

DARWIN HARBOUR WATER QUALITY: SUPPLEMENT TO THE 2013 DARWIN HARBOUR REGION REPORT CARD



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1. Introduction

Water quality monitoring has been undertaken in Darwin Harbour by the Department of Land Resource Management (and its predecessor organisations) since 1987 (see Wrigley *et al.* 1990). The water quality of the harbour has been summarised annually in the form of a Report Card since 2009. The Card's grades are summarised for 2013 and previous years in Table 1, and shown in Figure 1.

This report complements the 2013 Darwin Harbour Region Report Card by presenting supporting statistical and other information used to calculate the grades, as well as providing a more detailed analysis of Darwin Harbour water quality.

The 2013 grades indicate water quality mostly ranges from good to excellent. Deviations from excellent water quality, indicative of Water Quality Objective (WQO) compliance, are likely to be natural and an artefact of the grading methodology and WQOs. Buffalo Creek however has consistently poor water quality due mainly to effluent discharged from the Leanyer-Sanderson wastewater treatment plant, compounded by the poor flushing of the creek. Myrmidon Creek, which receives effluent from the Palmerston wastewater treatment plant, did not meet all Objectives but nevertheless has good water quality.

The Outer Harbour areas and East Arm had slightly higher (103, 104 and 105% saturation), or lower (72% saturation) dissolved oxygen than the WQO. These oxygen levels however were not harmful and are considered natural and not indicative of pollution. Their exceedence indicates the WQO needs to be revised to better take into account natural water quality variability. Buffalo Creek exceedence was caused by pollution, though it is unclear whether Myrmidon Creek was.

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

Parameters		Inner Harbour				Outer Harbour			Tidal Creeks	
		Elizabeth River	Blackmore River	West Arm	East Arm	Middle Harbour	Outer Harbour	Shoal Bay	Myrmidon Creek	Buffalo Creek
Dissolved oxygen	Dissolved oxygen	✓	✓	✓	✗	✗	✗	✗	✗	✗
Water clarity	Total suspended solids	✓	✓	✓	✓	✓	✓	✓	✓	✗
Algae	Chlorophyll <i>a</i>	✓	✓	✓	✓	✓	✓	✓	✓	✗
Nutrients	Nitrogen oxides									
	Ammonia									
	Total nitrogen	✓	✓	✓	✓	✓	✓	✓	✗	✗
	Total phosphorus									
	Filterable reactive phosphorus									
Grades	2013	A	A	A	B	B	B	B	C	E
	2012	A	A	A	A	A	B	B	C	E
	2011	A	C	A	A	A	A	C	**	E
	2010	A	B	A	A	B	A	C	D	E
	2009	C	B	**	B	A	A	C	**	E

** no grade calculated for the year

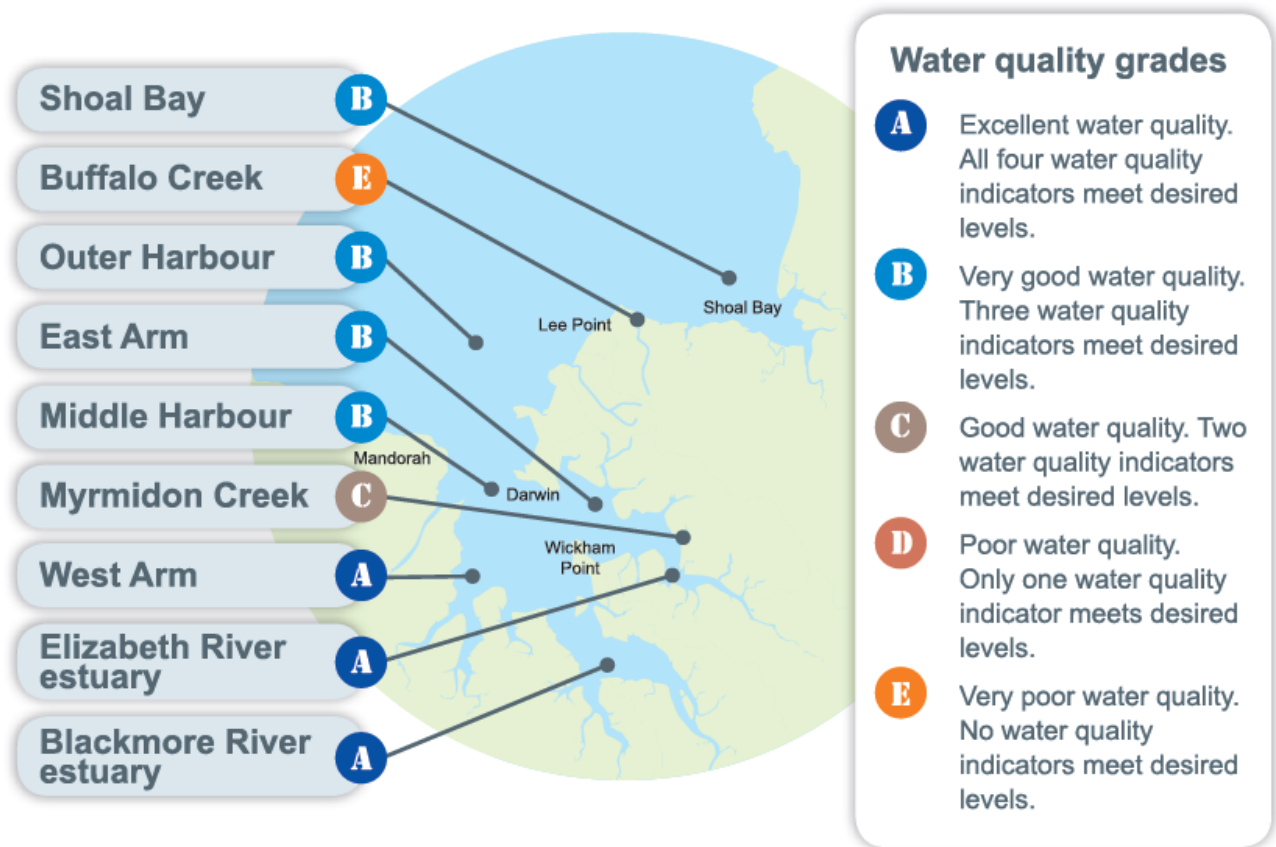


Figure 1 - Areas of the Darwin Harbour region.

2. Darwin Harbour region

The Darwin Harbour region is located in the wet-dry tropics of northern Australia (12°27'0"S 130°50'0"E) and extends from Gunn Point in the east, to Charles Point in the west. The climate consists of two distinct 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)

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.

3. Methods

3.1. Sites and sampling method

Darwin Harbour water quality data were collected from water samples collected and analysed in the laboratory, and by field measurements. 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 of waters in the vicinity of the Darwin Aquaculture Centre was undertaken by the Department of Primary Industry and Fisheries. The sites monitored by these organisations in 2013 were similar to those monitored in 2012. 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.

Water samples were collected from the surface (approximately 0.25 m depth) in plastic bottles 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 sampled data points is summarised in Table 2, and sites location shown in Figure 2.

Table 2 - Number of sites sampled and data points

Areas	Elizabeth River estuary	Blackmore River estuary	West Arm	East Arm	Middle Harbour	Outer Harbour	Shoal Bay	Myrmidon Creek	Buffalo Creek
Number of sites	18	38	18	14	27	57	12	8	11
Number of data points	91	194	66	110	64	200	20	96	98

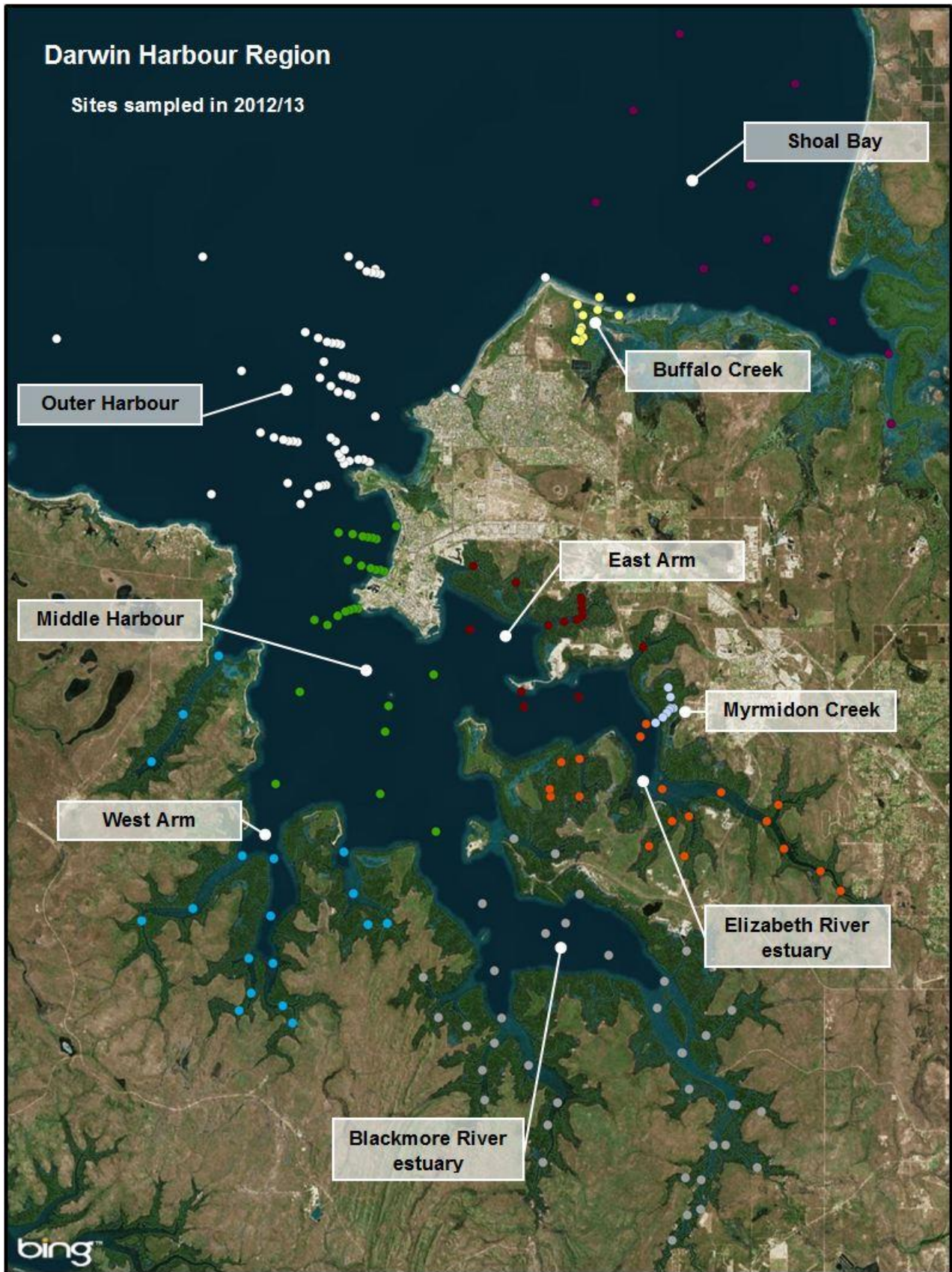


Figure 2 - Sites sampled in the Darwin Harbour region

3.2. Water quality parameters

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

3.2.1. 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), and the percentage of saturation (%saturation) calculated. 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. Oxygen saturation decreases with increasing water 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 (see Appendix 1).

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).

3.2.2. 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 (saline) 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.

3.3. Water Quality Objectives

The Water Quality Objectives for Darwin Harbour nominate the water quality that supports the maintenance of the ecosystem, and are nominated under the *Part 7 of the Water Act* as a local guideline level in accordance with the NWQMS¹ guidelines (see Fortune 2010).

Water quality data for each Harbour area were compared with WQOs 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 3. 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 not a pass, and 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.

The dissolved oxygen and pH water quality parameters use the 20th to 80th percentile range of local ambient water quality data instead of only an 50th value. The 20th and 80th percentile values calculated from the data are compared to the WQO values. If the data 20th percentile is lower than the WQO 20th percentile, then an exceedance has occurred. In the case of the 80th percentile, exceedance occurs with the data 80th exceeds the 80th percentile objective. The 2013 Report Card did not use pH to because it is not sensitive to pollution, and to reduce the number of parameters in order to simplify communication. The pH WQO range is large, which reflects a natural range caused most likely by freshwater inflows and linked to lower salinity.

¹ National Water Quality Management Strategy

Table 3 – Darwin Harbour Water Quality Objectives

Parameters		Water Quality Objectives		
		Inner area	Middle area	Outer area
Water clarity	Total suspended solids (mg/L)	<10	<10	<10
Algae	Chlorophyll <i>a</i> (µg/L)	<4	<2	<1
Nutrients	Nitrogen oxides (µg/L)	<20	<20	<10
	Ammonia (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
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	80-100	80-100
pH	pH units	6.5-8.5	7.0-8.5	7.0-8.5

3.4. Water quality grades

The water quality grades, from A to E, have been assigned for each area depending on compliance to local WQOs (see Table 4).

Table 4 - Water quality grades

Water quality rating	What the rating means	Compliance and method
A	Excellent water quality	All four water quality parameters meet desired levels.
B	Very good water quality	Three water quality parameters meet desired levels.
C	Good water quality	Two water quality parameters meet desired levels.
D	Poor water quality	One water quality parameter meets desired levels.
E	Very poor water quality	No water quality parameters meet desired levels.

4. Results

4.1. Darwin Harbour region

Figure 3 summarises the results of each water quality parameter monitored in the Darwin Harbour region for the period from July 2012 to August 2013.

4.1.1. Dissolved Oxygen saturation

Median dissolved oxygen ranged from 88% (Blackmore River estuary) to 102% saturation (Buffalo Creek). Values of DO % were generally lower in the inner parts of the Harbour and higher in the outer parts. Results did not always comply with the WQO, for example, East Arm (72%-95%), Middle Harbour (91%-104%), Outer Harbour (97%-105%), Shoal Bay (97%-103%), Myrmidon Creek (77%-94%) and Buffalo Creek (46%-132%). With the exception of the latter, these deviations from the WQOs are minor and likely to be natural, and highlight the need to revise the dissolved oxygen WQO. A confounding consideration when monitoring dissolved oxygen is the diurnal fluctuation, which can be large in highly productive creeks such as Buffalo Creek.

4.1.2. Total Suspended Solids

Median TSS ranged from 5.5 mg/L (Outer harbour) to 25 mg/L (Buffalo creek). Over the past year, all results complied with the WQO, except for Buffalo Creek.

4.1.3. pH

Median pH ranged from 7.5 (Elizabeth River estuary) to 8.1 (Outer Harbour). In all areas, pH complied with the WQO.

4.1.4. Salinity

Median salinity ranged from 31.2 ppt (Buffalo Creek) to 35.5 ppt (Elizabeth River estuary). No WQO has been defined for the salinity. The salinity data shows that East Arm, Myrmidon Creek, Buffalo Creek and Shoal Bay were most affected by freshwater inflows.

4.1.5. Temperature

Median temperature ranged from 25.9°C (Shoal Bay) to 30.2°C (Buffalo Creek). No WQO has been defined for the temperature. Temperature however is required to be monitored to assess dissolved oxygen saturation.

4.1.6. Chlorophyll *a*

Median chlorophyll *a* varied between 0.4 µg/L (Middle Harbour) and 66.7 µg/L (Buffalo Creek) over the sampling period. All complied with the WQO, except for Buffalo Creek.

4.1.7. Nitrogen Oxides

Median nitrogen oxides ranged from 7 µg/L (Elizabeth River estuary) to 31 µg/L (Buffalo Creek). Only Buffalo Creek did not comply with the WQO.

4.1.8. Ammonia

Median ammonia varied between 5 µg/L (Outer Harbour) and 857 µg/L (Buffalo Creek). Only values measured in Buffalo Creek did not comply with the WQO.

4.1.9. Total Nitrogen

Median TN varied between 165 µg/L (Middle Harbour and Shoal Bay) and 2275 µg/L (Buffalo Creek). Results complied with the WQO for most of the areas but not for Myrmidon Creek (400 µg/L) and Buffalo Creek.

4.1.10. Total Phosphorus

Median total phosphorus varied between 5 µg/L (Middle Harbour and Outer Harbour) and 594 µg/L (Buffalo Creek). Only Myrmidon Creek (35 µg/L) and Buffalo Creek did not comply with the WQO.

4.1.11. Filterable Reactive Phosphorus

Median filterable reactive phosphorus varied between 2 µg/L (Elizabeth River estuary) and 208 µg/L (Buffalo Creek). Values of FRP measured complied with the WQO, except for Buffalo Creek.

For total suspended solids, 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 areas and within some areas.

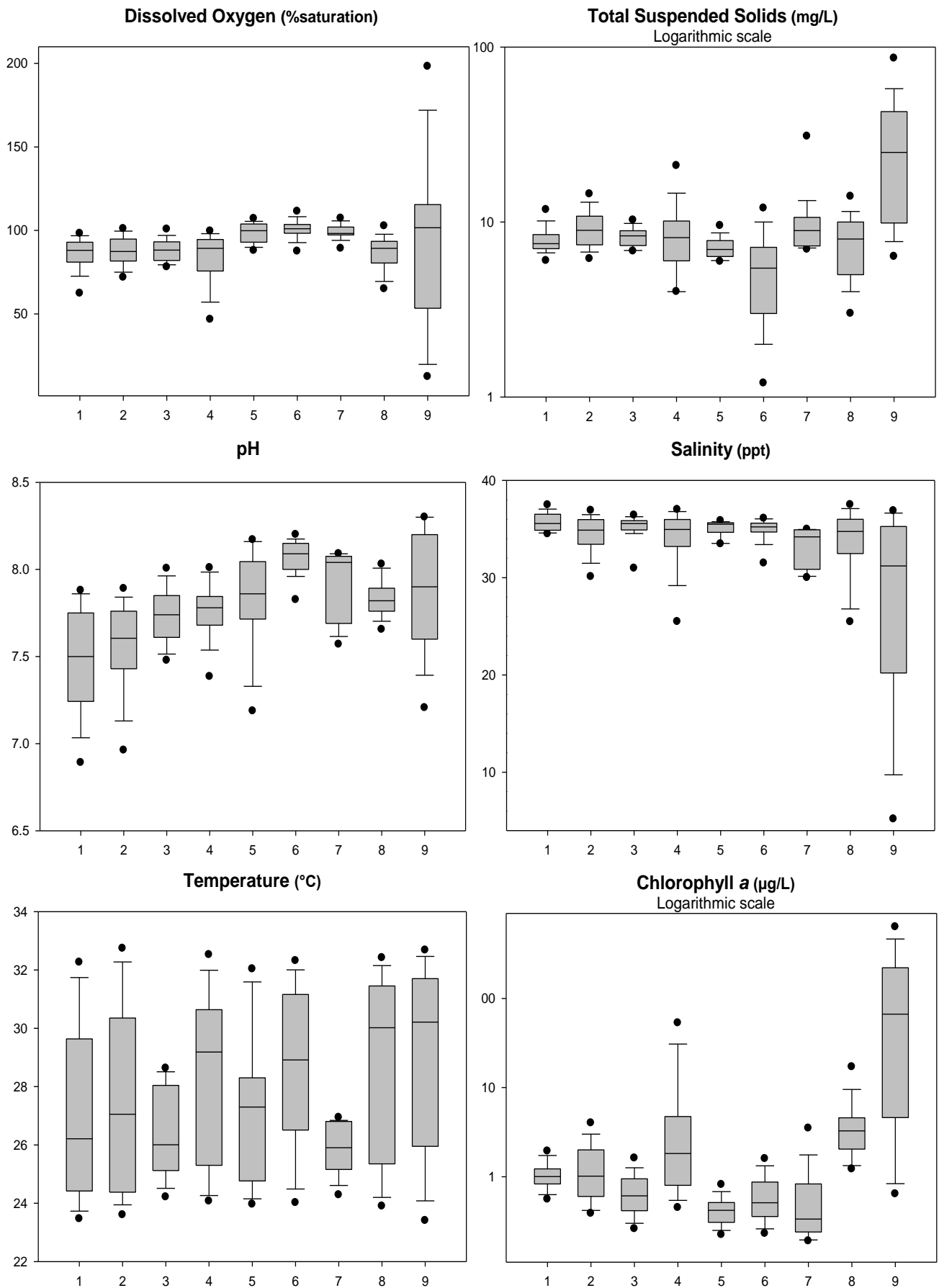
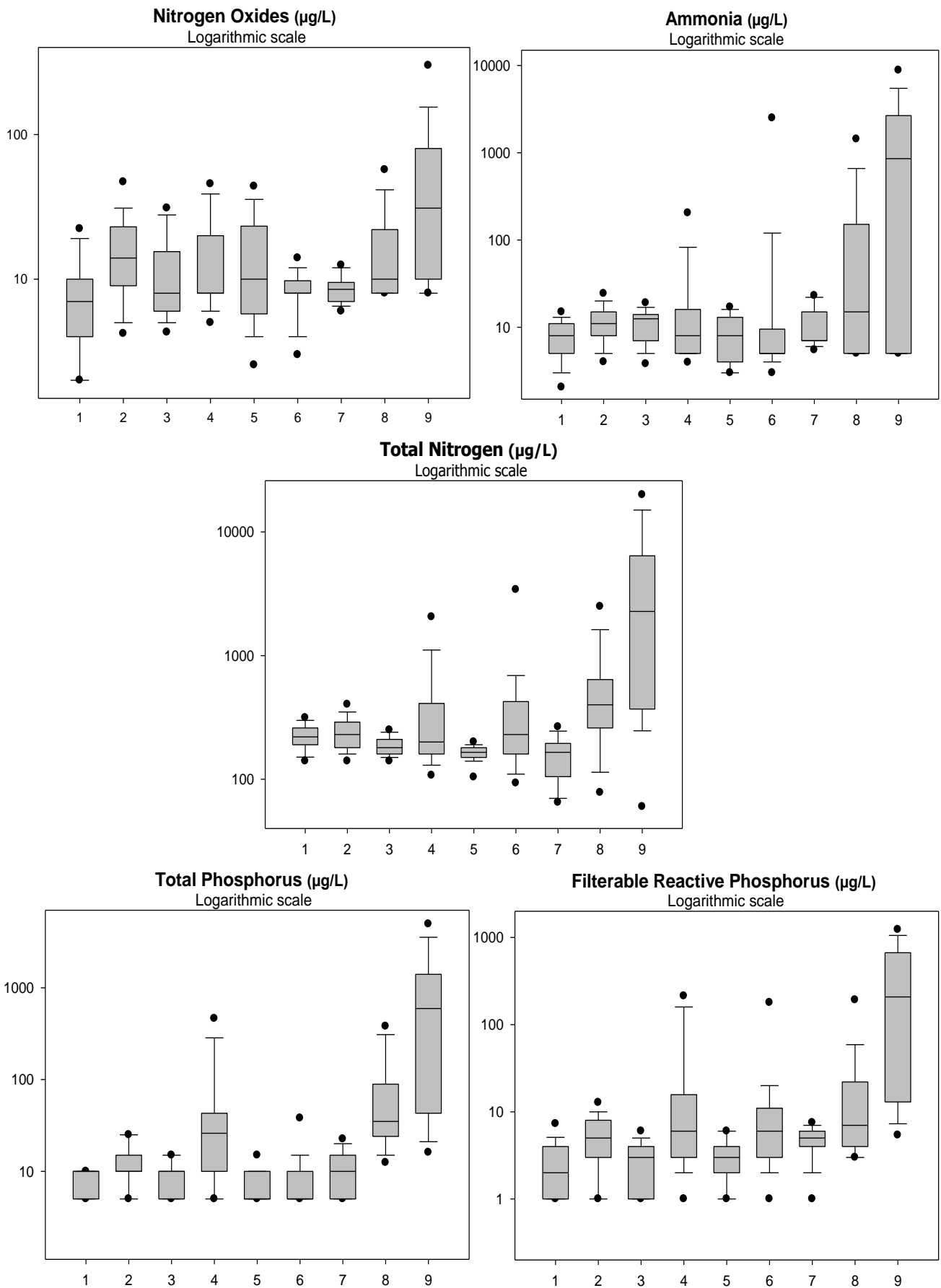


Figure 3a- Physico-chemical parameters and Algae measured in the Darwin Harbour region, (Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles)

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



**Figure 2b - Nutrients measured in the Darwin Harbour region,
(Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles)**

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

4.2. Darwin Harbour areas

4.2.1. Elizabeth River estuary

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

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

The Figure 4 summarises the results of each water quality parameter measured at the Elizabeth River Estuary monitoring sites.

The Table 5 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured.

Table 5 - Summary of water quality parameters measured in Elizabeth River estuary

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	80-93 (88)	51; 100	81; 93
Water clarity	Total suspended solids (mg/L)	<10	7.5	1; 20.7	7.1; 8.5
Algae	Chlorophyll <i>a</i> (µg/L)	<4	1	0.3; 2.5	0.8; 1.2
Nutrients	Nitrogen oxides (µg/L)	<20	7	2; 25	4; 10
	Ammonia (µg/L)	<20	8	1; 21	5; 11
	Total nitrogen (µg/L)	<300	220	60; 530	193; 260
	Total phosphorus (µg/L)	<30	10	5; 15	5; 10
	Filterable reactive phosphorus (µg/L)	<10	2	1; 7	1; 4
Other parameters	Salinity (ppt)	no WQO	35.5	33; 39	34.8; 36.5
	Temperature (°C)	no WQO	26.2	23; 32	24.4; 29.5
	pH	6.5-8.5	7.2-7.8 (7.5)	6.7; 7.9	7.2; 7.7
2013 rating		A			

All water quality parameters measured complied with the WQOs: *Water quality at the Elizabeth River estuary monitoring sites is in excellent condition.*

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

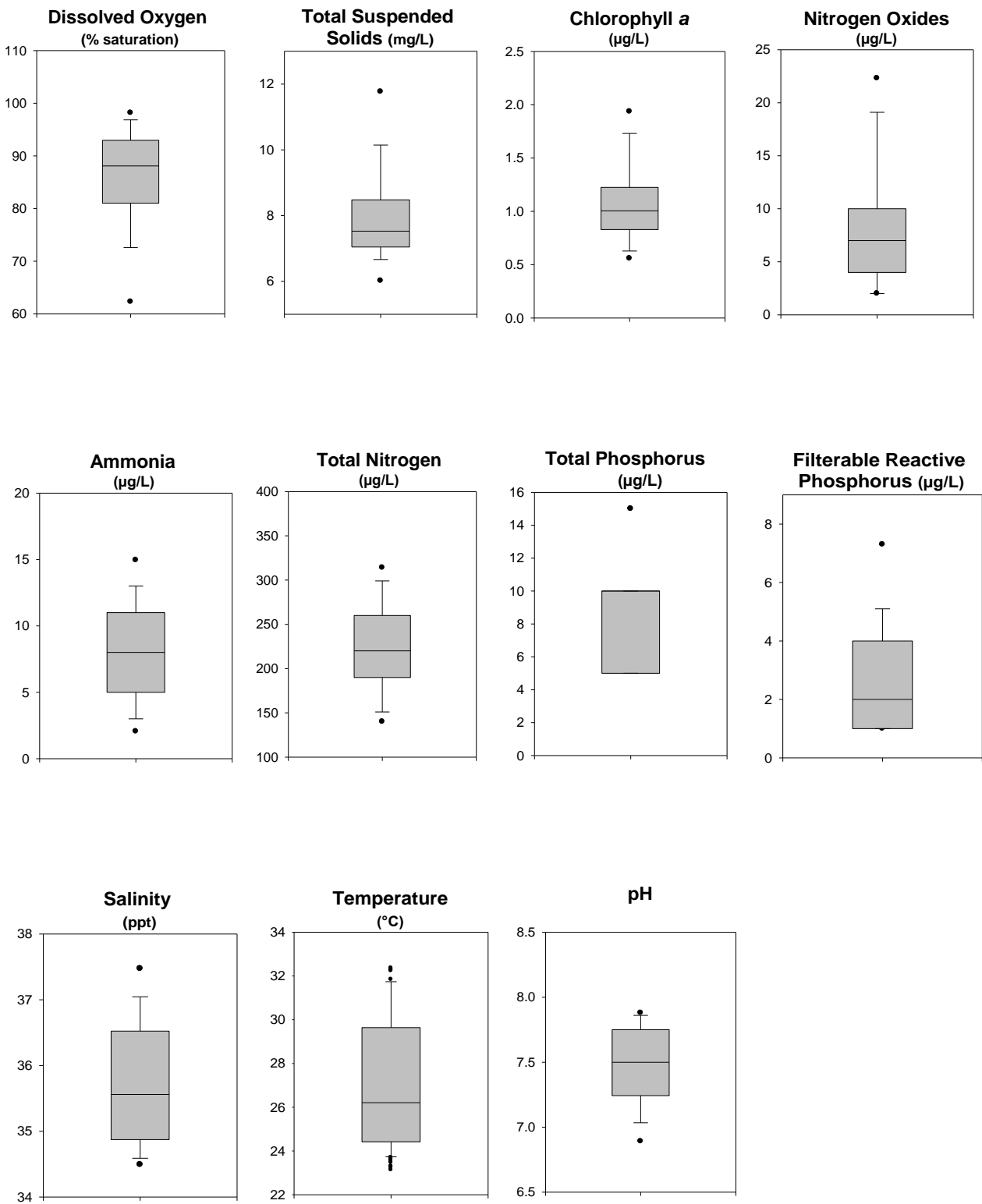


Figure 4 - Water quality indicators measured in Elizabeth River estuary
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

4.2.2. Blackmore River estuary

The estuary is characterised by a relatively long residence time 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.

Figure 5 summarises the results of each water quality parameter measured at the Blackmore River Estuary monitoring sites.

The Table 6 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured.

Table 6 - Summary of water quality parameters measured in Blackmore River estuary

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	80-97 (87)	66; 105	81.7; 94.8
Water clarity	Total suspended solids (mg/L)	<10	9	2; 19	7.4; 10.8
Algae	Chlorophyll a (µg/L)	<4	1	0.2; 20.8	0.6; 2.0
Nutrients	Nitrogen oxides (µg/L)	<20	14	2; 120	9; 23
	Ammonia (µg/L)	<20	11	2; 55	8; 15
	Total nitrogen (µg/L)	<300	230	50; 700	180; 290
	Total phosphorus (µg/L)	<30	10	1; 195	10; 15
	Filterable reactive phosphorus (µg/L)	<10	5	1; 36	3; 8
Other parameters	Salinity (ppt)	no WQO	34.8	18; 38	33.4; 35.9
	Temperature (°C)	no WQO	27.0	23; 33	24.4; 30.3
	pH	6.5-8.5	7.4-7.8 (7.6)	6.0; 8.0	7.4; 7.7
2013 rating		A			

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

The lowest pH values were measured in upper parts of the area.

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.

Total suspended solids and chlorophyll a data had generally lower values in the dry season months; and chlorophyll a measured was more variable in the wet season.

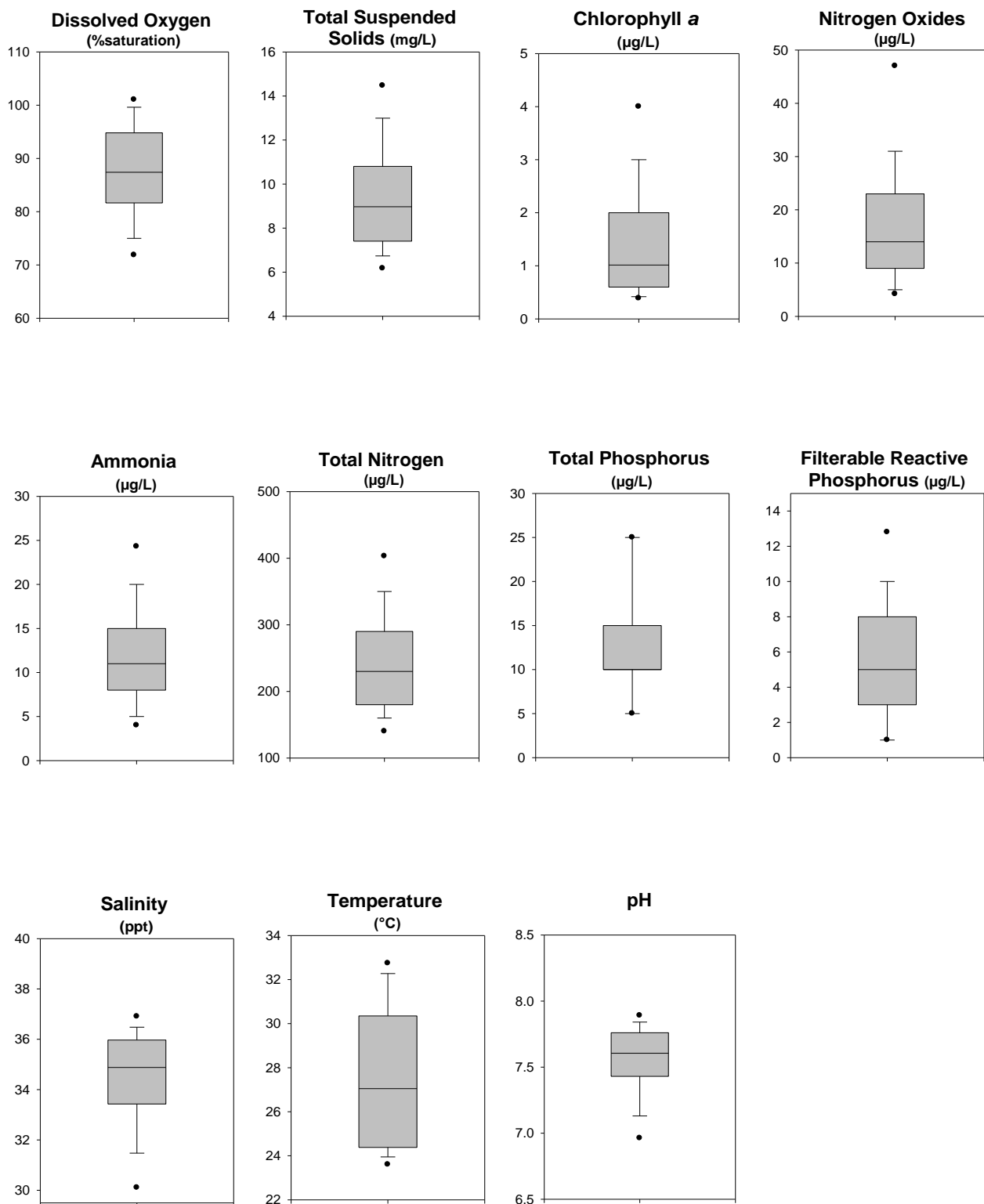


Figure 5 - Water quality indicators measured in Blackmore River estuary
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

4.2.3. West Arm

The Arm is characterized by an extensive mangrove habitat, inter-tidal mudflats and large areas that are exposed on spring tides.

West Arm is estimated to receive minimal pollution and is considered as ‘reference’ in Darwin Harbour.

The Figure 6 summarises the results of each water quality parameter measured.

The Table 7 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured.

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

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	82-94 (88)	75; 113	82; 93
Water clarity	Total suspended solids (mg/L)	<10	8.3	7; 9	7.4; 8.9
Algae	Chlorophyll <i>a</i> (µg/L)	<4	0.6	0.2; 1.8	0.4; 0.9
Nutrients	Nitrogen oxides (µg/L)	<20	8	4; 33	6; 15
	Ammonia (µg/L)	<20	12.5	3; 22	7; 14
	Total nitrogen (µg/L)	<300	180	120; 460	160; 210
	Total phosphorus (µg/L)	<30	10	5; 20	5; 10
	Filterable reactive phosphorus (µg/L)	<10	3	1; 6	1; 4
Other parameters	Salinity (ppt)	no WQO	35.5	25; 37	34.9; 35.8
	Temperature (°C)	no WQO	26.0	24; 29	25.1; 27.9
	pH	6.5-8.5	7.6-7.9 (7.7)	7.3; 8.1	7.6; 7.8
2013 rating		A			

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

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

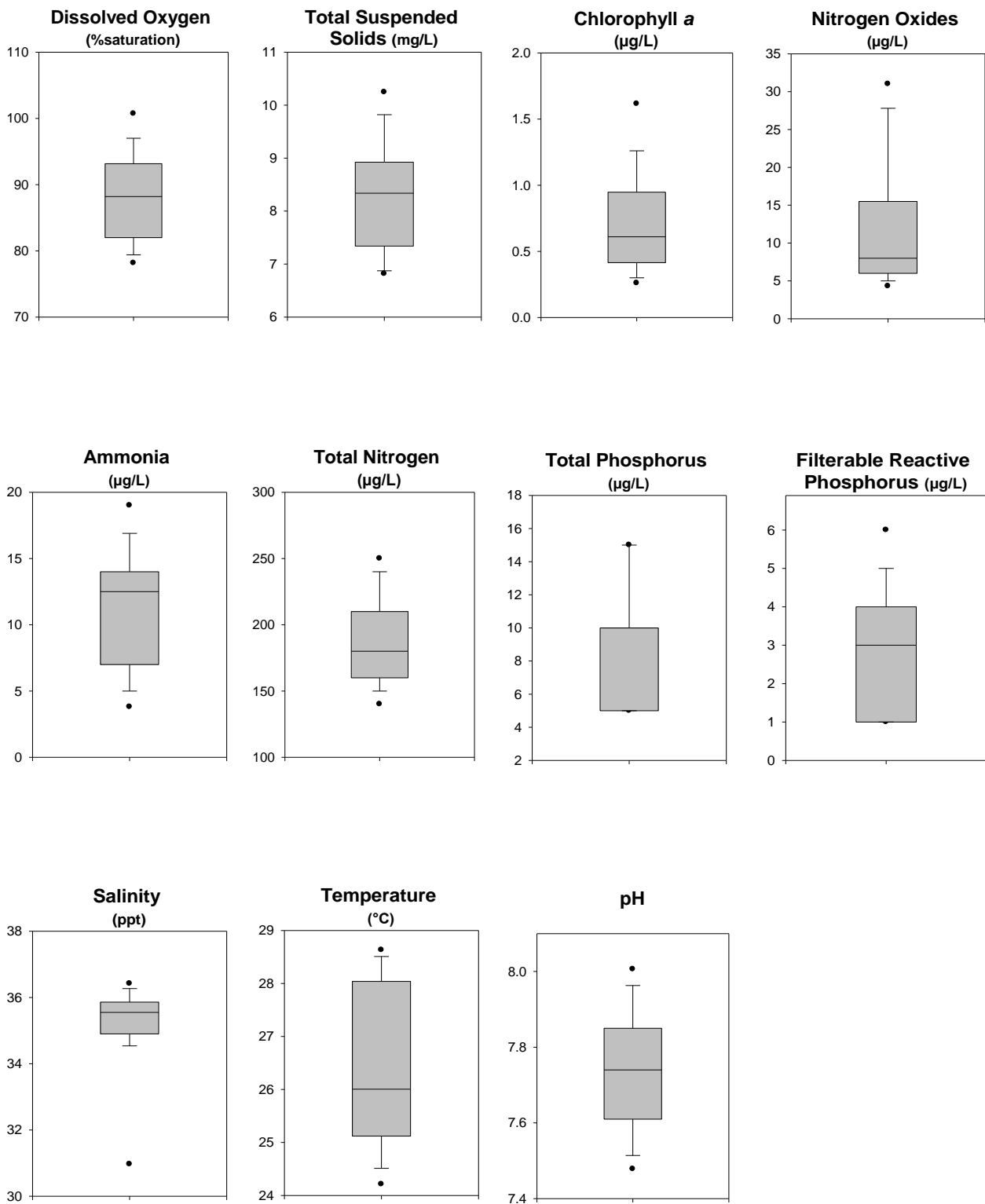


Figure 6 - Water quality indicators measured in West Arm
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

4.2.4. East Arm

A relatively large part of the catchment of East Arm has been urbanised, and includes the East Arm wharf and industrial areas.

East Arm receives treated wastewater discharge to Blessers creek. During the wet season high sediment, nutrient and other pollutant loads are received from urbanised areas. Sediment monitoring has shown there is minor impact or urban land-use, and overall low metal and nutrient concentrations in the sediments (Munksgaard et al. 2013).

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

The Table 8 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured.

Table 8 - Summary of water quality parameters measured in East Arm

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	72-95 (89)	23; 112	77; 95
Water clarity	Total suspended solids (mg/L)	<10	8	1; 41	6; 10
Algae	Chlorophyll <i>a</i> (µg/L)	<4	1.8	0.3; 530	0.8; 4.8
Nutrients	Nitrogen oxides (µg/L)	<20	8	4; 101	8; 20
	Ammonia (µg/L)	<20	8	1; 4088	5; 15
	Total nitrogen (µg/L)	<300	280	60; 6920	170; 490
	Total phosphorus (µg/L)	<30	26	5; 1070	10; 43
	Filterable reactive phosphorus (µg/L)	<10	6	1; 782	3; 15
Other parameters	Salinity (ppt)	no WQO	34.9	13; 37	33.3; 35.9
	Temperature (°C)	no WQO	29.2	23; 33	25.3; 30.6
	pH	6.5-8.5	7.6-7.9 (7.8)	6.4; 8.1	7.7; 7.8
2013 rating		B			

One water quality parameter (dissolved oxygen) 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.

The highest values of total nitrogen, total phosphorus and filterable reactive phosphorus were generally measured in the upper parts of Blessers Creek.

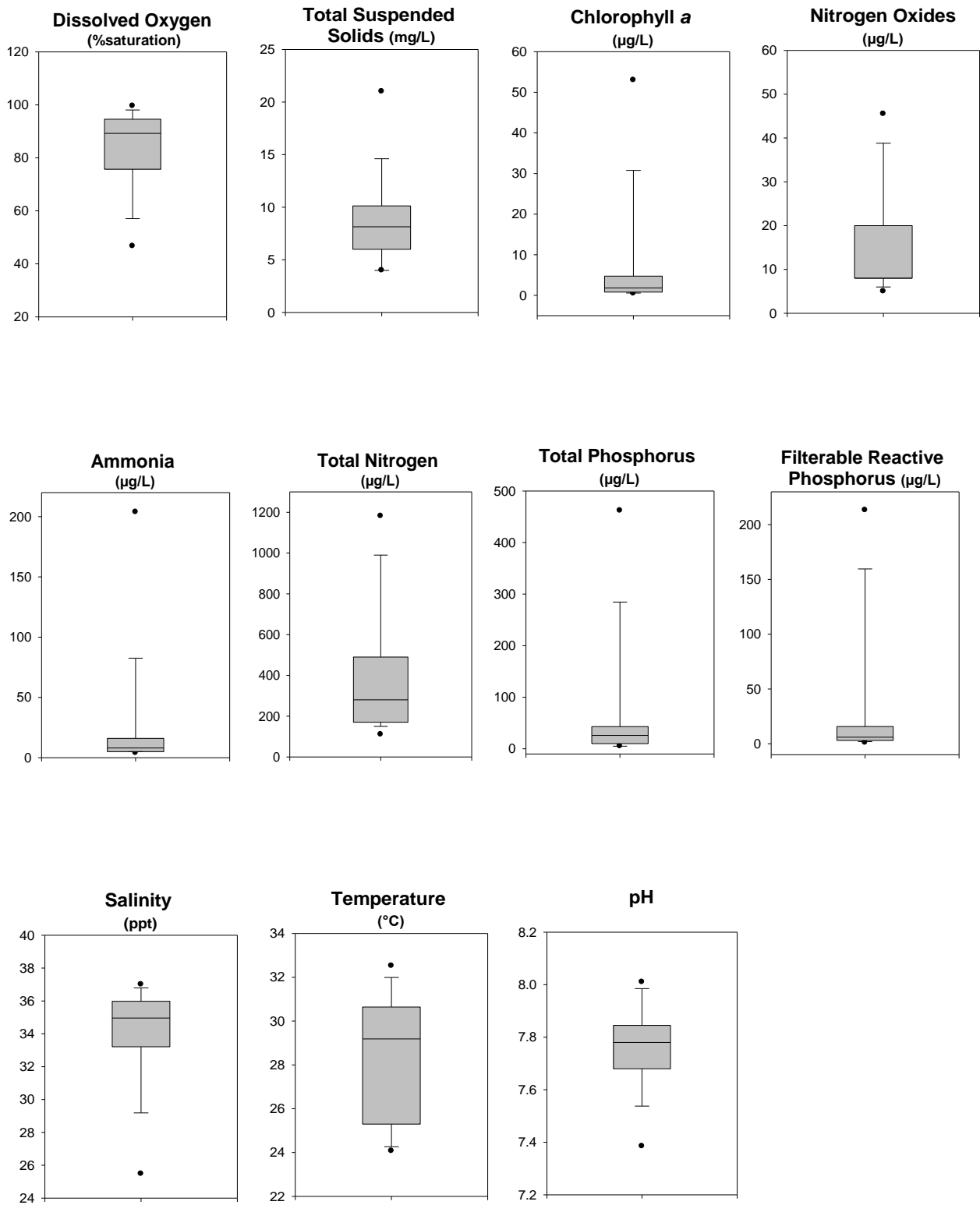


Figure 7 - Water quality indicators measured in East Arm
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

4.2.5. Middle Harbour

The eastern part of Middle harbour receives stormwater runoff from Darwin's urban area.

The Figure 8 summarises the results of every water quality parameter measured at the Middle Harbour monitoring sites.

The Table 9 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured.

Table 9 - Summary of water quality parameters measured in Middle Harbour

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	91-104 (100)	87; 114	93; 103
Water clarity	Total suspended solids (mg/L)	<10	6.9	5.8; 11.2	6.4; 7.8
Algae	Chlorophyll <i>a</i> (µg/L)	<4	0.4	0.2; 0.9	0.3; 0.5
Nutrients	Nitrogen oxides (µg/L)	<20	10	2; 53	6; 23
	Ammonia (µg/L)	<20	8	2; 20	4; 13
	Total nitrogen (µg/L)	<300	165	70; 470	150; 180
	Total phosphorus (µg/L)	<30	5	5; 20	5; 10
	Filterable reactive phosphorus (µg/L)	<10	3	1; 7	2; 4
Other parameters	Salinity (ppt)	no WQO	35.5	26; 36	34.7; 35.6
	Temperature (°C)	no WQO	27.3	23; 32	24.8; 28.2
	pH	6.5-8.5	7.7-8.1 (7.9)	6.6; 8.2	7.7; 8.0
2013 rating		B			

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

No specific spatial or temporal trend has been identified in Middle Harbour for the parameters studied over the last year.

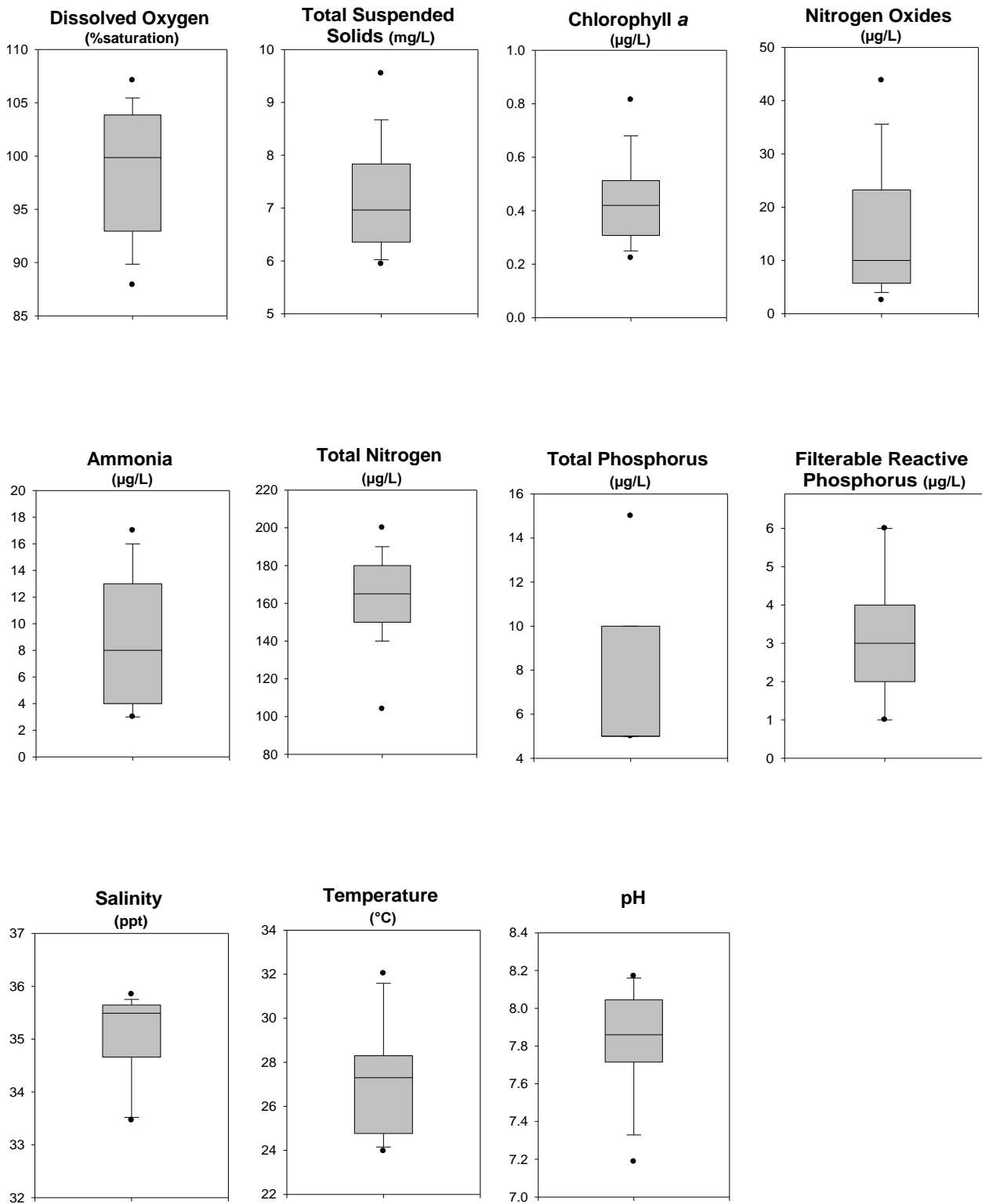


Figure 8 - Water quality indicators measured in Middle Harbour
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

4.2.6. Outer Harbour

The area is characterized by a well-mixed system open to coastal exchange

Effluent from the Ludmilla Wastewater Treatment Plant is discharged to this part of the Harbour.

The Figure 9 summarises the results of water quality parameters measured at Outer Harbour monitoring sites.

The Table 10 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured.

Table 10 - Summary of water quality parameters measured in Outer Harbour

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	97-105 (101)	81; 115	98; 103
Water clarity	Total suspended solids (mg/L)	<10	5.5	1; 25	3; 7
Algae	Chlorophyll a (µg/L)	<4	0.5	0.2; 4.9	0.4; 0.9
Nutrients	Nitrogen oxides (µg/L)	<20	8	1; 33	8.0; 9.5
	Ammonia (µg/L)	<20	5	2; 7588	5; 9
	Total nitrogen (µg/L)	<300	230	60; 10900	160; 422
	Total phosphorus (µg/L)	<30	5	5; 190	5; 10
	Filterable reactive phosphorus (µg/L)	<10	6	1; 1020	3; 11
Other parameters	Salinity (ppt)	no WQO	35.2	24; 36	34.7; 35.6
	Temperature (°C)	no WQO	28.9	23; 33	26.5; 31.2
	pH	6.5-8.5	8.0-8.2 (8.1)	7.3; 8.8	8.0; 8.1
2013 rating		B			

One water quality parameter (dissolved oxygen) measured did not comply with the WQOs: *Water quality at the Outer Harbour monitoring sites 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.

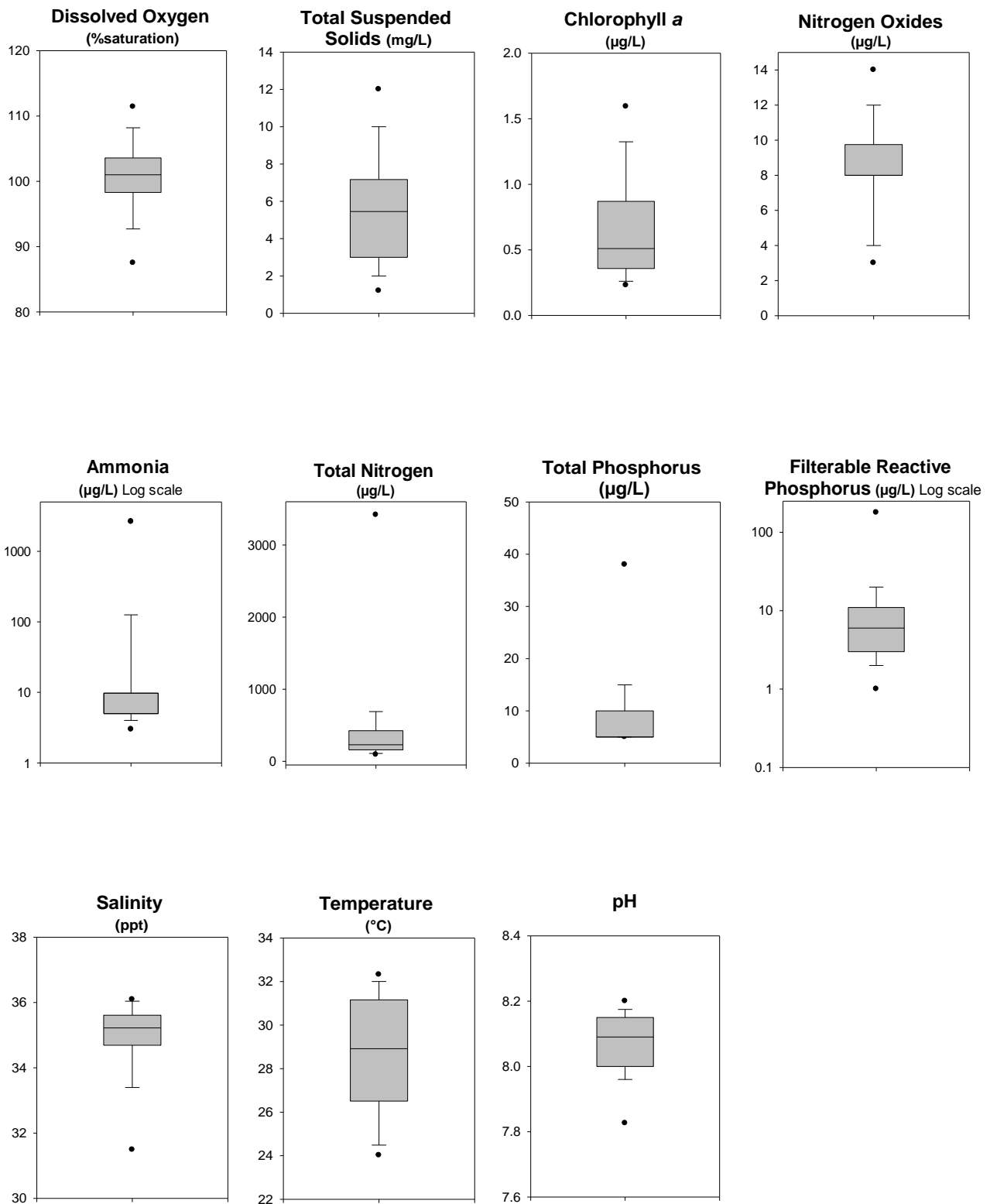


Figure 9- Water quality indicators measured in Outer Harbour
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

4.2.7. Shoal Bay

The area is characterised by shallow embayment waters and sandbars.

Shoal Bay receives sediments and nutrient loads from the Howard River catchment during the wet season.

The Figure 10 summarises the results of every water quality parameter measured at the Shoal Bay monitoring sites.

The Table 11 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured.

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

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	97-103 (98)	87; 108	98; 102
Water clarity	Total suspended solids (mg/L)	<10	8.9	6.8; 47.4	7.3; 10.4
Algae	Chlorophyll <i>a</i> (µg/L)	<4	0.3	0.2; 10.2	0.3; 0.8
Nutrients	Nitrogen oxides (µg/L)	<20	8.5	6; 13	7; 9
	Ammonia (µg/L)	<20	7	5; 23	7; 15
	Total nitrogen (µg/L)	<300	165	60; 270	117; 192
	Total phosphorus (µg/L)	<30	10	5; 25	5; 15
	Filterable reactive phosphorus (µg/L)	<10	5	1; 8	4; 6
Other parameters	Salinity (ppt)	no WQO	34.2	30; 35	30.9; 34.9
	Temperature (°C)	no WQO	25.9	24; 27	25.2; 26.8
	pH	6.5-8.5	7.7- 8.12 (8.0)	7.6; 8.1	7.7; 8.1
2013 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.*

No specific spatial or temporal trend has been identified in Shoal bay for the parameters studied over the last year.

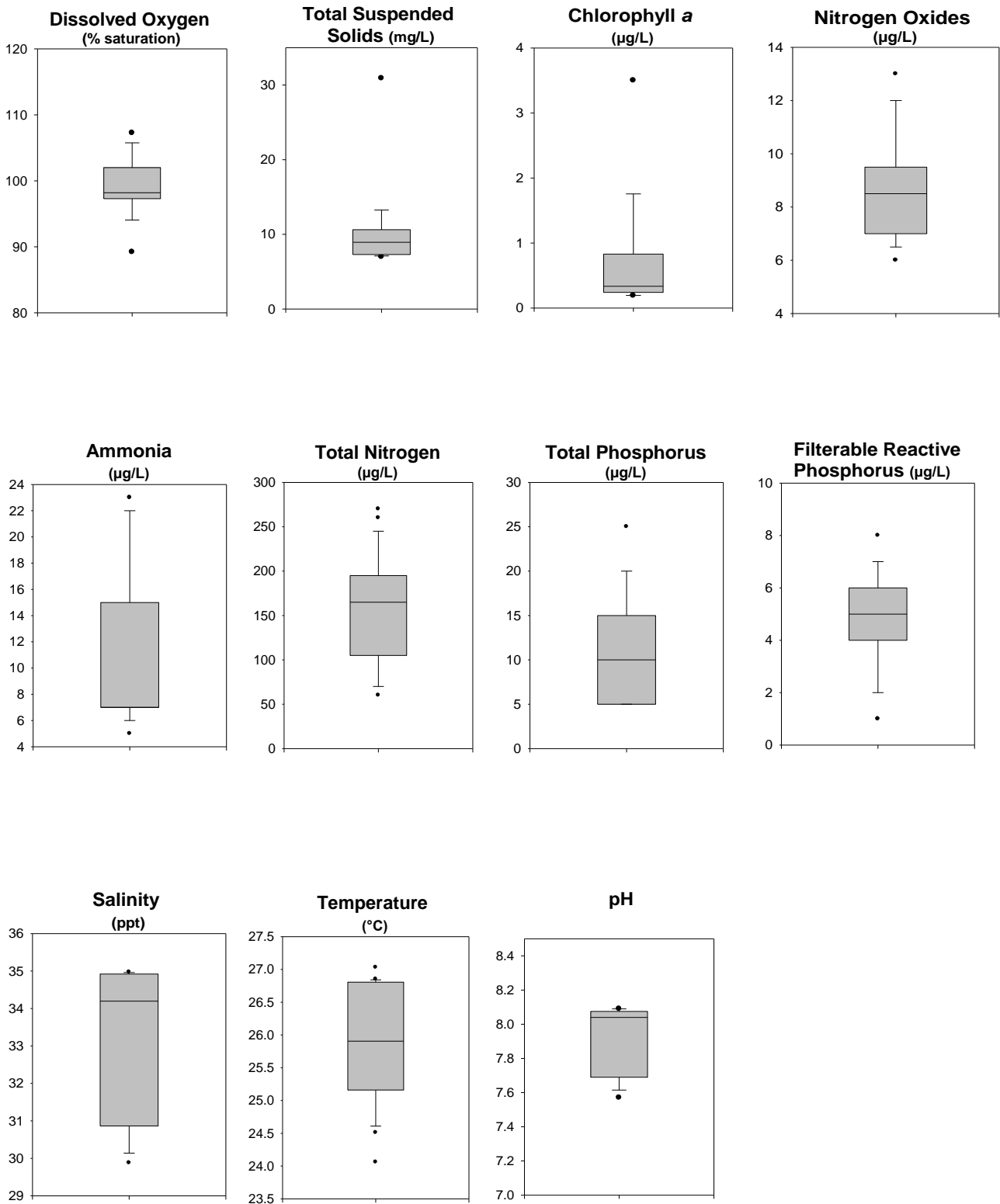


Figure 10 - Water quality indicators measured in Shoal Bay
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

4.2.8. Myrmidon Creek

Myrmidon Creek receives discharge from a sewage treatment plant and pollutant loads from urban areas during the wet season.

The Figure 11 summarises the results of every water quality parameter measured at the Myrmidon Creek monitoring sites.

The Table 12 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured.

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

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	77-94 (89)	49; 109	81; 93
Water clarity	Total suspended solids (mg/L)	<10	8	2; 25	5; 10
Algae	Chlorophyll <i>a</i> (µg/L)	<4	3.3	0.8; 80	2.0; 4.5
Nutrients	Nitrogen oxides (µg/L)	<20	10	6; 138	8; 22
	Ammonia (µg/L)	<20	15	5; 5052	5; 151
	Total nitrogen (µg/L)	<300	400	60; 8890	260; 640
	Total phosphorus (µg/L)	<30	35	5; 2020	24; 87
	Filterable reactive phosphorus (µg/L)	<10	7	3; 1850	4; 22
Other parameters	Salinity (ppt)	no WQO	34.8	25; 38	32.5; 35.8
	Temperature (°C)	no WQO	30.0	24; 33	25.4; 31.4
	pH	6.5-8.5	7.7-7.9 (7.8)	7.5; 8.1	7.7; 7.9
2013 rating		C			

Two water quality parameters (dissolved oxygen and nutrients) measured did not comply with the WQOs: *Water quality at the Myrmidon Creek monitoring sites is in good condition.*

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

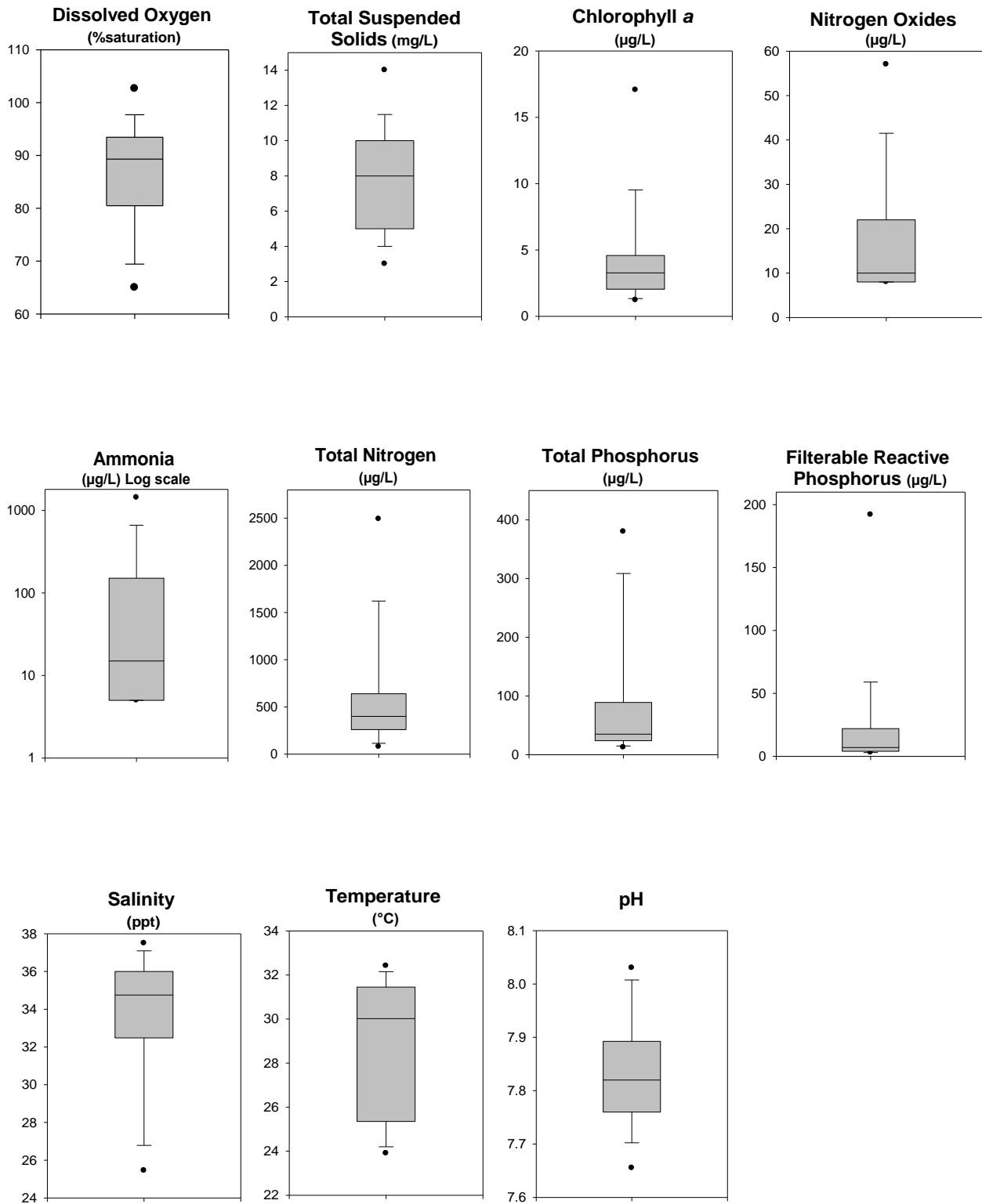


Figure 11 - Water quality indicators measured in Myrmidon Creek
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

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

The Figure 12 summarises the results of every water quality parameter measured at the Myrmidon Creek monitoring sites.

The Table 13 reports median values and 20th-80th percentiles (compliance), minimum and maximum values and 25th and 75th percentiles of the data measured in Buffalo Creek.

Table 13 - Summary of water quality parameters measured in Buffalo Creek

Parameters and units		Water Quality Objectives	Median	Minimum; Maximum values	25th; 75th percentiles
Dissolved oxygen	Dissolved oxygen (% saturation)	80-100	46-132 (102)	1; 230	54; 113
Water clarity	Total suspended solids (mg/L)	<10	25	1; 168	10; 42
Algae	Chlorophyll <i>a</i> (µg/L)	<4	66.7	0.4; 931.0	4.7; 220.7
Nutrients	Nitrogen oxides (µg/L)	<20	31	6; 548	10; 79
	Ammonia (µg/L)	<20	857	5; 14920	5; 2619
	Total nitrogen (µg/L)	<300	2275	60; 27800	370; 6402
	Total phosphorus (µg/L)	<30	594	8; 6000	43; 1390
	Filterable reactive phosphorus (µg/L)	<10	208	3; 1650	13; 668
Other parameters	Salinity (ppt)	no WQO	31.2	1.3; 37.5	20.6; 35.3
	Temperature (°C)	no WQO	30.2	22; 35	26.0; 31.7
	pH	6.5-8.5	7.6-8.2 (7.9)	6.8; 8.4	7.6; 8.2
2013 rating		E			

All four water quality parameters measured (dissolved oxygen, water clarity, algae and nutrients) did not comply with the WQOs: *Water quality at the Buffalo Creek monitoring sites is in very 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.

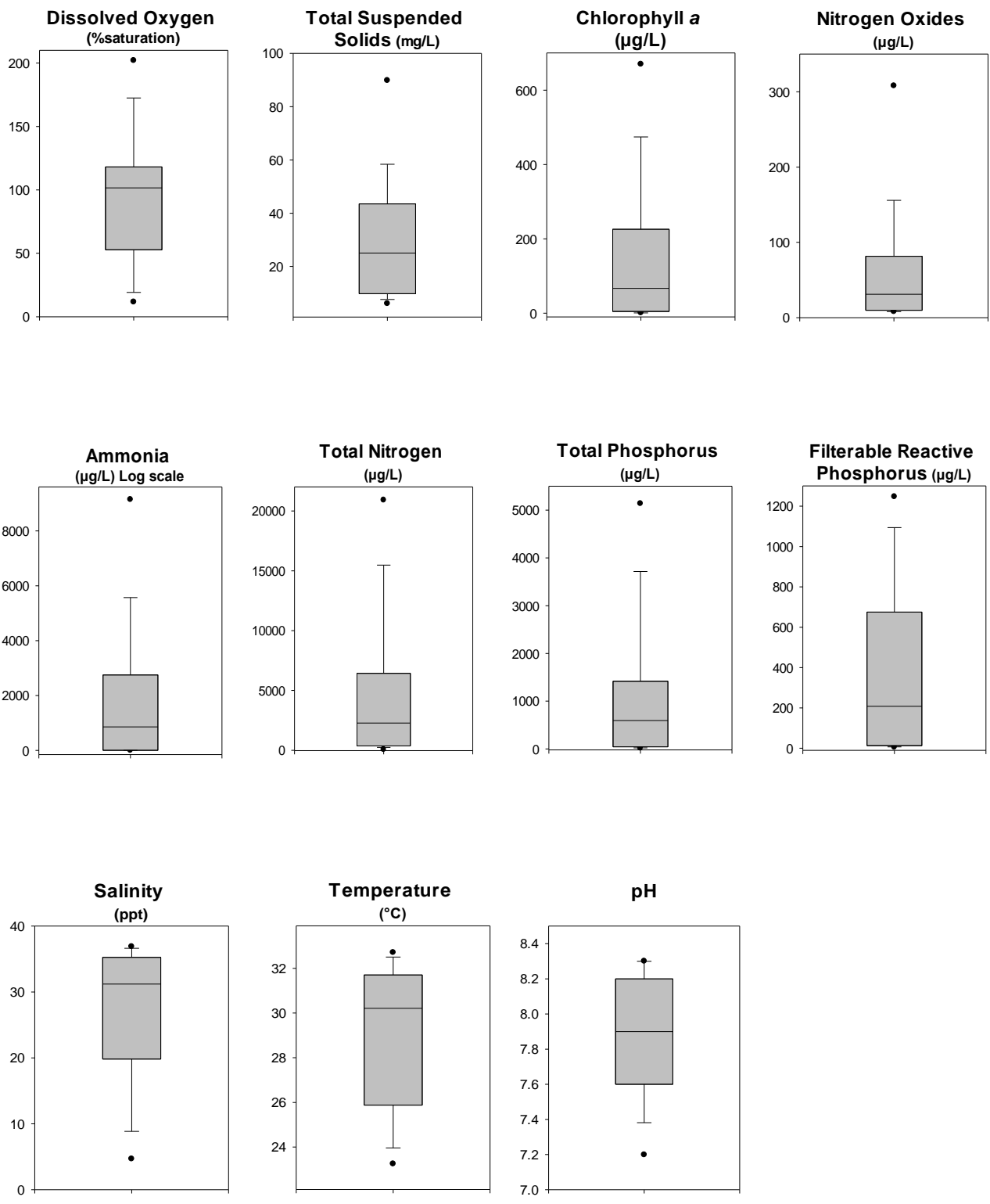


Figure 5 - Water quality indicators measured in Buffalo Creek
 Box Plots show 5th, 10th, 25th, Median, 75th, 90th and 95th percentiles

5. Conclusion

For the reporting period (mid-2012 to October 2013) , 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 and Blackmore River estuary were graded A, excellent water quality. Shoal Bay, the Outer Harbour, East Arm and Middle Harbour were graded B, very good water quality. Myrmidon Creek and Buffalo Creek were respectively graded C (good) and E (very poor). No waters were graded D (poor).

There has been no major change in the water quality of Darwin Harbour since 2009.

The potential sources of pollution to the waterways of Darwin Harbour include sediments, nutrients and 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 discharges is clear with the highest values for total nitrogen, total phosphorus and filterable reactive phosphorus measured at sites adjacent to respective outfalls, and in Buffalo Creek.

Seasonal variations (dry/wet season) and spatial variations (upper/outer sites) have been identified throughout the year in the Darwin Harbour region and these environmental factors can affect water quality.

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.

6. References

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

Munksgaard, N.C. Kaestli, M. Gibb, K. Dostine, P and Townsend, S. (2013) Darwin Harbour 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.

Appendix 1

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.

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

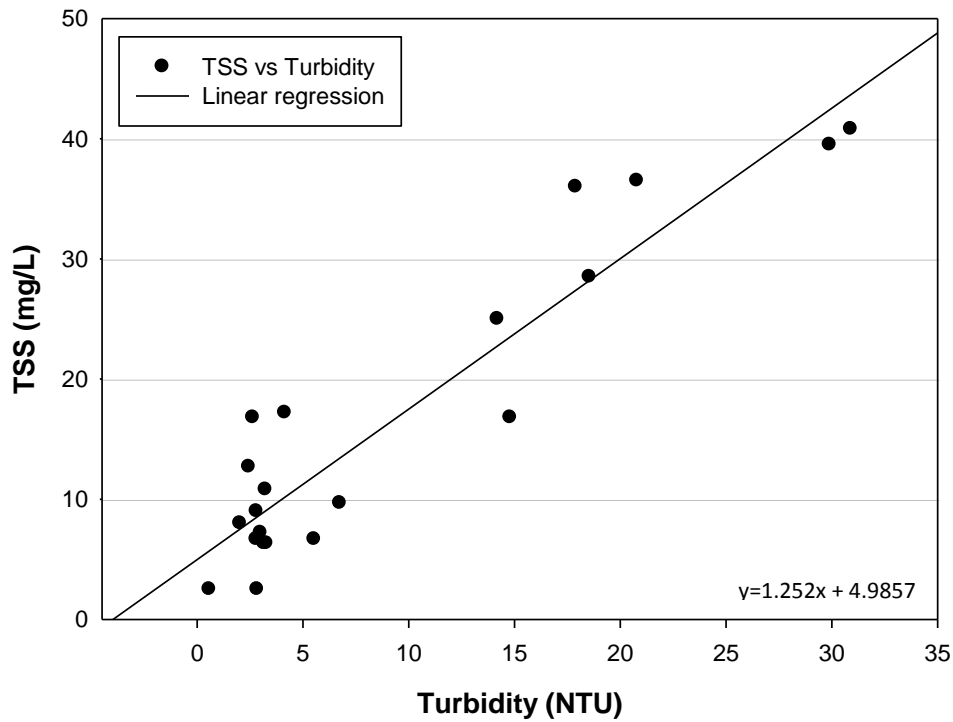


Figure 13 - Relationship between total suspended solids and turbidity in Darwin Harbour, 2012 (n=21)

