pesticide reporting. In the interim, we are reporting the ms-PAF value of what we know is the minimum protection level achieved during a deployment (i.e. the passive samplers with the highest concentrations and highest ms-PAF scores at each site).

Grab sampling along flood plume salinity gradients has demonstrated localised areas of elevated PSII herbicide concentrations near river mouths (Grant et al., 2018). Grab samples collected several kilometres into the Reef lagoon have demonstrated a linear correlation between pesticide concentration and salinity, indicating the conservative mixing of these pesticides and that dilution rather than physical (e.g. flocculation), chemical (e.g. photolysis) or biological (e.g. biodegradation) processes (Lewis et al., 2009) governs the fate and transport mechanisms that are driving pesticide movement into the nearshore environment.

Whilst the frequency and intensity of concentration pulses associated with high flow river events are reduced with distance from river sources, low-level chronic exposure to pesticides in nearshore marine areas may still have negative impacts at the receiving environments. Effects may include changes in microbial communities (Magnusson et al., 2012), negative effects on seagrass energetics and growth (Negri et al., 2015), as well as reduced photosynthesis and reproductive output of corals (Cantin et al., 2007; Negri et al., 2005) and other Reef/tropical photosynthetic species. Furthermore, cumulative impacts of pesticide exposure and other external stressors (such as rising sea surface temperature) are likely to increase in the future based on current climate trends (Negri et al., 2011; van Dam, 2012; van Dam et al., 2012).

Future directions

The longer-term change in nearshore marine pesticide levels attributable to changed basin land management practices, which is the focus of the Reef 2050 WQIP, continues to be challenging to elucidate. Developing statistical approaches in collaboration with CSIRO to separate inter-annual and inter-event effects of flow variability on long-term trends in pesticide levels, to potentially assess the true impact of improved land management practices is a priority for the upcoming monitoring year.

Land use in the Reef basins continues to change, and thus the impacts of these activities on the surrounding environment are dynamic. With changing land use, it is likely that changes in both the amounts and types of agricultural chemicals being used, as well as the timing and methods of application, will influence environmental concentrations and the level of risk to aquatic marine life.

There are no data available for the current local-scale usage of pesticides in the Reef basins, apart from limited estimates in the 1990's and more general estimates from 2008–2009 that are unlikely be relevant to current pesticide usage (ABS, 2010; Devlin et al., 2015).

[1] The average is calculated from a multiple imputation approach that uses statistical distributions to infill missing days of data.

This lack of data limits assessments of pesticide losses (relative to the amount applied) as well as accurate modelling of pesticide loads at the basin scale. Pesticide usage is seasonal, crop-specific and can fluctuate yearly based on specific pest pressures, climatic conditions, regulatory action (such as the restriction on diuron use in 2012), use of resistant crop varieties or the development of herbicide resistance in weeds (Devlin et al., 2015). The currently available information allows only comparison of the types of pesticides being released in basin runoff (i.e. end-of-basin loads) and those pesticides monitored in near shore areas.

Despite observed increases in pesticide levels at several sites overall, relatively low levels of PSII herbicides were detected in 2017–18 at most sites. Although PSII herbicide exposure is not expected to be a high-risk factor for adverse impacts on Reef health, it is important to understand the cumulative impacts of this low level chronic exposure together with other stressors, including the effects of global climate change (increasing sea temperatures, ocean acidification), the severity and frequency of damaging weather events such as cyclones and the frequency of flood events.

Ultimately, a whole-of-system pesticide exposure assessment may become possible through the eReefs framework, a hydrodynamic model developed for the Reef system. Recent changes to the framework have opened opportunities to potentially apply this model to end-of-basin pesticide loads and predict the distribution of discharged loads from each basin into the near-shore environment. Monitoring data generated through the current MMP could provide necessary field data for model validation both spatially and temporally. The framework potentially provides three-dimensional capability to predict pesticide concentrations at any point within the Reef lagoon, which increases spatial coverage, as well as generating information that can inform the optimal placement of passive samplers to capture and measure key pesticide pulses released from adjacent basins. This information will facilitate insight into impacts on ecosystem health and assist in prioritising management action. Whilst monitoring an area as vast and complex as the Reef remains a challenge, long-term monitoring programs such as the MMP are valuable tools.

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Appendix A Supplemental information on methodology

A-1 Sampler deployment, approaches for missing data and sources of uncertainty

Sampler deployment and approaches for missing data

Samplers are cleaned, assembled and calibrated by QAEHS but are deployed in the field by a team of volunteers. The participation of volunteers from various community groups, agencies and tourist operations is a key feature of the long-term pesticide monitoring program and integral to the success of maintaining the program in often remote locations. Volunteers receive, deploy, retrieve and return the passive samplers to QAEHS for subsequent extraction and analysis. Volunteers are trained by the Great Barrier Reef Marine Park Authority (the Authority) and/or QAEHS staff in the Standard Operating Procedures (SOPs) for deploying and retrieving the passive samplers, ensuring high quality usable data.

Whilst every effort is made to deploy samplers in accordance with the proposed sampling schedule, there are circumstances every year where this is not possible. This may result in periods where passive samplers are not deployed (for example, during bad weather) or samplers are under- or over-deployed, i.e. the period the sampler is left in the water is less than or greater than the preferred period (2 months in dry season, 1 month in wet season). In addition, samplers are regularly lost in extreme weather events or are stolen or otherwise damaged. For periods of non-deployment, gaps between successful deployments are often up to 1-2 weeks at most and have minimum impact on the long-term trends. Longer periods of non-deployment or when samplers are lost can result in uncertainty in the representativeness of the pesticide concentration data for that deployment season and, therefore, may affect the long-term trends (for example, when only one wet season sampler is successfully deployed in one year, but all 6 are deployed for previous years). This can make interpretation of long term trends challenging. Actual dates of deployment are given in Appendix F and average concentrations where only one sampler was received for that season are highlighted in the summary statistics tables in the Results section.

Passive samplers are calibrated for an optimum deployment period and if they are over- or under-deployed, this reduces the confidence in the reported concentrations. If under-deployed, the amount of pesticide taken up into the sampler may be too low to be detected on the analytical instruments, resulting in a non-detect result when in fact the pesticide was present in the marine waters. If over-deployed, the samplers may become saturated, violate the assumptions of pesticide uptake dynamics or become bio-fouled or otherwise contaminated in the field. In these cases, samplers are excluded from the analysis. Passive samplers that show evidence of inappropriate storage during transportation that may lead to contamination (such as transport lids not attached or EDs returned dry) or damage during deployment (mud underneath membrane or severe biofilm that impedes water flow) are also excluded from analysis.

Sources of uncertainty

To interpret both trends in the long-term data and true changes in concentrations year to year, there must be an understanding of the inherent variability of the data. Possible sources of uncertainty when using the passive samplers may include (but are not limited to) the

effects of salinity and water temperature on chemical uptake into the sampler, accurate measurement of exposure time, the integrity of the flow-limiting membrane over the deployment period, degree of biofouling on the surface of the sampler and its effect on the sampling area, analytical error and variability in the dissolution of the PFM used to approximate water flow (and sampling rates).

Salinity (ionic strength) has been found to have a very small effect on the solubility of the gypsum contained in the PFM, which is subsequently used to estimate sampling rates with respect to the water flow at a given site (O'Brien et al., 2011b). The effect of salinity on a hypothetical calculation of water concentration from an ED found that a change in salinity from 5 g L^{-1} (freshwater) to 35 g L^{-1} (marine water) did not change the estimated flow rate (to two significant figures) under either low or high dissolution rate conditions. The effect of water temperature on the dissolution of the PFM is not well understood, but as water temperature remains relatively constant between the wet and dry seasons (20-25°C) it is assumed to have a negligible effect.

Replicate PFMs are deployed at each passive sampler site, and the mass lost per day is used to estimate the sampling rate of chemicals. Normalised difference percentages between duplicate PFMs deployed at each site this monitoring year ranged between <1 and 32% (mean of 9.8%), showing good agreement (this excludes 26 sampler-sets where PFM duplicates were both empty upon retrieval).

Duplicate EDs are deployed at each sampling site. One duplicate sampler is analysed for approximately every 10 samples to determine the variability in the overall performance (chemical uptake) of the EDs (Table A-1). This monitoring year, 24 ED sampler sets were analysed in duplicate, and four grab samples were also analysed in duplicate (results combined). There were 284 pesticide detections in both duplicates and 24 herbicide detections in only one of the duplicates. Mean coefficients of variation (%CVs) for chemicals (which includes detections in both duplicates only) ranged from 3.3% (terbutryn; however only one duplicate detection) to 55% (fluazifop; also only one duplicate detection). Variability for the most frequently detected pesticides (diuron, atrazine, hexazinone) were 26%, 22% and 24% respectively, similar to the previous monitoring year (20%, 23% and 23%).

The objective of most passive sampling field studies is to derive an accurate estimate of the concentration of pollutants present in the environment. However, the environmental concentrations obtained from passive sampling can only be accurate when appropriate calibration data (i.e. sampling or chemical uptake rates usually in units of L day^{-1}) is used to derive these values. Sampling rates are influenced by the prevailing conditions at a sampling site and include temperature, water flow and the degree of sampler biofouling, and cannot be easily predicted based on a chemical's physico-chemical properties. Although there is an ever-increasing amount of calibration data available for commonly detected anthropogenic chemicals, calibration data is still lacking, particularly for new and emerging chemicals.

The sampling rates (R_s) of many polar chemicals relevant to the Reef have been reported in both field and laboratory calibration experiments throughout the literature (Booij et al., 2002; Kaserzon et al., 2014; O'Brien et al., 2011a; Shaw et al., 2009; Shaw and Mueller, 2009; Stephens et al., 2005; Stephens et al., 2009; Vermeirssen et al., 2009), although rates vary due to the conditions under which they were conducted. Atrazine was common to all of these

studies and was chosen as a reference point to estimate compound specific sampling rates of other herbicides on a proportional basis (i.e. R_s of chemical X / R_s of atrazine).

The relationship between the sampling rate of atrazine and flow effects has been extensively investigated (O'Brien et al., 2011a). Using this relationship, a sampling rate for each herbicide was calculated, specific to the flow conditions encountered at a particular site during each deployment. By inserting the relevant water velocity (estimated from PFM loss rate) into the equation and adjusting the resulting sampling rate by their proportion relative to atrazine, compound specific sampling rates were estimated for other herbicides, to provide estimates of herbicide water concentrations. For herbicides where no calibration data is available, the sampling rate of atrazine has been assumed. Whilst there is always variability in calibration data, regardless of whether calibration data is available or has been assumed, the objectives of the pesticide monitoring component (to monitor trends in pesticide concentrations) of the MMP can be achieved, provided the same calibration data is used year-on-year.

Table A-1: Summary of variability (% coefficient of variation, % CV) of replicate ED and grab sample analysis

	Detections in both duplicates (n)	Mean % CV	Min % CV	Max % CV
Ametryn	8	25	10	85
Atrazine	28	22	0.41	111
DE Atrazine	20	25	0.53	83
Diuron	28	26	0.67	108
Hexazinone	28	24	0.28	100
Metolachlor	26	23	0.15	93
Prometryn	0			
Simazine	19	31	4.8	111
Tebuthiuron	24	19	2.9	52
Terbutryn	1	3.3	3.3	3.3
Terbutylazine	3	40	0.74	76
Imazapic	2	26	12	39
Imidacloprid	16	30	2.9	91
DI Atrazine	8	20	1.3	35
Metsulfuron methyl	4	13	3.7	27
24-D	19	17	2.6	62
24-DB	1	22	22	22
Bromacil	4	12	2.6	21
Fluazifop	1	55	55	55
Fluometuron	0			
Fluroxypyr	6	24	1.6	66
Haloxyfop	10	26	1.4	101
MCPA	9	15	1.1	27
Metribuzin	8	32	0.91	95
Propazine	10	23	2.5	65
Tebuconazole	1	19	19	19

Note: Only instances where a chemical was detected in both replicates have been included

A-2. Target chemicals

The list of target chemicals originally derived at the commencement of the MMP through consultation with the Authority was based on the following criteria:

- pesticides detected in recent studies;
- those recognised as a potential risk;
- analytical affordability;
- pesticides within the analytical capabilities of Queensland Health and Forensic Scientific Services (QHFSS, who formerly conducted all analysis); and
- those likely to be accumulated using one of the passive sampling techniques (i.e. that exist as neutral species and are not too polar).

In 2015 in consultation with the Pesticide Working Group and the Authority, the list of target chemicals was further expanded to include several other pre- and post-emergent herbicides (Table A-4). The criteria by which these new target chemicals have been included are:

- registered for use in Reef basins to supplement or replace the use of some traditional Photosystem II (PSII) herbicides;
- included in the suite for PSII end-of-basin loads monitoring and basin pesticide modelling programs conducted by other agencies (and thus better harmonisation across complimentary monitoring programs); and
- detected in recent studies and monitoring programs.

Table A-2: QAEHS LC-MS/MS analyte list for positive and negative mode analysis

Positive Ion Mode	Negative Ion Mode
Ametryn	2,4-D
Asulam	2,4-DB
Atrazine	Fluroxypyr
Bromacil	Haloxyfop
Desethyl Atrazine	MCPA
Desisopropyl Atrazine	
Diuron	
Fluazifop	
Fluometuron	
Hexazinone	
Imazapic	
Imidacloprid	
Metolachlor	
Metribuzin	
Metsulfuron-methyl	
Prometryn	
Propazine	
Simazine	
Tebuconazole	
Tebuthiuron	
Terbutryn	

Table A-3: QAEHS GC-MS analyte list for PDMS extracts

Pesticide
Chlorpyifos
Pendimethalin
Propazine
Propiconazole
Trifluralin

Table A-4: Proposed priority pesticides and herbicides specified under the MMP (proposed by PWG 18 August 2015) and other pesticides of interest for potential inclusion in monitoring and reporting activities (feedback from the Paddock to the Reef program). Instrument limit of detection (LOD) and limit of reporting (LOR) are given (μg L^{-1}), where available.

Chemical	Description	Priority or of interest	LC-MS/MS		GC-MS
			LOD	LOR	LOR
2,4-D	Phenoxy-carboxylic-acid herbicide	Priority	0.03	0.10	
2,4-DB	Phenoxy-carboxylic-acid herbicide	Of interest	5.0	15	
Aciflurofen*	Herbicide: cell membrane disruptor	Of interest			
Ametryn	PSII herbicide – methylthiotriazine	Priority	0.56	1.69	
Asulam	Herbicide: inhibition of DHP – carbamate	Of interest			
Atrazine	PSII herbicide – chlorotriazine	Priority	0.05	0.15	
Atrazine – desethyl	PSII herbicide breakdown product (also active)	Priority	0.005	0.10	
Atrazine – desisopropyl	PSII herbicide breakdown product (also active)	Priority	0.02	0.10	
Bromacil	PSII herbicide – uracil	Of interest	0.02	0.10	
Chlorothalonil*	Organochlorine fungicide	Priority			
Chlorpyrifos	Organophosphate insecticide	Priority			0.5
Diazinon*	Insecticide: inhibits acetylcholinesterase	Of interest			
Diuron	PSII herbicide – pheynylurea	Priority	0.02	0.10	
Ethametsulfuron methyl*	Herbicide: acetolactate synthase (ALS) inhibition	Of interest			
Fipronil*	Phenylpyrazole insecticide	Priority			
Fluazifop	Herbicide: inhibition of acetyl CoA carboxylase	Of interest	0.02	0.10	
Fluometuron	PSII herbicide – urea	Of interest	0.01	0.10	
Fluroxypyr	Pyridine carboxylic acid herbicide	Priority	0.02	0.10	
Glyphosate*	Broad-spectrum systemic herbicide	Priority			
Haloxyfop	Aryloxyphenoxy-propionate herbicide	Priority	0.04	0.13	
Hexazinone	PSII herbicide – triazinone	Priority	0.01	0.10	
Imazapic	Imidazolinone herbicide	Priority	0.02	0.10	
Imidacloprid	Neonicotinoid insecticide	Priority	0.01	0.10	

Chemical	Description	Priority or of interest	LC-MS/MS		GC-MS
			LOD	LOR	LOR
Isoxaflutole and DKN*	Isoxazole herbicide	Priority			
MCPA	Phenoxy-carboxylic-acid herbicide	Priority	0.05	0.14	
Mesosulfuron methyl*	Herbicide: acetolactate synthase (ALS) inhibition	Of interest			
Metolachlor	Chloracetanilide herbicide	Priority	0.03	0.10	
Metribuzin	PSII herbicide – triazinone	Priority	0.03	0.11	
Metsulfuron methyl	Sulfonylurea herbicide	Priority	0.03	0.10	
MSMA*	Herbicide: inhibition of cell division	Of interest			
Paraquat*	Herbicide: photosystem-I-electron diversion	Of interest			
Pendimethalin	Dinitroaniline herbicide	Priority			1.0
Prometryn	PSII herbicide – methylthiotriazine	Priority	0.54	1.61	
Propazine	PSII herbicide – chlorotriazine	Priority	0.06	0.18	
Propiconazole*	Conazole fungicide	Priority			2.0
Prothiophos*	Insecticide: inhibits acetylcholinesterase	Of interest			
Simazine	PSII herbicide – chlorotriazine	Priority	0.08	0.24	
Tebuconazole	Conazole fungicide	Priority	0.10	0.31	
Tebuthiuron	PSII herbicide – thiadazolurea	Priority	0.01	0.10	
Terbuthylazine*	PSII herbicide – triazine	Priority			
Terbutryn	PSII herbicide – triazine	Of interest	0.55	1.7	
Triclopyr*	Pyridine carboxylic acid herbicide	Priority			
Trifloxysulfuron*	Herbicide: inhibition of ALS – sulfonyl urea	Of interest			
Trifluralin	Herbicide – dintiroaniline	Priority			0.2

* Not currently analysed by QAEHS
Shaded chemicals are included as part of the Paddock 2 Reef Integrated Monitoring, Modelling and Reporting Program
Red text indicates that the sampling rate of atrazine has been assumed.

A-3. Analytical details

QAEHS undertakes all herbicide analysis of passive and grab samples using Liquid Chromatography-tandem Mass Spectrometry (LC-MS/MS).

ED extracts and grab samples were analysed for herbicides using a Sciex QTRAP 6500+ mass spectrometer (Sciex, Concord, Ontario, Canada) equipped with an electrospray (TurboV) interface coupled to a Shimadzu Nexera HPLC system (Shimadzu Corp., Kyoto, Japan). Separation was achieved using a 2.6 micron 50 x 2.0mm Phenomenex Biphenyl column (Phenomenex, Torrance, CA) run at 45˚C, and a flow rate of 0.3 mL min^{-1} with a linear gradient starting at 5% B, ramped to 100% B in 5.2 minutes then held at 100% for 4.3 minutes followed by equilibration at 5% B for 3.5 minutes. (A = 1% methanol in HPLC grade water, B = 95% methanol in HPLC grade water, both containing 0.1% acetic acid). The mass

spectrometer was operated in both positive and negative ion multiple reaction-monitoring mode, using nitrogen as the collision gas and monitoring two transitions for each analyte.

Positive results were confirmed by retention time and by comparing transition intensity ratios between the sample and an appropriate concentration standard from the same run. Samples were reported as positive if the two transitions were present (with peaks having a signal to noise ratio greater than 3), retention time was within 0.15 minutes of the standard and the relative intensity of the confirmation transition was within 20% of the expected value. The value reported was that for the quantitation transition.

Analysis of PDMS extracts for non-polar pesticides was conducted on a Thermo Scientific TSQ Quantum XLS Triple Quadrupole GC-MS/MS. The mass spectrometer was operated in positive ion, multiple reaction monitoring mode, using argon as the collision gas. Prior to introduction into the mass spectrometer, compounds were separated on an Agilent J & W DB5-MS (25m; 0.25mm i.d.; 0.25µm film thickness) column. Samples were injected in splitless mode at 80°C. The GC oven was held at 80°C for 2 minutes and ramped to 180°C at 20°C/minute; held for 0.5 minutes and ramped to 300°C at 10°C/minute and held for 10.5 minutes. The transfer line and ion source were heated at 280°C and 270°C respectively. Helium was used as the carrier gas at a rate of 1.0 mL/minute. A quantitative and qualitative ion transition was monitored for each compound.

Appendix B Supplemental information on water quality guidelines

Water quality in Australia is currently managed in accordance with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2018). Trigger values are defined for a range of pesticides and an indication of the reliability of the value (low, moderate, high) is given in Table B-1. The guidelines paid considerable attention to values derived using the assessment factor approach (Batley et al., 2014). For several of the pesticides detected in this current monitoring year, no trigger values were yet available.

The use of species sensitivity distributions (SSDs) is the preferred method of deriving water quality guidelines (Warne et al., 2015). A SSD is a model of the variation in sensitivity of species in an ecosystem to a particular stressor and allows prediction of the percentage of species that is expected to be adversely affected at a given environmental stressor level (e.g. pesticide concentration). Under this approach, protective concentrations can be defined that typically offer four levels of protection: 99, 95, 90 and 80 per cent of species in the ecosystem being protected, referred to as PC99, PC95, PC90 and PC80, respectively (Batley et al., 2014).

Using this approach, marine protective concentrations were derived by the Great Barrier Reef Marine Park Authority (GBRMPA, 2010) for tropical species (Appendix B Table B-1). The Great Barrier Reef is considered as a high ecological value (HEV) ecosystem and, therefore, afforded the highest water quality protection level, i.e. protection of at least 99 per cent of species (PC99). This level of protection is judged the most suitable for this World Heritage Area, which is classified as having outstanding universal value and no change in the indicators of biological diversity beyond the natural variation is recommended.

Table B-1: Water quality limits available for pesticides (protective concentration (PC) values, PC95 and PC99, will protect 95% and 99% of the species in the ecosystem, respectively) (ng L^{-1}).

Chemical	DES proposed guideline values (PGVs)[a]		ANZECC[c]		GBRMPA[e]	
	PGV	Notes	Trigger Value	Notes	PC Value	Notes
2,4-D	1,040,000	PC99; low reliability; Marine water				
Ametryn	100	PC99; moderate reliability; Marine water			500	PC99; Moderate reliability
					1,000	PC95; Moderate reliability
Atrazine	-		700	PC99; Fresh water	600	PC99; Moderate reliability

Chemical	DES proposed guideline values (PGVs)[a]		ANZECC[c]		GBRMPA[e]	
	PGV	Notes	Trigger Value	Notes	PC Value	Notes
			1,300	PC95; Fresh water	1,400	PC95; Moderate reliability
			ID	PC99/95; Marine water		
Bromacil	230	PC99; moderate reliability; Marine water				
Chlorpyrifos	-		0.5	PC99; Marine water	0.5	PC99; High reliability
			9	PC95; Marine water	9	PC95; High reliability
			0.04	PC99; Freshwater		
Diuron	430[b]	PC99; very high reliability; Marine water	200[d]	IWL; low reliability; Freshwater	900	PC99; moderate reliability
			1,800[d]	IWL; low reliability; Marine water	1,600	PC95; moderate reliability
Fipronil	3.4	PC99; moderate reliability; Marine water				
Fluometuron	20,000	PC99; moderate reliability; Marine water				
Fluroxypyr	87,000	PC99; moderate reliability; Marine water				
Haloxyfop	589,000	PC99; low reliability; Marine water				
Hexazinone	1,800	PC99; low reliability; Marine water			1,200	Low reliability
Imazapic	49	PC99; very low reliability; Marine water				
Imidacloprid	57	PC99; moderate reliability; Marine water				
MCPA	1,000	PC99; low reliability; Marine water				
Metolachlor	Marine data n.a.		20[d]	IWL, low reliability; Freshwater		

Chemical	DES proposed guideline values (PGVs)[a]		ANZECC[c]		GBRMPA[e]	
	PGV	Notes	Trigger Value	Notes	PC Value	Notes
	Freshwater: 16		20[d]	IWL, low reliability; Marine water		
Metribuzin	2,000	PC99; moderate reliability; Marine water				
Metsulfuron methyl	Marine data n.a. Freshwater: 4.7					
Pendimethalin	240	PC99; moderate reliability; Marine water				
Prometryn	110	PC99; moderate reliability; Marine water				
Propazine	2,200	PC99; low reliability; Marine water				
Propiconazole	2,100	PC99; moderate reliability; Marine water				
Simazine	28,000	PC99; low reliability; Marine water	200	PC99; Freshwater	200	PC99; Low reliability
			3,200	PC95; Freshwater		
			ID	PC99/95: Marine water		
Tebuthiuron	4,700	PC99; moderate reliability; Marine water	20	PC99; Freshwater	20	PC99; low reliability
			2,200	PC95; Freshwater		
			ID	PC99/95: Marine water		
Terbuthylazine	400	PC99; moderate reliability; Marine water				
Terbutryn	79	PC99; moderate reliability; Marine water				
Triclopyr	36	PC99; low reliability; Marine water				
Trifluralin	-		2,600	PC99; Freshwater		

Chemical	DES proposed guideline values (PGVs)[a]		ANZECC[c]		GBRMPA[e]	
	PGV	Notes	Trigger Value	Notes	PC Value	Notes
			ID	PC99/95: Marine water		

[a] Reported in the 2017 Scientific Consensus Statement (Waterhouse et al., 2017a) as proposed ecotoxicity threshold values
[b] Sourced from King et al. (2017a) (King et al., 2017b; King et al., 2017c)(PC99, PC95, PC90 and PC80 are derived, only PC99 relevant to the Reef reported in the table)
[c d] Interim Working Level (IWL) (rather than trigger value) as indicated in f the ANZECC Guidelines (ANZECC, 2018)
[e] Sourced from Table 26 & Table 27 of the Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMPA, 2010)
ID - insufficient data were available to determine a trigger value

Appendix C Supplemental information on risk assessment metrics

C-1. Overview of risk assessment metric: Multisubstance-potentially affected fraction (ms-PAF) method

Pesticide condition for the 2018 report card was based on the monitored concentrations of up to 19 pesticides (Table 6) in passive sampler devices and grab samples over the year. This differs from pesticide condition in the catchments, which is based on multiple grab samples over the wet season. Passive samplers provide a single time integrated concentration for each sampler representing the entire deployment time (typically four weeks).

Passive samplers allow for a longer-term 'average' concentration to be identified, which suits annual condition reporting. While grab samples have the potential to identify acute, rapid, irregular peaks in pesticide concentration, this is only the case if taken at the opportune time.

Table 6: Pesticides detected in passive sampler devices that were assessed using the ms-PAF method for multiple pesticides. Not all of the listed pesticides were necessarily detected in collected water samples.

Name of pesticide	Type	MoA
Chlorpyrifos	Insecticide	Acetylcholine esterase (AChE) inhibitor
Imidacloprid	Insecticide	Nicotinic receptor agonist
Haloxyfop	Herbicide	Acetyl-coenzyme A carboxylase (ACCase) inhibitor
Imazapic	Herbicide	Group 1 Acetolactate synthase (ALS) inhibitor
Metsulfuron-methyl	Herbicide	Group 2 Acetolactate synthase (ALS) inhibitor
Pendimethalin	Herbicide	Microtubule synthesis inhibitor
Metolachlor	Herbicide	Acetolactate synthase (ALS) inhibitor
Ametryn	Herbicide	Group 1 PSII inhibitor
Atrazine	Herbicide	
Terbuthylazine	Herbicide	
Tebuthiuron	Herbicide	
Simazine	Herbicide	Group 2 PSII inhibitor
Diuron	Herbicide	Group 3 PSII inhibitor
Terbutryn	Herbicide	
Hexazinone	Herbicide	Group 4 PSII inhibitor
Metribuzin	Herbicide	Group 5 PSII inhibitor
2,4-D	Herbicide	Group 1 auxins (Phenoxy-carboxylic acid auxins)
MCPA	Herbicide	
Fluroxypyr	Herbicide	Group 2 auxins (Pyridine-carboxylic acid auxins)

In order to express the concentration data for all selected pesticides as a single number that represented the overall risk to aquatic ecosystems, it was necessary to convert all the concentration data into a numerical term that represented the toxicity of the mixture of pesticides in each passive sampler or water sample, and then aggregate all the pesticide concentration data as a single number. In previous reports, the hazard equivalence (Heq) method was used to express the toxicity of PSII herbicides based on their toxicities relative to diuron (Table C-1).

In this report the multi substance potentially affected fraction (ms-PAF) approach was adopted to bring this metric in line with freshwater catchments (Grant et al., 2018a; Traas et al., 2002). The ms-PAF approach was applied to pesticides with multiple modes of action (Table 1). The ms-PAF for pesticides with different modes of action was calculated using the independent action model of joint action (Plackett and Hewlett, 1952). Further details on how the pesticide risk metric calculations were made is provided in Warne et al.(Warne et al., (in prep)).

The result of the ms-PAF analysis provides an estimate of the toxicity of the mixture of pesticides in each passive sampler device or water sample expressed as a percentage of species affected.

The corresponding per cent species protected (calculated for each passive sampler at 11 monitoring sites) were then allocated to the risk categories presented in Table 7. These categories are consistent with the ecological condition categories used in the Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters.

For the 2018 report card onwards, ms-PAF values were used to determine pesticide grades. All values were rounded to the nearest whole number.

Table 7: Grading description for the pesticides indicator in the freshwater basin assessments.

Risk categories (% species affected)	Risk categories (% species protected)	Risk category	Risk Level
≤1.0%	≥99%	5	Very low risk
>1 – <5%	>95 – <99%	4	Low risk
5 – <10%	>90 – 95%	3	Moderate risk
10 – <20%	>80 – 90%	2	High risk
≥20.0%	≤80%	1	Very high risk

Table C-1: Scientific publications indicating the effect concentrations and the end-points for the reference PSII herbicide diuron used to define specific PSII-HEq Index categories as an indicator for reporting purposes

Category	PSII-HEq Range (ng L^{-1})	Supporting Literature with Respect to the Reference Chemical Diuron					
		Description	Species	Effects Concentration (ng L^{-1})	Endpoint	Toxicity measure	Reference (see footnotes)
5	HEq ≤ 10	No published scientific papers that demonstrate any effects on plants or animals based on toxicity or a reduction in photosynthesis. The upper limit of this category is also the detection limit for pesticide concentrations determined in field collected water samples.					
4	10 < HEq ≤ 50	Published scientific observations of reduced photosynthesis for two diatoms.	**Diatoms**				
			D. tertiolecta	50	↓photosynthesis	LOEC	Bengston Nash *et al* 2005
			N. closterium	50	Sensitivity	LOEC	Bengston Nash *et al* 2005
3	50 < HEq < 250	Published scientific observations of reduced photosynthesis for two seagrass species and three diatoms.	**Seagrass**				
			H. ovalis	100	↓photosynthesis	LOEC	Haynes et al 2000
			Z. capriconi	100	↓photosynthesis	LOEC	Haynes et al 2000
			Diatoms				
			N. closterium	100	Sensitivity	IC10	Bengston Nash *et al* 2005
			P. tricornutum	100	Sensitivity	IC10	Bengston Nash *et al* 2005
			D. tertiolecta	110	↓photosynthesis	IC10	Bengston Nash *et al* 2005
2	250≤ HEq ≤ 900	Published scientific observations of reduced photosynthesis for three coral species.	**Coral - Isolated zooxanthellae**				
			S. pistillata	250	↓photosynthesis	LOEC	Jones *et al* 2003
			Coral - Adult colonies				
			A. formosa	300	↓photosynthesis	LOEC	Jones & Kerswell, 2003
			S. hystrix	300	↓photosynthesis	LOEC	Jones *et al* 2003
			S. hystrix	300	↓photosynthesis	LOEC	Jones & Kerswell, 2003
1	HEq > 900	Published scientific papers that demonstrate effects on the growth and death of aquatic plants and animals exposed to the pesticide. This concentration represents a level at which 99 per	**Seagrass**				
			Z. capriconi	1000	↓photosynthesis	LOEC	Chesworth *et al* 2004
			Z. capriconi	5000	↓growth	LOEC	Chesworth *et al* 2004

Category	PSII-HEq Range (ng L^{-1})	Supporting Literature with Respect to the Reference Chemical Diuron					
		Description	**Species**	**Effects Concentration (ng L^{-1})**	**Endpoint**	**Toxicity measure**	**Reference (see footnotes)**
		cent of tropical marine plants and animals are protected, using diuron as the reference chemical.	*Z. capriconi*	10000	↓photosynthesis	LOEC	Macinnis-Ng & Ralph, 2004
			C. serrulata	10000	↓photosynthesis	LOEC	Haynes *et al* 2000b
			Coral - Isolated zooxanthellae				
			M. mirabilis	1000	↓C^{14} incorporation	LOEC	Owen *et al* 2003
			F. fragum	2000	↓C^{14} incorporation	LOEC	Owen *et al* 2003
			D. strigosa	2000	↓C^{14} incorporation	LOEC	Owen *et al* 2003
			Larvae				
			A. millepora	300	↓ Metamorphosis	LOEC	Negri *et al* 2005
			Coral recruits				
			P. damicornis	1000	↓ photosynthesis	LOEC	Negri *et al* 2005
			P. damicornis	10000	Loss of algae	LOEC	Negri *et al* 2005
			Coral - Adult colonies				
			A. formosa	1000	↓ photosynthesis	LOEC	Jones *et al* 2003
			P. cylindrica	1000	↓ photosynthesis	LOEC	Jones *et al* 2003
			M. digitata	1000	↓ photosynthesis	LOEC	Jones *et al* 2003
			S. hystrix	1000	↓ photosynthesis	LOEC	Jones *et al* 2003, Jones 2004
			A. millepora	1000	↓ photosynthesis	LOEC	Negri *et al* 2005
			P. damicornis	1000	↓ photosynthesis	LOEC	Negri *et al* 2005
			S. hystrix	2300	↓ photosynthesis	EC50	Jones *et al* 2003
			A. formosa	2700	↓ photosynthesis	EC50	Jones & Kerswell, 2003
			M. digitata	10000	Loss of algae	LOEC	Jones *et al* 2003
			P. damicornis	10000	Loss of algae	LOEC	Negri *et al* 2005
			S. hystrix	10000	Loss of algae	LOEC	Jones 2004
			P. cylindrica	10000	GPP* rate, GPP to respiration ration,	LOEC	Råberg *et al* 2003

Category	PSII-HEq Range (ng L^{-1})	Description	Supporting Literature with Respect to the Reference Chemical Diuron				
			Species	Effects Concentration (ng L^{-1})	Endpoint	Toxicity measure	Reference (see footnotes)
					effective quantum yield		
			Macro Algae				
			H. banksia	1650	↓ photosynthesis	EC50	Seery *et al* 2006
			Red Algae				
			P. onkodes	2900	↓ photosynthesis	LOEC	Harrington *et al* 2005
			Diatoms				
			Navicula sp	2900	↓ photosynthesis	IC50 Acute, 6 m	Magnusson *et al* 2006
			P. tricornutum	3300	↓ photosynthesis	I50	Schreiber *et al* 2002
			Mangroves				
			A. marina	1100	Health	NOEC	Duke *et al* 2003, 2005
			A. marina	1500	Reduced health	LOEC	Duke *et al* 2003, Bell & Duke 2005
			A. marina	2000	Dieback/ absence	Mortality	Duke et al 2003, Bell & Duke 2005
			A. marina	1500	Reduced health	LOEC	Duke *et al* 2003, Bell & Duke 2005

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Appendix D **Supplemental information on drivers**

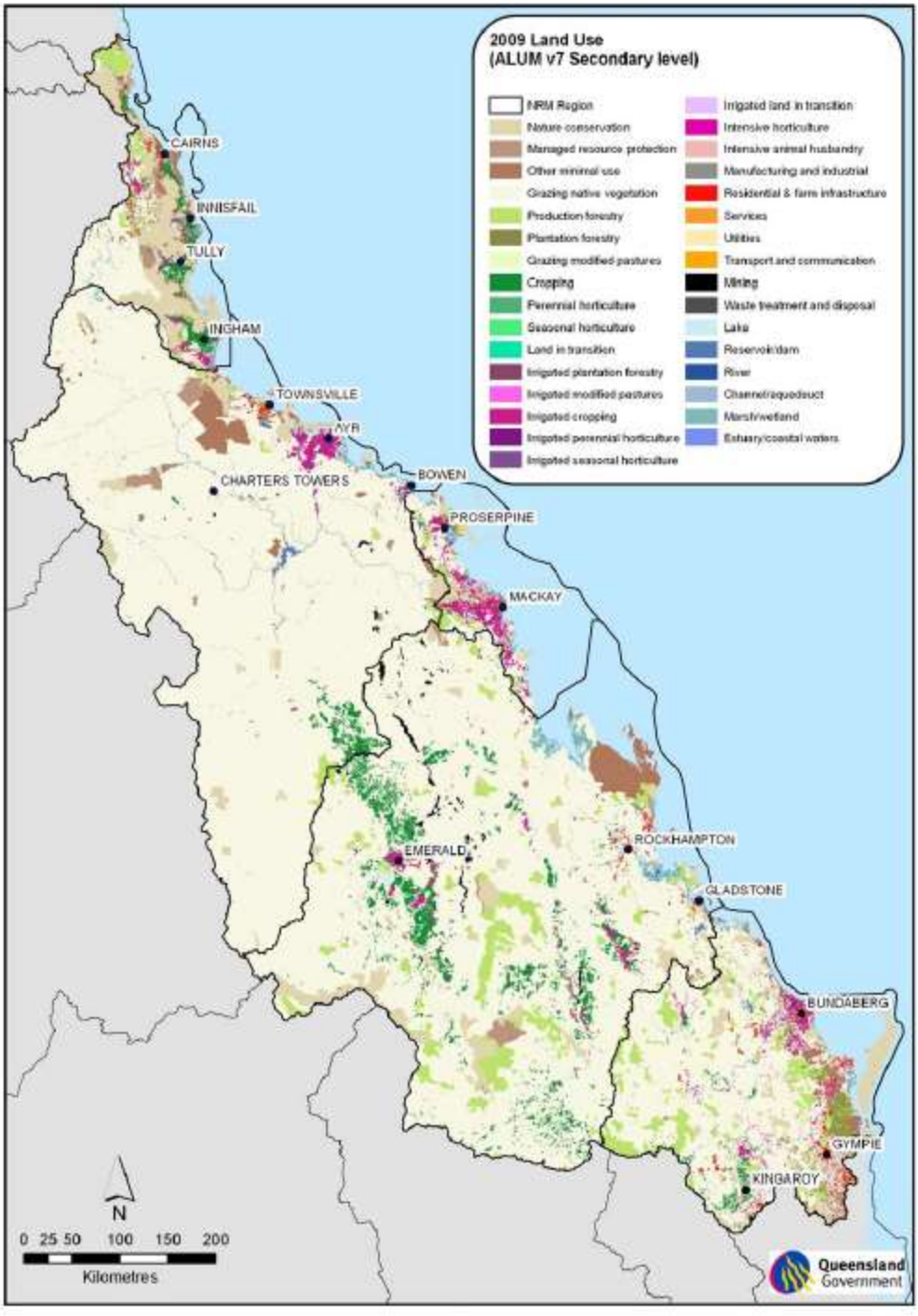

Figure D-1: Land Use map of the Reef basin (2009) from (DSITIA, 2012c).

Appendix E Supplemental information on pressures

Table E-1: Wet season discharge (ML; million litres) of the main GBR rivers (1 October 2010 to 30 September 2018, inclusive) compared to the previous five wet seasons and long-term (LT) median discharge (1986–2018). Colours indicate levels above the long-term median: yellow for 1.5 to 2 times, orange for 2 to 3 times and red greater than 3 times. Data source: DNRM (http://watermonitoring.dnrm.qld.gov.au/host.htm). Table provided by Steve Lewis, JCU. (– = data not available).

Basin	LT median	2010 - 2011	2011 - 2012	2012 - 2013	2013 - 2014	2014 - 2015	2015 - 2016	2016 - 2017	2017 - 2018
Jacky Jacky Creek	2,149,681	4,735,197	1,820,422	1,986,825	3,790,832	1,498,138	630,787	2,383,057	2,226,350
Olive Pascoe River	2,687,101	5,918,996	2,275,527	2,483,531	4,738,541	3,931,758	788,484	2,978,821	2,782,938
Lockhart River	1,701,831	3,748,697	1,441,167	1,572,903	3,001,076	1,186,026	499,373	1,886,587	1,762,527
Stewart River	689,498	2,180,850	616,070	523,353	1,311,775	298,816	311,901	685,263	826,295
Normanby River	4,093,744	11,333,284	2,181,990	3,462,238	5,059,657	2,914,859	3,407,359	3,780,651	4,327,093
Jeannie River	1,507,731	2,824,817	1,048,269	695,195	1,869,982	1,434,447	1,581,015	1,746,929	1,685,379
Endeavour River	980,025	1,836,131	681,375	451,877	1,215,488	932,391	1,027,660	1,135,504	1,095,496
Daintree River	1,722,934	3,936,470	2,396,905	1,668,302	5,137,023	1,905,224	1,623,478	1,931,878	1,242,633
Mossman River	1,207,012	2,014,902	1,526,184	1,147,367	1,918,522	874,068	1,245,275	1,142,698	1,418,476
Barron River	526,686	2,119,801	852,055	328,260	663,966	380,395	182,999	287,790	840,755
Mulgrave-Russell River	4,457,940	7,892,713	5,696,594	3,529,862	5,420,678	3,145,787	3,253,825	3,015,734	5,510,213
Johnstone River	4,743,915	9,276,874	5,338,591	3,720,020	5,403,534	3,044,680	3,416,331	4,017,617	5,644,908
Tully River	3,536,054	7,442,768	3,425,096	3,341,887	4,322,496	2,659,775	2,942,770	3,098,701	3,922,655
Murray River	1,227,888	4,267,125	2,062,103	1,006,286	1,531,172	366,212	974,244	947,985	1,648,662
Herbert River	3,556,376	12,593,674	4,545,193	3,189,804	4,281,607	1,095,372	1,895,526	2,248,436	6,284,190
Black River	228,629	1,424,283	747,328	188,468	419,290	17,654	129,783	64,873	456,795
Ross River	355,343	2,092,684	1,324,707	276,584	1,177,255	3,229	23,741	11,867	342,596
Haughton River	553,292	2,415,758	1,755,712	517,069	573,976	120,674	267,986	338,245	905,733
Burdekin River	4,406,780	34,834,316	15,568,159	3,424,572	1,458,772	880,951	1,807,104	4,165,129	5,376,922
Don River	342,257	3,136,184	802,738	578,391	324,120	171,305	101,562	920,610	135,367
Proserpine River	887,771	4,582,697	2,171,287	851,504	720,427	157,123	316,648	1,683,894	540,101
O'Connell River	796,718	4,112,676	1,948,591	764,170	646,537	141,008	284,171	1,511,187	484,706
Pioneer River	776,984	3,630,422	1,567,684	1,162,871	635,315	2,028,936	597,117	1,388,687	249,425
Plane Creek	1,052,831	4,809,239	2,854,703	1,948,929	737,580	241,254	832,508	2,613,261	261,201
Styx River	205,186	906,144	275,219	968,106	544,155	376,009	343,877	507,927	250,888
Shoalwater Creek	233,488	1,031,129	313,180	1,101,638	619,211	427,872	391,308	577,985	285,493

Water Park Creek	615,559	2,718,432	825,657	2,904,319	1,632,466	1,128,027	1,031,630	1,523,780	752,664
Fitzroy River	2,852,307	37,942,149	7,993,273	8,530,491	1,578,610	2,681,949	3,589,342	6,170,044	954,362
Calliope River	152,965	1,000,032	345,703	1,558,380	283,790	479,868	148,547	406,321	141,133
Boyne River	38,691	252,949	87,443	394,178	71,782	121,378	37,574	102,775	35,698
Baffle Creek	465,218	3,650,093	1,775,749	2,030,545	275,517	710,352	257,093	829,460	1,844,466
Kolan River	56,231	779,168	307,837	810,411	45,304	213,857	111,172	146,154	272,900
Burnett River	285,534	9,421,517	643,137	7,581,543	218,087	853,349	381,054	536,242	839,021
Burrum River	71,658	114,492	117,762	90,921	62,188	150,113	334,681	456,549	667,635
Mary River	1,144,714	8,719,106	4,340,275	7,654,320	594,612	1,651,901	480,854	582,510	1,886,517

Missing values represent years for which >15% of daily flow estimates were not available. Daily discharge for Euramo site (Tully River) from July, 2011 to November, 2012 and from October, 2014 to August, 2015 were estimated from Gorge station (Tully River) using: Euramo Disch = Gorge Disch * 3.5941; Daily discharge for Pioneer river now includes Miriani station, allowing flow record since 1977-11-09. Dumbleton and Miriani stations are correlated by the following equation: Dumbleton Disch = Miriani Disch * 1.4276; All data from the Ross gauge station, which ceased in 2007-08-01 with no substitute in the same river, was replaced by Bohle gauge station; Boyne gauge station was ceased in 2012-06-30 with no substitute in the vicinities of the closed station; Endeavour gauge station was ceased 2015-05-10 with no substitute in the vicinities of the closed station. Proserpine gauge station was ceased on 3.6.2014 with no substitute in the vicinities of the closed station. The full dataset does not exist for the Normanby gauging station.

E.1 Flood water type frequency mapping

Mapping the frequency, spatial extent and duration of flood events can inform management about the areas that may be the most at risk from acute or chronic effects of pollutant exposure resulting from river discharge. It should be noted that whilst flood plumes are a major contributor to the movement of pesticide loads from basins to the Reef lagoon, the amount of pesticides released with an individual flood plume will depend on many factors in addition to water flow, e.g. timing of pesticide applications relative to rainfall events, degradation rates etc. For many basins, the highest concentrations of pesticides are released at the beginning of the wet season with the first 'flush'. Flood plumes later in the year may deliver little or no pesticides to the marine environment. In this report, we present the plume maps and frequencies with the intention to inform the likelihood of a fixed (passive sampling) monitoring site to be located within a flood plume and how often and for how long it may be impacted by plume waters.

The Marine Water Quality component of the MMP maps the frequency and extent of (surface) flood plumes (Waterhouse et al., 2018). This is achieved using ocean colour (corresponding to different water types) collected via satellite imagery that exploits differences in colour of plume waters from ambient marine waters in 1km^2 'pixels' (Devlin et al., 2012). Plumes are classified into three water types:

- Primary – very high turbidity, low salinity (0 to 10 ppt), and very high values of CDOM and TSS;
- Secondary – intermediate salinity, elevated CDOM concentrations, and reduced TSS due to sedimentation, where phytoplankton growth is prompted by the increased light (due to lower TSS) and high nutrient availability delivered by the river plume;
- Tertiary – exhibits no or low TSS associated with the river plume, and above-ambient concentrations of chlorophyll *a* and CDOM.

It should be noted that plume exposure mapping may be complicated by the resuspension of fine sediments during periods of high winds and waves (rather than periods of actual river discharge) as well as cloud cover.

Six colour classes have been defined that correspond to three water types – primary, secondary and tertiary. Each water type is associated with different levels and combination of pollutants which potentially have different impacts on Reef ecosystems (Álvarez-Romero et al., 2013; Devlin et al., 2012). These impacts relate to turbidity and other effects of CDOM and are not the same as for pesticides, but water type is an indicator of the potential for a flood plume to reach a particular monitoring site. For each of the fixed monitoring sites, the weekly colour class (i.e. the minimum colour class at each pixel recorded for the week) was recorded, for 22 weeks of the wet season (beginning on 1 December 2017) (see Table E-2). Weeks that have no data (a value of 7) indicate that the sites were beyond the plume extent for those weeks. The annual frequency of occurrence for primary and secondary water types (colour classes 1 – 5) were calculated for each fixed monitoring sites by dividing the number of weeks that a pixel was retrieved as either primary or secondary water types, by the maximum number of weeks (i.e. 22) in a wet season. The frequency of occurrence of flood plumes can then be aggregated into frequency classes of low risk of a flood plume reaching the site (frequency of 0.1) to high risk (frequency of 1) to create frequency maps for primary and secondary water types.

Annual water type frequency maps can then be prepared by overlaying weekly composite maps as the number of weeks that a pixel was retrieved as either primary, secondary or tertiary water type, divided by the maximum number of weeks in a wet season (as shown in Figure 3). Annual exposure maps are useful to identify the year to year variation of the surface water types but can also be useful to develop a long-term surface exposure map that can identify areas that are at higher risk of exposure to surface pollutants over a longer temporal scale. To create multi-annual exposure maps, the annual frequency maps are overlaid and the water type category for each pixel reclassified using the median pixel value (all plume frequency maps were prepared by Dieter Tracy (JCU)).

Table E-2: Weekly water type colour class (1 – 6) for fixed site passive sampler and river transect locations during the 2017–18 wet season (beginning 1 December 2017)

Fixed passive sampling sites	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Multiannual Frequency (2003-2018)	Difference (Current year vs 2003-18)
Site	Water Type Frequency	01-Dec-17	08-Dec-17	15-Dec-17	22-Dec-17	29-Dec-17	05-Jan-18	12-Jan-18	19-Jan-18	26-Jan-18	02-Feb-18	09-Feb-18	16-Feb-18	23-Feb-18	02-Mar-18	09-Mar-18	16-Mar-18	23-Mar-18	30-Mar-18	06-Apr-18	13-Apr-18	20-Apr-18	27-Apr-18		
Low Isles	0.33	6	6	6	6	6	7	6	-	6	5	5	6	6	7	5	5	5	5	5	6	6	6	0.26	0.08
High Island West	0.41	6	6	6	6	6	6	6	7	5	6	5	6	6	6	4	5	2	4	5	5	5	6	0.63	-0.23
Frankland Group West	0.19	6	6	6	6	6	6	6	-	6	6	5	6	7	7	5	6	5	5	6	6	6	6	0.30	-0.11
Dunk Island North	1.00	5	5	5	5	5	5	5	-	5	5	5	5	5	4	4	5	4	4	5	5	5	5	0.98	0.02
Lucinda	0.90	5	5	5	5	5	6	6	-	5	5	5	5	5	5	4	5	-	4	5	5	5	5	0.93	-0.03
Barratta Creek mouth	1.00	3	4	4	5	2	3	3	4	2	2	2	3	-	-	2	1	-	5	4	2	2	1	1.00	0.00
Repulse Bay	0.95	1	3	5	4	5	5	5	4	4	2	5	5	6	4	4	5	4	5	4	4	5	4	0.99	-0.04
Round Top Island	1.00	5	5	5	5	5	5	5	5	5	4	5	5	5	5	4	5	5	-	4	4	5	5	0.99	0.01
Sarina Inlet	1.00	5	2	4	4	4	5	4	4	4	4	3	5	4	5	2	4	2	-	4	5	2	2	0.99	0.01
Sandy Creek	1.00	5	5	5	5	5	5	5	5	5	4	5	5	5	5	4	5	5	-	5	5	5	5	0.97	0.03
North Keppel Island	1.00	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	-	5	5	5	5	0.92	0.08
River transect sites																									
Russell-Mulgrave mouth	1.00	4	4	3	5	4	4	4	-	2	4	2	3	-	4	1	2	1	2	4	1	3	5	0.99	0.01
High Island	0.41	6	6	6	6	6	6	6	7	5	6	5	6	6	6	4	5	2	4	5	5	5	6	0.63	-0.23
Tully River mouth	1.00	4	5	4	5	4	4	5	-	2	4	2	4	3	2	1	2	2	2	4	2	4	4	1.00	0.00
Bedarra Island	1.00	5	5	5	5	5	5	5	-	5	5	5	5	5	4	2	5	3	4	5	5	5	5	0.96	0.04
Dunk Island north	1.00	5	5	5	5	5	5	5	-	5	5	5	5	5	4	4	5	4	4	5	5	5	5	0.97	0.03

A value of 7 indicates no data available (e.g. due to cloud cover or the pixel was beyond the plume area). Weekly data comprises the minimum colour class at each pixel recorded for the week. Dark blue colour class (6) = tertiary plume water; light blue (colour class 5) = secondary plume water; green, yellow, orange and red (colour classes 4 to 1 respectively) = primary plume water.

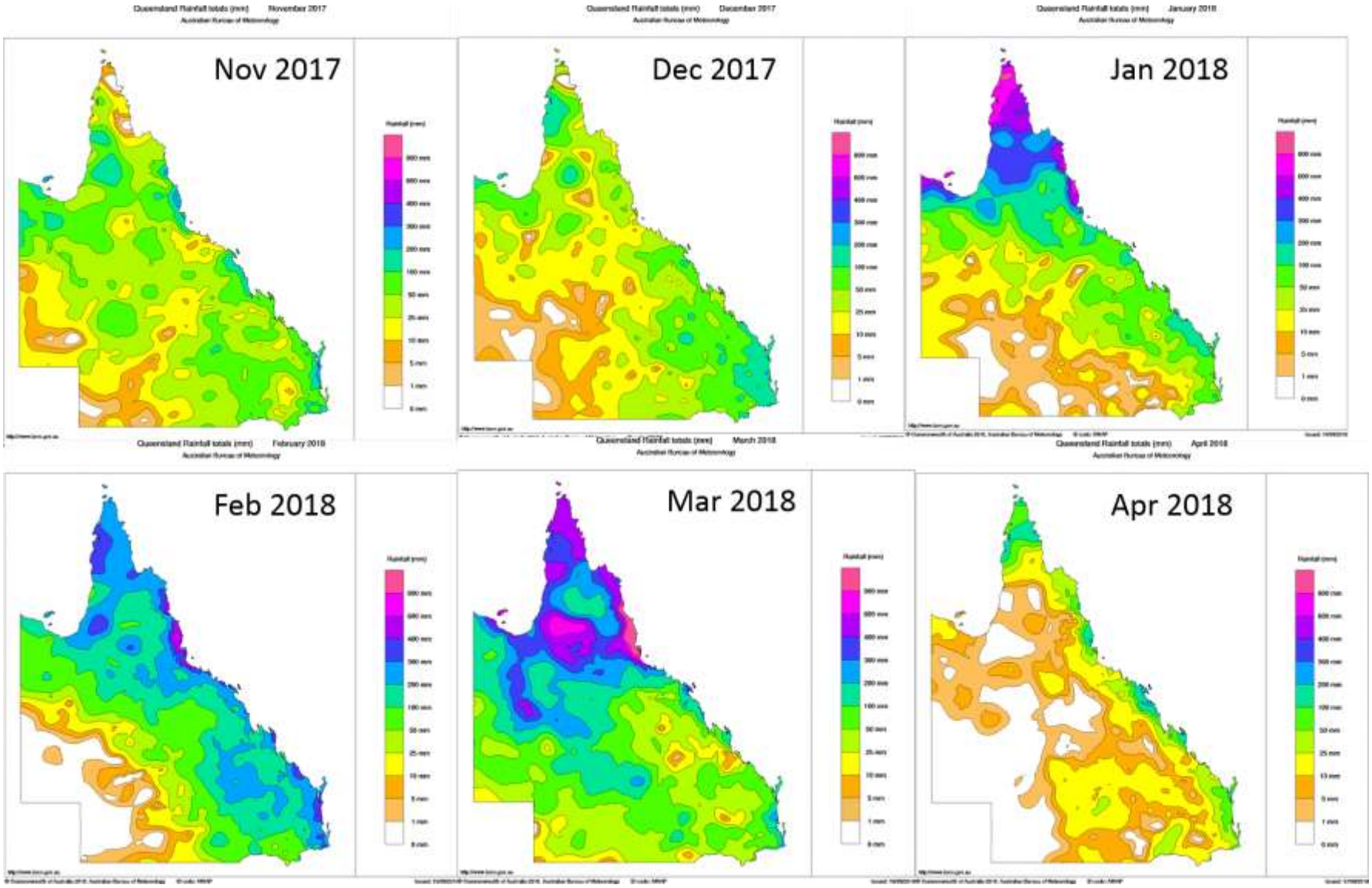

Figure E-1: Total monthly rainfall for the wet 2017–18 season across Queensland (Bureau of Meteorology, 2018)

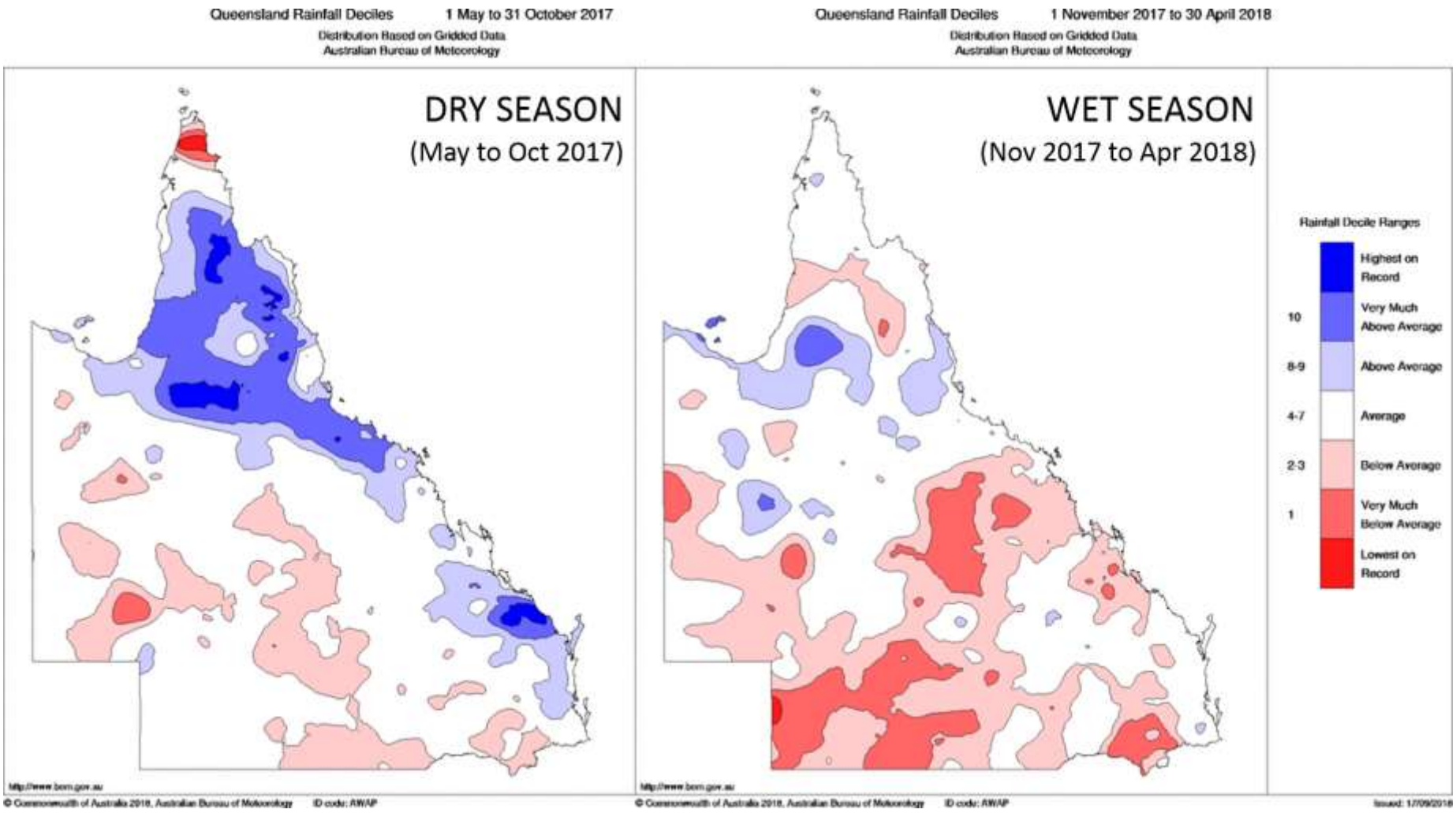

Figure E-2: Rainfall decile ranges (comparison of current period with long term average) for the dry season between May 2017- October 2018 (left) and wet season between November 2017 – 30 April 2018 (right). Figure sourced from (Bureau of Meteorology, 2018)

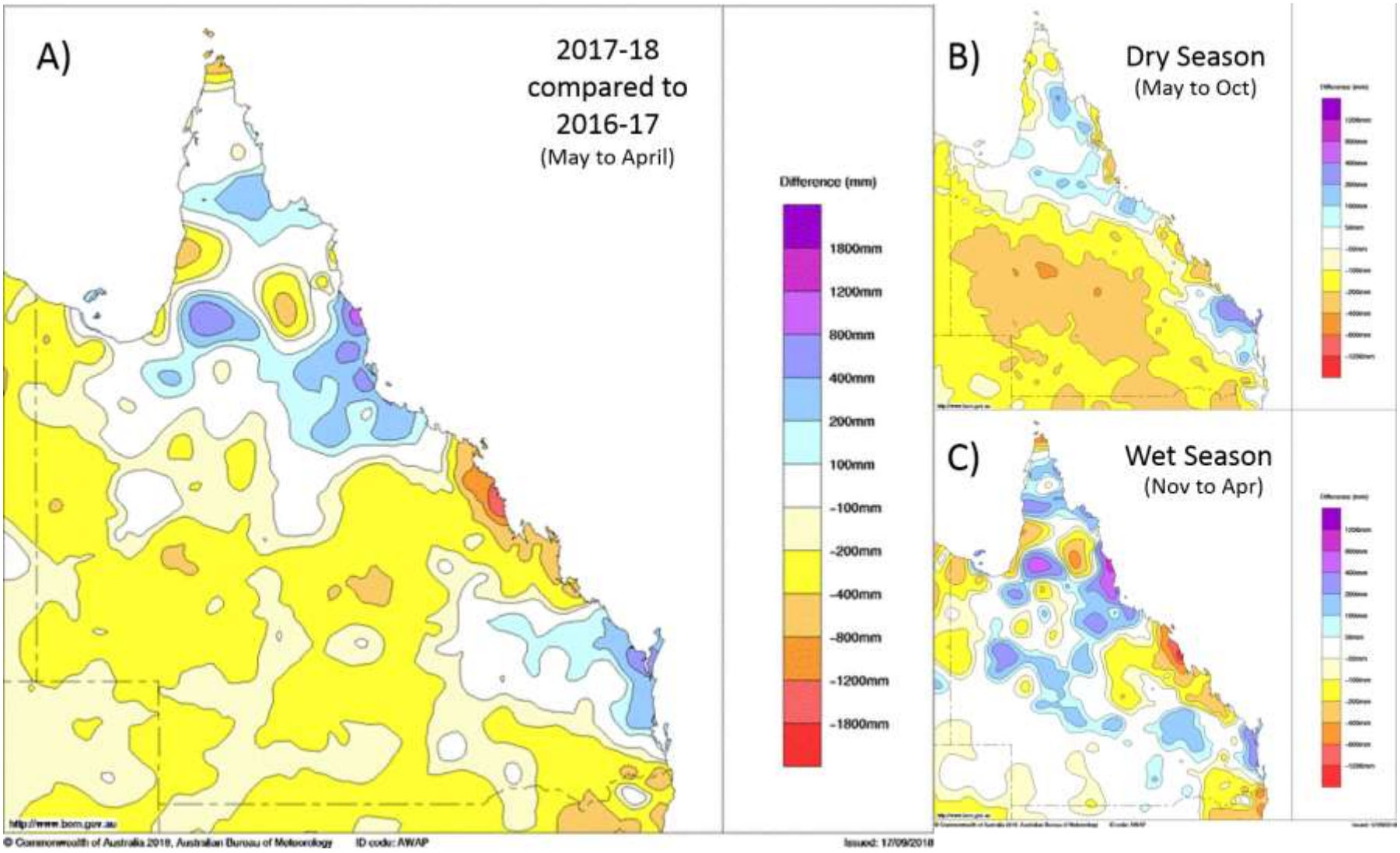

Figure E-3: A) Inter-annual rainfall difference between the previous monitoring year (2016-17) and the current monitoring year (2017-18). B) and C) show comparison between previous year and current year for dry and wet season, respectively. A negative value indicates that rainfall was lower this year compared to the previous year. Figure sourced from (Bureau of Meteorology, 2018)

Appendix F **Fixed monitoring sites – sampler returns and individual site results**

Table F-1: Passive sampling return record for the 2017–18 monitoring year. ED sampler numbers are given with PDMS (non-polar) samplers in brackets after.

NRM Region	Site Name	No of samplers sent	No of samplers returned and analysed	Comments
Wet Tropics	Low Isles	8	7	January kit and mooring lost. Delayed and long February deployment meant that April sampler kit not required to be sent.
	Normanby Island	7	6	Due to change of ownership of company, sampling in 2017/18 did not begin until September. Some minor over-deployments occurred resulting in April kit being deployed in May (2018/19 sampling year).
	Dunk Island	9	8	May/June samplers at both Dunk and High Islands lost with moorings. Re-established in July.
	High Island	9	8	May/June samplers at both Dunk and High Islands lost with moorings. Re-established in July.
	Lucinda Jetty (CSIRO)	8	8	Long December deployment due to shutdown of site included all of January. Double ED setup used (as used during bi-monthly dry season deployments). January kit not needed.
Burdekin	Barratta Creek	8	6	Over-deployments between November and February resulted in February sampler not being required, and March and April samplers being deployed from May 2018 (2018/19 sampling year). Minor losses of individual PDMS cage (January) and 1 ED (Sept/Oct).
Mackay Whitsunday	Repulse Bay	7	3	Sept/Oct and February kits not sent due to sampler/mooring losses of May/June and January. March and April samplers removed from mooring and later recovered out of water, so samplers not analysed. 1 ED lost in December.
	Round Top Island	8	6	Lost samplers/mooring in May/June and April. Sept/Oct samplers not sent due to late deployment of July/Aug due to earlier lost mooring. 1 ED lost from July/August samplers.
	Sarina Inlet	8	6	PDMS cages lost in Nov, Dec and January. 1 ED not deployed in January. Long deployments due to illness of volunteer led to Feb sampler not being sent and March and April kits being returned unused.
	Sandy Creek	9	2	Only May/June and Sept/Oct samplers returned successfully. All others lost/stolen.
Fitzroy	North Keppel Island	7	7	Delayed and long deployments led to Sept/Oct and February samplers not being sent. Some kits deployed out of sequence without causing any problems, due to clear deployment info.

TOTAL 2017-18	11 sites	89 (27)	67 (13)	2 PDMS cages returned but not analysed (Repulse Bay) not included in total PDMS returned/analysed (in brackets).
TOTAL 2016-17	**11 sites**	**84 (24)**	**63 (14)**	

TOTAL 2015-16	**11 sites**	**93 (21)**	**68 (13)**	

Table F-2: Low Isles, Wet Tropics region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
Jun-17 Jul-17	4-Jun-17	5-Aug-17	ED	0.02	1.4	1.2	0.35	0.16	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	n.d.	n.d.	0.40	0.28	0.02	0.13	0.06	n.d.	n.d.	0.02	n.d.	n.d.	n.d.	0.03	n.d.	n.d.
Aug-17	5-Aug-17	6-Sep-17	ED	n.d.	0.93	0.78	0.19	0.12	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	n.d.	0.40	0.11	0.02	0.16	<0.05	n.d.	n.d.	0.04	n.d.	n.d.	n.d.	n.d.	*0.01*	n.d.
Sep-17 Oct-17	6-Sep-17	8-Nov-17	ED**	n.d.	0.61	1.4	0.13	0.02	n.d.	n.d.	n.d.	n.d.	n.d.	0.07	n.d.	n.d.	0.10	0.10	n.d.	0.05	<0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	<0.19	n.d.	n.d.
Nov-17	8-Nov-17	8-Dec-17	ED	n.d.	0.43	1.6	0.39	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.07	n.d.	n.d.	0.20	n.d.	n.d.	0.13	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.19	n.d.	n.d.
Dec-17	8-Dec-17	29-Dec-17	ED	n.d.	0.88	2.6	0.36	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.21	n.d.	n.d.	0.20	0.13	n.d.	0.16	0.07	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.15	n.d.	n.d.
Jan-18	Sampler lost		ED																											
Feb-18 Mar-18	21-Feb-18	7-Apr-18	ED	n.d.	1.9	6.7	1.8	0.24	n.d.	n.d.	n.d.	n.d.	n.d.	0.46	n.d.	n.d.	0.20	0.43	0.07	0.13	0.21	n.d.	0.03	n.d.	n.d.	n.d.	n.d.	1.0	n.d.	n.d.
Apr-18	7-Apr-18	4-May-18		n.d.	0.42	1.1	0.30	0.29	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	n.d.	n.d.	0.10	0.23	n.d.	0.03	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.16	n.d.	n.d.
Summary																														
Samples (n)				7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Detects (n)				1	7	7	7	5	0	0	0	0	0	7	0	0	7	6	3	7	5	0	1	2	0	0	0	5	1	0
% Detects				14	100	100	100	71	0	0	0	0	0	100	0	0	100	86	43	100	71	0	14	29	0	0	0	71	14	0
Minimum concentration				n.d.	0.42	0.78	0.13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	n.d.		n.d.	n.d.	0.03	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum concentration				0.02	1.9	6.7	1.8	0.29	n.d.	n.d.	n.d.	n.d.	n.d.	0.46	n.d.	n.d.		0.43	0.07	0.16	0.21	n.d.	0.03	0.04	n.d.	n.d.	n.d.	1.01	0.01	n.d.
													Minimum % Species Affected				0.10													
													Maximum % Species Affected				0.40													
													Avg Dry % Species Affected				0.30													
													Avg Wet % Species Affected				0.18													

Table F-3: High Island, Wet Tropics region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
May-17 Jun-17	Sampler lost		ED																										
Jul-17 Sep-17	21-Jul-17	14-Sep-17	ED	0.05	1.8	0.75	0.34	0.18	n.d.	n.d.	n.d.	n.d.	n.d.	0.08	0.03	n.d.	0.40	0.27	0.05	0.26	0.06	n.d.	n.d.	0.02	n.d.	n.d.	n.d.	n.d.	0.03	n.d.
Sep-17 Oct-17	14-Sep-17	08-Nov-17	ED**	n.d.	9.1	17	2.6	0.04	n.d.	n.d.	0.45	n.d.	0.01	0.31	n.d.	n.d.	0.80	0.55	0.06	4.3	0.11	n.d.	0.01	n.d.	n.d.	n.d.	n.d.	1.3	n.d.	n.d.
Nov-17	8-Nov-17	9-Dec-17	ED**	0.13	9.3	22	4.8	0.06	n.d.	n.d.	0.10	n.d.	0.03	1.2	n.d.	n.d.	0.70	0.67	0.05	2.1	0.16	n.d.	0.09	n.d.	n.d.	n.d.	n.d.	1.2	n.d.	0.03
Dec-17	9-Dec-17	14-Jan-18	ED	n.d.	1.1	3.0	0.91	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	n.d.	n.d.	0.30	0.09	n.d.	0.28	0.13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.18	n.d.	n.d.
Jan-18	14-Jan-18	11-Feb-18	ED**	n.d.	2.8	24	6.8	0.03	n.d.	n.d.	0.06	n.d.	n.d.	n.d.	n.d.	n.d.	0.70	0.11	n.d.	0.51	1.1	n.d.	0.10	0.09	n.d.	n.d.	n.d.	2.5	n.d.	n.d.
Feb-18	11-Feb-18	15-Mar-18	ED**	n.d.	4.1	20	5.0	0.15	n.d.	n.d.	0.08	n.d.	0.02	0.85	n.d.	n.d.	0.60	0.73	0.07	0.38	1.1	n.d.	0.07	0.11	n.d.	n.d.	n.d.	5.0	n.d.	n.d.
Mar-18	15-Mar-18	17-Apr-18	ED	n.d.	1.4	5.4	1.5	0.75	n.d.	n.d.	n.d.	n.d.	n.d.	0.15	n.d.	n.d.	0.30	0.44	0.04	0.10	0.17	n.d.	0.05	0.03	n.d.	0.63	n.d.	1.9	0.02	n.d.
Apr-18	17-Apr-18	15-May-18	ED	n.d.	0.63	1.8	0.73	0.11	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	n.d.	n.d.	0.10	0.22	n.d.	0.05	n.d.	0.44	n.d.	n.d.	n.d.	n.d.	n.d.	0.31	n.d.	n.d.
Summary																														
Samples (n)				8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Detects (n)				2	8	8	8	7	0	0	4	0	3	7	1	0	8	8	5	8	7	1	5	4	0	1	0	7	2	1
% Detects				25	100	100	100	88	0	0	50	0	38	88	13	0	100	100	63	100	88	13	63	50	0	13	0	88	25	13
Minimum concentration				n.d.	0.63	0.75	0.34	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		0.09	n.d.	0.05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum concentration				0.13	9.30	23.96	6.81	0.75	n.d.	n.d.	0.45	n.d.	0.03	1.22	0.03	n.d.		0.73	0.07	4.28	1.11	0.44	0.10	0.11	n.d.	0.63	n.d.	4.96	0.03	0.03
												Minimum % Species Affected					0.10													
												Maximum % Species Affected					0.80													
												Avg Dry % Species Affected					0.60													
												Avg Wet % Species Affected					0.45													

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Table F-4: Dunk Island, Wet Tropics region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
May-17 Jun-17	Sampler lost		ED																											
Jul-17 Aug-17	22-Jul-17	13-Sep-17	ED	0.03	1.5	0.68	0.31	0.13	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	n.d.	n.d.	**0.40**	0.33	0.02	0.23	0.05	n.d.	n.d.	0.03	n.d.	n.d.	n.d.	n.d.	0.02	n.d.
Sep-17 Oct-17	13-Sep-17	09-Nov-17	ED	n.d.	3.2	4.6	1.3	0.0	n.d.	n.d.	n.d.	n.d.	0.01	0.67	n.d.	n.d.	**0.40**	0.29	n.d.	0.75	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.34	n.d.	n.d.
Nov-17	09-Nov-17	10-Dec-17	ED	n.d.	2.2	6.4	1.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.19	n.d.	n.d.	**0.40**	n.d.	n.d.	0.93	0.19	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.57	n.d.	n.d.
Dec-17	10-Dec-17	13-Jan-18	ED	n.d.	0.79	2.8	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.30**	n.d.	n.d.	0.33	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Jan-18	13-Jan-18	12-Feb-18	ED	n.d.	2.3	19	4.9	n.d.	n.d.	n.d.	0.23	n.d.	n.d.	n.d.	n.d.	n.d.	**0.30**	0.13	n.d.	0.17	0.55	n.d.	0.05	n.d.	n.d.	n.d.	n.d.	1.5	n.d.	n.d.
Feb-18	12-Feb-18	10-Mar-18	ED	n.d.	5.2	28	7.4	0.20	n.d.	n.d.	0.20	n.d.	0.03	3.0	n.d.	n.d.	**0.60**	0.35	n.d.	0.26	1.4	n.d.	0.10	0.03	n.d.	n.d.	n.d.	2.4	n.d.	n.d.
Mar-18	10-Mar-18	14-Apr-18	ED**	0.06	1.2	4.2	1.1	0.46	n.d.	n.d.	n.d.	n.d.	n.d.	0.14	n.d.	n.d.	**0.20**	0.29	n.d.	0.07	n.d.	n.d.	0.03	n.d.	n.d.	n.d.	n.d.	0.96	n.d.	n.d.
Apr-18 May-18	14-Apr-18	16-May-18	ED**	n.d.	0.64	2.2	0.70	0.14	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.10**	n.d.	n.d.	0.06	n.d.	0.10	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Summary																														
Samples (n)				8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Detects (n)				2	8	8	8	5	0	0	2	0	2	5	0	0	8	5	1	8	4	1	3	2	0	0	0	5	1	0
% Detects				25	100	100	100	63	0	0	25	0	25	63	0	0	100	63	13	100	50	13	38	25	0	0	0	63	13	0
Minimum concentration				n.d.	0.64	0.68	0.31	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		n.d.	n.d.	0.06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum concentration				0.1	5.2	27.9	7.4	0.5	n.d.	n.d.	0.2	n.d.	0.0	3.0	n.d.	n.d.		0.4	0.0	0.9	1.4	0.1	0.1	0.0	n.d.	n.d.	n.d.	2.4	0.0	n.d.
													Minimum % Species Affected				**0.10**													
													Maximum % Species Affected				**0.60**													
													Avg Dry % Species Affected				**0.38**													
													Avg Wet % Species Affected				**0.32**													

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Table F-5: Normanby Island, Wet Tropics region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
May-17 Jun-17	Sampler not deployed		ED																										
Jul-17 Aug-17	Sampler not deployed		ED																										
Sep-17 Oct-17	25-Sep-17	31-Oct-17	ED	n.d.	0.55	0.72	0.13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	n.d.	0.40	0.12	n.d.	0.25	0.03	n.d.	n.d.	0.02	n.d.	n.d.	n.d.	n.d.	*0.01*	n.d.
Nov-17	31-Oct-17	06-Dec-17	ED	n.d.	0.80	1.4	0.24	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.12	n.d.	n.d.	0.20	n.d.	n.d.	0.23	0.30	n.d.	0.10	n.d.	0.07	n.d.	n.d.	n.d.	n.d.	n.d.
Dec-17 Jan-18	06-Dec-17	27-Jan-18	ED	0.03	0.91	1.7	0.50	0.01	n.d.	n.d.	n.d.	n.d.	0.01	0.16	n.d.	n.d.	0.20	0.16	0.02	0.14	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.08	n.d.	0.02
Feb-18	27-Jan-18	03-Mar-18	ED	n.d.	1.8	6.3	1.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	n.d.	n.d.	0.20	0.14	n.d.	0.12	0.09	n.d.	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	0.30	n.d.	n.d.
Mar-18	03-Mar-18	01-Apr-18	ED	n.d.	1.4	6.4	1.2	0.72	n.d.	n.d.	n.d.	n.d.	n.d.	3.62	n.d.	n.d.	0.20	0.61	n.d.	0.08	0.18	n.d.	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	1.0	n.d.	n.d.
Apr-18	01-Apr-18	09-May-18	ED	n.d.	0.39	0.63	0.22	0.11	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	n.d.	0.10	0.11	0.02	0.02	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.15	0.04	n.d.
Summary																														
Samples (n)				6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Detects (n)				1	6	6	6	3	0	0	0	0	1	6	0	0	6	5	2	6	5	0	3	1	1	0	0	4	2	1
% Detects				17	100	100	100	50	0	0	0	0	17	100	0	0	100	83	33	100	83	0	50	17	17	0	0	67	33	17
Minimum concentration				n.d.	0.39	0.63	0.13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	n.d.		n.d.	n.d.	0.02	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum concentration				0.03	1.83	6.43	1.93	0.72	n.d.	n.d.	n.d.	n.d.	0.01	3.62	0.00	0.00		0.61	0.02	0.25	0.30	n.d.	0.10	0.02	0.07	n.d.	n.d.	1.02	0.04	0.02
												Minimum % Species Affected					0.10													
												Maximum % Species Affected					0.40													
												Avg Dry % Species Affected					0.30													
												Avg Wet % Species Affected					0.18													

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations
Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution
Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate
**Concentration is average of duplicate samplers

Table F-6: Lucinda, Wet Tropics region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
May-17 Jul-17	03-May-17	13-Jul-17	ED	0.34	8.9	5.6	1.8	0.49	n.d.	n.d.	n.d.	n.d.	0.05	0.20	0.24	n.d.	0.70	0.68	0.08	0.87	0.26	n.d.	0.02	0.07	n.d.	0.09	n.d.	n.d.	n.d.	n.d.
Jul-17 Aug-17	13-Jul-17	05-Sep-17	ED	0.11	4.6	2.1	0.67	0.45	n.d.	n.d.	n.d.	n.d.	n.d.	0.15	0.02	n.d.	0.60	0.92	0.10	0.65	0.10	n.d.	n.d.	0.04	n.d.	n.d.	n.d.	n.d.	0.04	n.d.
Sep-17 Oct-17	05-Sep-17	14-Nov-17	ED	n.d.	0.51	2.0	0.29	0.07	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.30	0.06	n.d.	0.29	<0.07	n.d.	n.d.	n.d.	0.02	n.d.	n.d.	0.14	n.d.	n.d.
Nov-17	14-Nov-17	18-Dec-17	ED	n.d.	9.4	7.9	2.3	0.06	n.d.	n.d.	n.d.	n.d.	0.05	0.51	n.d.	n.d.	0.40	0.46	0.11	0.51	0.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.22	n.d.	n.d.
Dec-17 Jan-18	18-Dec-17	31-Jan-18	ED	n.d.	0.99	2.9	0.73	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.20	0.04	n.d.	0.18	0.06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Feb-18	31-Jan-18	27-Feb-18	ED	n.d.	0.97	2.7	0.87	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.20	n.d.	n.d.	0.08	0.14	n.d.	0.01	n.d.	n.d.	n.d.	n.d.	0.09	n.d.	n.d.
Mar-18	27-Feb-18	03-Apr-18	ED	0.25	2.4	4.3	1.2	1.6	0.13	n.d.	0.11	n.d.	0.04	0.11	0.42	n.d.	0.40	0.52	0.10	0.15	0.22	n.d.	0.05	0.03	n.d.	n.d.	n.d.	0.89	0.05	n.d.
Apr-18	03-Apr-18	15-May-18	ED**	n.d.	0.84	2.1	0.66	0.38	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	n.d.	n.d.	0.06	n.d.	0.17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Summary																														
Samples (n)				8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Detects (n)				3	8	8	8	8	1	0	1	0	3	4	3	0	8	6	4	8	6	1	3	3	1	1	0	4	2	0
% Detects				38	100	100	100	100	13	0	13	0	38	50	38	0	100	75	50	100	75	13	38	38	13	13	0	50	25	0
Minimum concentration				n.d.	0.51	2.01	0.29	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		n.d.	n.d.	0.06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum concentration				0.34	9.41	7.95	2.32	1.63	0.13	n.d.	0.11	n.d.	0.05	0.51	0.42	n.d.		0.92	0.11	0.87	0.26	0.17	0.05	0.07	0.02	0.09	n.d.	0.89	0.05	n.d.
													Minimum % Species Affected				0.10													
													Maximum % Species Affected				0.70													
													Avg Dry % Species Affected				0.53													
													Avg Wet % Species Affected				0.26													

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Table F-7: Barratta Creek, Burdekin Region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)													Concentration pesticides (ng/L) in PDMS samplers				
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole	Propazine	Propiconazole	Pendimethalin	Chlorpyrifos	Trifluralin
May-17	16-May-17	14-Jul-17	ED	7.9	309	10	0.98	0.95	0.60	n.d.	1.03	n.d.	1.9	0.83	n.d.	n.d.	**3.6**	16	1.8	28	4.6	n.d.	0.60	1.8	n.d.	n.d.	n.d.	0.38	0.50	*0.01*					
Jul-17	PDMS samplers lost																																	
Jul-17	14-Jul-17	11-Sep-17	ED	0.48	6.3	1.3	0.33	0.57	n.d.	n.d.	0.02	n.d.	n.d.	0.05	0.03	n.d.	**0.60**	0.81	0.02	1.1	0.11	n.d.	0.01	0.03	n.d.	n.d.	n.d.	n.d.	0.04	n.d.					
Aug-17	PDMS samplers lost																																	
Sep-17	11-Sep-17	08-Nov-17	ED	0.61	16	6.9	0.62	0.44	n.d.	n.d.	n.d.	n.d.	0.11	2.6	n.d.	n.d.	**0.40**	5.1	0.99	0.65	0.08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	n.d.	n.d.					
Oct-17	PDMS samplers lost																																	
Nov-17	08-Nov-17	04-Jan-18	ED	0.79	15	7.4	0.71	0.29	n.d.	n.d.	0.08	n.d.	0.17	2.8	n.d.	n.d.	**0.60**	5.9	0.73	0.36	0.09	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.					
Dec-17			PDMS**																												0.09	n.d.	0.01	0.05	n.d.
Jan-18	04-Jan-18	12-Feb-18	ED**	1.6	17	14	0.90	0.80	n.d.	n.d.	0.39	n.d.	0.18	0.48	n.d.	n.d.	**1.10**	5.0	0.58	0.69	0.25	n.d.	n.d.	0.25	n.d.	n.d.	n.d.	0.03	n.d.	n.d.					
Feb-18			PDMS																												0.19	n.d.	0.01	0.06	n.d.
Feb-18	12-Feb-18	27-Apr-18	ED	1.3	26	16	1.7	1.6	0.96	n.d.	2.8	n.d.	0.40	0.22	0.08	n.d.	**0.60**	9.6	0.98	1.3	0.24	n.d.	0.21	n.d.	0.01	n.d.	n.d.	0.64	0.13	*0.04*					
Apr-18	PDMS samplers lost		PDMS																															
Summary																																			
Samples (n)				6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	2	2	2	2	2
Detects (n)				6	6	6	6	6	2	0	5	0	5	6	2	0	6	6	6	6	6	0	3	3	1	0	0	4	3	2	2	0	2	2	0
% Detects				100	100	100	100	100	33	0	83	0	83	100	33	0	100	100	100	100	100	0	50	50	17	0	0	67	50	33	100	0	100	100	0
Minimum concentration				0.48	6.31	1.34	0.33	0.29	n.d.	n.d.	0.02	n.d.	0.11	0.05	n.d.	n.d.	0.40	0.81	0.02	0.36	0.08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	n.d.	0.01	0.05	n.d.
Maximum concentration				7.9	309.0	16.4	1.7	1.6	1.0	n.d.	2.8	n.d.	1.9	2.8	0.08	n.d.	3.6	16.2	1.8	28.0	4.6	n.d.	0.60	1.8	0.01	n.d.	n.d.	0.64	0.50	0.04	0.19	n.d.	0.01	0.06	n.d.

Minimum % Species Affected	**0.40**
Maximum % Species Affected	**3.60**
Avg Dry % Species Affected	**1.53**
Avg Wet % Species Affected	**0.77**

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Table F-8: Repulse Bay, Mackay Whitsunday region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)													Concentration pesticides (ng/L) in PDMS samplers				
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole	Propazine	Propiconazole	Pendimethalin	Chlorpyrifos	Trifluralin
May-17 Jun-17	Samplers lost		ED																																
Jul-17 Sep-17	Samplers lost		ED																																
Oct-17	10-Oct-17	07-Nov-17	ED	0.03	2.0	9.6	4.3	0.33	n.d.	n.d.	0.09	n.d.	n.d.	0.04	n.d.	n.d.	0.70	1.7	0.04	0.53	1.3	n.d.	n.d.	0.16	n.d.	n.d.	0.22	n.d.	0.05	n.d.					
Nov-17 Dec-17	Samplers lost		ED																																
Jan-18	15-Jan-18	04-Feb-18	ED	n.d.	9.8	13	12	0.24	n.d.	n.d.	n.d.	n.d.	0.04	0.09	n.d.	n.d.	0.50	2.0	0.63	0.08	0.33	n.d.	n.d.	0.04	n.d.	n.d.	0.16	0.14	n.d.	n.d.					
			PDMS																												0.38	n.d.	n.d.	<0.006	n.d.
Feb-18	04-Feb-18	15-Mar-18	ED	0.20	9.6	22	11	2.6	0.47	n.d.	0.09	n.d.	0.12	0.19	0.10	n.d.	1.10	3.7	1.1	1.9	2.2	n.d.	0.06	0.19	n.d.	n.d.	0.39	8.5	0.07	n.d.					
			PDMS																												0.44	0.260	n.d.	0.01	n.d.
Mar-18	Samplers lost		ED PDMS																																
Apr-18	Samplers lost		ED																																
Summary																																			
Samples (n)				3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
Detects (n)				2	3	3	3	3	1	0	2	0	2	3	1	0	3	3	3	3	3	0	1	3	0	0	3	2	2	0	2	1	0	1	0
% Detects				67	100	100	100	100	33	0	67	0	67	100	33	0	100	100	100	100	100	0	33	100	0	0	100	67	67	0	100	50	0	50	0
Minimum concentration				n.d.	2.0	9.6	4.3	0.2	n.d.	n.d.	n.d.	n.d.	n.d.	0.0	n.d.	n.d.		1.7	0.0	0.1	0.3	n.d.	n.d.	0.0	n.d.	n.d.	0.2	n.d.	n.d.	n.d.	0.4	n.d.	n.d.	0.0	n.d.
Maximum concentration				0.20	9.82	21.77	11.83	2.64	0.47	n.d.	0.09	n.d.	0.12	0.19	0.10	n.d.		3.65	1.14	1.88	2.19	n.d.	0.06	0.19	n.d.	n.d.	0.39	8.48	0.07	n.d.	0.44	0.26	0.00	0.01	n.d.

Minimum % Species Affected	0.50
Maximum % Species Affected	1.1
Avg Dry % Species Affected	0.70
Avg Wet % Species Affected	0.80

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Table F-9: Round Top Island, Mackay Whitsunday region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)													Concentration pesticides (ng/L) in PDMS samplers				
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole	Propazine	Propiconazole	Pendimethalin	Chlorpyrifos	Trifluralin
May-17			ED																																
Jul-17	Samplers lost																																		
Aug-17			ED																																
Sep-17	Samplers lost																																		
Oct-17	10-Oct-17	07-Nov-17	ED	0.04	2.6	3.8	0.67	0.36	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	n.d.	n.d.	0.60	1.1	0.12	0.41	0.35	n.d.	n.d.	0.08	n.d.	n.d.	n.d.	n.d.	0.08	n.d.					
Nov-17	07-Nov-17	06-Dec-17	ED	3.8	405	778	134	1.1	n.d.	n.d.	42	n.d.	2.3	2.1	0.68	n.d.	21.9	32	6.2	16	8.1	n.d.	n.d.	3.9	n.d.	n.d.	3.9	42	0.72	n.d.					
			PDMS**																												1.9	0.94	0.05	0.05	n.d.
Dec-17	06-Dec-17	22-Jan-18	ED	2.3	46	137	37	0.58	n.d.	n.d.	2.95	n.d.	0.60	0.28	0.66	n.d.	3.7	4.5	0.15	2.7	0.14	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	7.1	0.19	n.d.					
Jan-18			PDMS**																												0.18	0.64	0.09	0.03	0.01
Jan-18	22-Jan-18	15-Feb-18	ED	3.4	168	531	49	0.79	n.d.	n.d.	0.36	n.d.	1.2	1.5	1.0	n.d.	14.8	16	4.38	3.2	1.9	n.d.	0.17	0.39	n.d.	n.d.	n.d.	7.8	0.62	n.d.					
Feb-18			PDMS																												0.85	0.14	0.00	0.02	n.d.
Feb-18	15-Feb-18	15-Mar-18	ED	0.93	69	229	21	0.25	n.d.	n.d.	0.84	n.d.	0.27	0.56	n.d.	n.d.	6.7	8.2	0.86	1.2	2.3	n.d.	0.10	0.75	n.d.	n.d.	0.47	6.7	0.41	n.d.					
Mar-18			PDMS**																												1.2	0.31	0.01	0.02	0.00
Mar-18	15-Mar-18	12-Apr-18	ED	0.96	48	225	14	0.25	0.05	n.d.	0.50	n.d.	0.28	0.22	0.40	n.d.	6.8	6.4	1.38	0.52	2.5	n.d.	0.05	1.6	n.d.	n.d.	0.79	6.2	0.90	n.d.					
	Samplers out of water		PDMS																												0.00	0.23	0.00	0.09	0.00
Apr-18			ED																																
	Samplers lost		PDMS																																
Summary																																			
Samples (n)				6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5
Detects (n)				6	6	6	6	6	1	0	5	0	5	6	4	0	6	6	6	6	6	0	3	5	0	0	3	5	6	0	5	5	5	5	3
% Detects				100	100	100	100	100	17	0	83	0	83	100	67	0	100	100	100	100	100	0	50	83	0	0	50	83	100	0	100	100	100	100	60
Minimum concentration				0.04	2.6	3.8	0.67	0.25	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	n.d.	n.d.	0.60	1.1	0.12	0.41	0.14	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.08	n.d.	0.18	0.14	0.00	0.02	n.d.
Maximum concentration				3.8	404.5	777.6	134.4	1.1	0.05	n.d.	41.6	n.d.	2.3	2.1	1.0	n.d.	21.9	32.5	6.2	15.7	8.1	n.d.	0.17	3.9	n.d.	n.d.	3.9	42.0	0.90	0.0	1.9	0.94	0.09	0.09	0.01

Minimum % Species Affected	0.60
Maximum % Species Affected	21.9
Avg Dry % Species Affected	0.60
Avg Wet % Species Affected	10.8

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Table F-10: Sarina Inlet, Mackay Whitsunday region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												Concentration pesticides (ng/L) in PDMS samplers				
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole	Propazine	Propiconazole	Pendimethalin	Chlorpyrifos	Trifluralin
May-17 Jun-17	10-May-17	06-Jul-17	ED	0.24	2.2	5.3	2.1	3.1	0.93	n.d.	n.d.	n.d.	0.03	0.66	0.83	n.d.	0.40	0.39	0.03	0.16	0.72	n.d.	0.02	0.02	n.d.	n.d.	0.20	0.11	0.34	n.d.					
Jul-17 Aug-17	06-Jul-18	05-Sep-17	ED**	0.02	0.68	1.3	0.63	1.8	n.d.	n.d.	n.d.	n.d.	n.d.	0.22	0.05	n.d.	0.30	0.21	0.02	0.15	0.05	n.d.	n.d.	0.01	n.d.	n.d.	n.d.	n.d.	0.08	n.d.					
Sep-17 Oct-17	05-Sep-17	10-Nov-17	ED	n.d.	1.3	6.2	3.1	1.2	n.d.	n.d.	n.d.	n.d.	n.d.	0.15	0.10	n.d.	0.30	0.05	n.d.	0.26	<0.08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.09	0.03	n.d.					
Nov-17 Jan-18	10-Nov-17	29-Jan-18	ED	0.46	27	60	27	1.8	n.d.	n.d.	0.07	n.d.	0.18	0.37	0.47	n.d.	1.50	0.81	n.d.	1.8	0.52	n.d.	n.d.	0.09	n.d.	n.d.	n.d.	0.62	n.d.	n.d.					
	PDMS sampler lost		PDMS																															
Feb-18 Mar-18	29-Jan-18	30-Mar-18	ED	0.11	5.9	16	10	0.24	n.d.	n.d.	n.d.	n.d.	0.04	0.14	0.55	n.d.	0.40	0.91	0.13	0.09	0.58	n.d.	n.d.	0.06	n.d.	n.d.	n.d.	0.51	0.15	n.d.					
	PDMS sampler lost		PDMS																															
Apr-18	30-Mar-18	05-May-18	ED	0.26	3.4	10.0	6.3	1.7	0.14	n.d.	n.d.	n.d.	0.04	0.20	1.2	n.d.	0.40	0.60	0.11	0.17	0.04	n.d.	n.d.	0.01	n.d.	n.d.	0.73	0.46	0.23	n.d.					
	PDMS sampler lost		PDMS																															
Summary																																		
Samples (n)				6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6					
Detects (n)				5	6	6	6	6	2	0	1	0	4	6	6	0	6	6	4	6	5	0	1	5	0	0	2	5	5	0					
% Detects				83	100	100	100	100	33	0	17	0	67	100	100	0	100	100	67	100	83	0	17	83	0	0	33	83	83	0					
Minimum concentration				n.d.	0.68	1.34	0.63	0.24	n.d.	n.d.	n.d.	n.d.	n.d.	0.14	0.05	n.d.		0.05	n.d.	0.09	0.05	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.					
Maximum concentration				0.46	27	60	27	3.13	0.93	n.d.	0.07	n.d.	0.18	0.66	1.22	0.00		0.91	0.13	1.78	0.72	n.d.	0.02	0.09	n.d.	n.d.	0.73	0.62	0.34	n.d.					
													Minimum % Species Affected				0.30																		
													Maximum % Species Affected				1.5																		
													Avg Dry % Species Affected				0.33																		
													Avg Wet % Species Affected				0.77																		

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Table F-11: Sandy Creek, Mackay Whitsunday region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												Concentration pesticides (ng/L) in PDMS samplers				
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole	Propazine	Propiconazole	Pendimethalin	Chlorpyrifos	Trifluralin
May-17 Jul-17	25-May-17	07-Aug-17	ED**	0.07	1.3	3.0	1.0	2.8	0.08	0.02	n.d.	n.d.	n.d.	0.17	n.d.	n.d.	0.50	0.39	0.04	0.27	0.12	n.d.	n.d.	0.04	2.3	n.d.	n.d.	0.11	n.d.	n.d.					
Aug-17 Sep-17	Samplers lost		ED																															
Oct-17	10-Oct-17	07-Nov-17	ED**	n.d.	3.0	10	3.8	0.55	n.d.	n.d.	n.d.	n.d.	0.04	1.9	n.d.	n.d.	0.30	0.62	0.16	0.50	0.22	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	<0.17	0.05	n.d.					
Nov-17	Samplers lost		ED																															
Dec-17	Samplers lost		ED PDMS																															
Jan-18	Samplers lost		ED PDMS																															
Feb-18	Samplers lost		ED PDMS																															
Mar-18	Samplers lost		ED PDMS																															
Apr-18	Samplers lost		ED PDMS																															
Summary																																		
Samples (n)				2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2					
Detects (n)				1	2	2	2	2	1	1	0	0	1	2	0	0	2	2	2	2	2	0	0	1	1	0	0	1	1	0					
% Detects				50	100	100	100	100	50	50	0	0	50	100	0	0	100	100	100	100	100	0	0	50	50	0	0	50	50	0					
Minimum concentration				n.d.	1.33	3.01	1.02	0.55	n.d.	n.d.	n.d.	n.d.	n.d.	0.17	n.d.	n.d.		0.39	0.04	0.27	0.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.11	n.d.	n.d.					
Maximum concentration				0.07	3.03	10	3.80	2.82	0.08	0.02	n.d.	n.d.	0.04	1.93	n.d.	n.d.		0.62	0.16	0.50	0.22	n.d.	n.d.	0.04	2.25	0.00	n.d.	0.11	0.05	n.d.					

Minimum % Species Affected	0.30
Maximum % Species Affected	0.5
Avg Dry % Species Affected	0.40
Avg Wet % Species Affected	-

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Table F-12: North Keppel Island, Fitzroy Region – Time integrated estimated concentrations in water (ng L^{-1})

Sampling Period	Deployment Dates		Sampler Type	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												
	START	END		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
Mar-17 Jun-17	08-Mar-17	19-Jun-17	ED																										
Jun-17 Aug-17	19-Jun-17	16-Aug-17	ED**	n.d.	0.07	0.19	0.03	0.16	n.d.	n.d.	n.d.	n.d.	n.d.	0.06	n.d.	n.d.	0.10	n.d.	n.d.	0.07	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Aug-17 Oct-17	16-Aug-17	18-Oct-17	ED**	n.d.	0.16	n.d.	0.06	0.33	n.d.	n.d.	n.d.	n.d.	n.d.	0.05	0.12	n.d.	0.30	n.d.	n.d.	0.05	0.03	n.d.	n.d.	0.01	n.d.	n.d.	0.01	0.03	n.d.	n.d.
Oct-17 Nov-17	18-Oct-17	27-Nov-17	ED	n.d.	0.56	6.1	0.45	0.20	n.d.	n.d.	n.d.	n.d.	n.d.	0.23	n.d.	n.d.	0.60	n.d.	n.d.	0.24	0.26	n.d.	n.d.	0.19	n.d.	n.d.	n.d.	0.21	n.d.	n.d.
Dec-17	27-Nov-17	24-Dec-17	ED	n.d.	0.84	3.2	0.50	0.94	n.d.	n.d.	n.d.	n.d.	n.d.	0.18	n.d.	n.d.	0.50	0.07	n.d.	0.22	<0.15	n.d.	n.d.	0.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Jan-18	24-Dec-17	08-Feb-18	ED	n.d.	0.53	1.6	0.38	0.45	n.d.	n.d.	n.d.	n.d.	n.d.	0.10	0.48	n.d.	0.20	0.03	n.d.	0.17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Feb-18	08-Feb-18	12-Mar-18	ED	n.d.	2.8	5.2	1.4	0.50	n.d.	n.d.	n.d.	n.d.	n.d.	0.16	0.48	n.d.	0.40	0.25	n.d.	0.60	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	<0.04	n.d.	n.d.
Mar-18	12-Mar-18	11-Apr-18	ED	n.d.	0.54	2.7	0.32	0.69	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	0.10	n.d.	0.20	0.11	0.02	0.14	0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.18	0.01	0.14
Apr-18	11-Apr-18	02-May-18	ED**	n.d.	0.12	1.1	0.08	0.09	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.30	0.11	0.04	0.04	n.d.	n.d.	n.d.	0.05	n.d.	n.d.	n.d.	0.02	n.d.	n.d.
Summary																														
Samples (n)				8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Detects (n)				0	8	7	8	8	0	0	0	0	0	7	4	0	8	5	2	8	3	0	0	4	0	0	1	4	1	1
% Detects				0	100	88	100	100	0	0	0	0	0	88	50	0	100	63	25	100	38	0	0	50	0	0	13	50	13	13
Minimum concentration				n.d.	0.07	n.d.	0.03	0.09	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		n.d.	n.d.	0.04	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum concentration				n.d.	2.83	6.1	1.4	0.94	n.d.	n.d.	n.d.	n.d.	n.d.	0.23	0.48	n.d.		0.25	0.00	0.60	0.26	n.d.	n.d.	0.19	n.d.	n.d.	n.d.	0.21	0.00	0.00
													Minimum % Species Affected				0.10													
													Maximum % Species Affected				0.60													
													Avg Dry % Species Affected				0.20													
													Avg Wet % Species Affected				0.37													

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

Shaded pesticides and herbicides indicate that no calibration data is available and the sampling rate of atrazine was assumed. Water estimatations are approximate

**Concentration is average of duplicate samplers

Appendix G Terrestrial run-off assessment results

Table G-1: Concentrations in grab water samples (ng L^{-1}) measured at various locations offshore and in river mouths (along transects) during the 2017–18 monitoring year

Sample Description	Date collected	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)												
		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
BURDEKIN FOCUS REGION																												
Barratta Creek mouth	09-Jun-17	n.d.	*0.42*	n.d.	n.d.	*0.06*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.01**	*0.09*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3.8	n.d.	n.d.
Barratta Creek mouth	14-Jun-17	n.d.	1.9	*0.40*	*0.20*	*0.22*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.30**	*0.43*	*0.12*	*0.37*	*0.26*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Barratta Creek mouth	15-Jun-17	n.d.	12	3.8	1.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.50**	4.1	1.1	1.1	0.80	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Barratta Creek mouth (repl)	15-Jun-17	n.d.	12	n.d.	1.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.50**	3.6	1.1	1.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Barratta Creek mouth	08-Nov-17	n.d.	1.3	*0.27*	*0.07*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.04**	*0.23*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*0.27*	n.d.	n.d.
Barratta Creek mouth (repl)	08-Nov-17	*3.9*	1.4	*0.34*	*0.07*	n.d.	n.d.	n.d.	n.d.	*3.1*	n.d.	n.d.	n.d.	*3.6*	**0.00**	*0.24*	*0.11*	n.d.	*0.19*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*0.22*	n.d.	n.d.
Barratta Creek mouth	04-Jan-18	n.d.	*0.55*	*0.22*	*0.09*	*0.09*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.00**	*0.18*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Barratta Creek mouth	12-Feb-18	n.d.	0.88	*0.35*	*0.30*	*0.47*	*0.37*	*0.36*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.30**	*0.41*	*0.27*	*0.27*	*0.42*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
RUSSELL-MULGRAVE RIVERS TRANSECT																												
Russell/Mulgrave mouth	17-Jun-17	n.d.	4.1	1.7	0.83	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	1.1	**0.01**	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Russell/Mulgrave mouth	14-Jan-18	n.d.	25	35	18	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*4.9*	**1.97**	5.3	1.3	3.9	3.1	n.d.	1.2	n.d.	n.d.	n.d.	2.6	6.2	3.3	n.d.
Russell/Mulgrave mouth (repl)	14-Jan-18	n.d.	24	29	17	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*5.1*	**1.57**	5.0	1.3	3.5	2.8	n.d.	1.2	*0.50*	n.d.	n.d.	3.1	6.0	3.6	n.d.
Russell/Mulgrave mouth	11-Feb-18	13	9.6	22	11	*0.10*	n.d.	n.d.	*0.27*	9.9	n.d.	n.d.	n.d.	9.5	**1.71**	2.1	*0.39*	0.97	13	n.d.	2.9	n.d.	n.d.	n.d.	39	10	1.4	n.d.
Russell/Mulgrave mouth	15-Mar-18	n.d.	6.3	33	19	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**2.81**	5.3	0.75	1.9	18	n.d.	2.0	6.4	n.d.	4.3	5.4	55	n.d.	n.d.
Russell/Mulgrave mouth	19-Mar-18	n.d.	17	8.5	8.9	*0.09*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**2.63**	6.2	1.0	3.8	62	n.d.	0.71	44	n.d.	20	3.2	17	n.d.	n.d.
High Island	17-Jun-17	n.d.	3.7	2.2	0.86	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.30**	0.51	n.d.	0.55	0.77	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.57	n.d.	n.d.
High Island	14-Jan-18	n.d.	1.1	1.5	0.67	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*5.6*	**0.20**	n.d.	n.d.	*0.19*	0.56	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
High Island	29-Jan-18	n.d.	0.99	2.3	1.1	*0.17*	<0.11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.00**	*0.25*	*0.14*	<0.25	0.61	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*0.32*	n.d.	n.d.
High Island	11-Feb-18	*3.7*	2.4	2.6	1.2	*0.08*	n.d.	n.d.	n.d.	*3.4*	n.d.	n.d.	n.d.	*3.8*	**0.40**	*0.28*	*0.10*	*0.27*	1.8	n.d.	n.d.	n.d.	n.d.	n.d.	0.50	*0.42*	n.d.	n.d.
High Island	15-Mar-18	n.d.	4.6	14	4.4	*0.41*	n.d.	n.d.	n.d.	n.d.	n.d.	*0.44*	n.d.	n.d.	**0.90**	1.7	*0.43*	0.64	9.4	n.d.	*0.51*	1.1	n.d.	2.5	n.d.	5.7	n.d.	n.d.
High Island	19-Mar-18	n.d.	2.9	6.2	1.7	*0.41*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.30**	0.88	n.d.	*0.40*	6.7	n.d.	n.d.	n.d.	n.d.	1.3	n.d.	1.8	n.d.	n.d.
High Island (repl)	19-Mar-18	n.d.	2.9	5.3	1.7	*0.49*	*0.38*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	**0.30**	0.87	0.51	0.59	5.0	n.d.	n.d.	n.d.	n.d.	1.5	0.55	1.7	n.d.	n.d.

Table G-1 (cont.): Concentrations in grab water samples (ng L^{-1}) measured at various locations offshore and in river mouths (along transects) during the 2017–18 monitoring year

Sample Description	Date collected	Concentration PSII herbicides (ng/L)													% Species Affected	Concentration other herbicides/ pesticides (ng/L)											
		Ametryn	Atrazine	Diuron	Hexazinone	Tebuthiuron	Bromacil	Fluometuron	Metribuzin	Prometryn	Propazine	Simazine	Terbuthylazine	Terbutryn		DE Atrazine	DI Atrazine	Metolachlor	24 D	2,4 DB	Haloxyfop	MCPA	Fluazifop	Fluroxypyr	Imazapic	Imidacloprid	Metsulfuron-Methyl	Tebuconazole
TULLY RIVER TRANSECT																												
Tully River Mouth	15-Jun-17	n.d.	17	2.6	2.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	< 1.7	0.40	2.5	0.59	0.60	12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	15	n.d.	n.d.
Tully River Mouth	21-Oct-17	n.d.	7.5	6.2	2.4	*0.21*	n.d.	n.d.	2.7	n.d.	n.d.	*0.70*	n.d.	n.d.	0.82	0.92	*0.39*	2.2	2.1	n.d.	n.d.	n.d.	n.d.	n.d.	6.2	4.9	*0.19*	n.d.
Tully River Mouth	13-Jan-18	n.d.	2.3	3.3	1.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*5.6*	0.26	0.65	n.d.	*0.29*	0.67	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.59	n.d.	n.d.
Tully River Mouth	21-Jan-18	n.d.	3.5	21	8.3	n.d.	n.d.	n.d.	3.5	n.d.	n.d.	n.d.	n.d.	n.d.	0.65	1.0	*0.34*	0.83	3.9	n.d.	0.89	n.d.	n.d.	n.d.	4.8	6.6	*0.18*	n.d.
Tully River Mouth	28-Jan-18	n.d.	3.3	12	6.5	*0.14*	n.d.	n.d.	5.0	n.d.	n.d.	n.d.	n.d.	n.d.	0.85	1.7	0.55	0.58	2.7	n.d.	2.0	n.d.	n.d.	n.d.	7.1	18	2.2	n.d.
Tully River Mouth	09-Feb-18	n.d.	154	198	159	n.d.	n.d.	n.d.	15	n.d.	1.6	*1.0*	n.d.	*4.1*	8.06	22	8.0	2.3	113	n.d.	4.5	n.d.	*0.41*	n.d.	15	83	n.d.	n.d.
Tully River Mouth	12-Mar-18	n.d.	14	91	15	*0.07*	n.d.	n.d.	2.1	n.d.	n.d.	n.d.	n.d.	n.d.	3.03	4.9	1.4	0.99	43	90	2.4	n.d.	n.d.	1.3	1.7	59	n.d.	n.d.
Tully River Mouth	14-Mar-18	n.d.	11	44	15	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*0.42*	n.d.	n.d.	1.80	6.7	1.4	1.0	19	n.d.	1.5	n.d.	n.d.	n.d.	1.4	51	1.5	n.d.
Tully River Mouth	20-Mar-18	n.d.	5.1	20	9.5	*0.30*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.58	3.1	0.61	0.85	9.6	n.d.	0.84	n.d.	n.d.	1.5	0.72	23	n.d.	n.d.
Dunk Island north	15-Jun-17	n.d.	5.9	2.5	0.89	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	<1.1	1.00	n.d.	n.d.	0.87	n.d.	n.d.	n.d.	1.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dunk Island north (repl)	15-Jun-17	n.d.	6.1	1.5	0.85	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	<1.1	1.00	0.57	n.d.	1.1	n.d.	n.d.	n.d.	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dunk Island north	21-Oct-17	n.d.	8.7	7.2	2.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*0.72*	n.d.	*4.9*	0.60	0.78	n.d.	1.7	2.5	n.d.	n.d.	n.d.	n.d.	n.d.	1.6	3.4	n.d.	n.d.
Dunk Island north	13-Jan-18	n.d.	0.79	1.0	*0.33*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*5.3*	0.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dunk Island north	21-Jan-18	12	1.7	4.2	1.8	*0.07*	n.d.	n.d.	0.85	11	n.d.	n.d.	n.d.	9.7	0.30	*0.28*	*0.11*	n.d.	1.2	n.d.	n.d.	n.d.	n.d.	n.d.	0.68	0.97	n.d.	n.d.
Dunk Island north	28-Jan-18	n.d.	*0.30*	*0.43*	*0.15*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.00	<0.09	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*0.27*	n.d.	n.d.	n.d.
Dunk Island north (repl)	28-Jan-18	n.d.	*0.27*	*0.38*	*0.16*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.00	<0.08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Dunk Island north	10-Feb-18	n.d.	5.3	7.0	2.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*5.7*	0.00	0.52	n.d.	n.d.	2.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.67	n.d.	n.d.
Dunk Island north	12-Mar-18	n.d.	7.3	22	6.3	*0.43*	*0.24*	n.d.	n.d.	n.d.	n.d.	1.7	n.d.	n.d.	0.60	2.1	1.3	0.90	20	50	0.65	n.d.	n.d.	3.8	0.78	10	n.d.	n.d.
Dunk Island north	14-Mar-18	n.d.	7.0	24	5.8	0.50	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.50	2.1	0.86	0.81	18	n.d.	n.d.	n.d.	n.d.	2.9	*0.35*	9.6	n.d.	n.d.
Dunk Island north	20-Mar-18	n.d.	3.1	4.5	1.6	0.55	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.30	1.1	n.d.	*0.29*	5.2	n.d.	n.d.	n.d.	n.d.	1.6	n.d.	1.2	n.d.	n.d.
Bedarra Island	15-Jun-17	n.d.	5.8	2.6	1.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	<0.63	0.70	0.83	n.d.	0.78	0.75	n.d.	n.d.	0.69	n.d.	0.81	n.d.	0.89	n.d.	n.d.
Bedarra Island (repl)	15-Jun-17	n.d.	5.7	2.6	1.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.70	0.81	n.d.	1.0	0.70	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.77	*0.25*	n.d.
Bedarra Island	21-Oct-17	n.d.	33	26	10	n.d.	n.d.	n.d.	4.8	n.d.	*0.34*	2.28	n.d.	n.d.	1.80	3.6	1.4	11	6.5	n.d.	*0.65*	n.d.	n.d.	n.d.	18	15	n.d.	n.d.
Bedarra Island	13-Jan-18	n.d.	2.09	0.80	*0.47*	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*5.2*	0.00	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Bedarra Island	21-Jan-18	n.d.	7.2	30	12	n.d.	n.d.	n.d.	6.9	n.d.	n.d.	n.d.	n.d.	n.d.	0.90	1.6	0.61	0.93	6.3	n.d.	0.83	n.d.	n.d.	n.d.	7.8	9.1	n.d.	n.d.
Bedarra Island	28-Jan-18	n.d.	n.d.	<0.12	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.00	<0.06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	*0.22*	n.d.	n.d.	n.d.
Bedarra Island	10-Feb-18	n.d.	50	78	35	n.d.	n.d.	n.d.	n.d.	n.d.	*0.33*	n.d.	n.d.	*4.5*	1.80	4.7	1.9	0.75	31	n.d.	2.1	n.d.	n.d.	n.d.	3.6	14	n.d.	n.d.
Bedarra Island	12-Mar-18	n.d.	13	61	19	0.72	0.50	n.d.	1.8	n.d.	n.d.	3.0	n.d.	n.d.	1.60	4.3	1.9	1.9	49	79	1.2	n.d.	n.d.	5.1	3.1	29	n.d.	n.d.
Bedarra Island	14-Mar-18	n.d.	8.2	31	9.3	0.72	n.d.	n.d.	n.d.	n.d.	n.d.	*0.82*	n.d.	n.d.	0.80	3.8	1.1	1.2	27	n.d.	0.85	n.d.	n.d.	4.1	1.2	22	n.d.	n.d.
Bedarra Island	20-Mar-18	n.d.	3.9	6.3	2.4	0.63	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.30	1.5	n.d.	*0.47*	6.3	n.d.	n.d.	n.d.	n.d.	2.0	n.d.	2.8	n.d.	n.d.

n.d. - non detect, for these samples the extract concentration was below the instrument LOD. n.d. values are inlcuded as 0 for summary statistics and ms-PAF calculations

Concentrations that did not exceed 3 x blank levels and are shown preceded by "<" in the tables and are included as for n.d. in summary statistics

Concentrations where the extract concentration was above the instrument LOD but below the instrument LOR (see Table A4, Appendix A) are shown in italics. These values are included in the ms-PAF calculations but should be treated with caution

(repl) indicates a replicate sample was extracted

Appendix H **Historical concentration profiles at fixed monitoring sites**

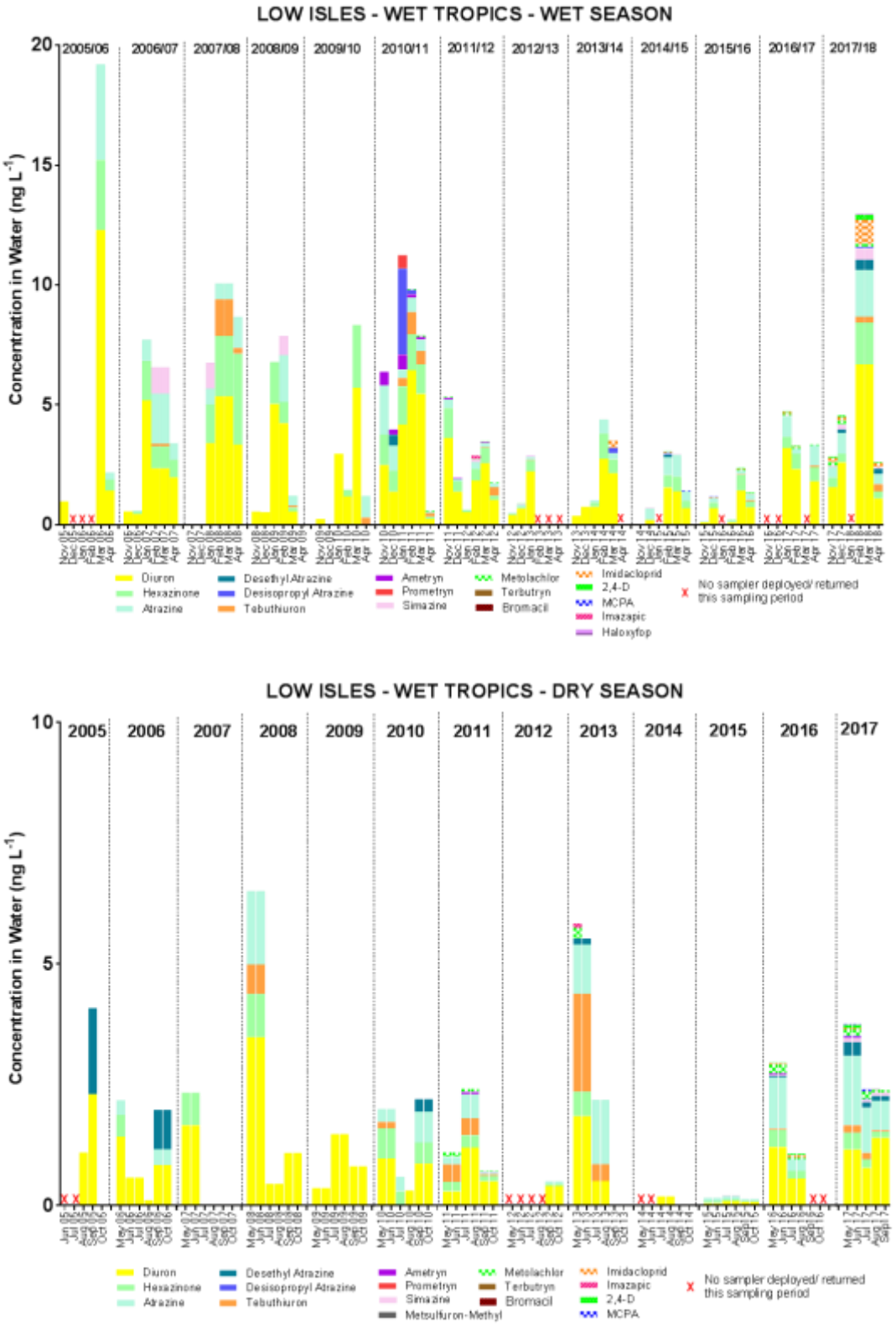

Figure H-1: Temporal concentration profiles of individual herbicides at Low Isles in the Wet Tropics region

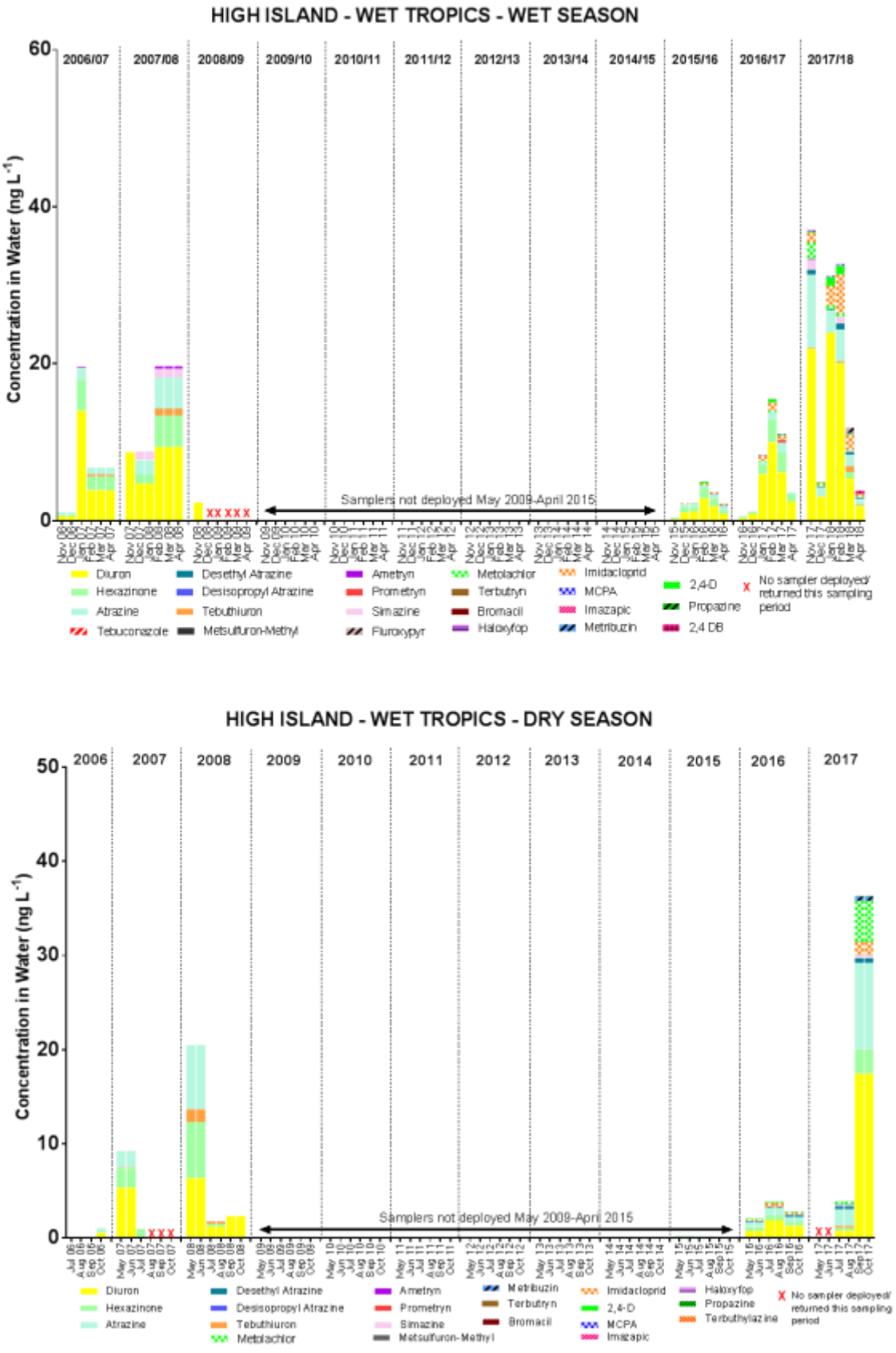

Figure H-2: Temporal concentration profiles of individual herbicides at High Island in the Wet Tropics region

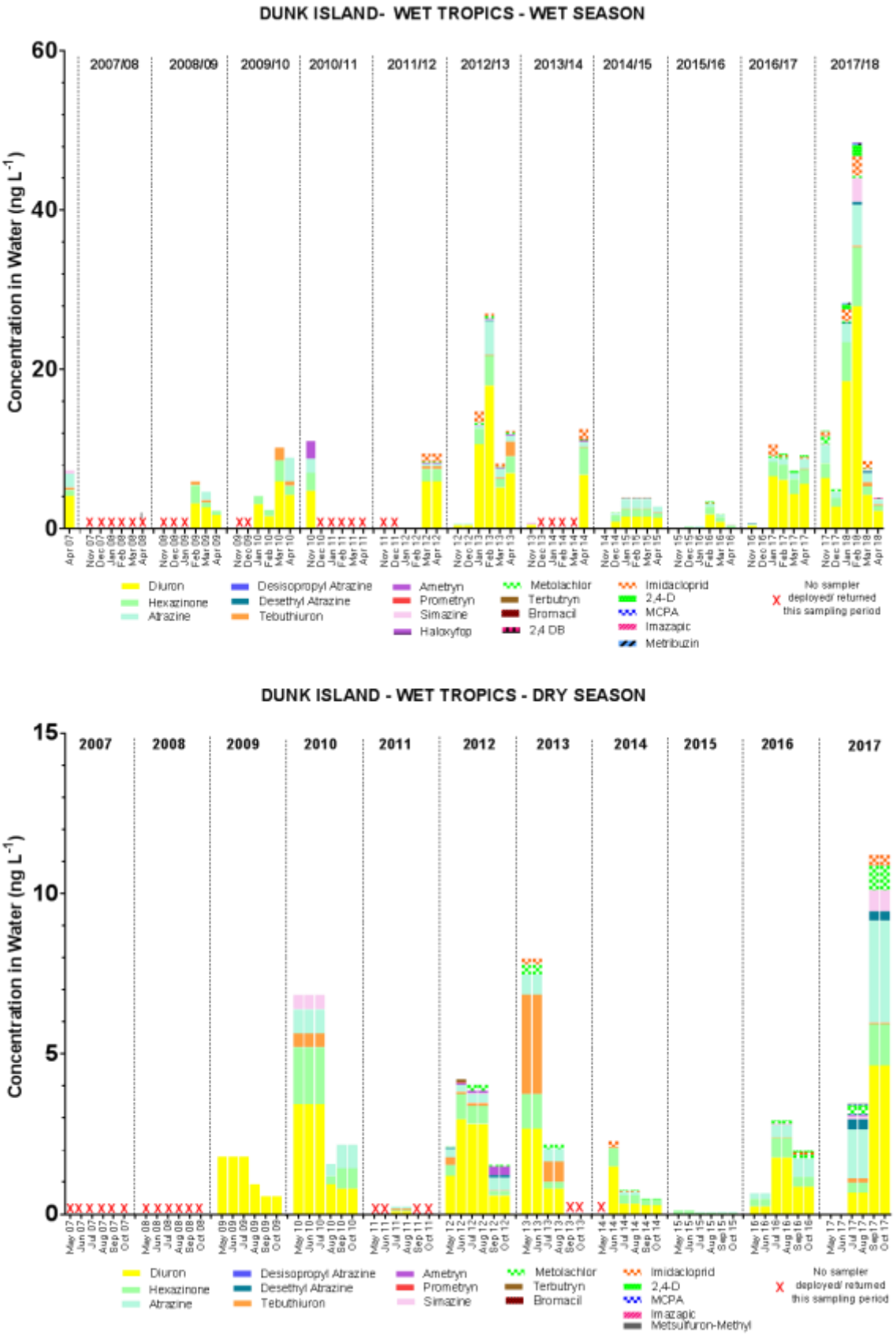

Figure H-3: Temporal concentration profiles of individual herbicides at Dunk Island in the Wet Tropics region

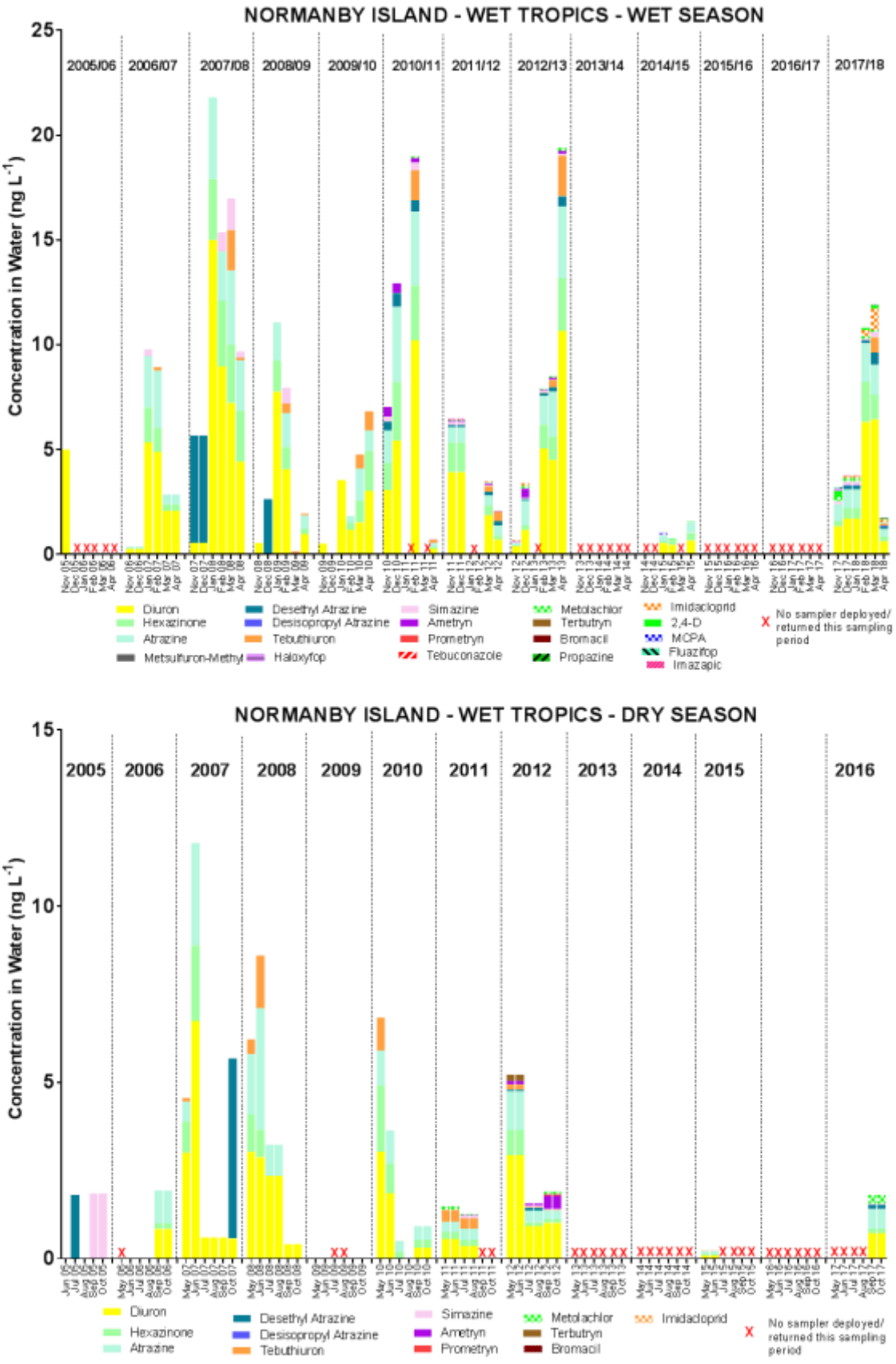

Figure H-4: Temporal concentration profiles of individual herbicides at Normanby Island in the Wet Tropics region

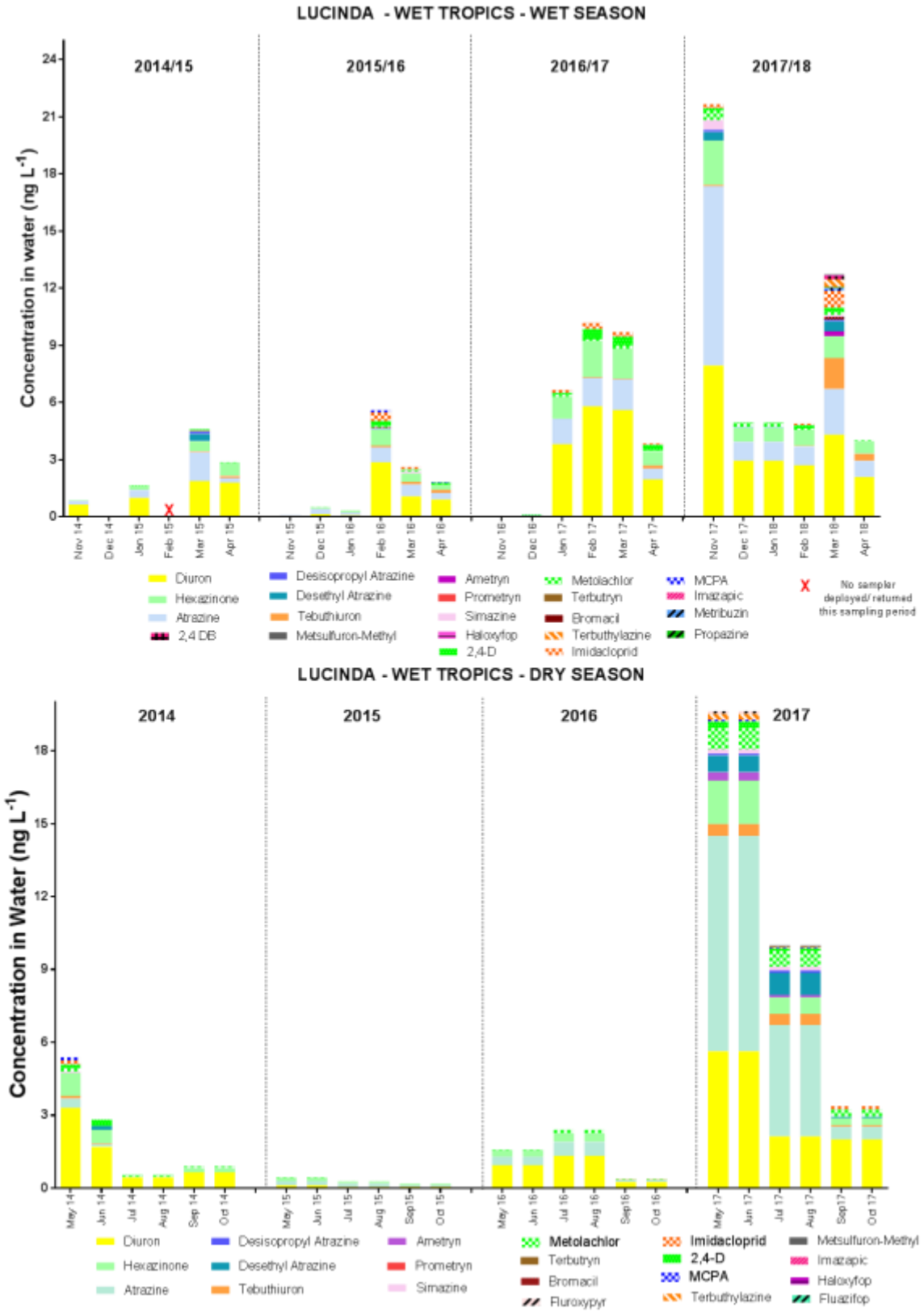

Figure H-5: Temporal concentration profiles of individual herbicides at Lucinda in the Wet Tropics region

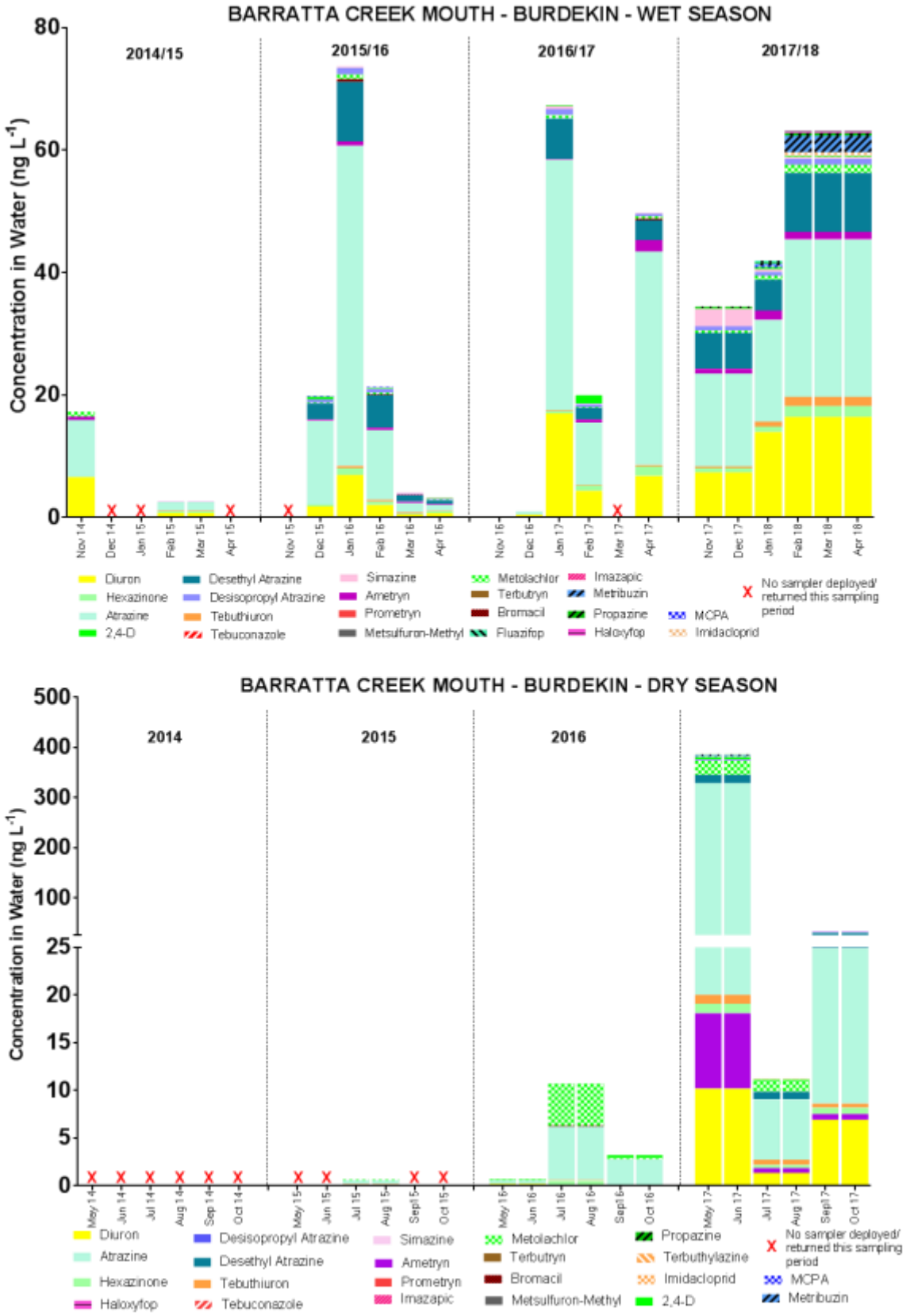

Figure H-6: Temporal concentration profiles of individual herbicides at Barratta Creek mouth in the Burdekin region

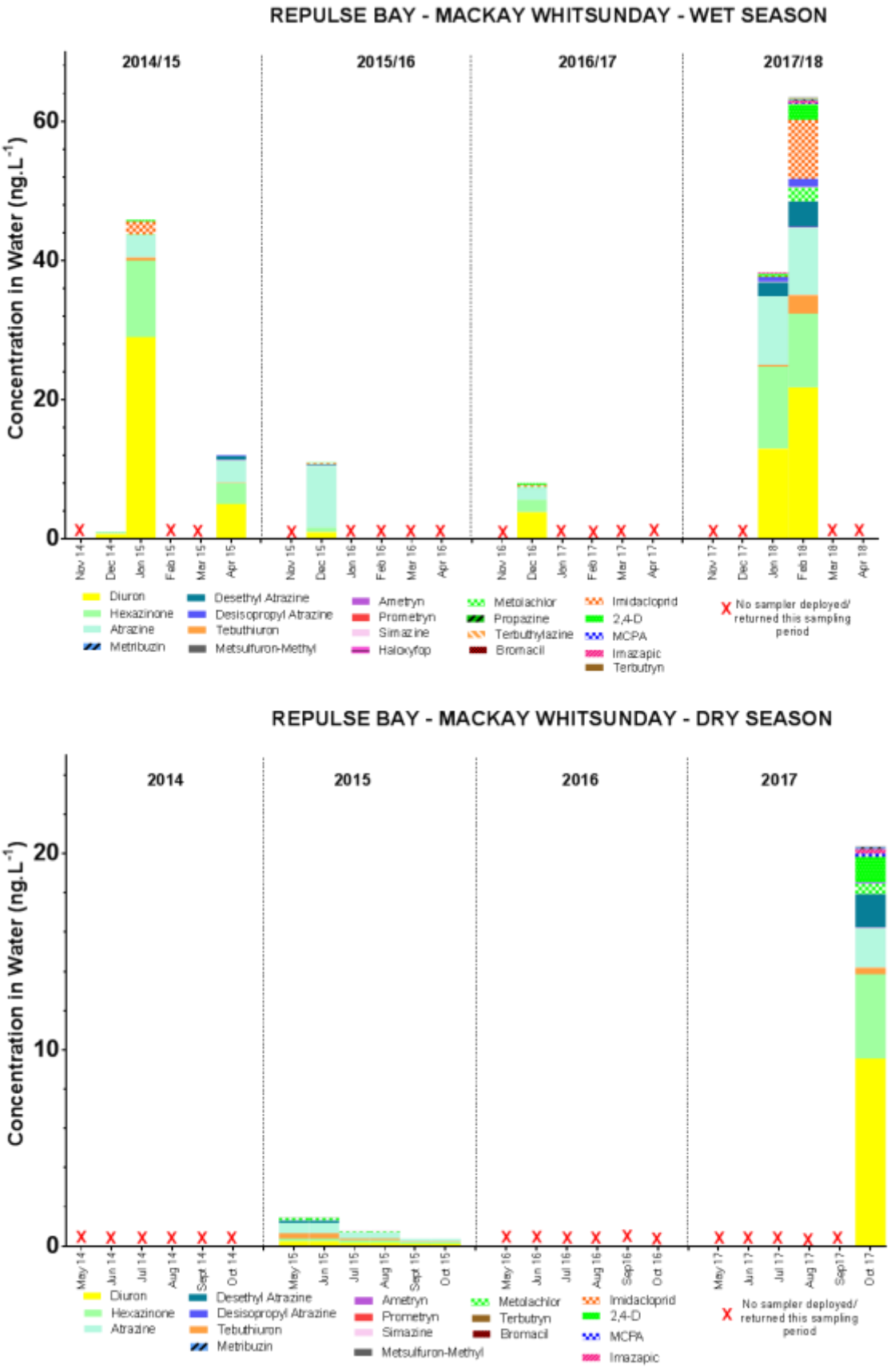

Figure H-7: Temporal concentration profiles of individual herbicides at Repulse Bay in the Mackay Whitsunday region

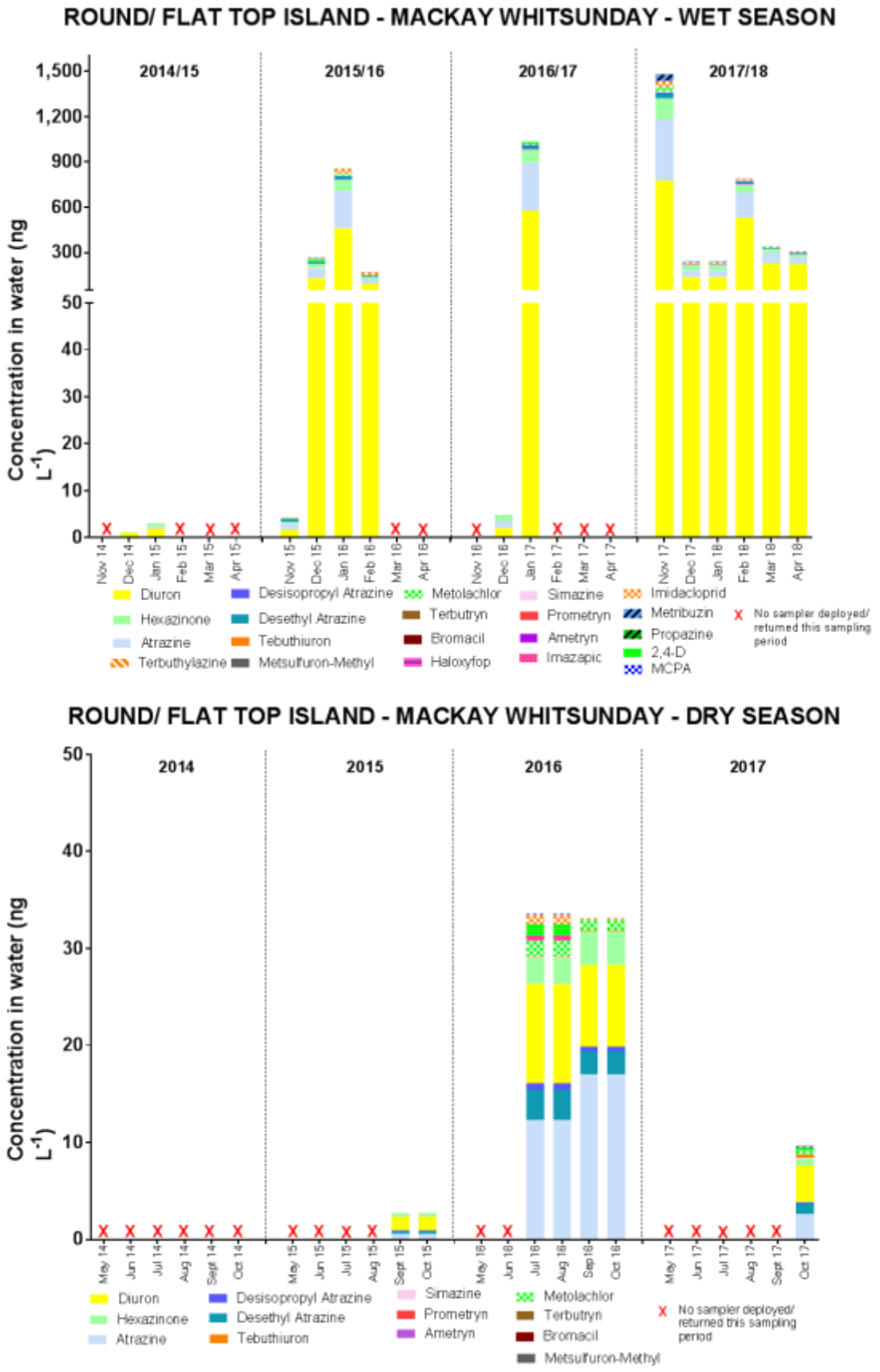

Figure H-8: Temporal concentration profiles of individual herbicides at Round Top Island in the Mackay Whitsunday region

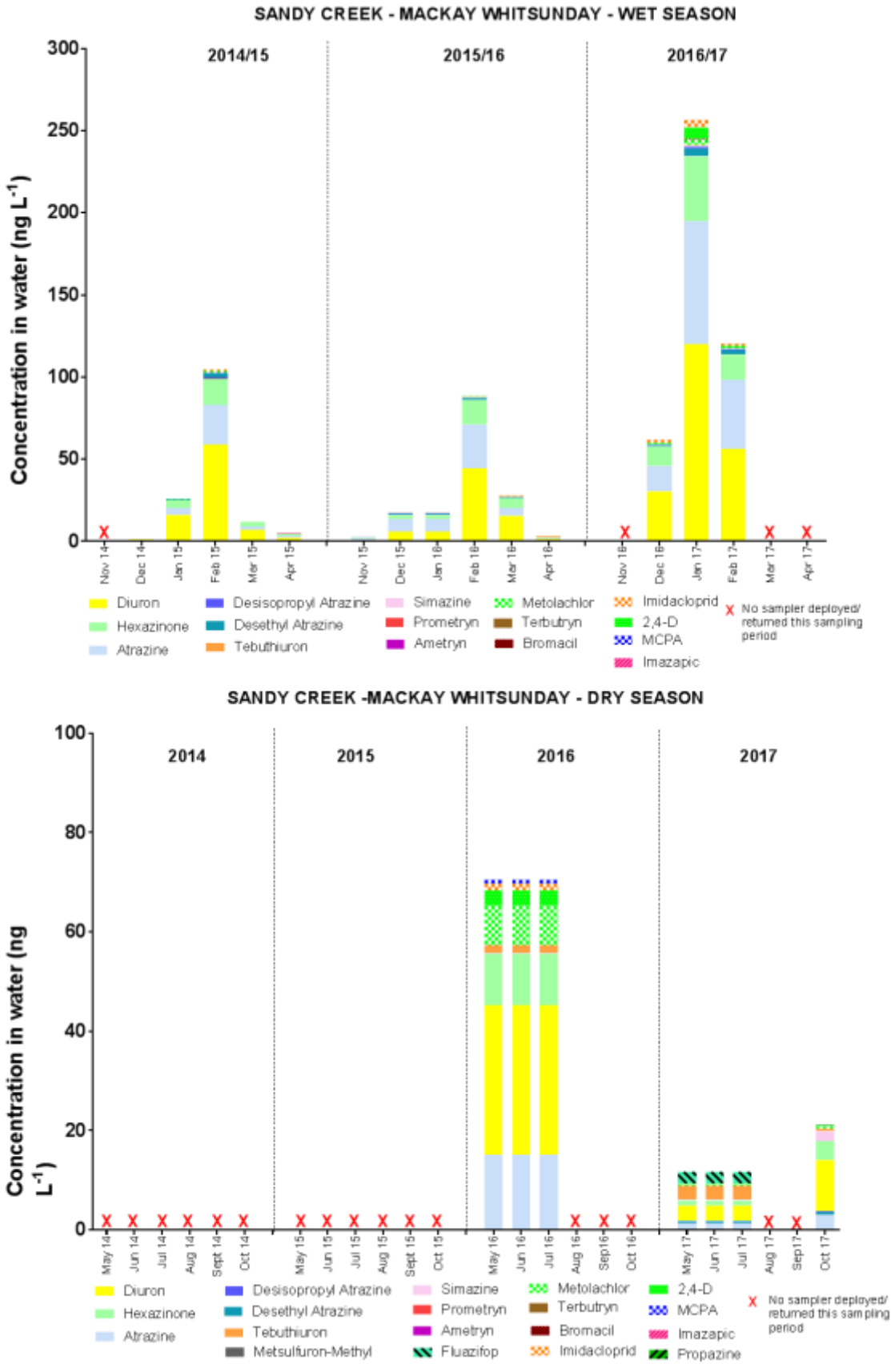

Figure H-9: Temporal concentration profiles of individual herbicides at Sandy Creek in the Mackay Whitsunday region

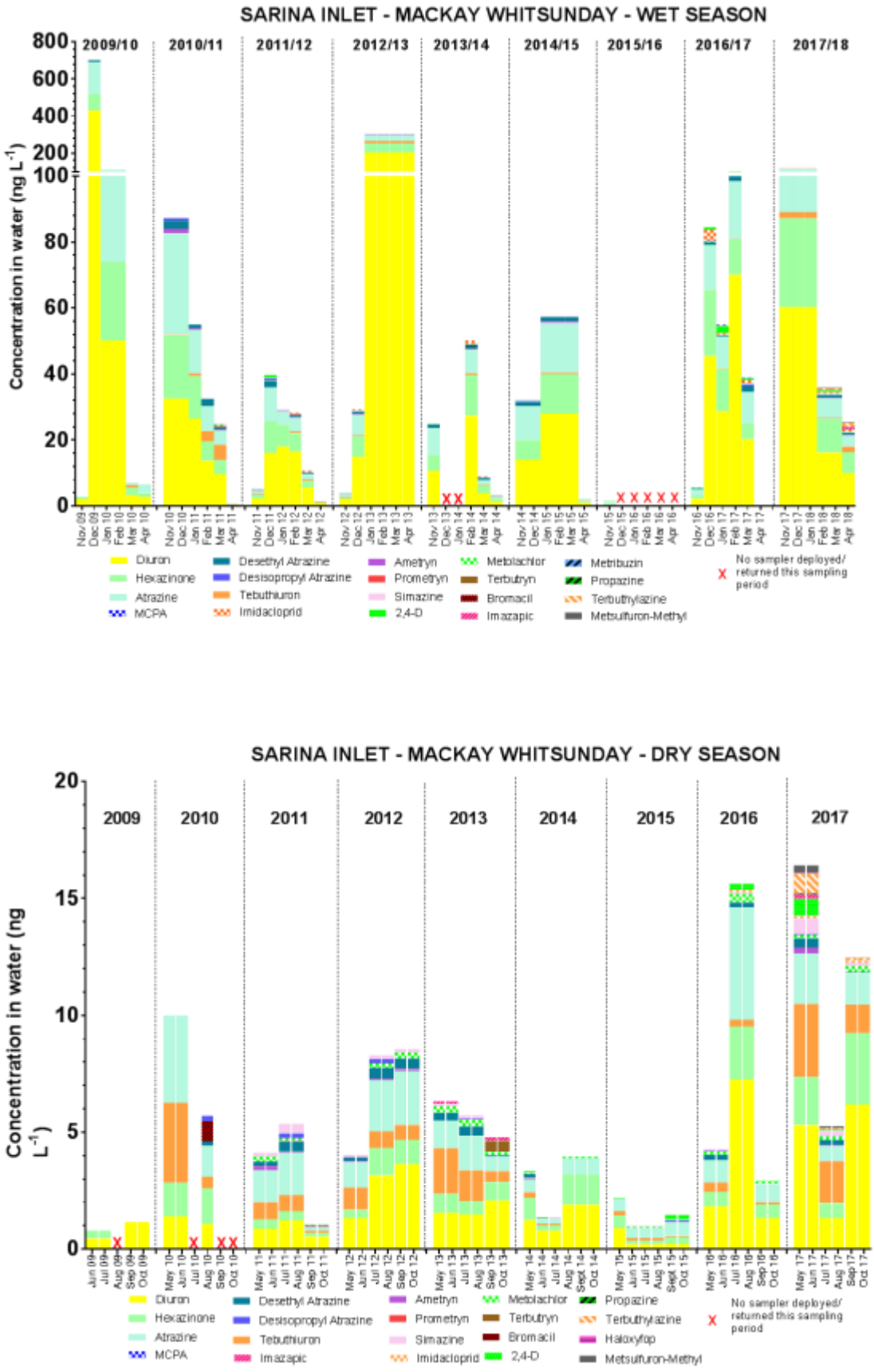

Figure H-10: Temporal concentration profiles of individual herbicides at Sarina Inlet in the Mackay Whitsunday region

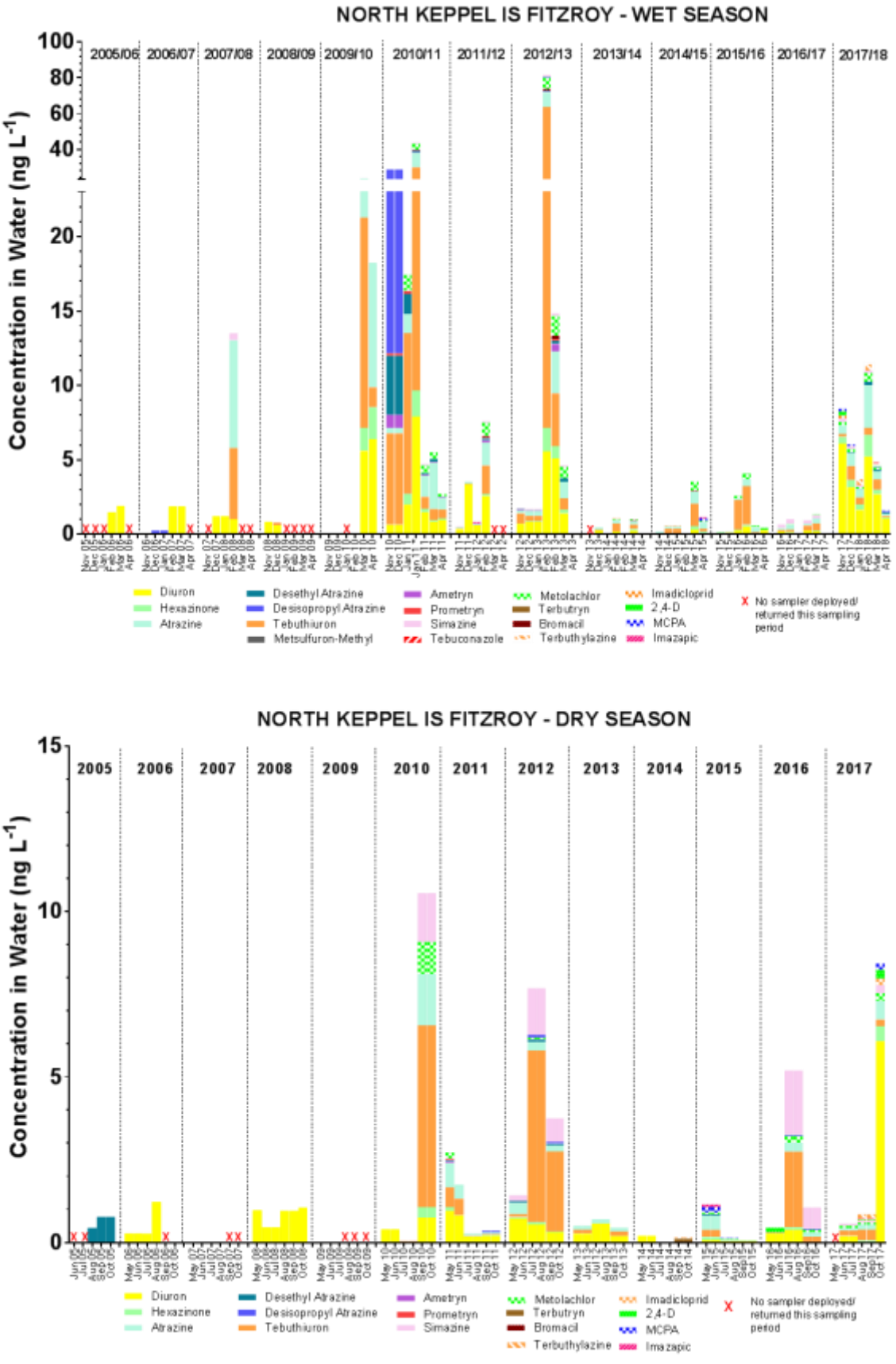

Figure H-11: Temporal concentration profiles of individual herbicides at North Keppel Island in the Fitzroy region