Northern Territory Government

SUPPLEMENT TO THE 2014 DARWIN HARBOUR REGION REPORT CARD

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Report 01/2015D

Supplement to the 2014 Darwin Harbour Region Report Card.

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Cover: Aquatic Health Unit (DLRM) technician water sampling, Marine Ecosystems (DLRM) technician retrieving BRUVS unit, PowerWater staff in lab and CDU researcher Dr Niels Munksgaard sampling sediments in Rapid Creek.

Acknowledgements

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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.

REPORTING ZONES

Middle Darwin Harbour

East Arm

Elizabeth Upper & Myrmidon Creek

Blackmore River

Shoal Bay & Buffalo Creek

Outer Harbour

West Arm

Table of Contents

1. Introduction

Water quality monitoring has been undertaken in Darwin Harbour by the Department of Land Resource Management (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 2009. The 2014 grades are shown in Figure 1, and presented with the grades for previous years in Table 1.

This report supplements the 2014 Darwin Harbour Region Report Card by presenting supporting data and other information used to calculate the grades, as well as providing a more detailed analysis of Darwin Harbour water quality.

The 2014 grades indicate that water quality was 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. However although poor, the 2014 reporting year indicates a minor improvement to water quality in Buffalo Creek with improved conditions for the parameter of dissolved oxygen. Low over-night concentrations however probably occur. Myrmidon Creek, which receives effluent from the Palmerston wastewater treatment plant, has good water quality.

The Shoal Bay and Myrmidon Creek had large variation in dissolved oxygen at times higher than
water quality objectives or quite low, particularly in Myrmidon Creek within the influence of the
licensed discharge. These oxygen levels however were not harmful and were not persistent. Their exceedence indicates the WQO needs to be revised to better take into account natural water quality variability, particularly in the case of Shoal Bay where no point sources influence water quality.

2. Darwin Harbour region

The Darwin Harbour region is located in the wet-dry tropics of northern Australia and extends from Gunn Point in the east, to Charles Point in the west. The climate consists of two seasons: the wet and the dry. The wet season occurs between November and April and is characterised by heavy cloud cover, rain and humidity. The dry season occurs from May to October and is characterised by cooler temperatures, south east winds and little or no rain.

The region has a population of over 130,000 people (ABS 2013) 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 characterised by strong tidal currents which result in extensive turbid plumes on outgoing tides.

Figure 1 – Reporting zone grades for Darwin Harbour region 2014.

Table 1 - Summary of water quality parameters and grades of the Darwin Harbour region

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	✔	✖[1]	✔	✔	✔	✔	✔	✔[3]	✔
Algae	✔	✔	✔	✔	✔	✔	✔	✖	✔
Nutrients	✖[2]	✔	✔	✔	✖	✔	✔	✖	✖[4]
	Report Card grades								
2014	B	B	A	A	B	A	A	D	C
2013	B	B	B	A	B	A	A	E	C
2012	B	B	A	A	A	A	A	E	C
2011	A	C	A	C	A	A	A	E	-
2010	A	C	B	B	A	A	A	E	C

Rating table notes:

1. Shoal Bay had dissolved oxygen levels slightly above the desired range, however these are not considered harmful.

2. Total Nitrogen was higher than the Water Quality Objective. Locally high nutrient levels do occur in the vicinity of East Point due to discharge from the Ludmilla Wastewater Treatment Plant but do not cause higher amounts of algal biomass in the water.

3. Buffalo Creek receives wastewater from the Leanyer-Sanderson Wastewater Treatment Plant and stormwater during the wet season. The improved Buffalo Creek dissolved oxygen levels are due to better day-time levels. Low night-time levels still occur.

4. Myrmidon Creek receives wastewater from the Palmerston Wastewater Treatment Plant. No grade was calculated in 2011.

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, while simple communities of few water-bug types indicate a damaged or degraded stream. Regular 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 steams; 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.

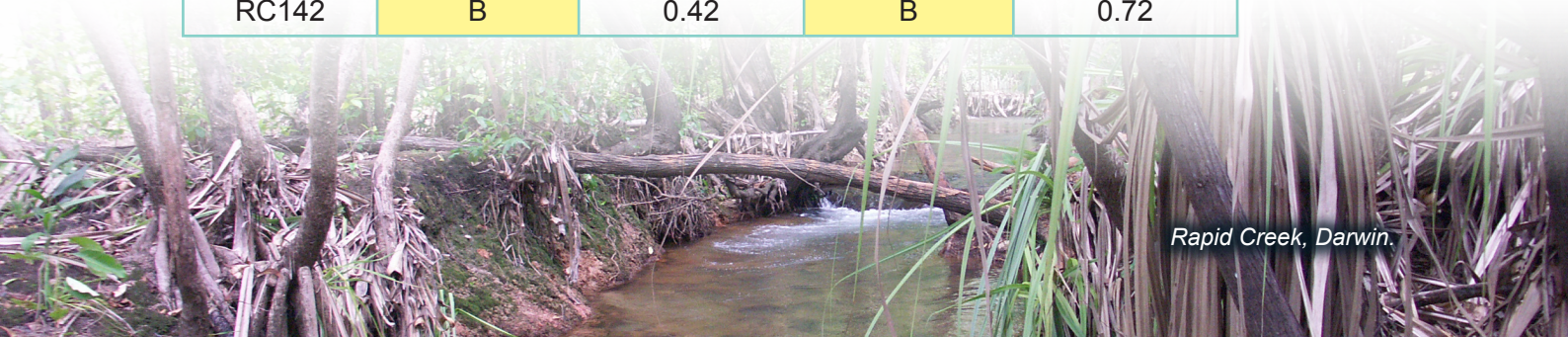
Band	Description	What it represents
X	More biologically diverse than reference	More types found than expected. Potential biodiversity “hot-spot” or mild organic enrichment.
A	Similar to reference	O/E scores range found at 80% of the reference sites, or equivalent to reference condition.
B	Significantly 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 2014

Two macroinvertebrate sites were sampled in the 2014 reporting year. These sites are in the upper reaches of the Rapid Creek system which is a small seasonally flowing coastal 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 2014.

Site number	2013	O/E Score	2014	O/E Score
RC182	B	0.61	C	0.43
RC142	B	0.42	B	0.72



Rapid Creek, Darwin.

4. 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 July 2013 to September 2014. Broad scale, ambient water quality monitoring was undertaken by the Aquatic Health Unit of the Department of Land Resource Management, whilst more spatially targeted monitoring was undertaken by the PowerWater Corporation as part of its wastewater discharge license. Water quality monitoring in the vicinity of the upper reaches of the Blackmore River was undertaken by the Department of Primary Industry and Fisheries for the aquaculture industry. The sites monitored by these organisations in 2014 were similar to those monitored in 2013. Data collection is biased towards the dry season, due to the often unsafe and difficult sea conditions present during the wet season.

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. Turbidity was measured with a turbidity meter. Total Suspended Solids (TSS) was derived from the relationship between Turbidity and TSS established in 2013 (Mauraud, 2013). More detail on this relationship is in Appendix 1.

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, total nitrogen, total phosphorus and 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 Upper	Myrmidon Creek	Blackmore Upper	West Arm	East Arm	Middle Harbour	Outer Harbour	Shoal Bay	Buffalo Creek
Number of sites	17	9	36	14	13	9	20	10	5
Number of samples	32	98	70	90	90	18	153	20	67

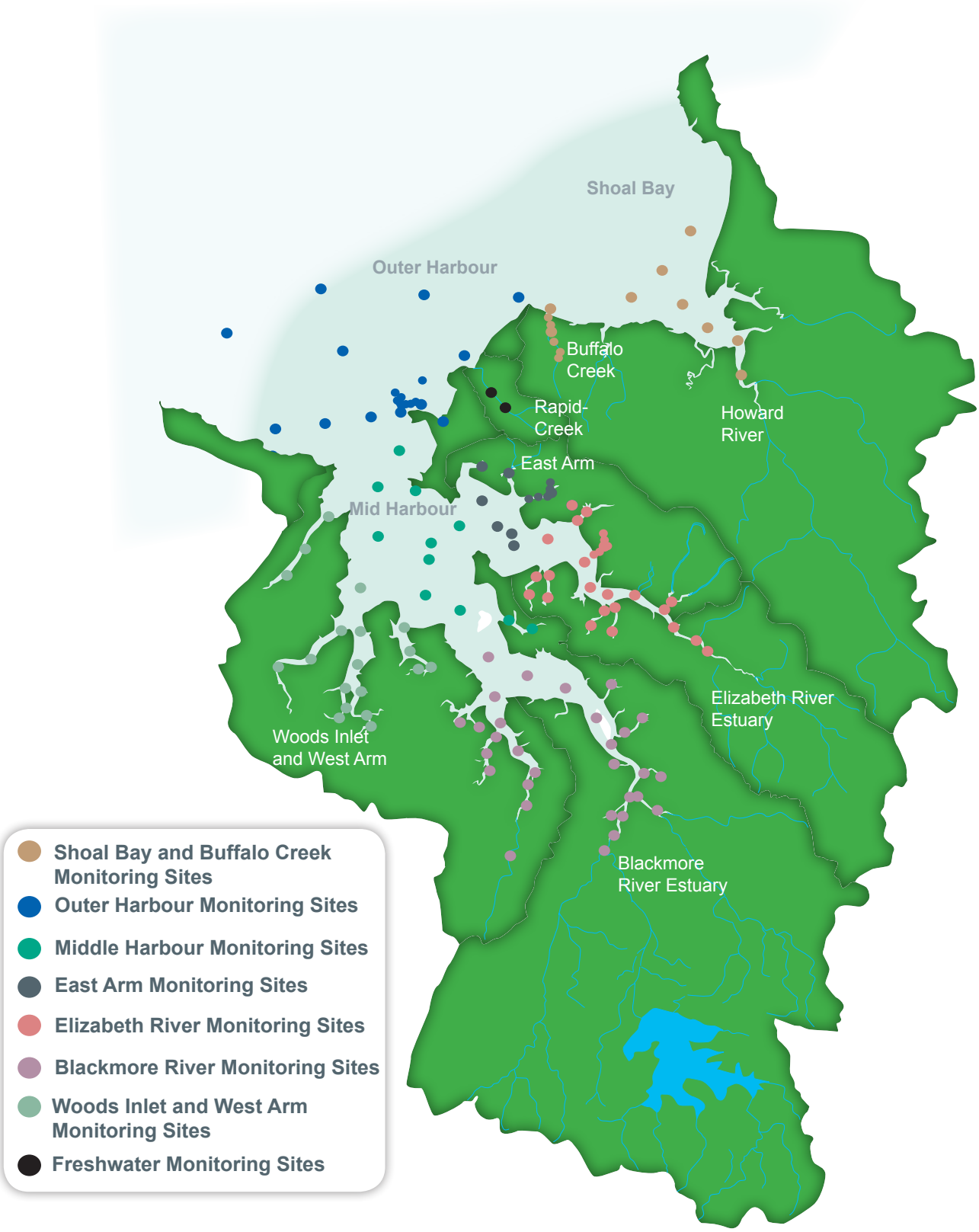


Figure 2 - Monitoring locations in Darwin Harbour.

4.1. Water quality parameters

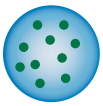
The following water quality parameters were monitored to assess water quality in the Darwin Harbour region.

4.1.2. Parameters used in the Report Card

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.

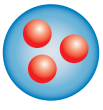
Water clarity.
Clear water allows sunlight to reach plants to grow, such as seagrass and algae (macroscopic and microscopic) that live on the seabed. Water clarity is affected by the tides, being clearest during neap tides and during the turn of the tides. Water clarity can also be affected by storm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

To assess the water clarity, total suspended solids (TSS) can be used. Also known as total suspended sediment, this is a measure of the amount of particulates in the water column. TSS concentrations were estimated from turbidity using a TSS-turbidity relationship.



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 too much 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.



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, total nitrogen (TN), total phosphorus (TP) and filterable reactive phosphorus (FRP).

4.1.3. Complementary parameters

pH.
This is a measure of the concentration of hydrogen ions [H+] and is an indicator of water alkalinity or acidity. Changes in pH affect metal solubility and toxicity, and an organism's ability to absorb minerals and nutrients, and respiratory efficiency of fish and aquatic invertebrates. Marine waters are normally alkaline.

Temperature.
The water temperature is a significant measure as it affects other parameters such as the amount of oxygen dissolved in the water, the rate of photosynthesis of plants, and growth of aquatic organisms.

Salinity.
Salinity is a measure of the total concentration of ions (mainly inorganic salts) in the water. Salinity affects aquatic organisms depending on their adaptability to a narrow or wide range of salinities. River inflows dilute marine waters to be less saline.

4.2 Water Quality Objectives

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 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 (50th percentile) 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 exceedance. An exceedance 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.

Table 5 – Darwin Harbour Water Quality Objectives

Indicators		Water Quality Objectives		
		Upper area	Middle area	Outer area
Dissolved Oxygen	**Dissolved oygen (% saturation)**	80-100	80–100	80–100
Water Clarity	**Suspended solids** (mg/L)	<10	<10	<10
Algae	**Chlorophyll *a*** (µg/L)	<4	<2	<1
Nutrients	**NO_x-N** (µg/L)	<20	<20	<10
	Ammonia as N (µg/L)	<20	<20	<20
	Total nitrogen (µg/L)	<300	<270	<440
	Total phosphorus (µg/L)	<30	<20	<20
	Filterable reactive phosphorus (µg/L)	<10	<5	<10
pH	**pH**	6.5-8.5	7.0-8.5	7.0-8.5

4.3 Water quality grades

The water quality grades, from A to E, have been assigned for each area depending on compliance 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.

D - Poor water quality. Only one water quality indicator meets desired levels.

E - Very poor water quality. No water quality indicators meet desired levels.

5. Results

5.1 Darwin Harbour region

Figures 2 and 3 summarise the results of each water quality parameter monitored in the Darwin Harbour region for the period from July 2013 to September 2014 (inclusive).

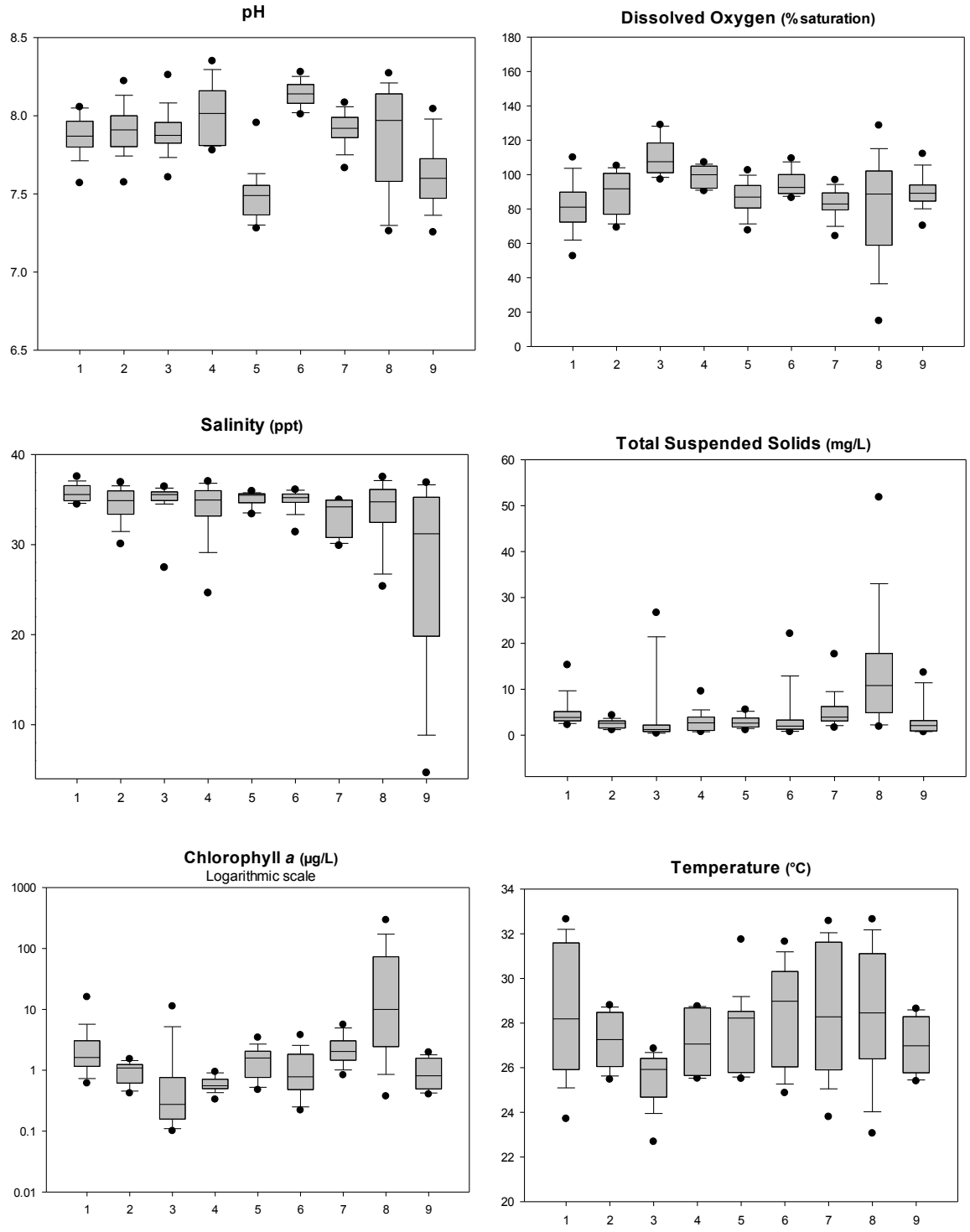


Figure 2 - Physico-chemical parameters and Algae measured in the Darwin Harbour region (Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles)

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

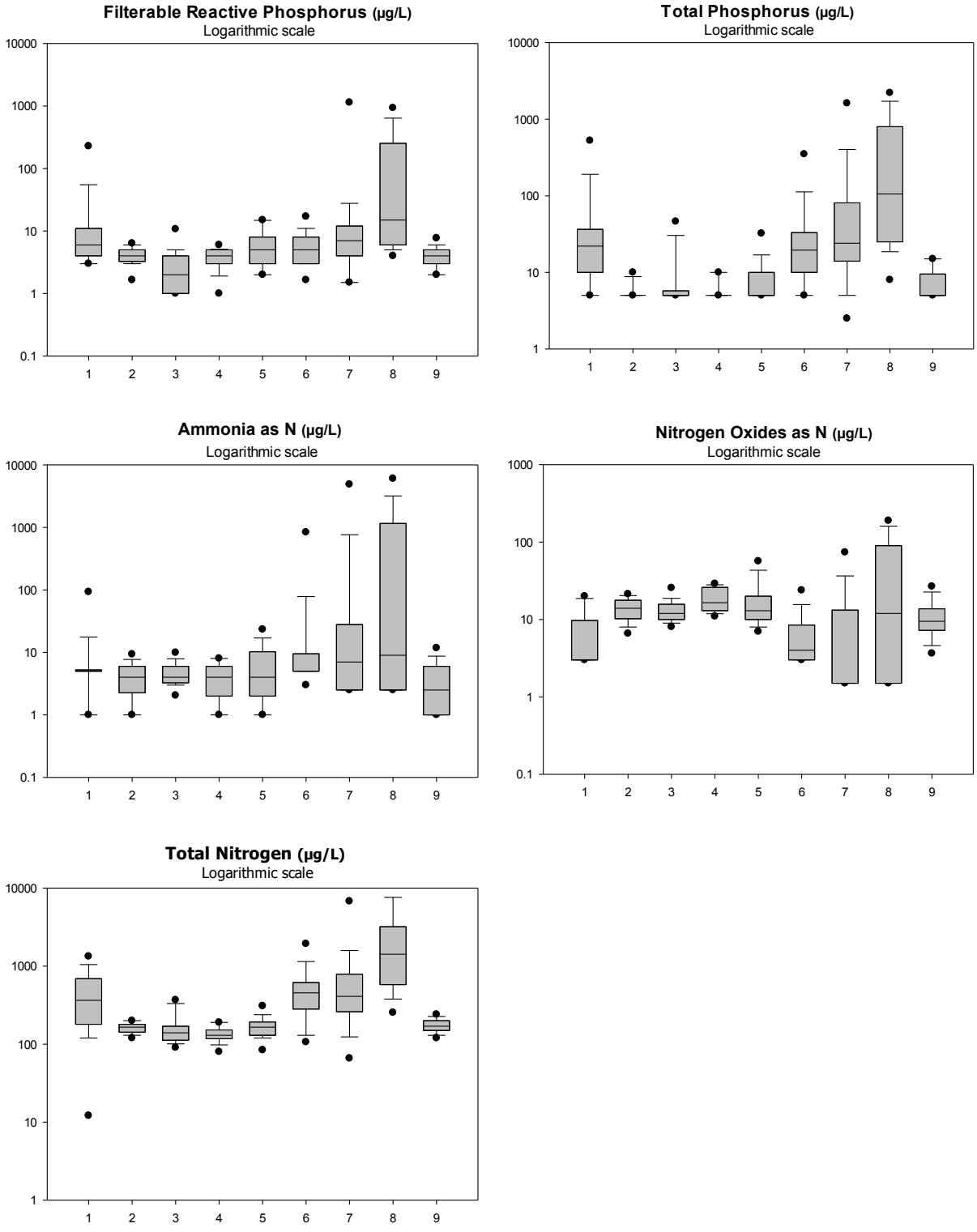


Figure 3 - Nutrients measured in the Darwin Harbour region,
(Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles)

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

5.1.1. Dissolved Oxygen saturation

Median dissolved oxygen ranged from 107% (Shoal Bay) to 88% saturation (Buffalo creek). Values for DO% were generally lower in the upper reaches of the harbour and higher in the outer zones such as the main body to outer harbour reporting zone. Results did not always comply with the WQO, for example elevated DO was observed in Shoal Bay (119%), Middle Harbour (105%) and Buffalo Creek (103%). These higher values were typically short-lived episodes usually driven by algal biomass (particularly for Buffalo Creek) and tidal slack in the upper reaches of systems examined.

5.1.2. Total Suspended Solids

Suspended solids remained low in Darwin Harbour over neap dry season conditions. Medians across all reporting zones ranged from 1.2 mg/L (Shoal Bay) through to 10.8 mg/L (Buffalo Creek). Similarly corresponding turbidity across the harbour and Shoal Bay were also low (<10 NTU) with the exception of the upper reaches of Buffalo Creek where the median value was 15.6 NTU and elevations as high as 110 NTU were recorded.

5.1.3. pH

Median pH ranged from 7.5 (Blackmore Upper) to 8.1 in the outer harbour zone. This limited range was typical of dry season conditions where negligble to no flow persists with the exception of the Blackmore River.

5.1.4. Salinity

Median salinities ranged from 32-36 ppt with lower salinities detected in the upper reaches of the Blackmore River and Buffalo Creek. The freshwater flows continue during the dry season in the Blackmore contributing to lower salinities. The Buffalo Creek system is subject to treated discharge from the Leanyer-Sanderson treatment plant.

5.1.5. Temperature

Temperature ranged from 23°C to 32°C. Systems such as Elizabeth River, Blackmore River, Middle Harbour, Shoal Bay and West Arm had a narrow temperature range. Conversely systems such as Buffalo Creek, Myrmidon Creek and East Arm revealed a wider range of water temperatures.

5.1.6. Chlorophyll *a*

Median Chlorophyll ranged from 0.2 μg/L in Shoal Bay to 10μg/L in Buffalo Creek. Extremely high concentrations were observed in Buffalo Creek particularly in upper reach sites in association with treated wastewater entering the creek. Most systems recorded very low chlorophyll-*a* values (<4 μg/L) with higher algal biomass generally observed in upper reach sites and tidal creeks.

5.1.7. Nitrogen Oxides

Median NOx values ranged between 3 μg/L (Myrmidon Creek) and 16.5 μg/L (Middle Harbour) with highly variable minimum and maxima values across reporting zones of Darwin Harbour. High nitrate values were episodically observed in Myrmidon and Buffalo Creeks. All other reporting zones had medians within water quality objectives.

5.1.8. Ammonia

Median values for ammonia ranged between 2.5 μg/L (Elizabeth River) and 9 μg/L (Buffalo Creek). Significant extremes were observed in Myrmidon Creek, Buffalo Creek and the Outer Harbour region around the East Point outfall servicing the Ludmilla treatment plant.

5.1.9. Total Nitrogen

Median total nitrogen values ranged from 130 μg/L (Middle Harbour) to 1420 μg/L (Buffalo Creek).

Although most sites in the outer harbour zone met WQO's, sites adjacent to the East Point outfall failed to meet benchmarks for total nitrogen. Results for this region of the reporting zone skewed data with the outer harbour zone not meeting WQO's for total nitrogen. Total nitrogen was typically observed to be higher in the upper reaches of main systems and within tidal creeks.

5.1.10. Total Phosphorus

Total phosphorus for all reporting zones with the exception of Buffalo Creek met WQO's with median's ranging between 5-24 μg/L. The median for Buffalo Creek was 106 μg/L. However elevated concentrations were recorded in Blessers Creek (East Arm reporting zone), Myrmidon Creek and Outer Harbour at East point**.**

5.1.11. Filterable Reactive Phosphorus

Filterable reactive phosphorus, the soluble fraction of phosphorus was low across Darwin Harbour. Median values ranged from 2 μg/L - 6 μg/L for all reporting zones with the exception of Buffalo Creek (15 μg/L) exceeding locally derived WQO's. Extremes for FRP were observed in systems associated with licensed wastewater discharge such as Buffalo Creek, Myrmidon Creek and Blessers Creek, a tidal creek in the East Arm reporting zone.

For chlorophyll a, nitrogen oxides, ammonia, total nitrogen, total phosphorus and filterable reactive phosphorus data needed to be log10 transformed. This transformation was necessary to make results clear on the graphs, due to the wide variability of results between reporting zones and sites.

Aquatic Scientist sampling the mid harbour area. Stokes Hill Wharf in the background.

Figure 4 - Mid Harbour reporting zone

5.2 Middle Harbour

The eastern part of Middle harbour receives stormwater runoff from Darwin's urban area. Monitoring locations extend from the East Arm boundary across to the Western side of the harbour and south towards Channel Island. The area is a busy conduit for shipping traffic and marine services.

Figure 5 summarises the results of all water quality parameters measured at the Middle Harbour monitoring sites.

Table 5 reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured.

Table 5 - Summary of water quality parameters measured in Middle Harbour

Indicators	Water Quality Objectives	Middle Harbour	
		min-max	*20th-80th percentiles and (median)*
pH	*7.0-8.5*	7.78-8.35	7.8-8.2 (8.0)
Dissolved oxygen (% saturation)	*80–100*	90.5-107.2	92-105 (100)
Suspended solids (mg/L)	*<10*	0.72-5.646	2
Chlorophyll *a* (µg/L)	*<2*	0.33-0.94	0.5
NO_x (µg/L)	*<20*	11-29	16.5
Ammonia (µg/L)	*<20*	1-8	4
Total nitrogen (µg/L)	*<270*	80-190	130
Total phosphorus (µg/L)	*<20*	5-10	5
Filterable reactive phosphorus (µg/L)	*<5*	1-6	4
2014 rating			**A**

All water quality parameters complied with WQO's for the mid estuary category: *Water quality at the Middle Harbour reporting zone is in excellent condition.*

No specific spatial or temporal trend has been identified in Middle Harbour for the parameters studied over the last year. Last reporting year the Middle Harbour rated a 'B' with departures for dissolved oxygen. The 2014 median values were all compliant with local benchmarks.

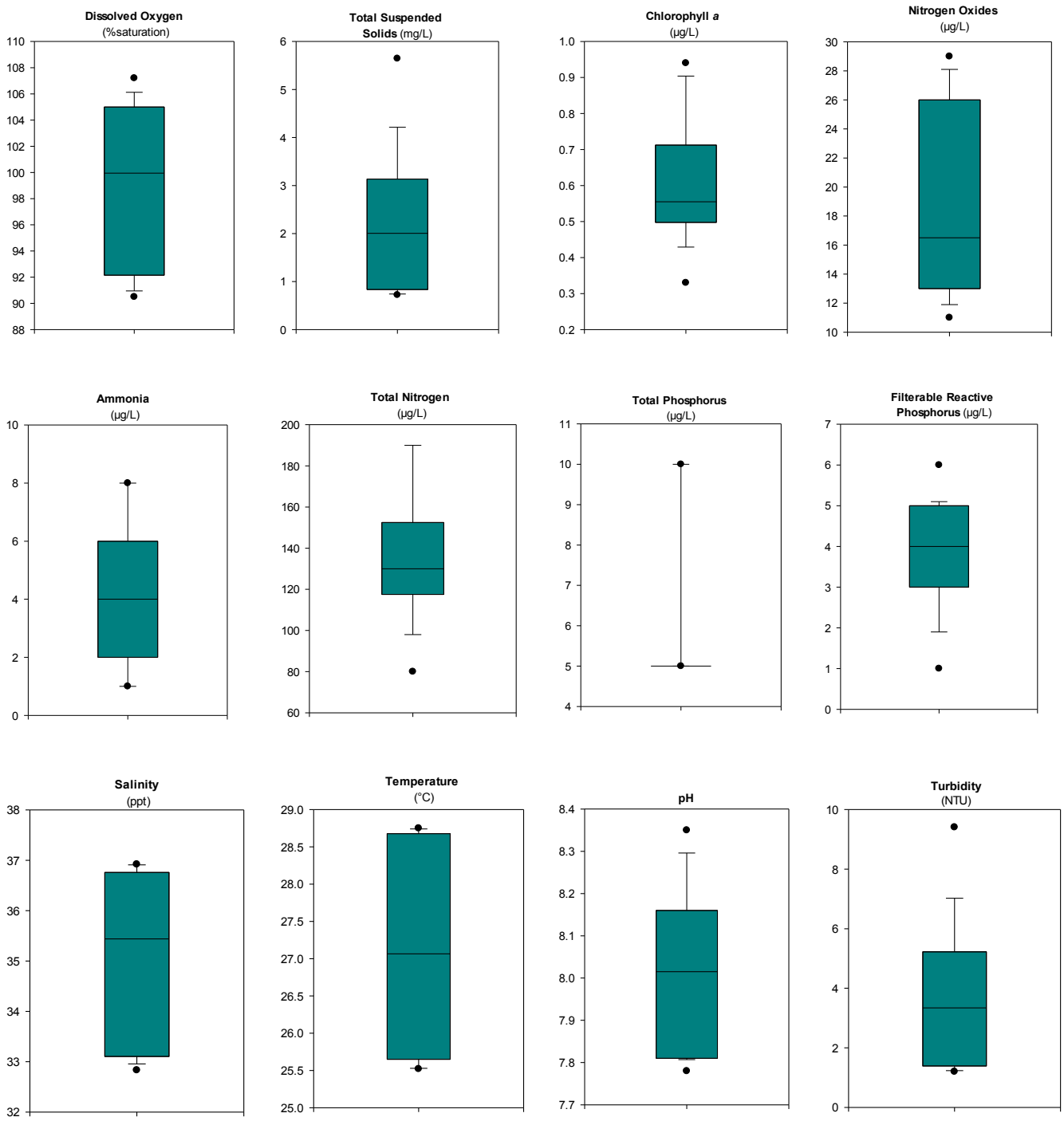


Figure 5 - Water quality indicators measured in Middle Harbour
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

Aquatic Health Unit staff sampling nearby Lameroo area

Figure 6 - East Arm reporting zone

5.3 East Arm

A relatively large part of the catchment of East Arm is principally urbanised, and includes the East Arm wharf, marine support services and industrial areas.

Treated wastewater discharge to Blessers creek which is in the East Arm reporting area. During the wet season high sediment, nutrient and other pollutant loads are received from urbanised areas.

Sediment monitoring has shown there is minor impact from urban land-use, and overall low metal and nutrient concentrations in the sediments (Munksgaard et al. 2013).

Figure 7 summarises the results of each water quality parameter measured at the East Arm monitoring sites.

Table 7 reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured.

Table 7 - Summary of water quality parameters measured in East Arm

Indicators	Water Quality Objectives	East Arm	
		min-max	*20th-80th percentiles and (median)*
pH	*6.5-8.5*	7.32-8.24	7.7-8 (7.8)
Dissolved oxygen (% saturation)	*80-100*	24.4-113.5	70-92 (81)
Suspended solids (mg/L)	*<10*	1.38-46.3	3.8
Chlorophyll *a* (µg/L)	*<4*	0.22-68.4	1.6
No_x (µg/L)	*<20*	3-135	3
Ammonia (µg/L)	*<20*	1-333	5
Total nitrogen (µg/L)	*<300*	3-2960	350
Total phosphorus (µg/L)	*<30*	5-1100	22
Filterable reactive phosphorus (µg/L)	*<10*	2-696	6
2014 rating			**B**

One water quality parameter (total nitrogen) measured did not comply with the WQOs: *Water quality at the East Arm monitoring sites is in very good condition.*

Dissolved oxygen values were generally lower in upper parts of the area and ypically associated with the immediate area of the discharge point. Similarly nutrients were generally higher in the upper reaches.

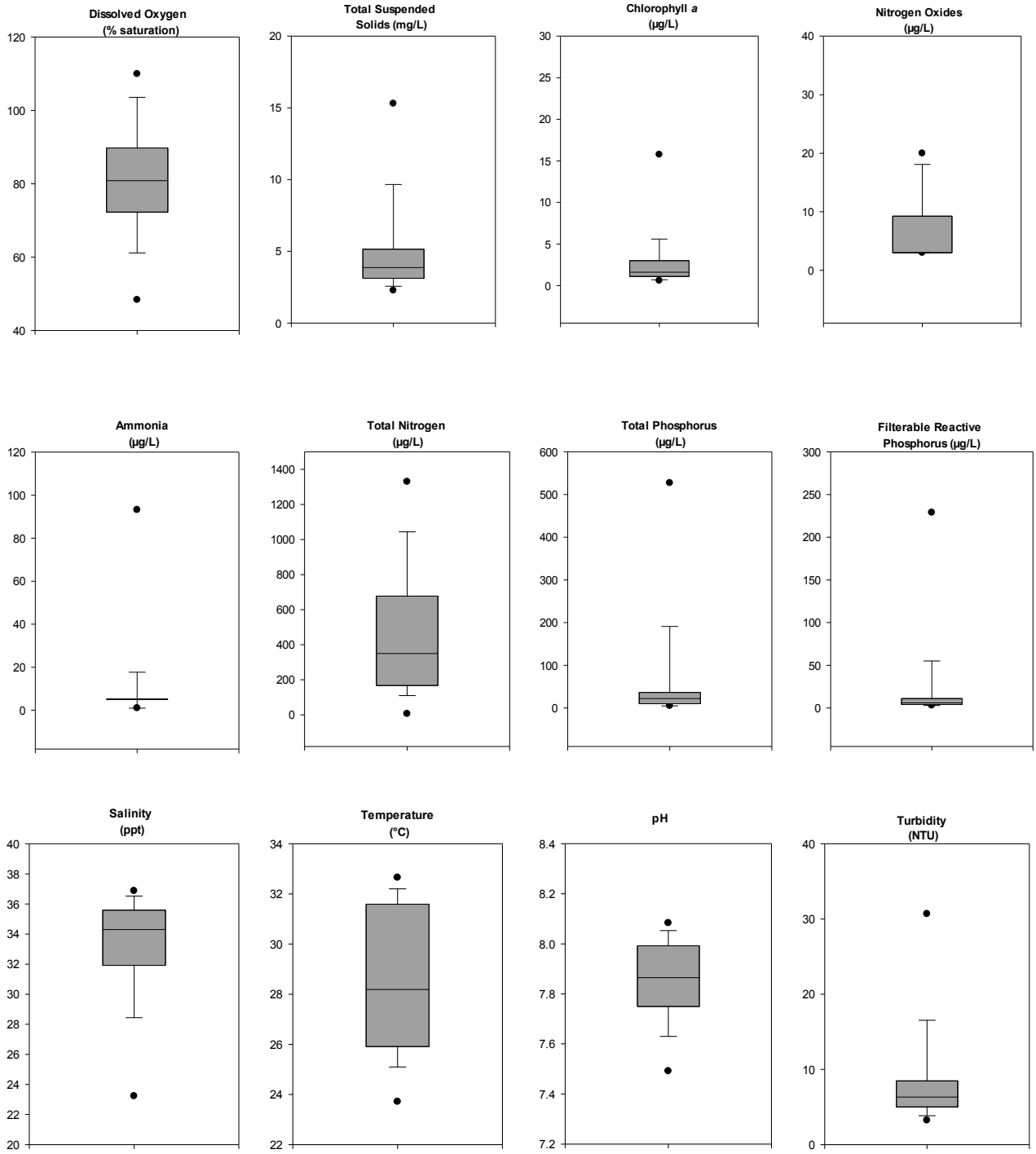


Figure 7 - Water quality indicators measured in East Arm
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

East Arm boat ramp

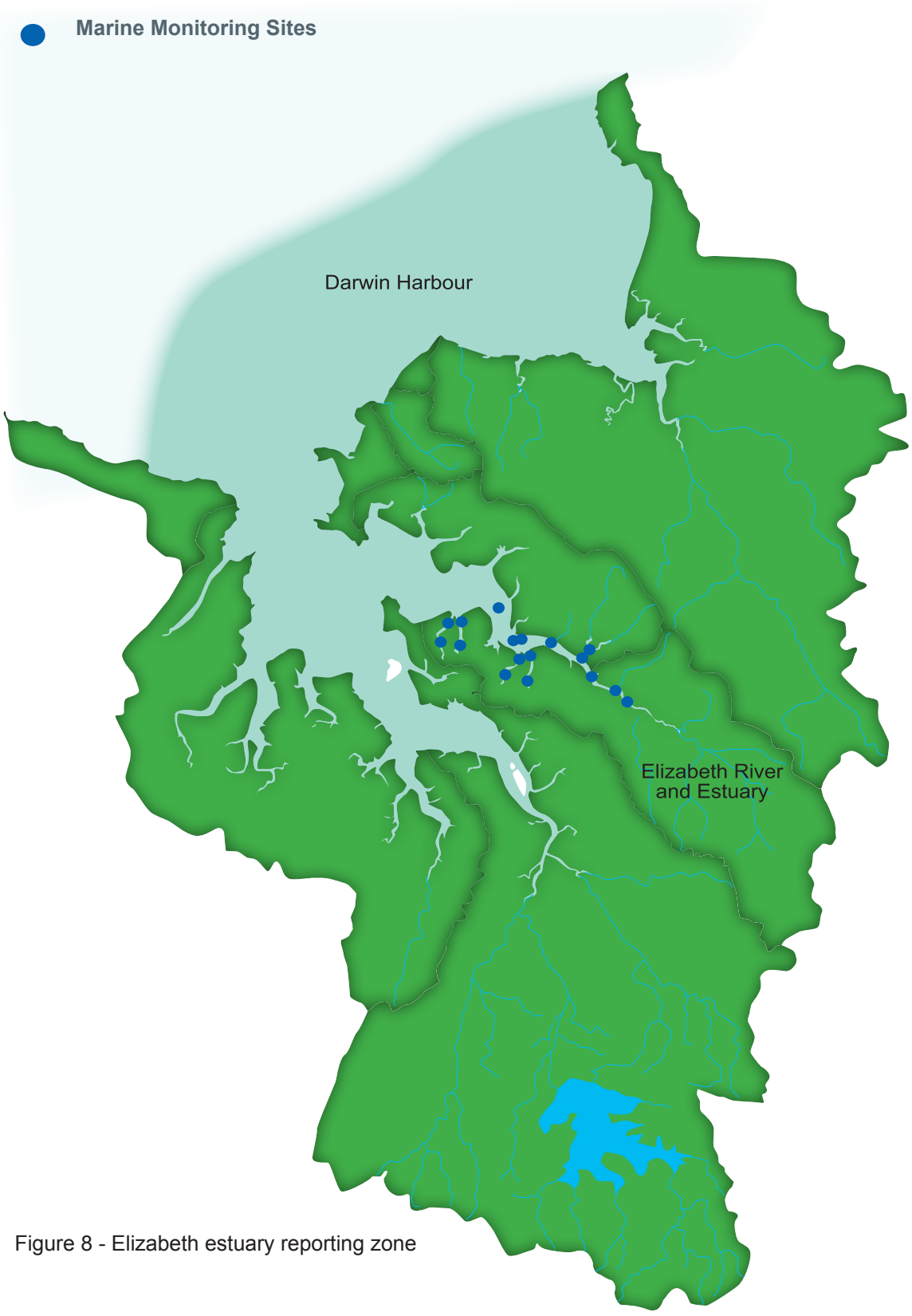


Figure 8 - Elizabeth estuary reporting zone

5.4 Elizabeth River Estuary

The estuary is characterised by a relatively long residence time in the upper reaches compared to outer and middle parts of the harbour. The catchment area around the estuary is subject to increasing commercial and urban development with the mid to outer reaches characterised by port activities and other industrial development.

Elizabeth River estuary indirectly receives licensed wastewater discharge from Myrmidon Creek, and sediment and nutrient loads from diffuse sources during the wet season.

Figure 9 summarises the results of each water quality parameter measured at the Elizabeth River Estuary monitoring sites.

Table 8 below reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured.

Table 8 - Summary of water quality parameters measured in Elizabeth River estuary

Indicators	Water Quality Objectives	Elizabeth Upper	
		min-max	*20th-80th percentiles and (median)*
pH	*6.5-8.5*	7.3-8.05	7.4-7.7 (7.6)
Dissolved oxygen (% saturation)	*80-100*	79.9-114.7	82-94 (89)
Suspended solids (mg/L)	*<10*	0.66-12.84	2.09
Chlorophyll *a* (µg/L)	*<4*	0.39-2.04	0.8
No_x (µg/L)	*<20*	3-30	9.5
Ammonia (µg/L)	*<20*	1-10	2.5
Total nitrogen (µg/L)	*<300*	120-260	170
Total phosphorus (µg/L)	*<30*	5-15	5
Filterable reactive phosphorus (µg/L)	*<10*	2-9	4
2014 rating			**A**

All water quality parameters measured complied with the WQOs: *Water quality within the reporting zone of the Elizabeth River estuary is in excellent condition.*

pH and dissolved oxygen measured in upper parts were generally lower compared to those measured in more open parts of the harbour.

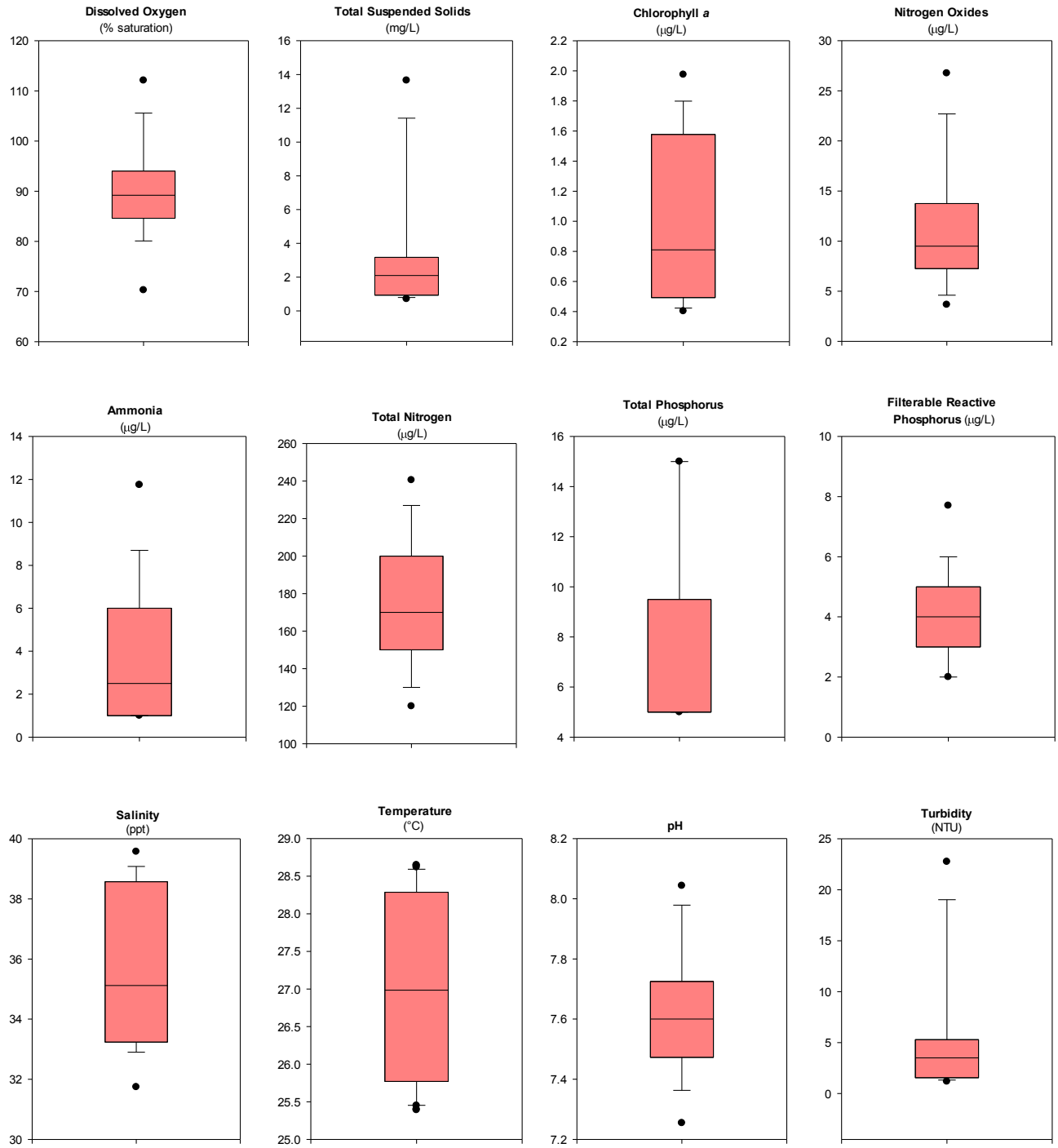


Figure 9 - Water quality indicators measured in Elizabeth River estuary
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

Figure 10 - Myrmidon Creek reporting zone

5.5 Myrmidon Creek

Myrmidon Creek receives discharge from a sewage treatment plant which services Palmerston and surrounding areas. The influence of the discharge entering the creek appears to be largely confined with no discernable impact to water quality detected downstream at the mouth.

Pollutant loads from rural and urban areas during the wet season enter the estuary from the upper reaches where mixed land uses prevail.

Figure 11 summarises the results of water quality parameters measured at the Myrmidon Creek monitoring sites. Much of this data has been provided by the Power Water Corporation.

Table 9 reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured.

Table 9 - Summary of water quality parameters measured in Myrmidon Creek.

Indicators	Water Quality Objectives	Myrmidon Creek	
		min-max	*20th-80th percentiles and (median)*
pH	*6.5-8.5*	7.59-8.2	7.8-8 (7.9)
Dissolved oxygen (% saturation)	*80-100*	46.2-114	78-91 (83)
Suspended solids (mg/L)	*<10*	1.3-51	3.9
Chlorophyll *a* (µg/L)	*<4*	0.17-15.3	2.04
NO_x (µg/L	*<20*	1.5-352	1.5
Ammonia (µg/L)	*<20*	1-18680	7
Total nitrogen (µg/L)	*<300*	30-24600	400
Total phosphorus (µg/L)	*<30*	2.5-4360	24
Filterable reactive phosphorus (µg/L)	*<10*	1.5-3460	6
2014 rating			**C**

Two water quality parameters (nutrients – total phosphorus and nitrogen) measured did not comply with the WQOs: *Water quality at the Myrmidon Creek monitoring zone is in good condition.*

The highest values of ammonia, total nitrogen and total phosphorus were measured at sites closest to the Myrmidon Creek outfall.

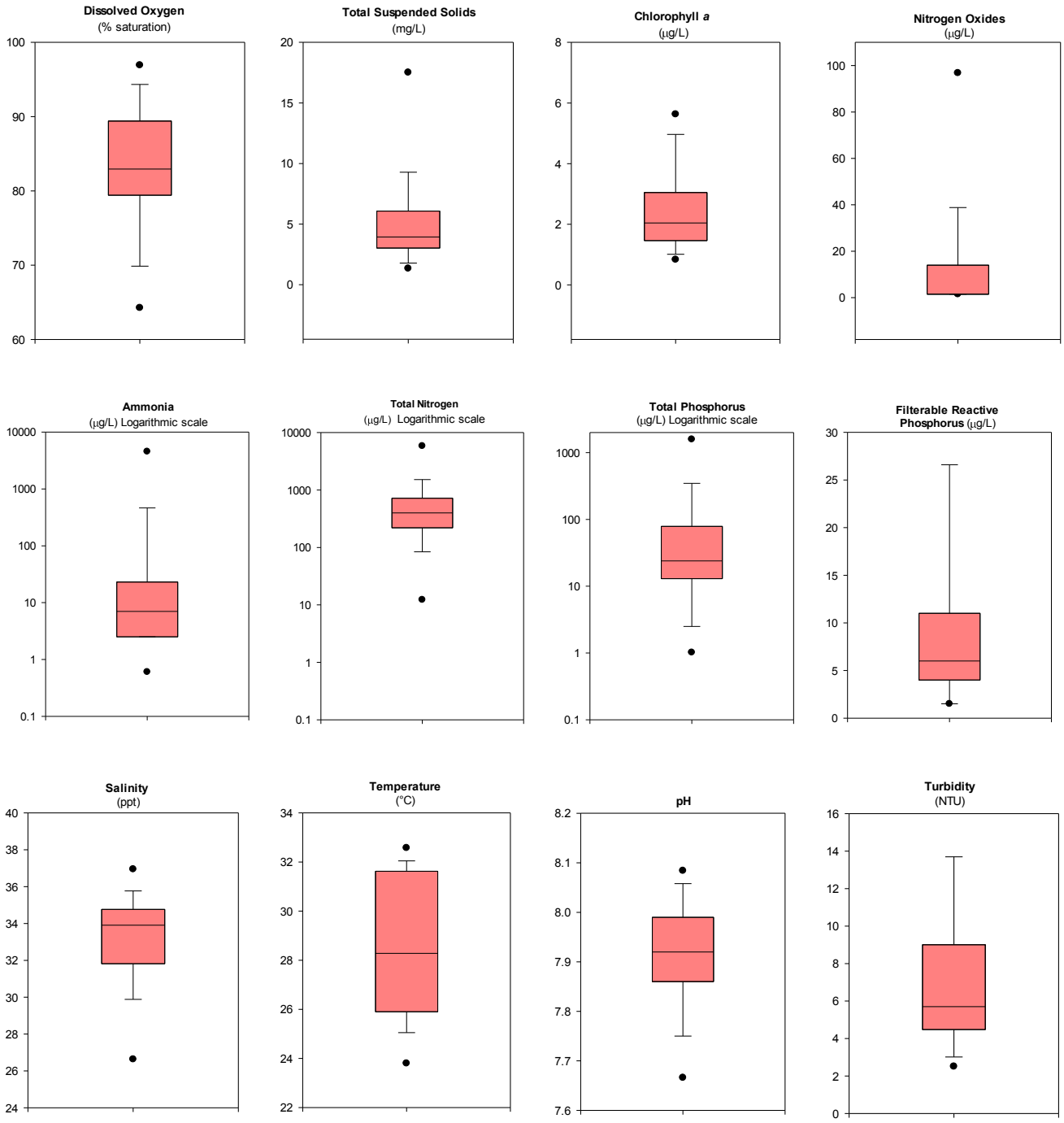


Figure 11 - Water quality indicators measured in Myrmidon Creek
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

Figure 12 - Blackmore River estuary reporting zone

5.6 Blackmore River Upper

The estuary is characterised by a relatively long residence time in the upper reaches compared to outer and middle parts of the harbour.

Blackmore River Estuary receives occasional discharges from licensed aquaculture operations, and sediment and nutrient loads from diffuse sources in the wet season. The upper reaches are also subject to persistent freshwater flows from springs which continue to flow during the dry season in addition to flows maintained in Darwin River downstream of the Darwin River Dam.

Figure 13 summarises the results of each water quality parameter measured at the Blackmore River Estuary monitoring sites.

Table 10 below reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured.

Table 10 - Summary of water quality parameters measured in Blackmore River estuary

Indicators	Water Quality Objectives	Blackmore Upper	
		min-max	*20th-80th percentiles and (median)*
pH	*6.5-8.5*	6.83-7.98	7.5-7.7 (7.5)
Dissolved oxygen (% saturation)	*80-100*	66.6-108	72-93 (87)
Suspended solids (mg/L)	*<10*	0.9-10	2.6
Chlorophyll *a* (µg/L)	*<4*	0.41-5	1.59
No_x (µg/L)	*<20*	3-66	13
Ammonia (µg/L)	*<20*	1-35	3
Total nitrogen (µg/L)	*<300*	40-470	150
Total phosphorus (µg/L)	*<30*	5-40	5
Filterable reactive phosphorus (µg/L)	*<10*	1-20	4
2014 rating			**A**

All water quality parameters measured complied with the WQOs: *Water quality in the Blackmore River estuary reporting zone is in excellent condition.*

The lowest pH and dissolved oxygen values were measured in upper parts of the estuary.

Dissolved oxygen, ammonia, total nitrogen and total phosphorus measured in upper parts of the area were generally higher compared to those measured in more open parts and indicated strong gradients decreasing with distance along the estuary. Total suspended solids and chlorophyll a is generally lower during the dry season months in comparison to the wet season where water quality can fluctuate widely.

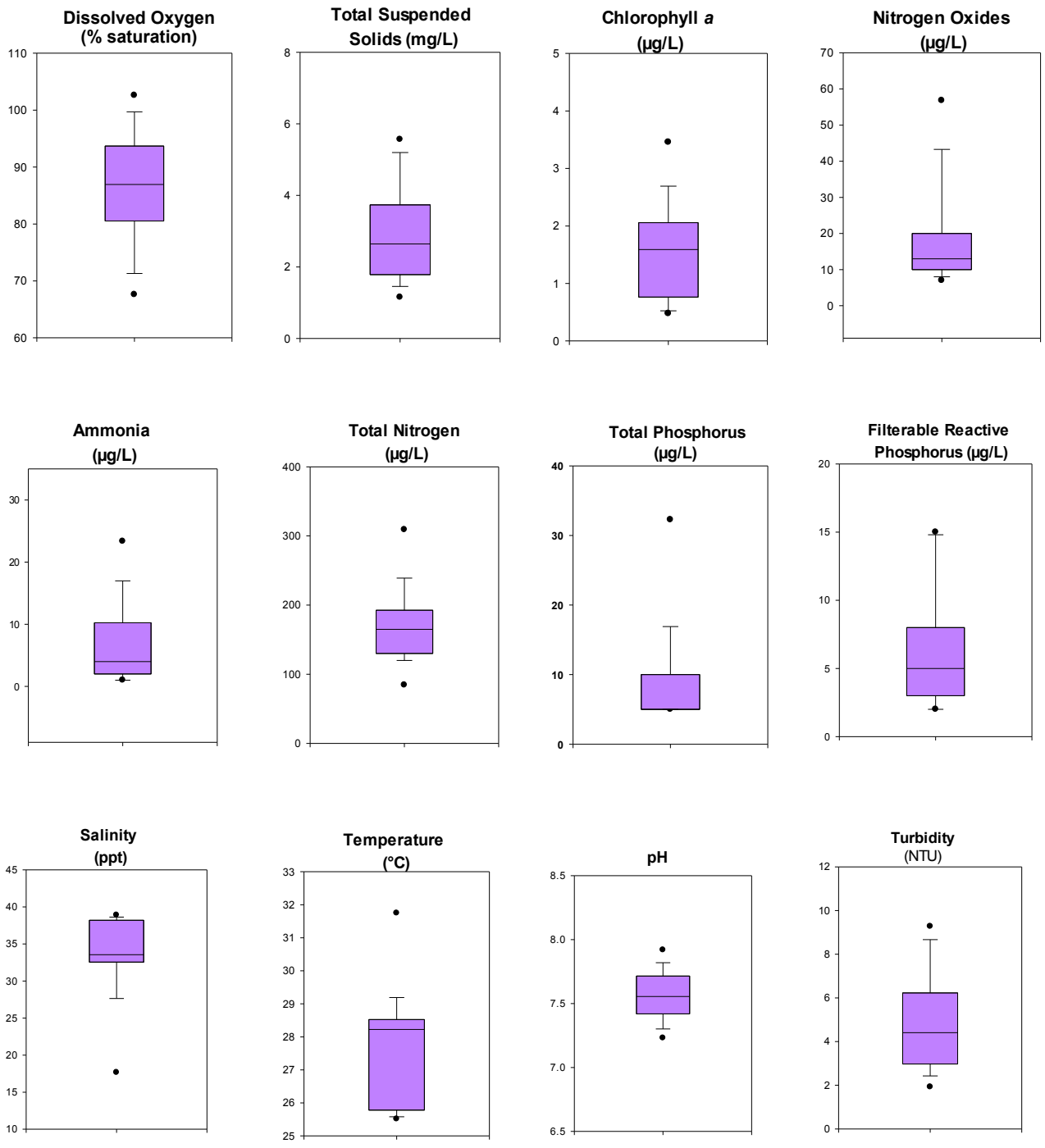


Figure 13 - Water quality indicators measured in Blackmore River estuary
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles.

Tidal Creeks of Darwin Harbour. These mangrove-lined systems drain the main arms of the Blackmore and Elizabeth estuary

Figure 14 - Shoal Bay and Buffalo creek reporting zone

5.7 Shoal Bay

The area is a shallow embayment with a number of sandbars along the coastal fringe and entrance to tidal creeks. Shoal Bay receives sediments and nutrient loads from the Howard River catchment during the wet season. A number of smaller mangrove-lined creeks flow to Shoal Bay, these include King, Mickett and Buffalo Creeks.

Figure 10 summarises the results of water quality parameters measured at the Shoal Bay monitoring sites.

Table 11 reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured.

Table 11 - Summary of water quality parameters measured in Shoal Bay

Indicators	Water Quality Objectives	Shoal Bay	
		min-max	*20th-80th percentiles and (median)*
pH	*7.0-8.5*	7.6-8.2	7.8- 7.9 (7.8)
Dissolved oxygen (% saturation)	*80–100*	97.1-129	100-119 (107)
Suspended solids (mg/L)	*<10*	0.4-26.8	1.23
Chlorophyll *a* (µg/L)	*<1*	0.1-11.5	0.2
No_x (µg/L)	*<10*	8-26	12
Ammonia (µg/L)	*<20*	2-10	4
Total nitrogen (µg/L)	*<440*	90-370	140
Total phosphorus (µg/L)	*<20*	5-47	5
Filterable reactive phosphorus (µg/L)	*<10*	1-11	2
2014 rating			**B**

One water quality parameter (dissolved oxygen) measured did not comply with the WQOs: *Water quality at the Shoal Bay monitoring sites is in very good condition.*

Dissolved oxygen (DO) can fluctuate widely over short temporal scales particularly with changing tides. Elevations above guidelines can be associated with the natural variation observed in the region. Revision of water quality objectives is needed to better accommodate this natural variation. Sometimes elevated DO can be associated with high algal biomass (Chlorophyll-a).

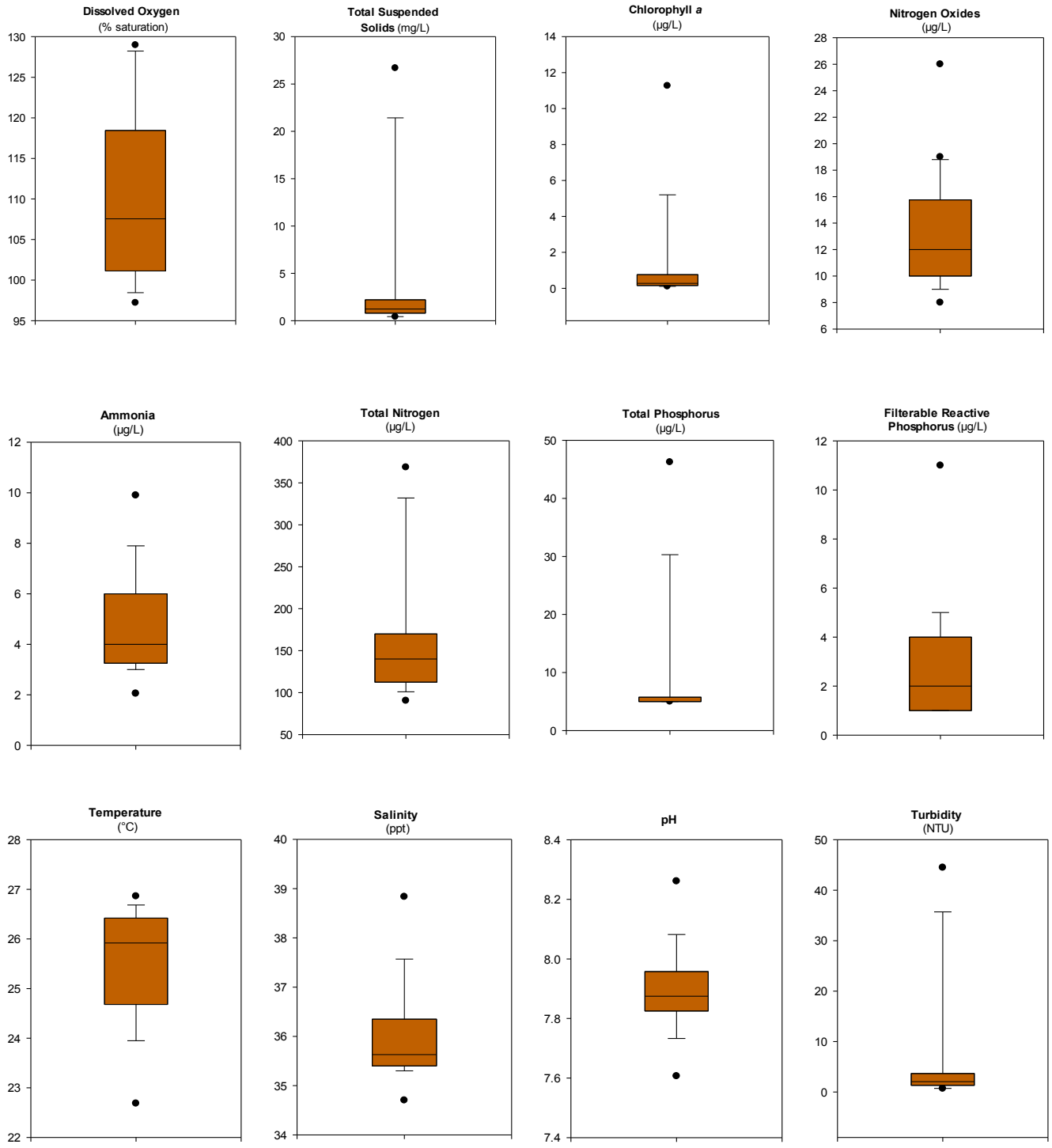


Figure 15 - Water quality indicators measured in Shoal Bay
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

5.8 Buffalo Creek

The area is characterized by long residence time and poor flushing due to the sand bar at the creek's mouth.

Buffalo Creek receives discharge from the Leanyer-Sanderson Wastewater Treatment Plant, and pollutant loads from urban areas during the wet season.

Figure 16 summarises the results of water quality parameters measured at the Buffalo Creek monitoring sites. This data is collected by the Power Water Corporation.

Table 12 reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured in Buffalo Creek.

Table 12 - Summary of water quality parameters measured in Buffalo Creek

Indicators	Water Quality Objectives	Buffalo Creek	
		min-max	*20th-80th percentiles and (median)*
pH	*6.5-8.5*	6.5-8.3	7.5-8.1 (7.9)
Dissolved oxygen (% saturation)	*80-100*	10.5-170	52-103 (88)
Suspended solids (mg/L)	*<10*	1.37-76	10.8
Chlorophyll *a* (µg/L)	*<4*	0.05-582	10
No_x (µg/L)	*<20*	1.5-254	12
Ammonia (µg/L)	*<20*	2.5-10300	9
Total nitrogen (µg/L)	*<300*	100-22400	1420
Total phosphorus (µg/L)	*<30*	2.5-4840	106
Filterable reactive phosphorus (µg/L)	*<10*	1.5-1120	15
2014 rating			D

Three water quality parameters measured (water clarity, algae and nutrients) did not comply with the WQOs: *Water quality at the Buffalo Creek reporting zone is in poor condition.*

The highest values of chlorophyll a, ammonia, total nitrogen, total phosphorus and filterable reactive phosphorus were measured at sites closest to the Buffalo Creek outfall.

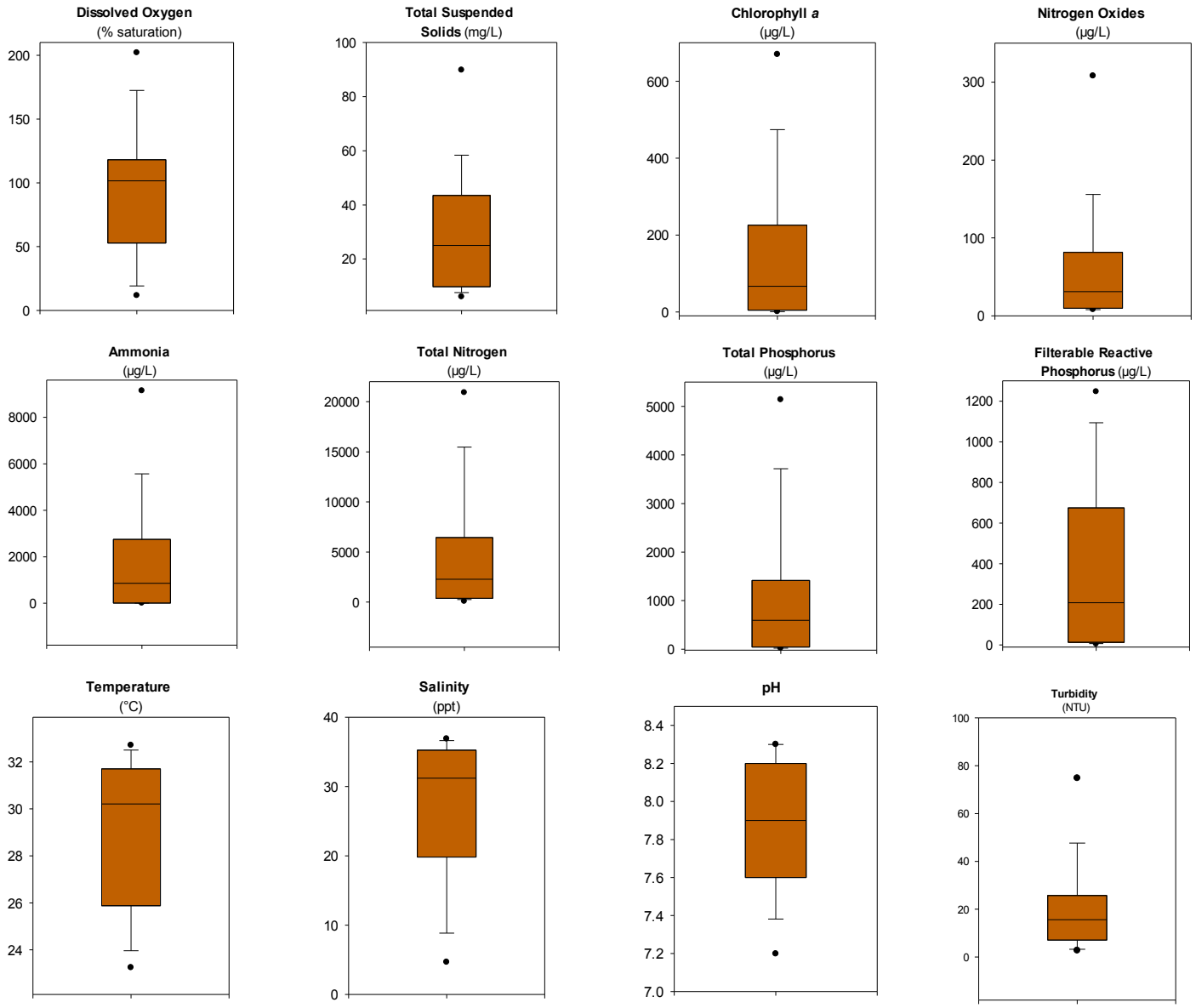


Figure 16 - Water quality indicators measured in Buffalo Creek
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

Leanyer-Sanderson Wastewater Treatment Plant

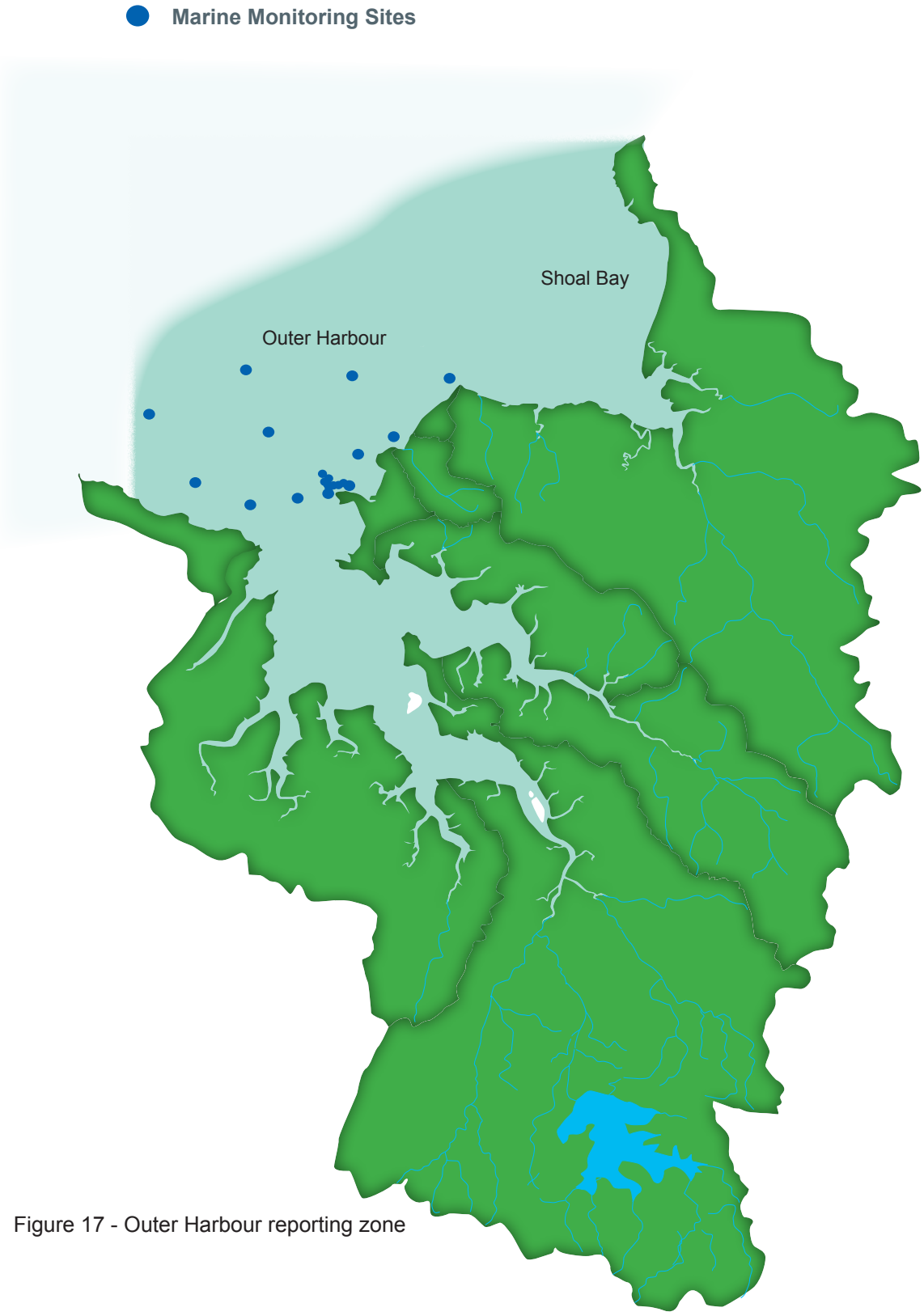


Figure 17 - Outer Harbour reporting zone

5.9 Outer Harbour

The area is a well-mixed system open to coastal exchange. Effluent from the Ludmilla Wastewater Treatment Plant is discharged to this part of the Harbour at the East Point outfall.

Figure 18 summarises the results of water quality parameters measured at Outer Harbour monitoring sites.

Table 13 reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured.

Table 13 - Summary of water quality parameters measured in the Outer Harbour

Indicators	Water Quality Objectives	Outer Harbour	
		min-max	*20th-80th percentiles and (median)*
pH	*7.0-8.5*	7.99-8.79	8.0-8.2 (8.1)
Dissolved oxygen (% saturation)	*80–100*	47.4-112	88-101 (92)
Suspended solids (mg/L)	*<10*	0.5-45	2
Chlorophyll *a* (µg/L)	*<1*	0.13-5.16	0.8
No_x (µg/L)	*<10*	3-40	4
Ammonia (µg/L)	*<20*	1-7584	5
Total nitrogen (µg/L)	*<440*	60-9180	475
Total phosphorus (µg/L)	*<20*	5-4540	20.5
Filterable reactive phosphorus (µg/L)	*<10*	1-175	5
2014 rating			**B**

One water quality parameter (total nitrogen) measured did not comply with the WQOs: *Water quality at the Outer Harbour monitoring zone is in very good condition.*

Highest values of ammonia, total nitrogen and filterable reactive phosphorus were measured at sites closest to the East Point outfall site.

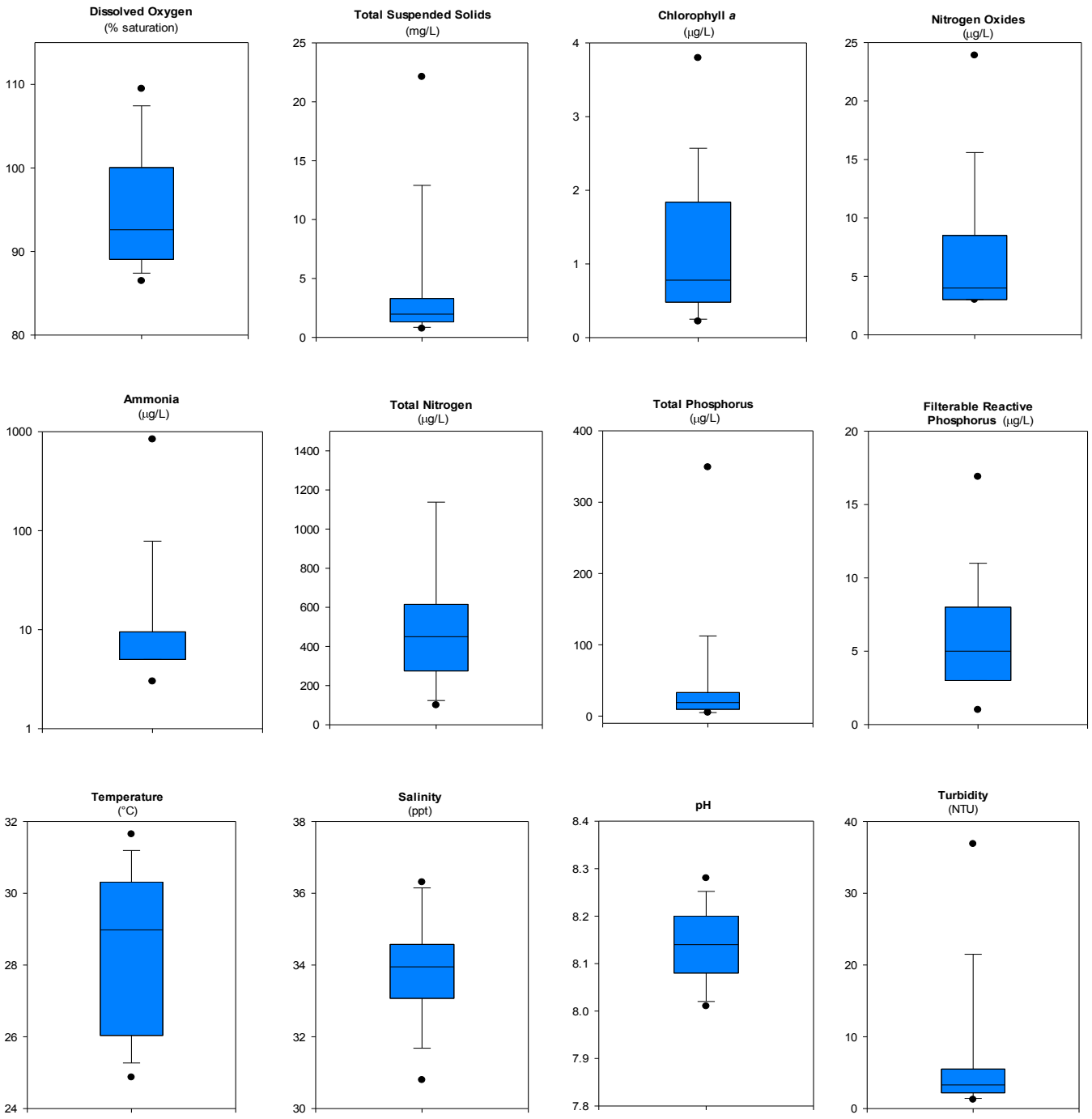


Figure 18 - Water quality indicators measured in Outer Harbour
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

Aquatic Health Technician examining seagrass on Vesteys Beach. This fine sparse seagrass in most places is no longer than 8cm in length.

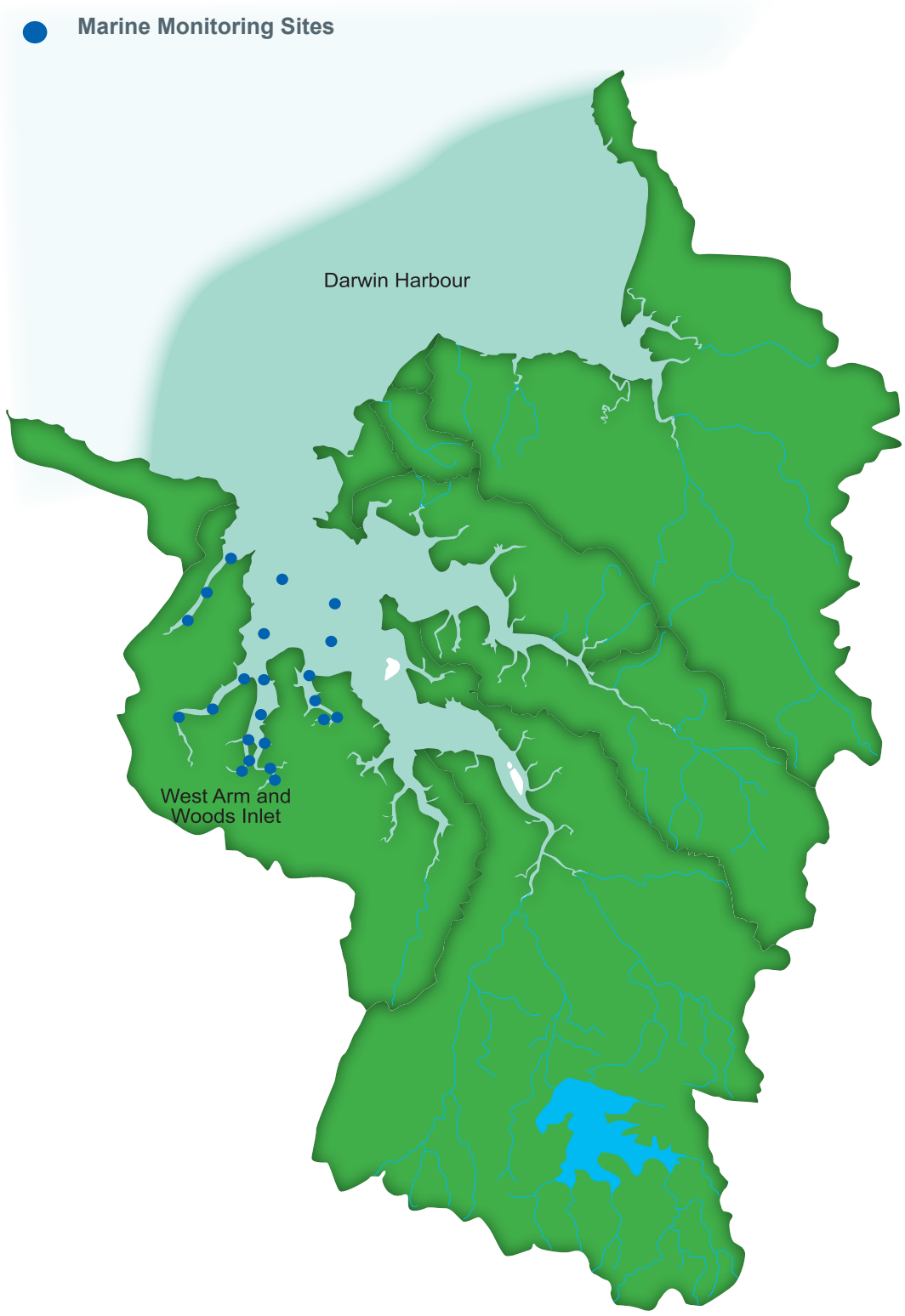


Figure 19 - West Arm and Woods Inlet reporting zone

5.10 West Arm

The Arm has extensive mangrove habitat, inter-tidal mudflats and large areas that are exposed on spring tides. The West Arm reporting zone includes a series of large tidal creeks and Woods inlet. The western boundary of Darwin Harbour comprises only minor development (small rural blocks of Cox Peninsula) with flows constrained to wet season run-off from largely intact undisturbed catchment.

West Arm is considered to be undisturbed and typically used as 'reference' condition in Darwin Harbour. Figure 20 summarises the results of each water quality parameter measured.

Table 14 reports median values and 20th-80th percentiles (compliance), minimum and maximum values of the data measured.

Table 14 - Summary of water quality parameters measured in West Arm

Indicators	Water Quality Objectives	West Arm	
		min-max	*20th-80th percentiles and (median)*
pH	*6.5-8.5*	7.49-8.3	7.7-7.8 (7.9)
Dissolved oxygen (% saturation)	*80-100*	67-106	76-101 (91.8)
Suspended solids (mg/L)	*<10*	1.1-5.1	2.3
Chlorophyll *a* (µg/L)	*<4*	0.38-1.63	1.09
No_x (µg/L)	*<20*	4-22	14
Ammonia (µg/L)	*<20*	1-10	4
Total nitrogen (µg/L)	*<300*	120-200	165
Total phosphorus (µg/L)	*<30*	5-10	5
Filterable reactive phosphorus (µg/L)	*<10*	1-7	4
2014 rating			**A**

All water quality parameters measured complied with the WQOs: *Water quality within the West Arm monitoring zone is in excellent condition.*

No specific spatial or temporal trend has been identified in West Arm for the parameters studied over the last year maintaining excellent water quality condition.

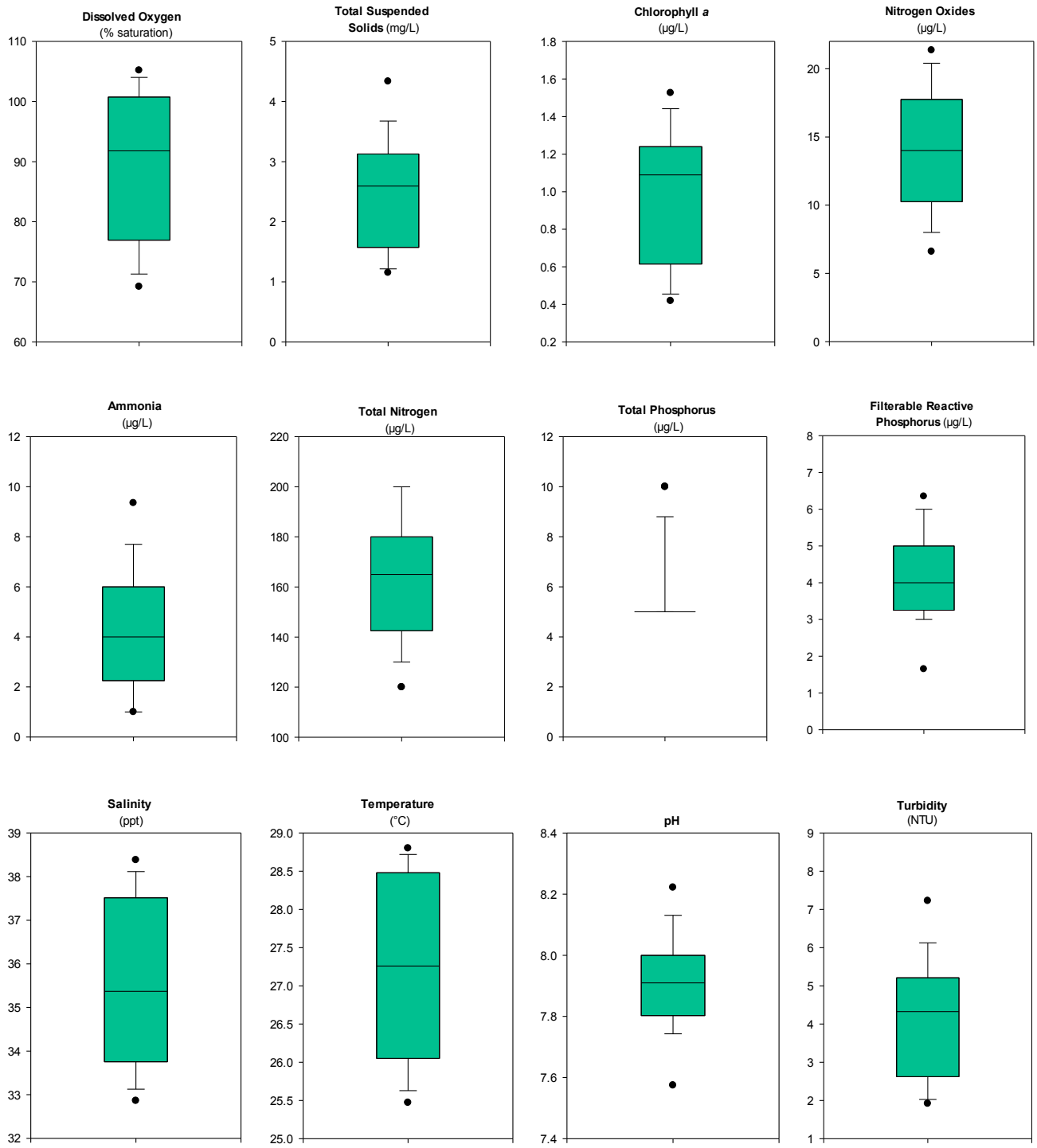


Figure 20 - Water quality indicators measured in West Arm
Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

Indo-pacific dolphins (Sousa chinesis) are residents of Darwin Harbour. They frequent the harbour for foraging, calving and raising young. Photo: Catherine Orme.

6. Conclusion

For the reporting period (mid-2013 to September 2014) the water quality of the Darwin Harbour region was very good to excellent with the exception of Myrmidon and Buffalo Creeks. West Arm, the Elizabeth River estuary, Blackmore River estuary and Middle Harbour were graded A, excellent water quality. Shoal Bay, the Outer Harbour and East Arm were graded B, very good water quality.

Myrmidon Creek and Buffalo Creek were respectively graded C (good) and D (poor). No waters were graded E (very poor) this reporting year.

Improvements in the Buffalo Creek system were observed for dissolved oxygen. Day time DO levels were slightly better than the previous reporting year with the annual median meeting designated water quality objectives. However, DO levels typically decrease in the upper reaches of the creek during the night.

The Middle Harbour reporting zone also indicated improvements. Dissolved oxygen revealed better agreement with WQO's in the 2014 reporting year. However previous departures did not pose any need for further investigation and were more indicative of natural variation typically observed with tidal and spatial changes (Mauraud, 2013).

There has been no major change in the water quality of Darwin Harbour since 2009. The system overall remains largely in very good condition with only small localised areas subject to degradation.

Potential sources of pollution to the waterways of Darwin Harbour include sediments, nutrients and other human-related pollutants. All these compounds can come from both 'point' and 'diffuse' sources, coming from a specific location (i.e. sewage treatment plant) or from a wide area (i.e. stormwater during the wet season).

The influence of the sewage treatment plant wastewater discharge is clear with the highest values for total nitrogen, total phosphorus, ammonia and filterable reactive phosphorus measured at sites adjacent to respective outfalls, and in Buffalo Creek. These systems represent the extremes in water quality, however their influence is localised and not detected more broadly in the harbour.

Seasonal variations (dry vs wet season) and spatial variations (upper vs outer sites) have been previously identified as important factors driving water quality, amongst others.

Results from previous years have varied slightly but differences may be due to the location and the number of the sites sampled, the frequency and the time of the sampling event, the method and parameters used for the grade calculation and natural ecological processes affecting the environment.

References

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

Mauraud, N. (2013). Darwin Harbour water Quality: Supplement to the 2013 Darwin Harbour Region Report Card. Report 12/2013D. Aquatic Health Unit, Department of Land Resource Management. Palmerston, NT.

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Baseline Sediment Survey 2012. Research Institute for the Environment and Livelihoods, Charles Darwin University, Darwin.

Wrigley T.J., Cumberland D.A., and Townsend S.A. (1990) Ambient Water Quality of Darwin Harbour Report 71/90, Water Resources Division, Power and Water Authority.

Predicting TSS from turbidity

Values of TSS used in the Report Card and this report were calculated from turbidity using a TSS-turbidity relationship. The linear regression model used was based on a Darwin Harbour data set collected in 2012-13.

The plot below shows the regression between total suspended solids concentrations and turbidity.

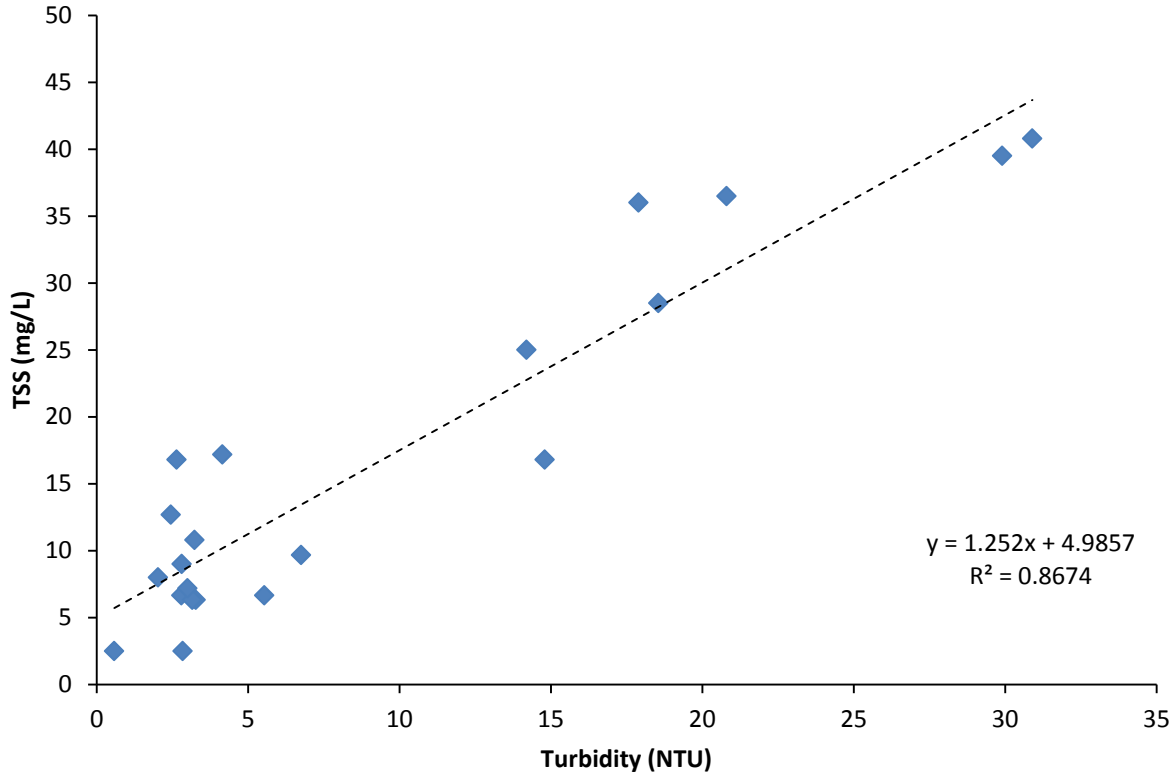

Figure 21 - Relationship between Total Suspended Solids (TSS) and turbidity in Darwin Harbour, 2012 (*n*=21).

Source: Mauraud, 2013.

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