

DARWIN HARBOUR REGION 2016 REPORT CARD WATER QUALITY SUPPLEMENT

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Report Number 22/2016D



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Citation: Fortune, J. (2016). Darwin Harbour Region 2016 Report Card Water Quality Supplement. Report No. 22/2016D. Aquatic Health Unit, Department of Environment and Natural Resources. Palmerston, NT.

Website: <http://www.denr.nt.gov.au/water/darwin-harbour/reportcards>

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Annual publication

ISSN 1838-4625 (Print)
ISSN 1838-4633 (Online)

Report No. 22/2016D

Cover: Insert 1: Blackmore River estuary, Insert 2: Water quality sampling (Ruth Patterson, Larrakia Rangers - Steven Dawson and Alena Talbot), Insert 3: Coastal Reef Casuarina Coastal Reserve and Insert 4: Sediment core sampling in mangroves (Matthew Majid).

Acknowledgments

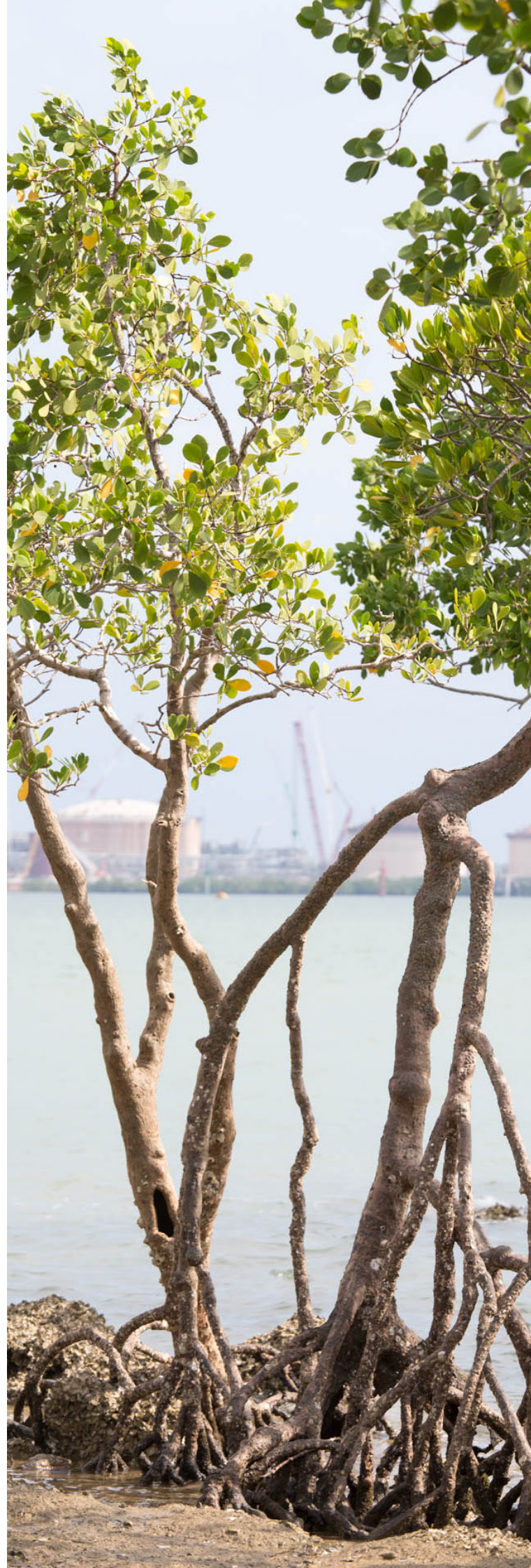
Water quality monitoring was partially funded by the INPEX-led Ichthys LNG Project.

We thank the many people who contributed photographs including the INPEX-led Ichthys LNG Project. Also thanks to the Larrakia Nation Sea Ranger group who assisted with monitoring effort throughout the reporting year.

Symbols are courtesy of the Integration and Application Network (ian.umces.edu/symbols/), University of Maryland Centre for Environmental Science, USA. Several conceptual symbols were adapted from base diagrams from the Integration and Application Network.

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1. Introduction

Water quality monitoring has been undertaken in Darwin Harbour by the Department of Environment and Natural Resources (and its predecessor organisations) since 1987 (Wrigley et al. 1990). The water quality of the harbour has been summarised annually in the form of a Report Card since 2010. The 2016 grades are shown in Figure 1, and presented with the grades for previous years in Table 1.

This report supplements the 2016 Darwin Harbour Region Report Card by presenting supporting data used to calculate the grades.

The 2016 grades indicate that water quality was very good to excellent. Deviations from excellent water quality, indicative of Water Quality Objective (WQO) non-compliance, are likely to be natural and an artefact of the grading methodology and WQOs. An exception though is Buffalo Creek which has consistently poor water quality due mainly to the combined effects of effluent discharged from the Leanyer-Sanderson wastewater treatment plant, and poor flushing of the creek.

2. Darwin Harbour region

The Darwin Harbour region extends from Gunn Point in the east, to Charles Point in the west (Fig 1). The climate consists of two seasons: the wet and the dry. The wet season occurs between November and April and is characterised by warm air temperatures, convective storms, monsoonal weather which brings heavy rain and strong north-westerly winds, and in some years cyclonic weather. The dry season occurs from May to October and is characterised by cooler air temperatures, south east winds and little or no rain.

The region has a population of over 130,000 people and covers over 3200 km² (65% terrestrial and 35% coastal and marine at high tide). Darwin Harbour is a large, macro-tidal estuary with semi-diurnal tides (two high tides and two low tides) and is characterised by strong tidal currents which result in extensive turbid plumes on outgoing tides.



The Health of the Harbour



WATER QUALITY GRADES

- A** Excellent water quality. All four water quality indicators meet desired levels.
- B** Very good water quality. Three water quality indicators meet desired levels.
- C** Good water quality. Two water quality indicators meet desired levels.
- D** Poor water quality. Only one water quality indicator meets desired levels.
- E** Very poor water quality. No water quality indicators meet desired levels.

Figure 1 – Reporting zone grades for Darwin Harbour region 2016.

Summary

Below is a table that shows water quality indicators for each region of the harbour, with a

✓ indicating those that met the desired level (known formally as a Water Quality Objective) and a

✗ indicating those that were unsatisfactory.

Table 1 - Water quality evaluation for 2016 and previous grade.

Indicator	Harbour region								
	Outer Harbour			Inner Harbour				Tidal creeks	
	Outer Darwin Harbour	Shoal Bay	Middle Darwin Harbour	Blackmore	East Arm	Elizabeth	West Arm	Buffalo Creek	Myrmidon Creek
Water clarity	✓	✓	✓	✓	✓	✓	✓	✗	✓
Dissolved oxygen	✓	✓	✓	✓	✓	✓	✓	✗	✓
Algae	✓	✓	✓	✓	✓	✓	✓	✗	✓
Nutrients	✗	✗	✓	✓	✓	✓	✓	✗	✗
	Report Card grades								
2016	B	B	A	A	A	A	A	E	B
2015	B	A	B	B	B	B	B	E	B

Note: Minor deviations from the upper threshold for dissolved oxygen (DO) objectives were observed in the Outer harbour and Myrmidon Creek reporting zones. These values highlight the variability of water quality and the need to revise water quality objectives in the context of significant tidal, seasonal and temporal variation. For the Outer harbour and Myrmidon Creek zones expert opinion deemed that these DO departures from guidelines did not reflect any anthropogenic impact nor degradation in water quality and was given an 'B' grade.

3. Biological Indicators for freshwater systems.

Organisms living in streams and rivers can tell us about the condition or “health” of waterways. Diverse communities of macroinvertebrates (or water-bugs) indicate a stream in good condition, whereas simple communities of few water-bug types indicate a damaged or degraded stream. Annual monitoring of stream health is currently undertaken in Rapid Creek and uses an assessment system known as AUSRIVAS. This stands for Australian River Assessment System, and works by comparing water-bugs present in a stream with those expected to be present in reference streams of a similar type. AUSRIVAS produces a score based on the number of types found in a sample relative to the number of types expected. To simplify interpretation of these scores a banding system has been developed (Table 2). Band A means streams are equivalent to high quality reference streams; bands B, C, or D indicate that the stream is below reference condition and is degraded to varying degrees.

Table 2 - How to interpret bands from AUSRIVAS.

Band	Description	What it represents
X	More biologically diverse than reference	More types found than expected. Potential biodiversity “hot-spot” or mild organic enrichment.
A	Similar to reference	O/E scores range found at 80% of the reference sites, or equivalent to reference condition.
B	Significantly impaired	Potential impact either on water and/or habitat quality resulting in a loss of types.
C	Severely impaired	Many fewer types than expected. Loss of water and/or habitat quality.
D	Extremely impaired	Few of the expected types and only the hardy, pollution tolerant families remain.

3.1 Rapid Creek 2016

Two macroinvertebrate sites were sampled in 2016. These sites are in the upper reaches of the Rapid Creek system which is a small seasonally flowing stream in the Darwin urban area. Results of the AUSRIVAS scores are described below in Table 3. These results are similar to previous years. The creek has an impoverished macroinvertebrate fauna which is to be expected for a stream with an urbanised catchment.

Table 3 - Rapid Creek AUSRIVAS Scores for 2016.

Site number	2013	2014	2015	2016
RC182	B	C	B	B
RC142	B	B	B	B



Rapid Creek weir downstream of freshwater reach

4. Darwin Harbour water quality sites and sampling method

Darwin Harbour water quality data were collected from water samples and analysed in the laboratory, and by field measurements for the period of May 1, 2016 to October 30, 2016. Broad scale, ambient water quality monitoring was undertaken by the Aquatic Health Unit of the Department of Environment and Natural Resources. Data collection is for dry season, and transition seasons due to the often unsafe and difficult sea conditions present during the wet season. Furthermore, standardising for dry season sampling presents the most stable water quality conditions mitigating the significant variation associated with seasonal and tidal influence. These conditions also permit the detection of change in the waterways examined.

At each site, surface water (approximately 0.25 m depth) was measured for pH, dissolved oxygen (% saturation), salinity and temperature using a multi-parameter probe with a flow-cell for continuous measures. Turbidity was measured with a turbidity meter. Total Suspended Solids (TSS) was not used as an indicator of water clarity this reporting year with turbidity adopted as the key water clarity indicator. More detail on the current approach for turbidity as a measure of water clarity is explained in section 4.1 and 4.2.

Water samples were collected from the surface in plastic bottles then stored on ice in the field for the laboratory analysis of nutrients (nitrogen oxides (nitrate and nitrite), ammonia, filterable reactive phosphorus) and chlorophyll-a.

The number of sampled sites and number of samples is summarised in Table 4, and site location shown in Figure 2.

Table 4 - Sites and sample number for each reporting zone.

Indicators	Elizabeth River	Myrmidon Creek	Blackmore River	West Arm	East Arm	Middle Harbour	Outer Harbour	Shoal Bay	Buffalo Creek
Number of sites	9	3	17	8	10	7	10	7	4
Number of samples	18	6	34	16	20	14	20	14	8

Over 60 discrete sampling sites were monitored to inform the Report Card and over 3000 physico-chemical measures taken via the flow cell monitoring method (FCM). Water is continuously pumped over several water quality sensors (pH, salinity, dissolved oxygen, temperature, conductivity, turbidity and chlorophyll-a) within a flow-cell as the vessel moves along the waterway. Water quality is measured and GPS coordinates collected at 1 second intervals. This method allows thousands of surface water quality data points to be continuously collected across each reporting zone. These monitoring locations represent major estuarine categories such as outer marine, mid estuary and upper estuary sections which include the many mangrove lined tidal creeks.



Figure 2 - Monitoring locations in Darwin Harbour.

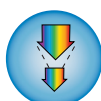
4.1. Water quality parameters

The following water quality parameters were monitored to assess water quality in the Darwin Harbour region.



Dissolved oxygen.

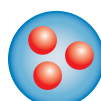
Water contains small amounts of oxygen which is needed by animals. Storm water and industrial waste can lower the amount of the oxygen in the water to levels that could be harmful to aquatic animals. Chemical reactions and microbial activity that determine the amount and type of nutrients in the harbour are affected by low oxygen (hypoxia). Dissolved oxygen (DO) is measured as a concentration (mg/L). Oxygen saturation is the amount of oxygen compared to the amount water naturally holds when in equilibrium with the air (assuming no biological processes), expressed as percentage and varying with temperature and salinity. The amount of oxygen at 100% saturation decreases with temperature. The lower holding capacity of warm waters, as well as the higher microbial activity of warm temperatures that use oxygen, makes Darwin Harbour's waters vulnerable to low dissolved oxygen.



Water clarity.

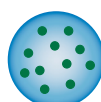
Clear water allows sunlight to reach plants to grow, such as seagrass and algae (macroscopic and microscopic) that live on the seabed. Water clarity is affected by the tides, being clearest during neap tides and during the turn of the tides. Water clarity can also be affected by storm water, dredging activity and large amounts of algae.

To assess the water clarity, turbidity (NTU) has been used rather than Total Suspended Solids (TSS). A standardised neap tide interim guideline value derived for Darwin Harbour has been used as a benchmark (Cassilles-Southgate, 2016). The value of 4 NTU has been applied where monitoring data has been standardised for neap conditions.



Nutrients.

Nitrogen and phosphorus are plant nutrients. Pollution by nutrients can produce too much algae, and affect the ecosystem. The nutrients measured were nitrogen oxides (NO_x - nitrate and nitrite), ammonia and filterable reactive phosphorus (FRP). Monitoring data collected this year included NO_x, ammonia and FRP as the most relevant nutrient suite for water quality grading and also represents the most bioavailable fraction.



Algae.

Algae are aquatic plants. Microscopic algae can gather together in colonies to be visible to the naked eye in either the water or on the sediments and other seabed substrates. Algae are a natural part of the ecosystem and provide food for large (e.g. mangrove snails) and small animals (zooplankton). However, when waters become polluted with nutrients, the amount of algae can be excessive and can adversely affect the marine ecosystem. The types of algae will also be affected by pollution. Sometimes though, large amounts of algae can occur naturally, such as the *Trichodesmium* blooms that occur during the "build-up" months.

To assess the quantity of algae, we measure chlorophyll-a (Chl a), a green pigment of aquatic plants, used in the process of photosynthesis.

4.2 Water Quality Objectives and grade method

The Water Quality Objectives for Darwin Harbour recommend the water quality that supports the maintenance of the ecosystem, and are designated under Part 7 of the N.T. Water Act as a local guideline level in accordance with the National Water Quality Management Strategy and ANZECC guidelines (Fortune, 2010).

Water quality data for each Harbour reporting zone were compared with WQOs as benchmarks to evaluate water quality condition.

The Report Card grades were assessed with respect to the WQOs for Darwin Harbour. The median was calculated for each Report Card water quality parameter, and compared against the WQOs shown in Table 5. If the median was less than the WQO, then the data complied with the WQO, and was assigned a green tick in the Report Card. However, if the median exceeded the WQO, then this was considered to be a departure, and may warrant investigation as to the cause of the exceedence. An exceedence can be caused by the natural variability of water quality and be unrelated to pollution. The Report Card marks this as a fail, symbolised by a red cross.

For the parameter of dissolved oxygen significant natural variation persists in Darwin Harbour in conjunction with both tidal and diurnal variation. Where data were observed not to meet the lower limit this was deemed a failure. Minor deviations from the upper threshold for dissolved oxygen (DO) objectives were observed in the outer harbour and Myrmidon Creek reporting zone in 2016. These values highlight the variability of water quality and the need to revise water quality objectives in the context of significant tidal, seasonal and temporal variation. For the outer harbour and Myrmidon Creek zones expert opinion deemed that these DO deviations from guidelines did not reflect any anthropogenic impact nor degradation in water quality and passed the WQO.

Turbidity was used to assess water clarity rather than TSS. Turbidity is a responsive measure of water clarity efficiently measured in the field. A general threshold of 4 NTU was adopted for the report cards in 2015 and is used for this reporting year. This value was derived from a recent evaluation of turbidity data to determine a relevant neap dry season benchmark. Minor deviations were observed for Myrmidon Creek and expert opinion deemed that this did not reflect any anthropogenic impact nor degradation in water quality and passed the water clarity parameter.

Only the filterable fractions of nutrients (NO_x-N, Ammonia (NH₃-N) and FRP) were assessed against the relevant guideline values for the harbour grades because total nutrient concentrations are affected by suspended solids. For a site to pass the nutrient parameter, all indicators must agree with the guideline value.

Table 5 – Darwin Harbour Water Quality Objectives.

Indicators		Upper Estuary	Mid Estuary	Outer Estuary
Dissolved Oxygen	Dissolved oxygen (% saturation)	80-100	80-100	80-100
Water clarity	Suspended solids (mg/L) or	<10	<10	<10
	Turbidity (NTU)	<4	<4	<4
Algae	Chlorophyll-a (µg/L)	<4	<2	<1
	NO _x -N (µg/L)	<20	<20	<10
Nutrients	Ammonia as N (µg/L)	<20	<20	<20
	Filterable Reactive Phosphorus (µg/L)	<10	<5	<10

4.3 Water quality grades

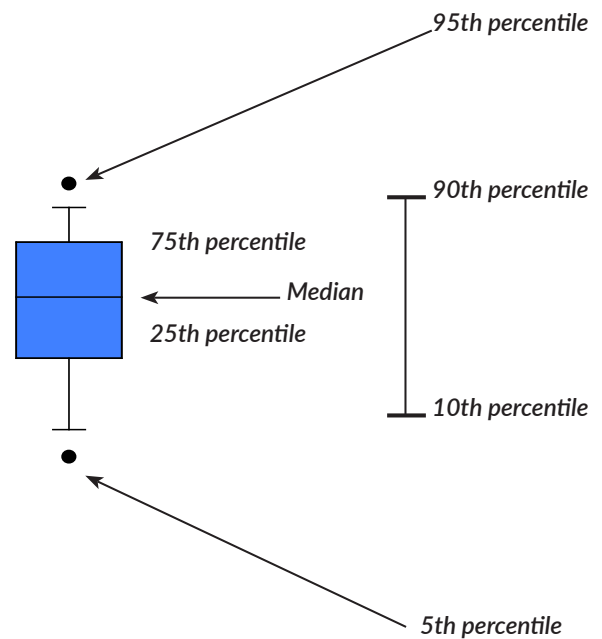
The water quality grades, from A to E, have been assigned for each area depending on agreement with local WQOs (see Table 5).

WATER QUALITY GRADES

- A** Excellent water quality. All four water quality indicators meet desired levels.
- B** Very good water quality. Three water quality indicators meet desired levels.
- C** Good water quality. Two water quality indicators meet desired levels.
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- E** Very poor water quality. No water quality indicators meet desired levels.

Box and Whisker Plots

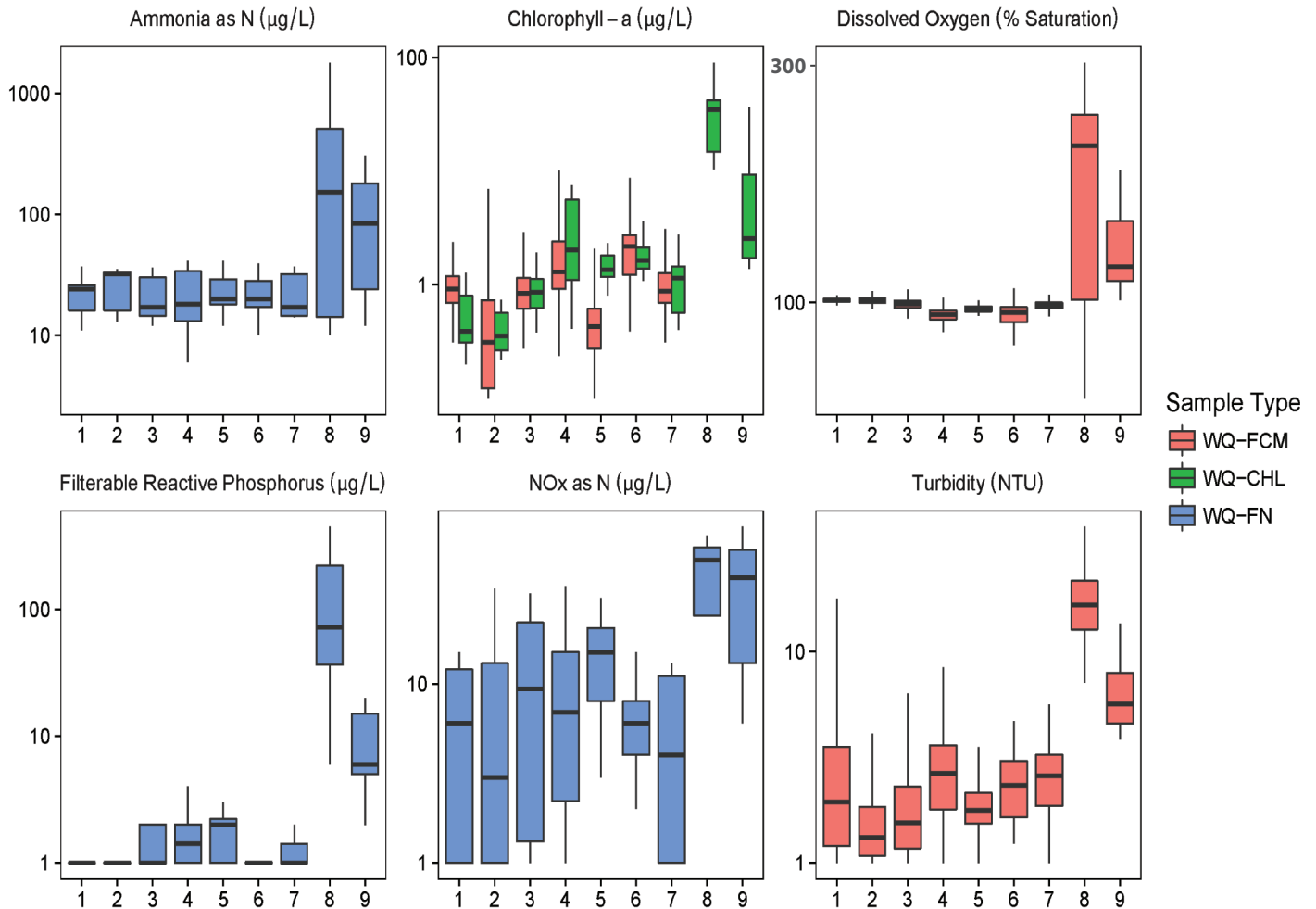
The primary purpose of box and whisker plots in this report is to provide a comparison of results between reporting zones and indicator values. Measures such as medians and percentiles provide details on the variability of data and the presence of unusually high or low values. Outliers are also represented as dots beyond the 5th and 95th percentiles for reporting zones where applicable (Fig. 4 - 12). Plots are presented for all data combined within each reporting zone.



5. Results

5.1 Darwin Harbour region

Figure 3 summarises the results of each water quality parameter monitored in the Darwin Harbour region for the period 1 May 2016 to 30th October 2016.



1- Outer Harbour, 2 - Shoal Bay, 3 - Middle Harbour, 4 - Blackmore River, 5 - East Arm, 6 - Elizabeth River, 7 - West Arm, 8 - Buffalo Creek, 9 - Myrmidon Creek.

Figure 3. Report Card water quality parameters measured in the Darwin Harbour region (Box plots show 10th, 25th, Median, 75th, and 90th percentiles). Data is shown for discrete (Filtered Nutrients -FN, Chlorophyll-a - CHL) and flow-cell monitoring (FCM).

For chlorophyll-a, nitrogen oxides, ammonia and filterable reactive phosphorus data is presented on a log scale. This was necessary to make results clear on the box plots, due to the wide variability of results between reporting zones and sites.

5.2 Outer Harbour reporting zone

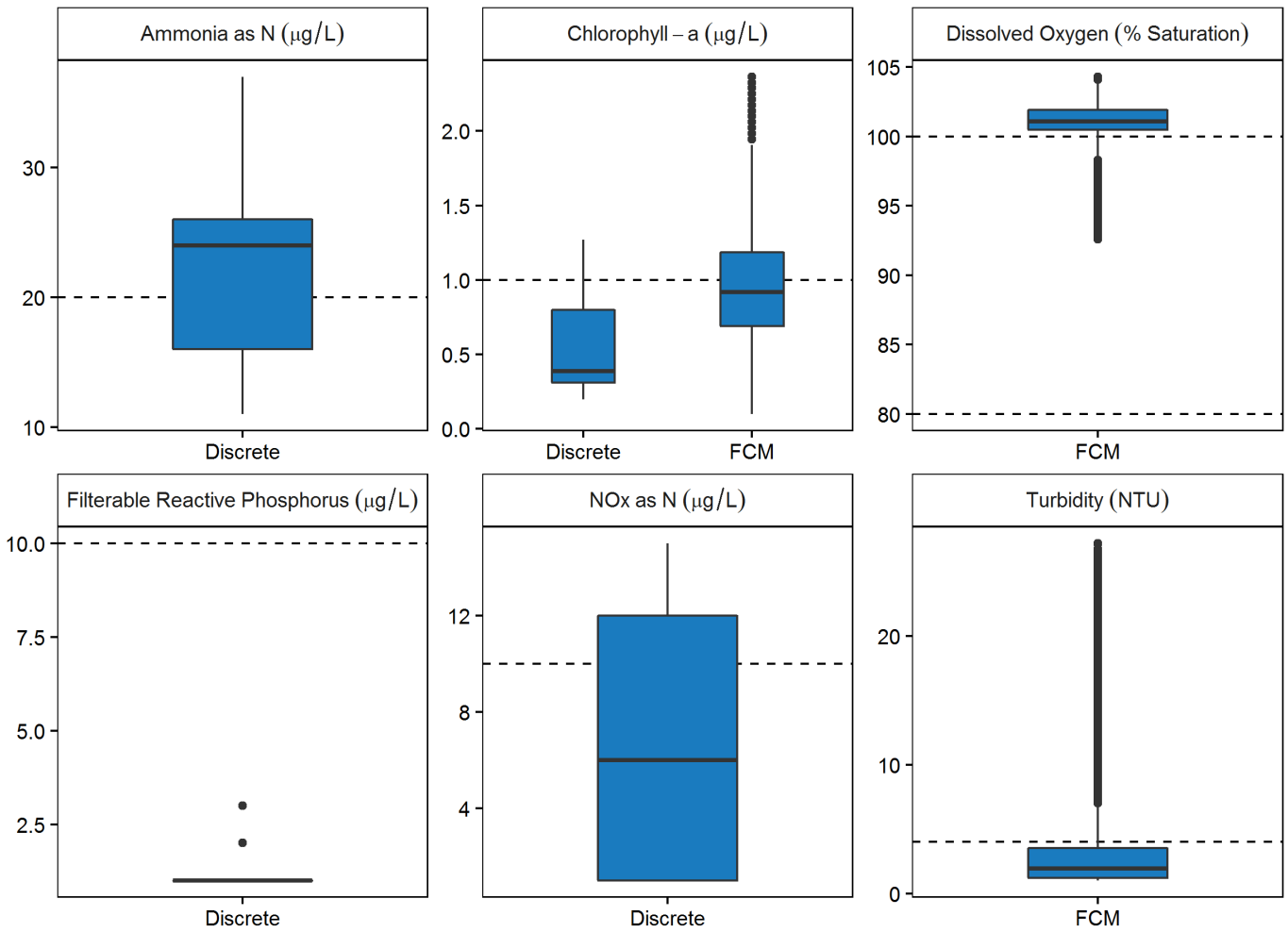


Figure 4. Water quality indicators measured in the Outer Harbour reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

5.3 Shoal Bay reporting zone

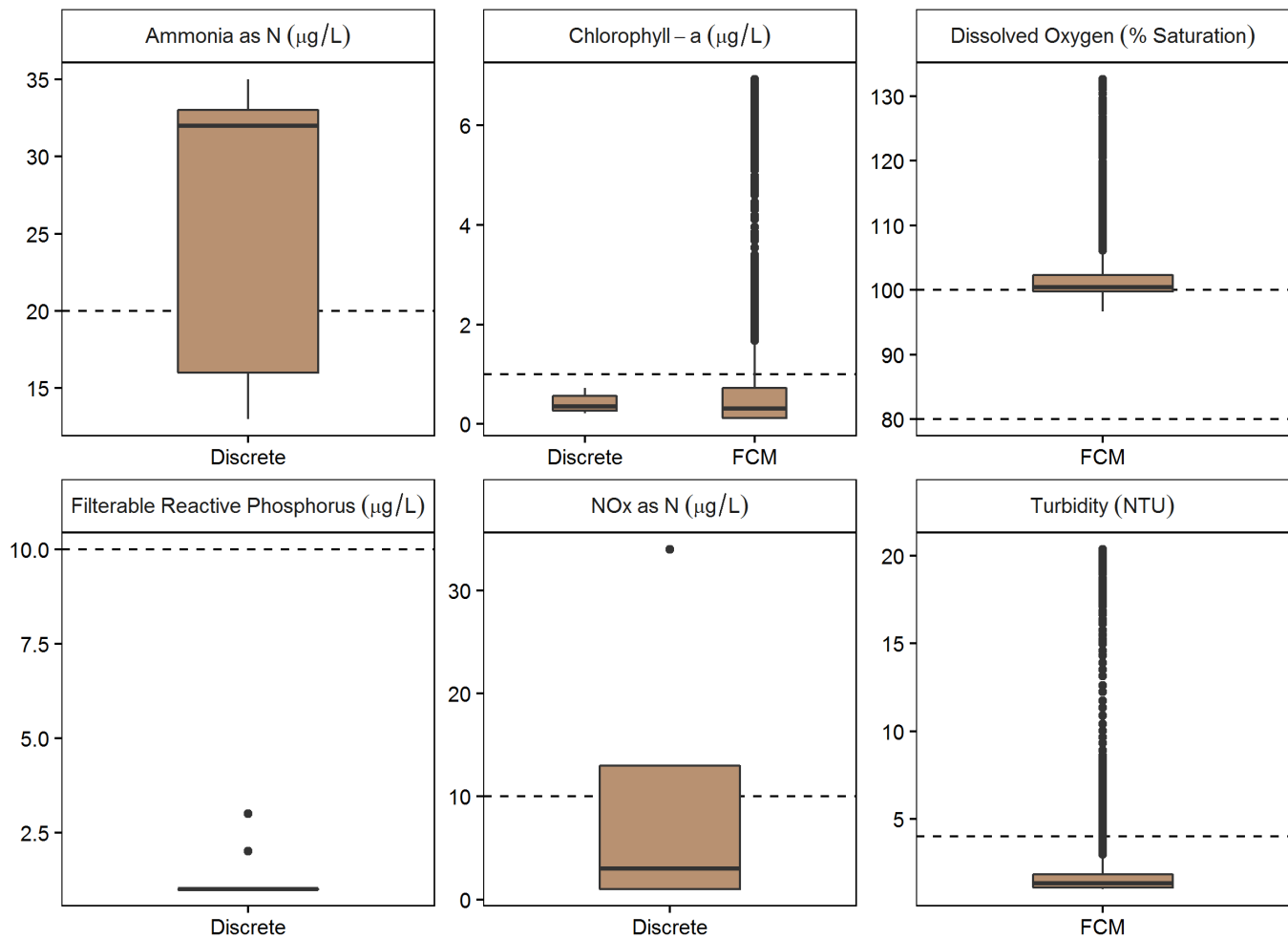


Figure 5. Water quality indicators measured in the Shoal Bay reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

5.4 Middle Harbour reporting zone

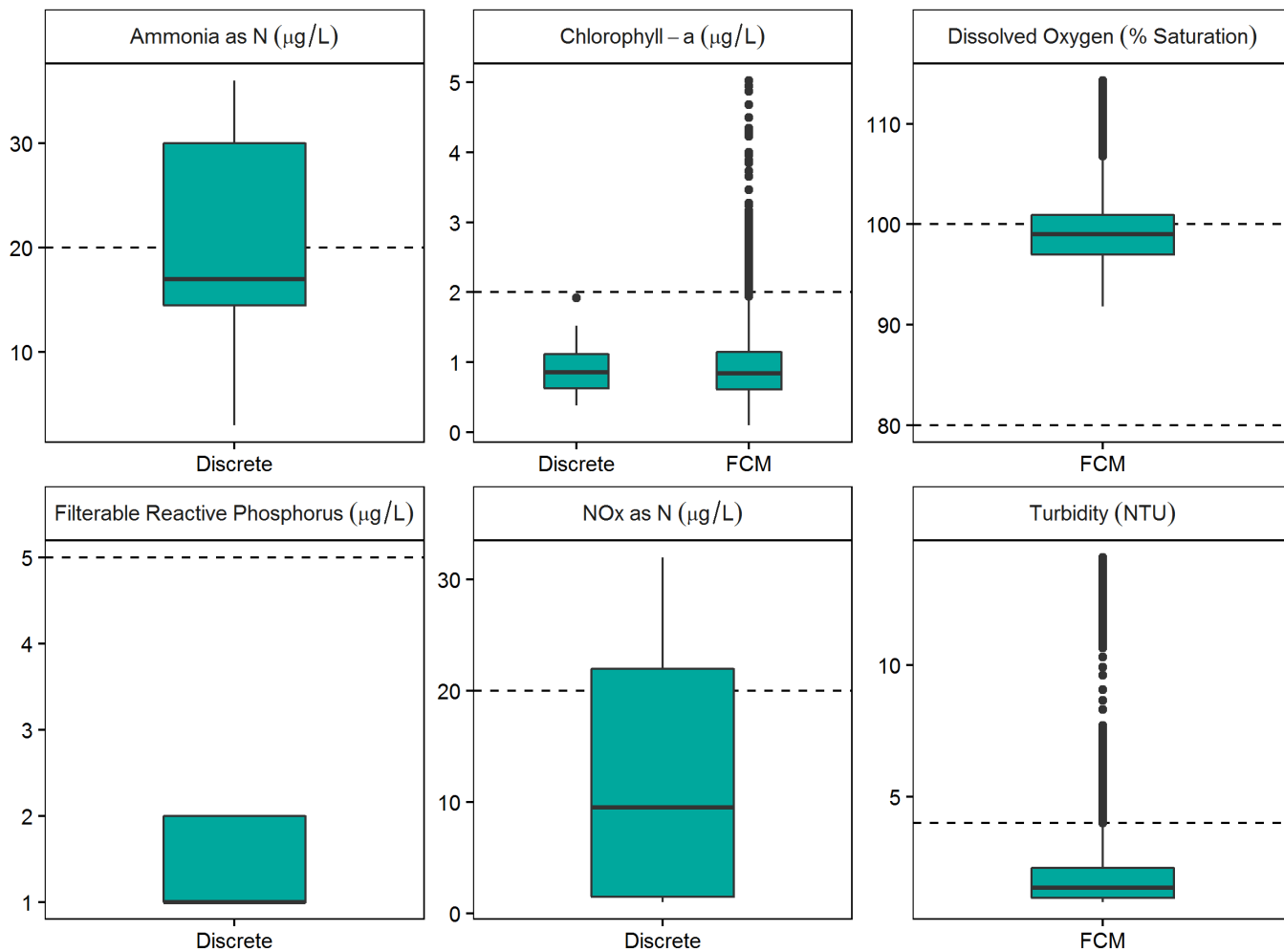


Figure 6. Water quality indicators measured in the Middle Harbour reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

5.5 Blackmore River reporting zone

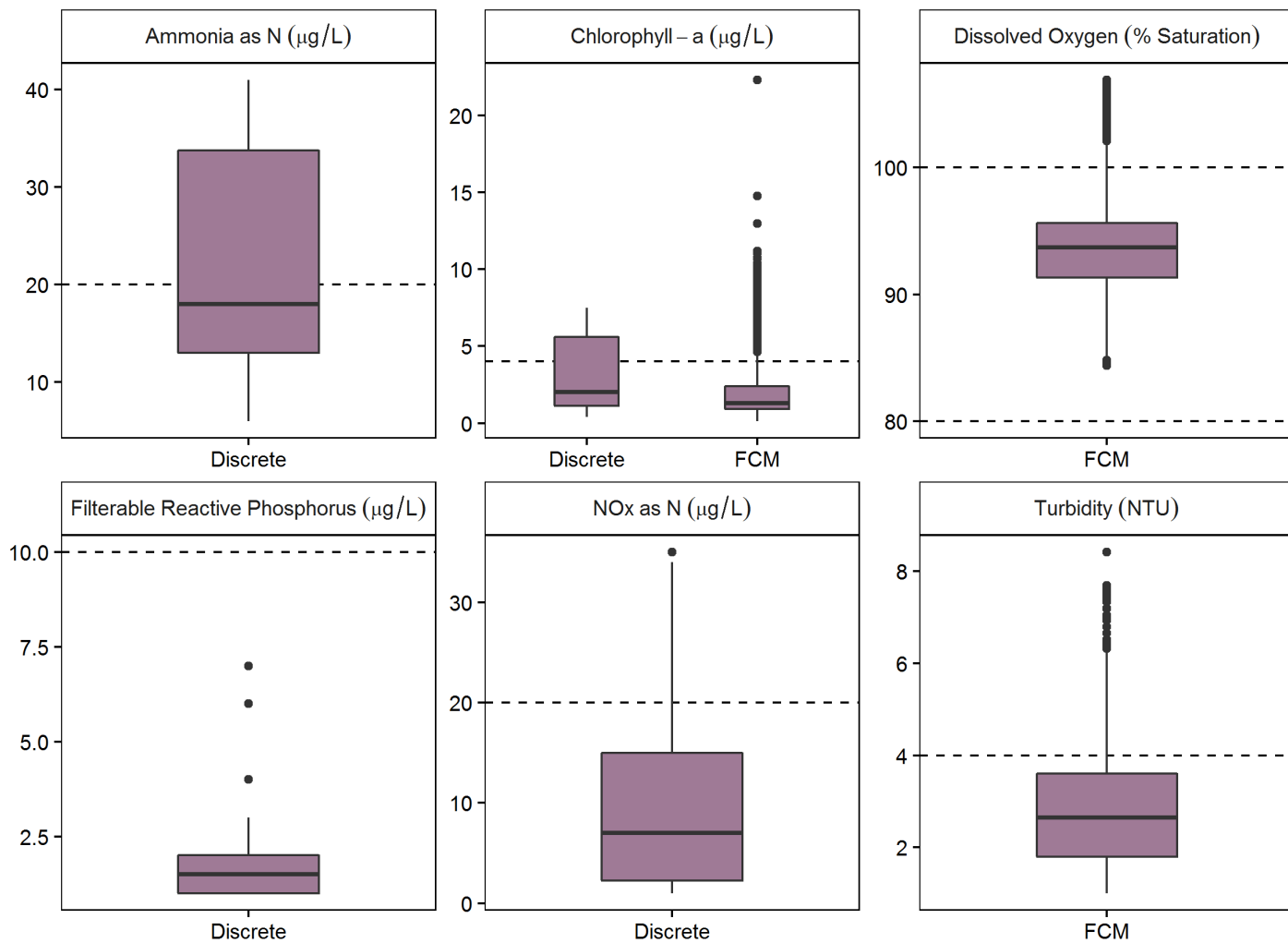


Figure 7. Water quality indicators measured in the Blackmore River reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

5.6 East Arm reporting zone

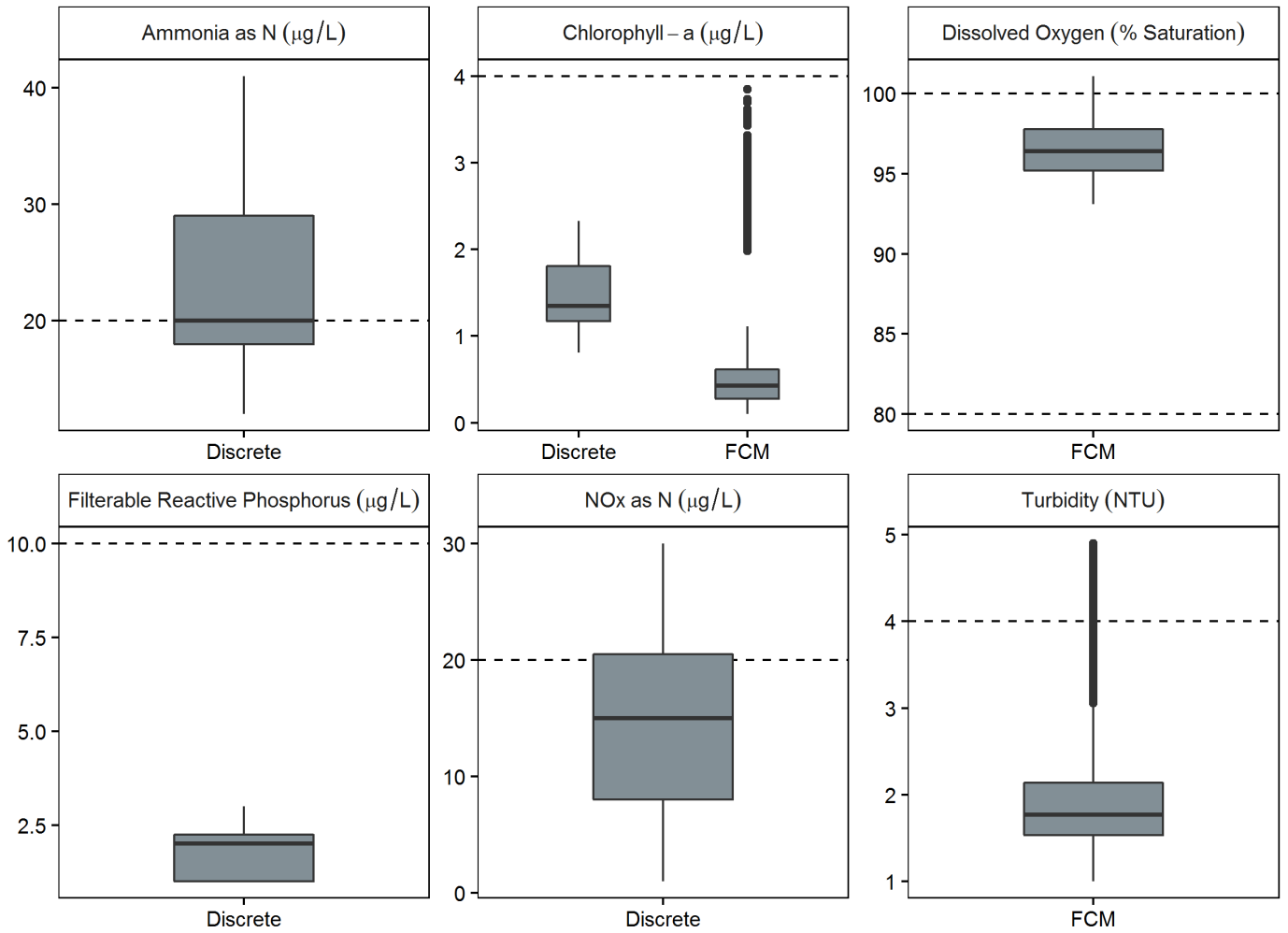


Figure 8. Water quality indicators measured in the East Arm reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

5.7 Elizabeth River reporting zone

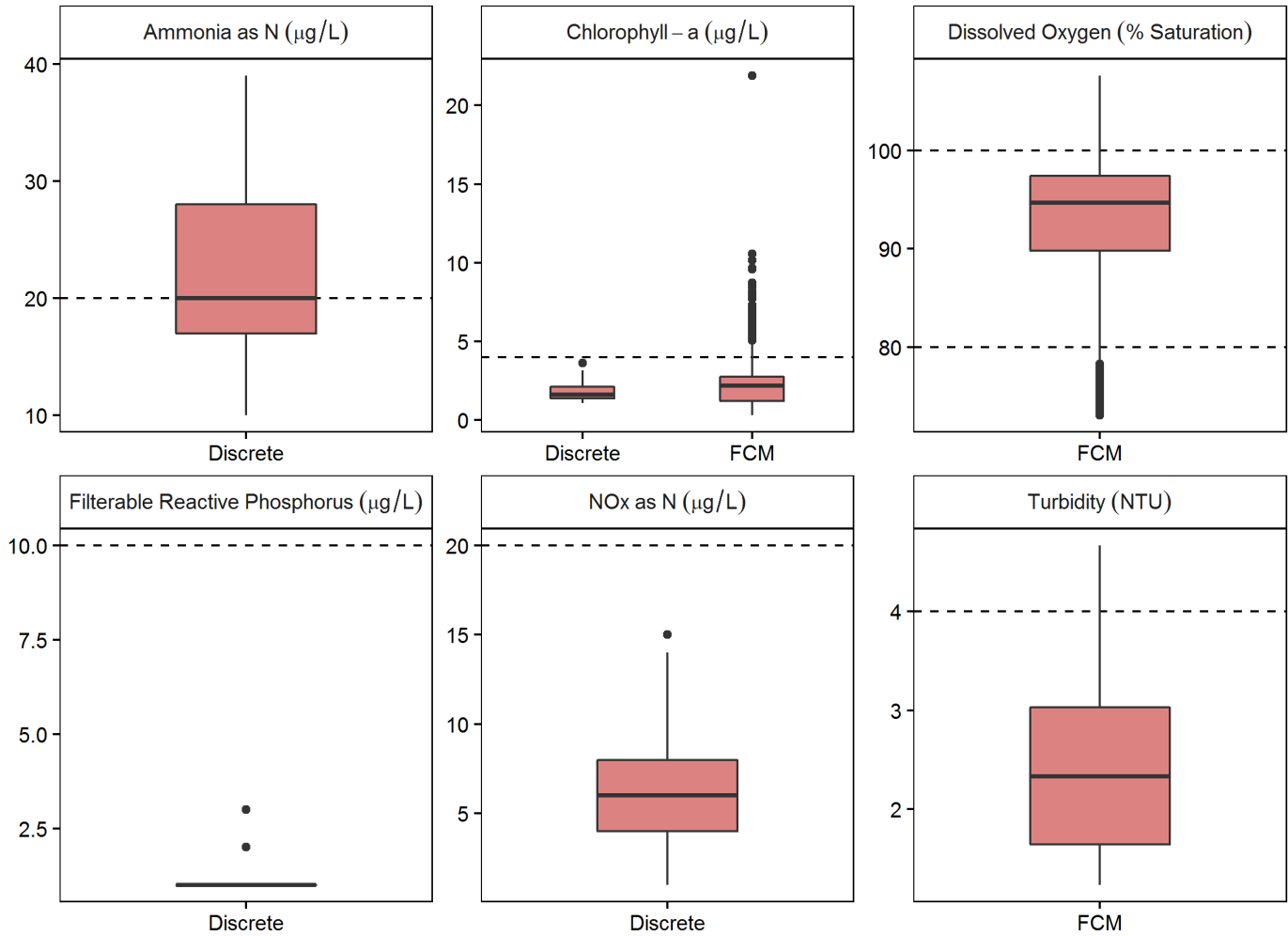


Figure 9. Water quality indicators measured in the Elizabeth River reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

5.8 West Arm reporting zone

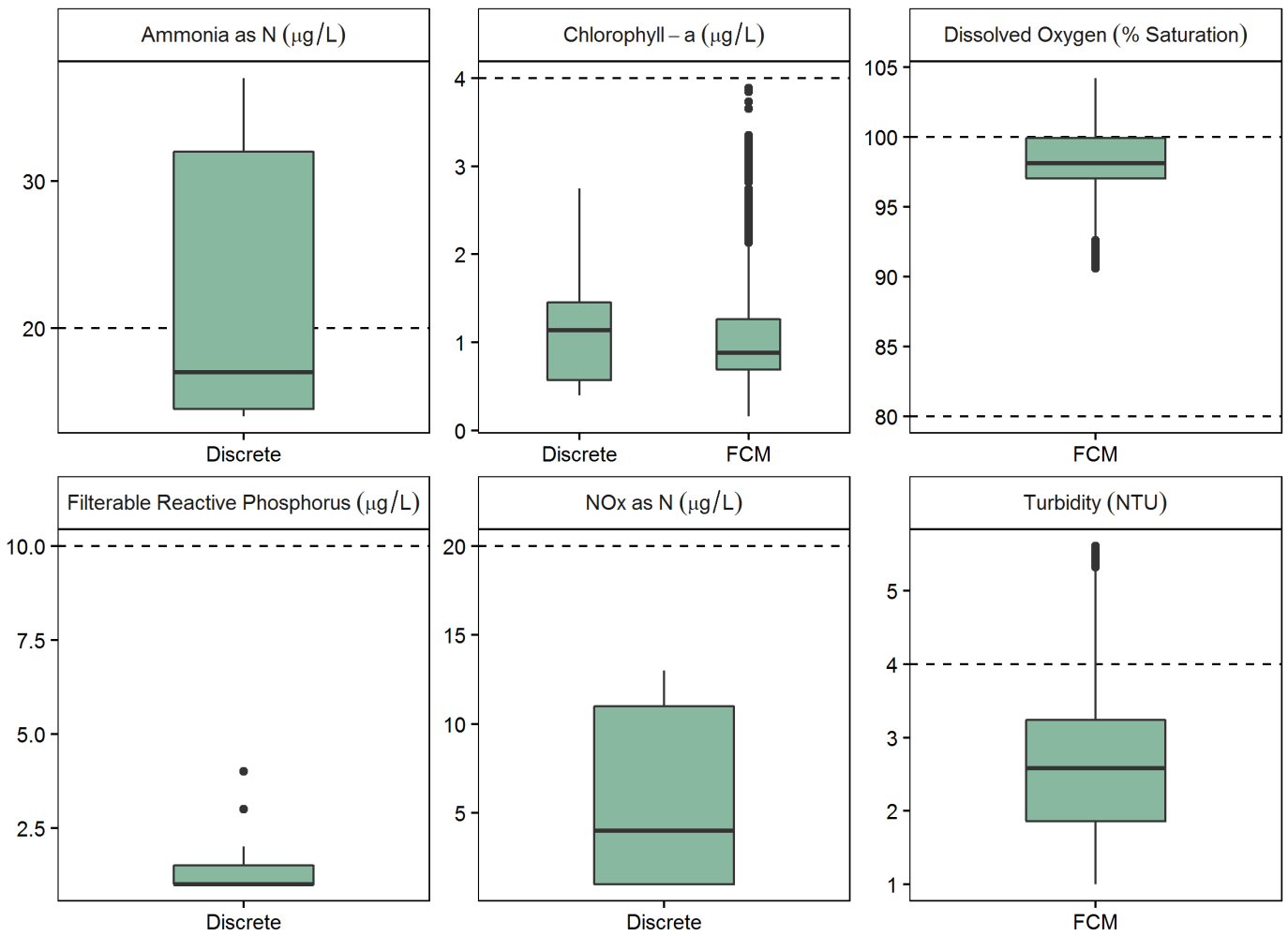


Figure 10. Water quality indicators measured in the West Arm/Wood Inlet reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

5.9 Buffalo Creek reporting zone

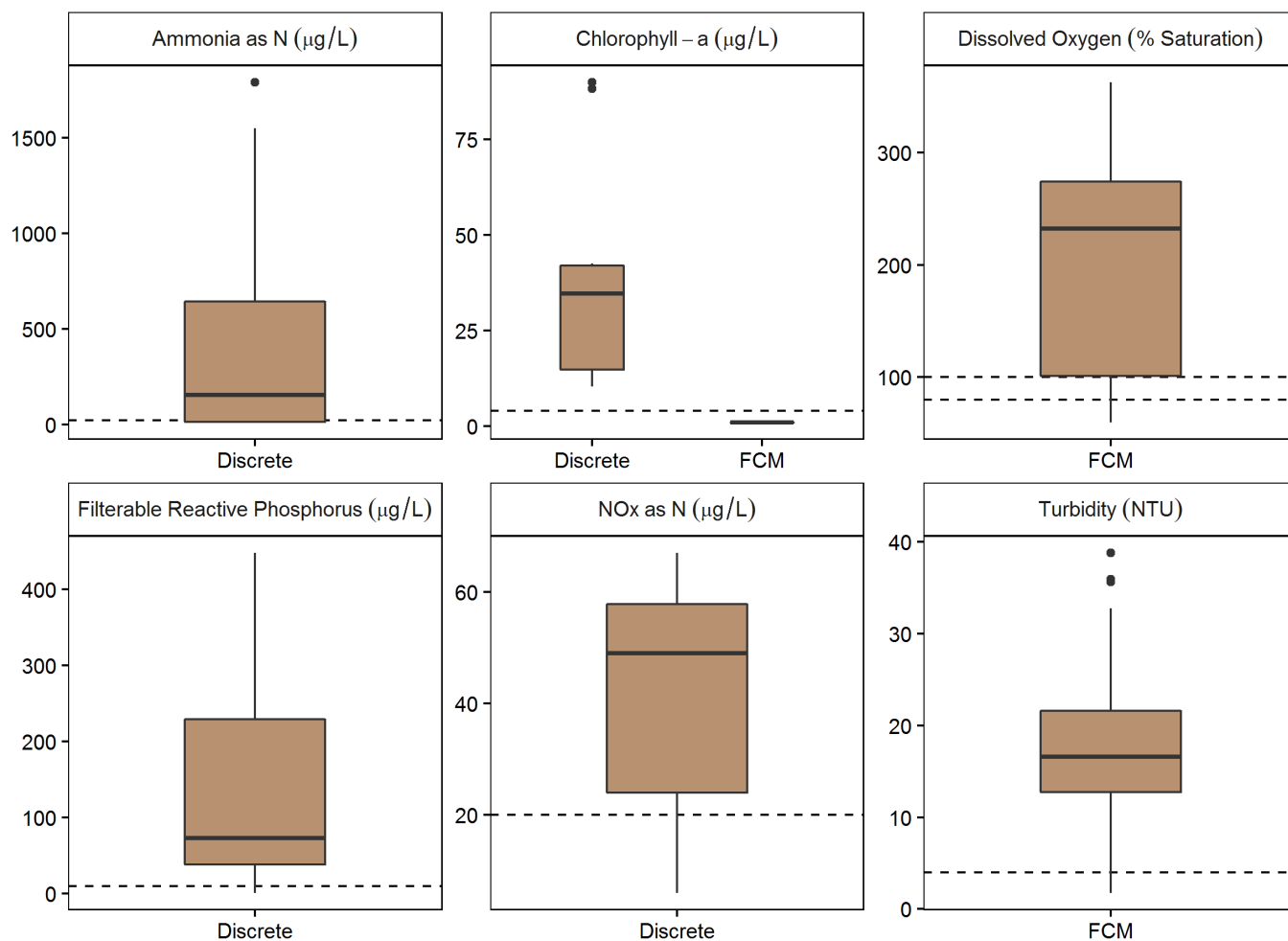


Figure 11. Water quality indicators measured in the Buffalo Creek reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

5.10 Myrmidon Creek reporting zone

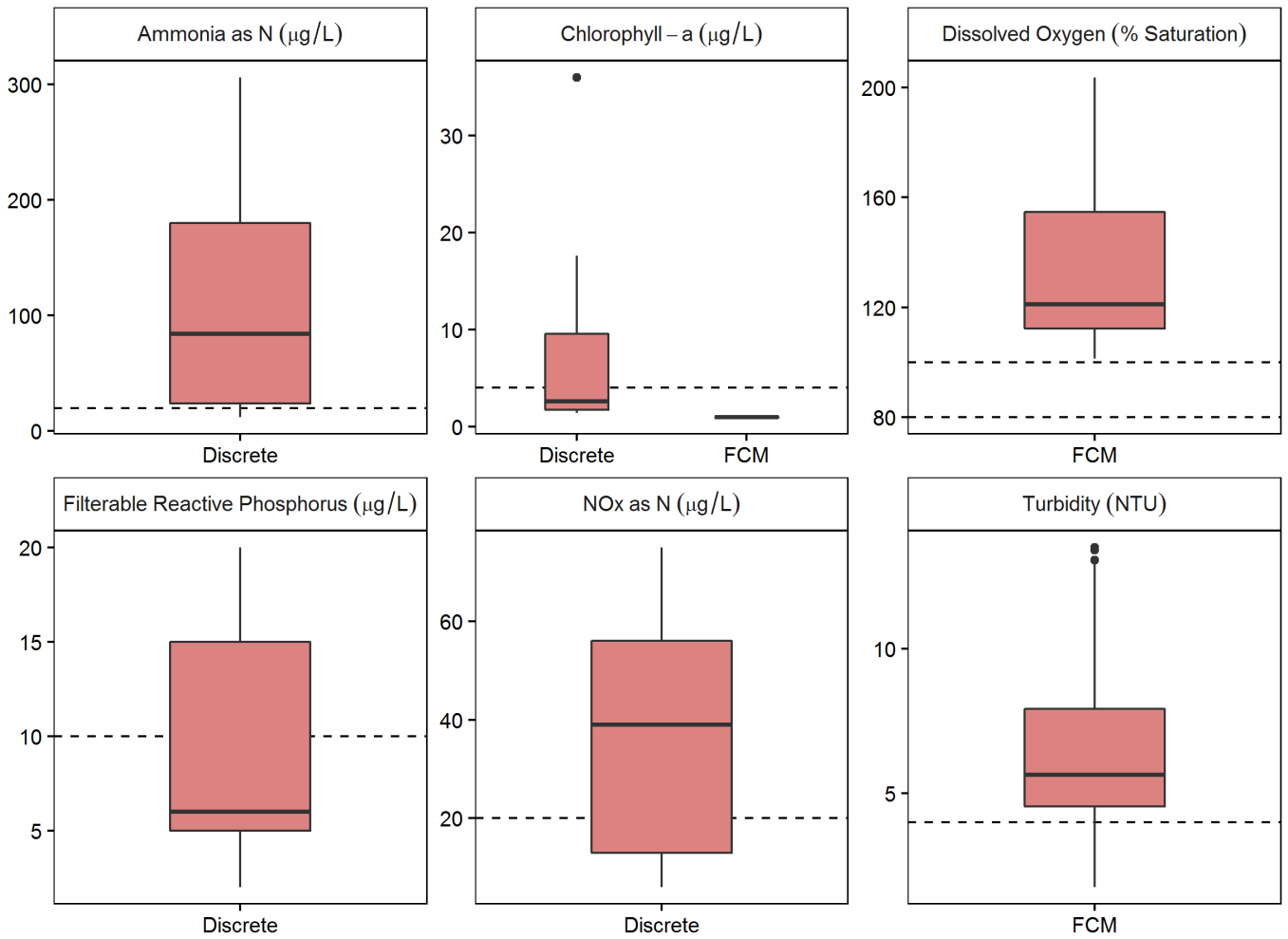


Figure 12. Water quality indicators measured in the Myrmidon Creek reporting zone. Box plots show 5th, 10th, 25th, Median, 75th, 90th, and 95th percentiles. The dashed line represents the water quality objective.

Cassilles-Southgate, N. (2016). Interim Darwin Harbour Turbidity Water Quality Objectives for Neap Tide Conditions. Report Number 14/2016D. Aquatic Health Unit, Water Resources Division. Department of Land Resource Management. NT.

Fortune , J. (2010). Water Quality Objectives for the Darwin Harbour Region - Background Document. Department of Natural Resources, Environment, The Arts and Sport, Palmerston NT.

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