GOVERNMENT OF WESTERN AUSTRALIA

Department of **Water and Environmental Regulation**

Department of **Primary Industries and Regional Development**

REGIONAL ESTUARIES INITIATIVE

Estuary Condition Report: Oyster Harbour 2016/17

Regional Estuaries Initiative

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Oyster Harbour 2016/17

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Cover photograph: Oyster Harbour (Simon Neville, 2010): The city of Albany is on the left of image, Kalgan River mouth to the top right and King River on the top left of image.

This publication is available at our website https://rei.dwer.wa.gov.au/ or for those with special needs it can be made available in alternative formats such as audio, large print, or Braille.

Contents

Figures

Tables

1. Summary

Oyster Harbour is permanently open to the Southern Ocean, and the water quality status of the estuary from October 2016 to September 2017 reflects this, showing a predominantly marine system with some influence from catchment inflows.

The water was well-mixed from surface to bottom throughout the year and without advanced eutrophic symptoms such as low dissolved oxygen or nuisance algal blooms.

Nutrient concentrations were generally below the Australian and New Zealand Environment Conservation Council (ANZECC) guidelines with a few exceptions. Filtered reactive phosphorus was exceeded in the northern most sites on a few occasions associated with catchment inflows. The dominant nitrogen nutrient form was total organic nitrogen in all samples.

Chlorophyll *a* concentrations were at times equal to or above the ANZECC guideline. A summary of historical data has indicated that there was a decrease in chlorophyll *a* means from 1978–79 to 1987–88. For the current data, the 2016–17 means were similar in magnitude to the 1978-79 data.

The highest concentrations, up to 10 micrograms per litre (μgL^{-1}), were observed in the northern-most basin site. This is high compared with ocean chlorophyll *a* concentrations of approximately one μgL^{-1}.

Phytoplankton densities and species identification are not currently monitored at the northern sites and it is recommended that the monitoring program be adjusted to include phytoplankton surveillance in this area.

Phytoplankton cell densities were low compared with all other Regional Estuaries Initiative (REI) estuaries. Diatoms were the dominant group in the estuary. A few instances of a harmful dinoflagellate species (e.g. *Dinophysis acuminata*) were detected at all three phytoplankton monitoring sites, generally at low densities.

D. acuminata is associated with Diarrhoretic Shellfish Poisoning caused by the consumption of contaminated shellfish. The guideline value for *D. acuminata* is one cell per millilitre (mL^{-1}) and this was met or exceeded on four occasions. The Department of Health administers a shellfish toxin management program for the shellfish farming operations (mussels and oysters). There are currently two licences operating in the harbour. For the current period, there were no exceedances of guidelines due to harmful phytoplankton.

The most recent maps of seagrass cover in Oyster Harbour, from 2006, indicate that approximately 35 per cent of the sediment had seagrass cover, dominated by *Posidonia australis* and *Posidonia sinuosa*.

Whilst Oyster Harbour has relatively good water quality status compared with some other South West estuaries, it is still a system recovering from substantial seagrass loss due to

nutrient enrichment in the 1900s and loss of shellfish abundance due to extensive dredge fishing in the 1800s.

The data suggest it is still vulnerable to adverse impacts from catchment inflows, however at the current flow volumes, the exchange with ocean waters is maintaining the estuary's good water quality status. Analysis of the catchment monitoring program in 2018 will help inform the degree of catchment pressures.

It is acknowledged that the water quality indicators, monitored monthly as described in this report, constitute one part of the estuary ecosystem. Other ecosystem elements such as the seagrass, fish health and abundance, and shellfish reef are other important elements but not part of the REI monitoring program.

Regular monitoring and reporting of the condition of Oyster Harbour, will continue for the duration of the Regional Estuaries Initiative (2016-2019) and information will be available on the REI website (rei.dwer.wa.gov.au).

2. Introduction

A comprehensive water quality monitoring program in Oyster Harbour and its catchment was commenced in October 2016 under the Regional Estuaries Initiative (REI).

The monitoring program is designed to provide information on the condition of the estuary, primarily in terms of water quality variables as an indicator of overall estuary health. The water quality monitoring program provides potential human and environmental health alerts if toxic phytoplankton are detected at elevated levels and informs the management of fish kill events.

Long-term continuous monitoring is also essential to assess the effectiveness of management actions, and/or the impact of both natural variability and anthropogenic changes, such as climate change or significant land use changes.

The purpose of this annual estuary condition report, the first since the inception of the REI monitoring program, is to describe the water quality condition of Oyster Harbour for the period 1 October 2016 to 30 September 2017.

It is one of a series of reports, covering all REI estuaries (Peel-Harvey Estuary, Leschenault Estuary, Vasse-Wonnerup Estuary, Hardy Inlet, Wilson Inlet and Oyster Harbour) (Figure 1). It is anticipated that condition reports for all estuaries will be produced annually during the REI program. Community-friendly summaries of these technical reports will also be developed for ease of reference.

The current reporting period, from October 2016 to September 2017, is so because the REI sampling commenced in October 2016. The reporting period of subsequent annual condition reports may be adjusted to coordinate effectively with the catchment reporting program and other REI communication products such as community presentations.

The concurrent catchment monitoring program will be reported as a complimentary catchment report in the first half of 2018. Catchment data will be reported on the calendar year to follow the complete hydrological cycle. The catchment reports will provide information on the flows and delivery of nutrients to the estuary from the broader catchment.

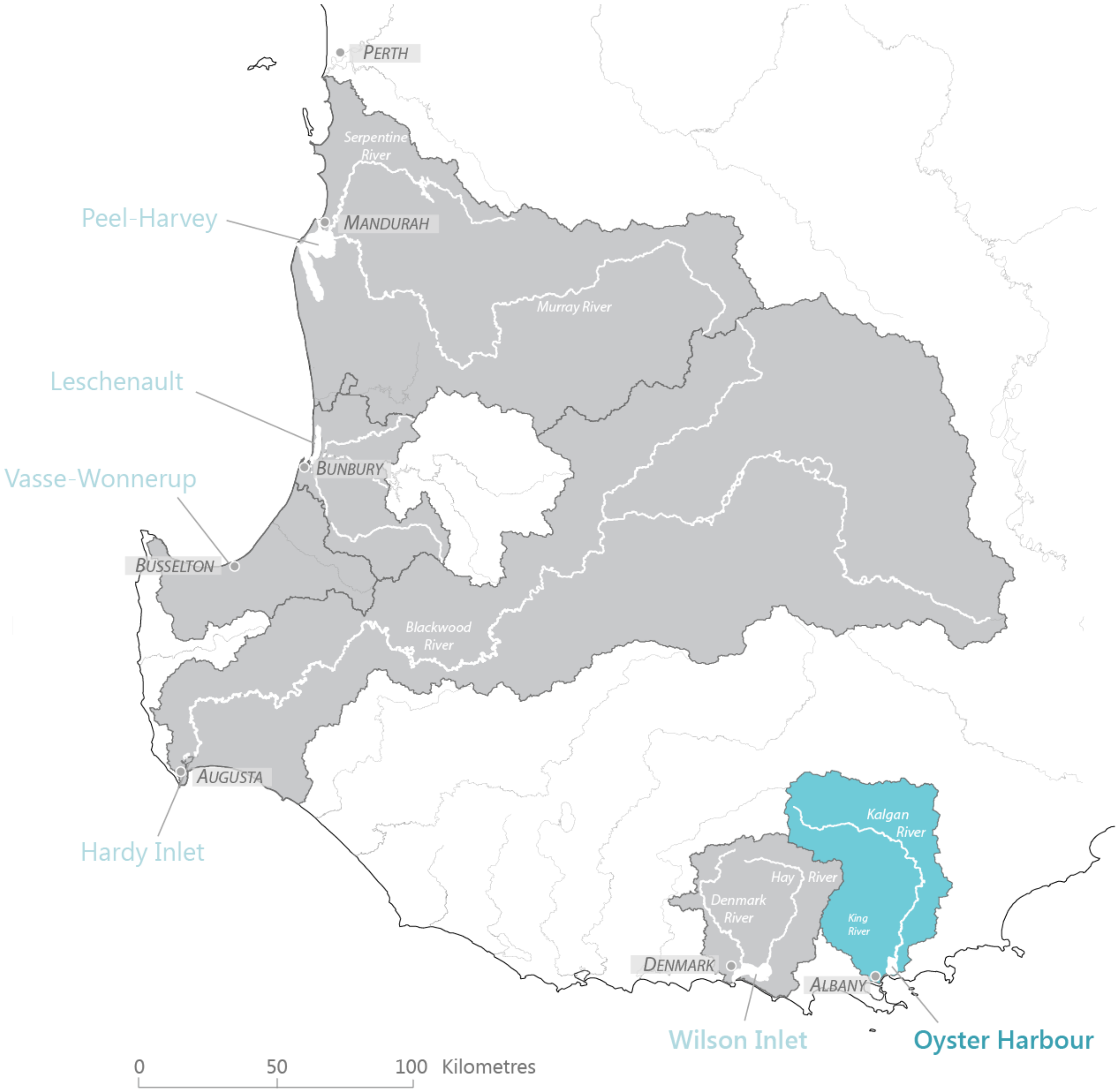

Figure 1 *Oyster Harbour catchment and catchment boundaries of the other Regional Estuaries Initiative estuaries*

Oyster Harbour, adjacent to the city of Albany, is highly valued for its role in tourism, commercial and recreational fishing, and oyster and mussel farming.

The estuary is located on the south coast and its catchment extends north to the Porongurup and Stirling ranges. The major inflows are the Kalgan and King rivers.

The estuary is relatively small, around 16 km^2, compared to the catchment, 3000 km^2. The estuary is permanently open to King George Sound and is the only south coast estuary without a sandbar. The entrance channel at Emu Point is five to six metres deep.

Approximately 70 per cent of the catchment has been cleared (EPA, 1990a). The Kalgan and King rivers are tidal for approximately nine kilometres and seven kilometres respectively (EPA, 1990a).

The ecosystem, considered healthy in 1962, has since suffered from deterioration in water quality culminating in significant seagrass loss in the 1990s (EPA, 1990b). It has been on a recovery pathway since then, following activities in the catchment coordinated by the Oyster Harbour Catchment Group (OHCG). The estuary has also been the site of seagrass restoration efforts through transplantation of *Posidonia australis* (Cambridge et al, 2002).

The native Angasi oyster (*Ostrea angasi*) was abundant in Oyster Harbour in the late 1700s and by the late 1800s suffered losses of the order of 90 per cent due to dredge fishing (Warnock and Cook, 2015).

Oyster Harbour is the site for an oyster reef restoration project by The Nature Conservancy (SCNRM, 2017). It is anticipated that shellfish reef restoration will benefit fish abundance and improve water quality.

The goal of the REI with respect to Oyster Harbour is to continue to support the recovery pathway; specifically it has or will:

- Establish a routine monitoring program for the estuary and its catchment.
- Facilitate engagement and communication of condition and management actions to all stakeholders.
- Support the Oyster Harbour Catchment Group (OHCG) activities – restore stream function, move stock away from waterways and improve water quality by implementing river action plans.
- Improve fertiliser management practices in the catchment in partnership with the Department of Primary Industries and Regional Development, farmers, industry and the OHCG, to reduce nutrient runoff from farms while supporting farm productivity.
- Support the restoration of Yakamia Creek, in partnership with the City of Albany and South Coast Natural Resource Management.

3. Measuring estuary condition

Estuary condition is typically measured by a suite of biological, chemical and physical indicators.

In the South West of Western Australia the major threat to water quality of estuaries is eutrophication.

Eutrophication is a deterioration of water quality caused by the excessive input of nutrients. It leads to overgrowth of aquatic plants, macroalgae and/or phytoplankton, and the ultimate decomposition of this plant growth leads to anoxia (an absence or deficiency of oxygen). Both of these effects can contribute to fish deaths and even an ecosystem shift from a healthy macrophyte/seagrass dominated system to a less desirable phytoplankton dominated system (Figure 2).

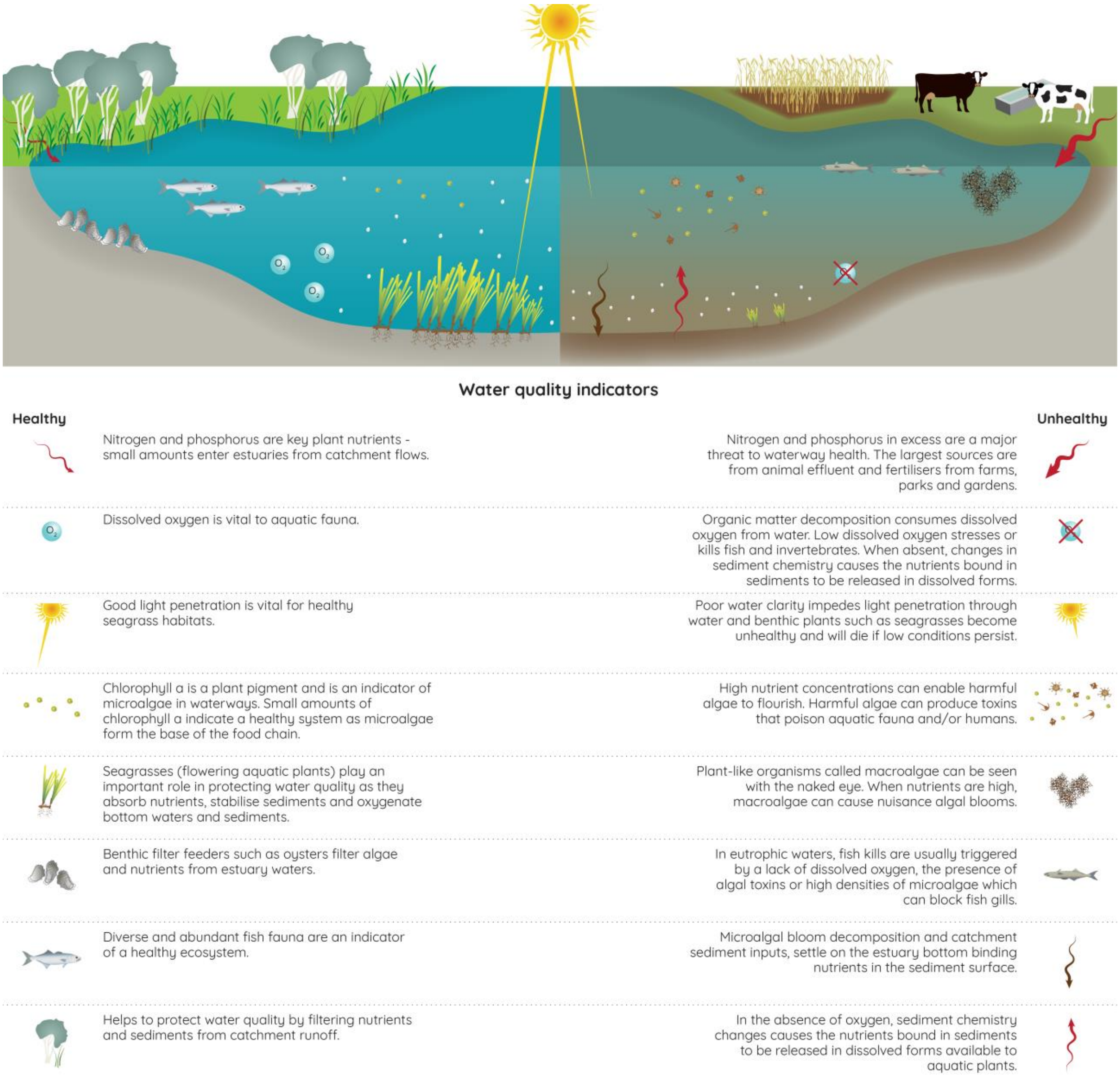

Figure 2 Conditions in a healthy and unhealthy estuary

Our goal in measuring the condition or water quality status of an estuary is to describe the extent to which a system is eutrophic.

Throughout the world a number of consistent indicators are routinely monitored for this purpose. The Regional Estuaries Initiative monitoring program measures a similar set of water quality indicators, and these include the following variables:

- salinity, dissolved oxygen, temperature, pH and turbidity at 0.5 to 1 metre intervals in vertical profile
- Secchi depth
- nitrogen and phosphorus as both total concentrations and their bioavailable components
- chlorophyll *a*
- phytoplankton cell densities and their taxonomic group and species name.

Data are presented as raw data and as means of surface water samples and bottom water samples at each site. Means are also compared with the ANZECC guideline values (ANZECC & ARMCANZ 2000).

The ANZECC water quality guidelines are derived from biological and ecological effects data and through the use of reference data. If data exceed the guideline values then it is considered a trigger for further investigations or management actions both of which are underway in Oyster Harbour. We have used the guideline default values as reference points to compare data over the hydrological cycle and spatially. For each analyte the data are plotted against the default guideline value for comparison and not as a pass or fail test. For a more detailed description of the use of ANZECC guideline values, see Appendix A.

4. The monitoring program

The Oyster Harbour water quality monitoring program measures physical, chemical and biological variables (Table 1) once a month at seven estuary sites (Figure 3).

Profiles of the physical and chemical variables [i.e. temperature, dissolved oxygen, salinity and the scale of acidity (pH)] were taken at 0.5 metre intervals throughout the water column and, in addition, 0.2 metres above the sediment and below the water surface with a sonde (YSI EXO2™).

Water samples were collected at 0.5 metres below the surface, representing the surface layer and at 0.5 metres above the sediment, representing the bottom layer, and analysed by an analytical laboratory for nutrient concentrations [total nitrogen (TN), nitrate and nitrite (total oxidised nitrogen; NO_x), ammonium (NH_3/NH_4), total phosphorus (TP), and filterable reactive phosphorus (FRP)].

Surface samples were also analysed for chlorophyll concentrations.

A list of all variables, the analytical method and limits of reporting are presented in Appendix A.

Phytoplankton species were identified, cell densities determined and chlorophyll concentrations were quantified from integrated samples (surface to 0.5 metres above the sediment) at three sites, i.e. AOH-2, AOH-4 and AOH-12.

Table 1 *Oyster Harbour sampling regime*

Code	AWRC Ref.	Easting	Northing	Max Depth	Dist. from mouth	Salinity, DO, temperature, pH, Secchi	Chlorophyll		Phyto-plankton	TN, NO_x, NH_3/NH4, TP, FRP	
		metres	metres	metres	km	Vertical profile	Surface	Int	Int	Surface	Bottom
AOH–1	6021173	587225	6128386	12	1.6	m	m			m	m
AOH–12	6021260	586093	6128427	1.8	1.8	m	m	m	m	m	m
AOH–2	6021174	588118	6128413	4.9	2	m	m	m	m	m	m
AOH–4	6021176	587133	6130708	5.5	4	m	m	m	m	m	m
AOH–5	6021177	587221	6131995	2.8	5.2	m	m			m	m
AOH–6	6021254	589277	6132168	1.5	6.1	m	m			m	m
KRLB	6021063	586540	6132747	1.3	6.2	m	m			m	m

DO = dissolved oxygen, TN = total nitrogen, NO_x = nitrate + nitrite, NH_3/NH_4 = ammonium, TP = total phosphorus, FRP= filterable reactive phosphorus, Int = integrated, m = monthly

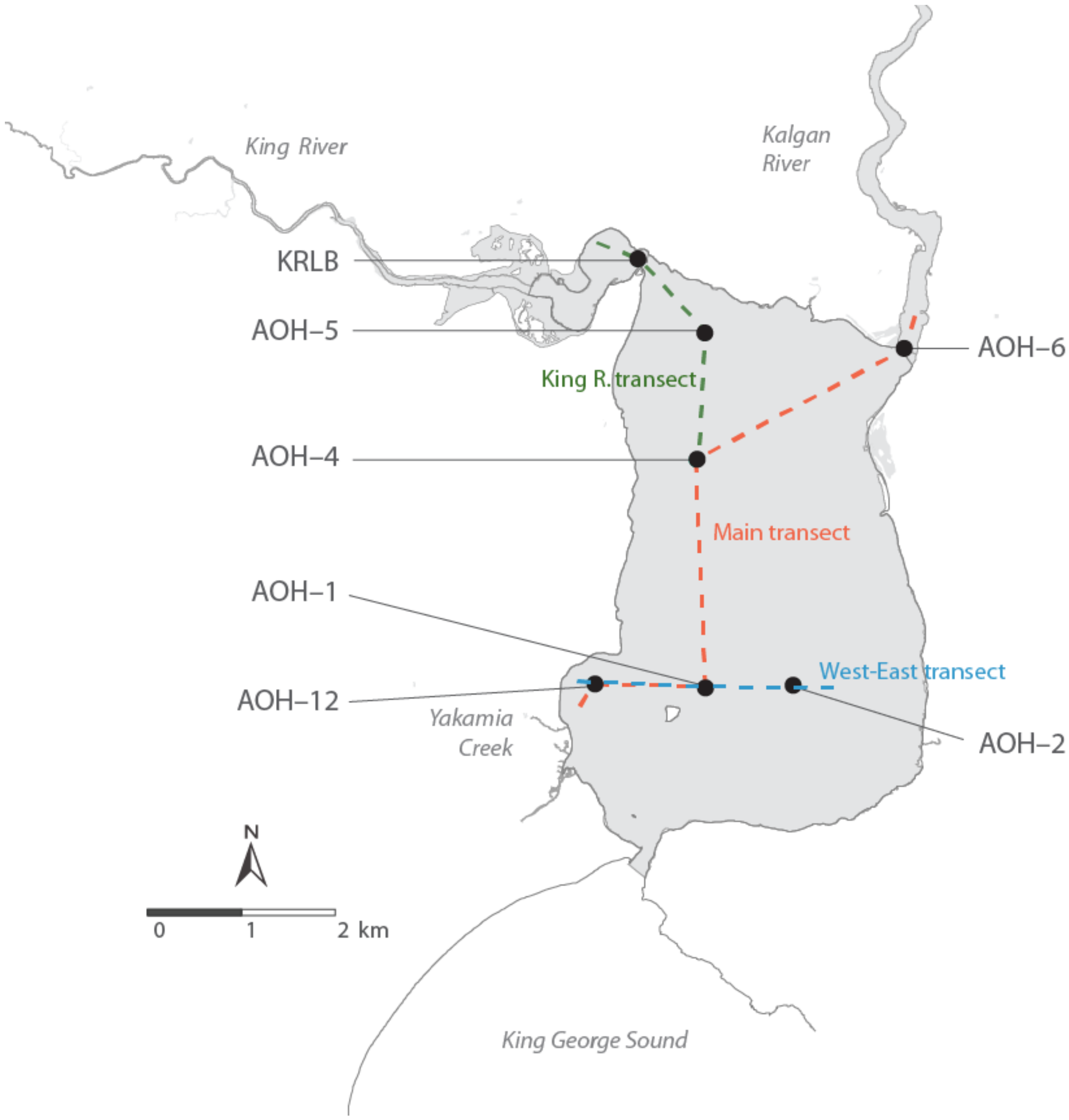

Figure 3 *Oyster Harbour site map with sampling locations*

The transects relate to the physical profiles shown in Section 5.7 and in Appendix B. Albany–Oyster Harbour (AOH), King River Lower Bridge (KRLB).

5. Physical-chemical dynamics

5.1 Salinity

Mean salinity for all sites except AOH–6 (lower Kalgan River), were in the range 32 to 35 parts per thousand (ppt) indicating the estuary is close to marine salinity (35 ppt) (Figure 4).

The surface mean for AOH–6 was 25 ppt with large variation illustrating the influence of freshwater inflows. For all other sites the difference between surface and bottom water means was small (1 to 3 ppt) also indicating that the water column is generally well-mixed and without any persistent stratification events.

The time series of physical data in surface and bottom waters for individual sites are shown in Appendix C.

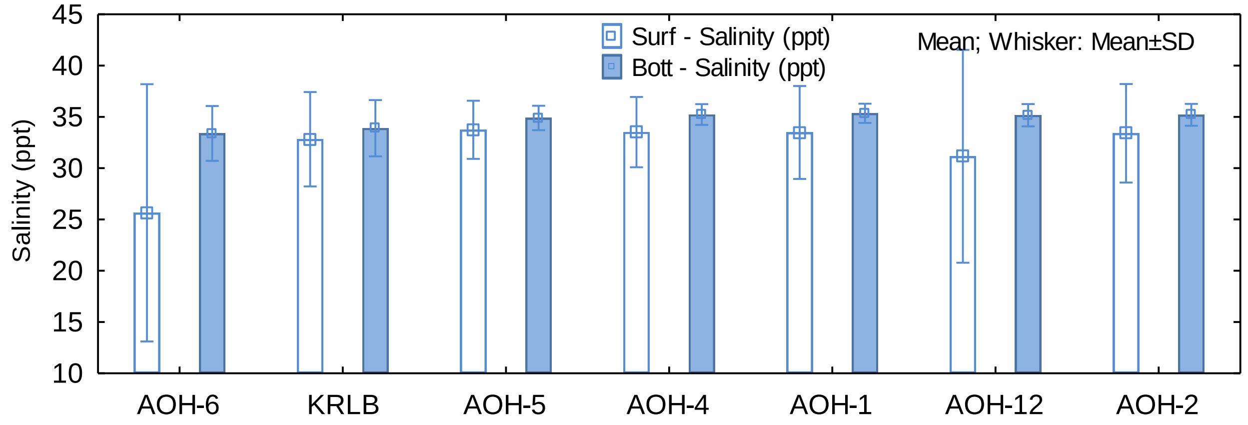

Figure 4 *Site means and standard deviations of salinity in surface and bottom waters*

5.2 Dissolved oxygen

Mean dissolved oxygen concentrations in surface and bottom waters were in the range 7 to 8.3 milligrams per litre (mgL^{-1}) throughout the monitoring period (Figure 5).

The time series data for all sites show that the surface concentrations were at times slightly above bottom water concentrations, however there were no hypoxic events and all observations were above 5 mgL^{-1} (Appendix C). These oxygen concentrations are considered healthy in estuarine environments.

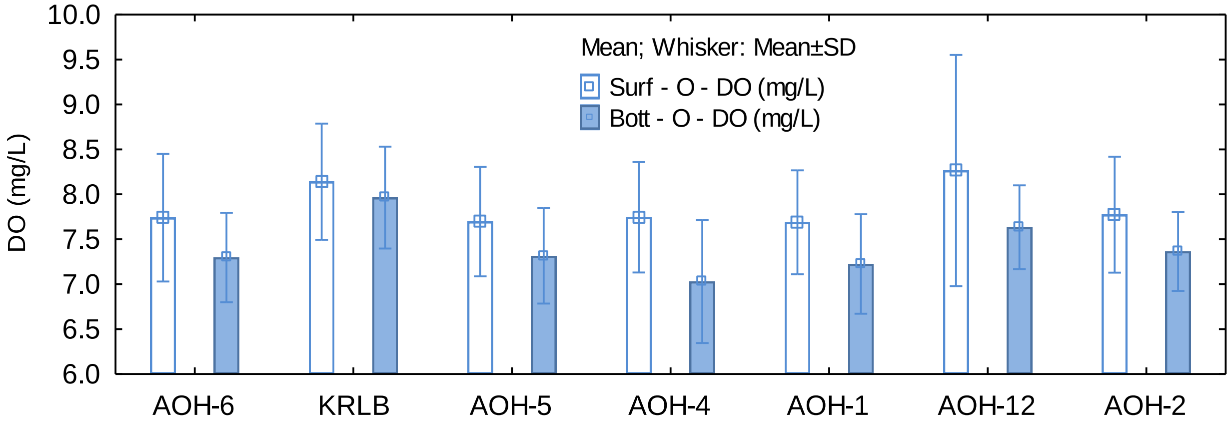

Figure 5 *Site means and standard deviations of dissolved oxygen in surface and bottom waters*

5.3 Temperature

Mean temperatures in both surface and bottom waters were around 17 to 19ºC (Figure 6).

Temperatures followed a consistent seasonal pattern, summer and autumn highs of 20 to 24ºC to winter lows of 12 to 16ºC (see Appendix C).

October and November samples showed some differentiation between surface and bottom waters of around 2 to 4ºC possibly due to warmer, less saline river water inflows forming the surface.

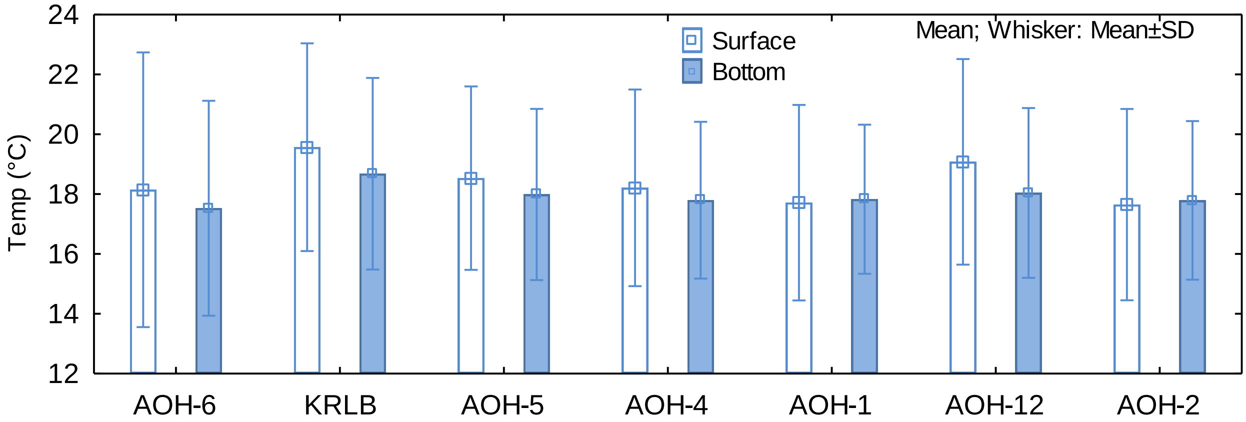

Figure 6 *Site means and standard deviations of temperature in surface and bottom waters*

5.4 Acidity

The scale of acidity (pH) means ranged from 7.9 to 8.1, well within the ANZECC default limits for south west estuaries, 7.5 to 8.5 (ANZECC & ARMCANZ, 2000) (Figure 7).

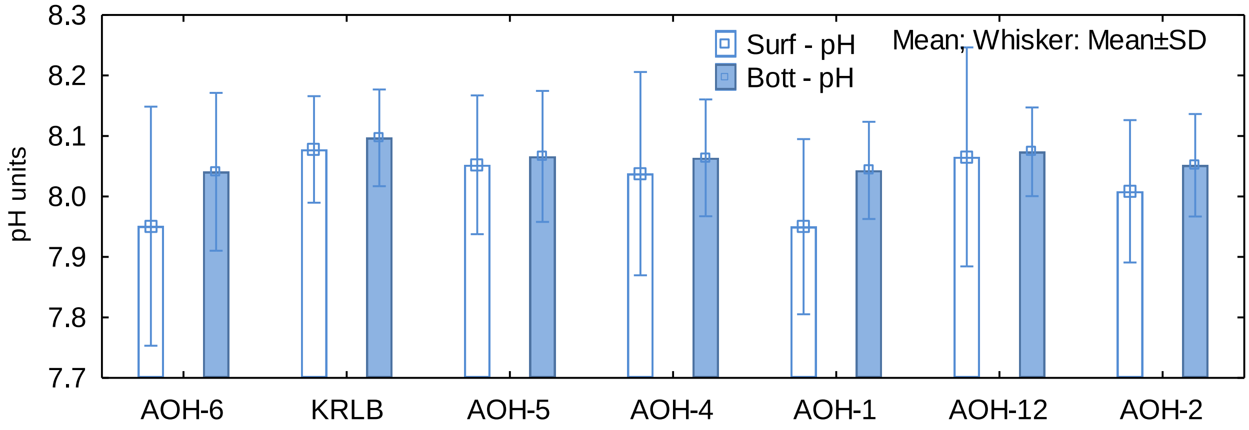

Figure 7 *Site means and standard deviations of pH in surface and bottom waters*

5.5 Turbidity

Turbidity site means were typically 0.4 to 3 Nephelometric Turbidity Units (NTU) in surface and bottom waters, which is indicative of clear water with good light penetration (Figure 8).

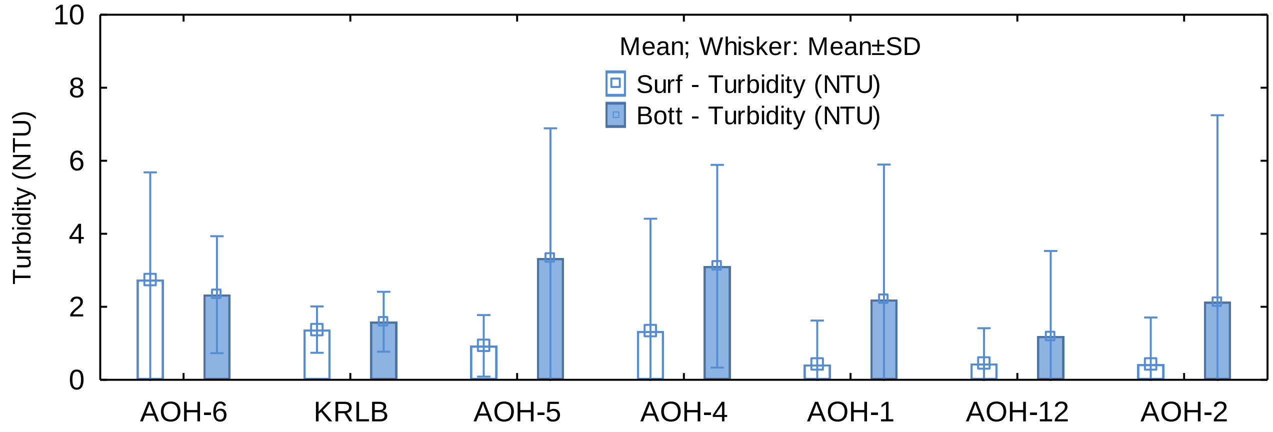

Figure 8 *Site means and standard deviations of turbidity in surface and bottom waters*

5.6 Water clarity

Most Oyster Harbour Secchi depth site means were close to the sites' maximum depth, also indicating good water clarity (Figure 9).

Deeper sites, AOH–4 and AOH–1 had mean Secchi depths of 4 and 5 metres. The time series plots for each site indicate that lower Secchi depths occurred during catchment inflow events, again suggesting that catchment inputs, which can carry sediments, nutrients and organic matter from surrounding land uses, are the primary threat to water quality of the estuary. For time series of all physical data see Appendix C.

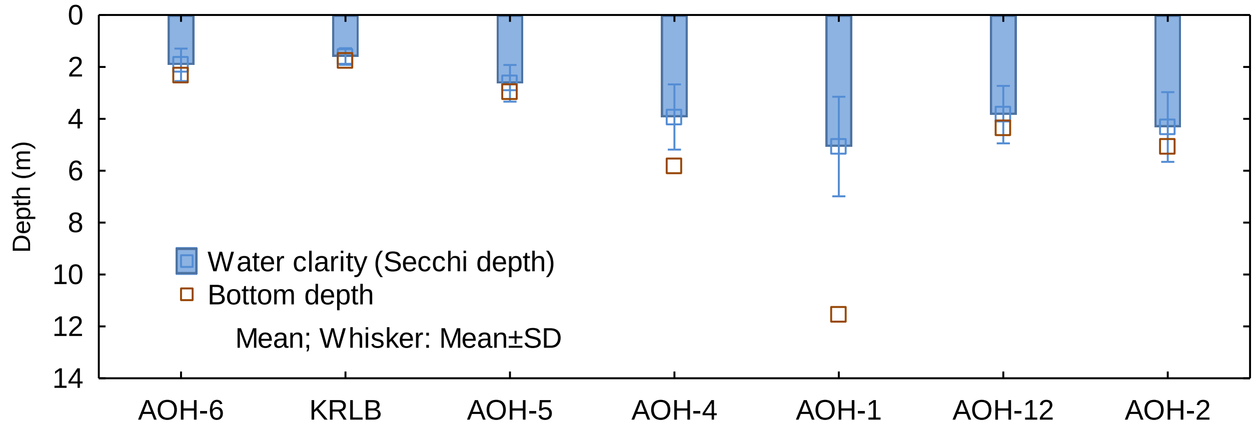

Figure 9 *Site means and standard deviations of Secchi depths and maximum site depths*

5.7 Hydrodynamics

The full vertical profile of physical data is also visualised as contour plots (Appendix B). These show a vertical slice through the estuary along three transects (Figure 3), on each sampling date. At each site, data is measured at approximately 0.5 metre intervals vertically through the water column (dots on the contour plots).

The contour plots show that the estuary was generally marine and well-oxygenated throughout the monitoring period (see Appendix B for monthly Surfer profiles of the current monitoring period).

The range of hydrodynamic conditions are illustrated by the summer (Figure 10) and winter (Figure 11) contour plots.

The summer profile (8 February 2017) shows a marine (36 to 37 ppt), fully mixed water column, well-oxygenated (7 to 8 mgL^{-1}) and temperatures of around 20ºC (Figure 10).

The late winter profile (23 August 2017) had a very shallow surface layer of lower salinities following catchment rainfall, and salinities ranged from 6.7 to 34 ppt (Figure 11).

The low salinity value of 6.7 was only at the AOH–6 site, which is at the mouth of the Kalgan River, in the surface sample. All other sites had surface salinities above 19 ppt. One month later, all samples were greater than 30 ppt.

Oxygen concentrations remained good, in the range of 7 to 8 mgL^{-1} and waters were cooler (16 – 17ºC).

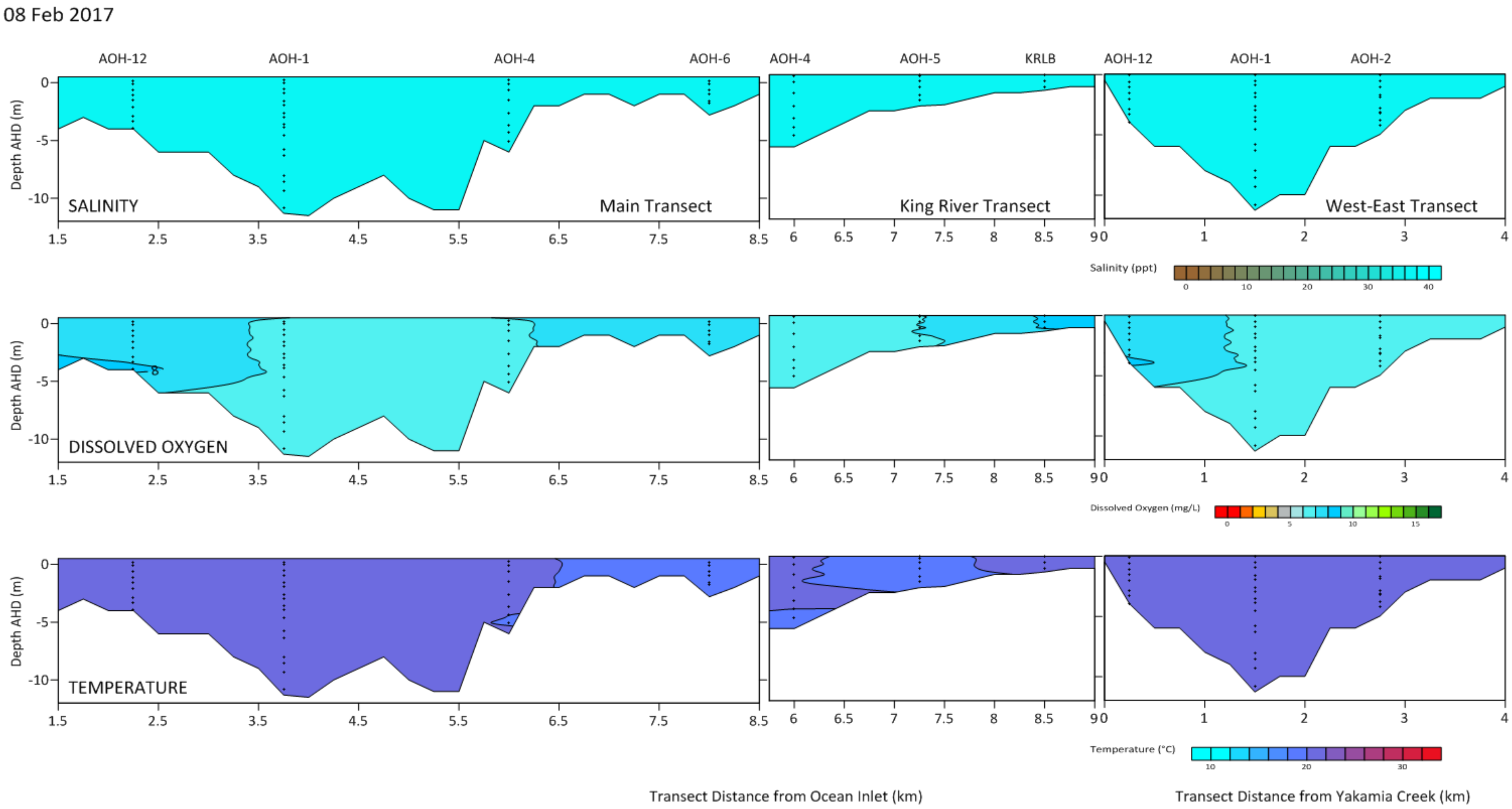

Figure 10 *Summer salinity, dissolved oxygen and temperature profiles, 8 February 2017*

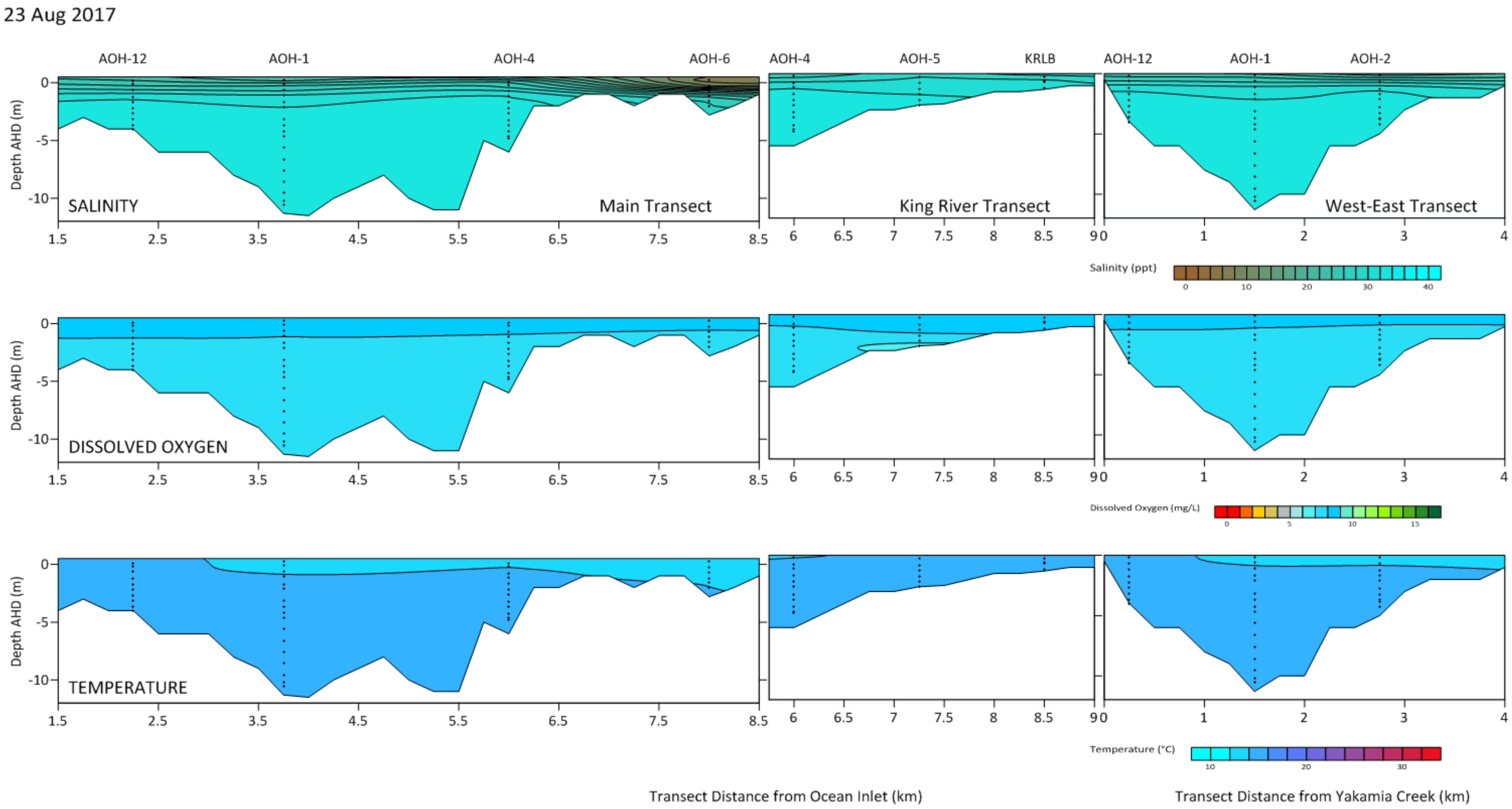

Figure 11 *Winter salinity, dissolved oxygen and temperature profiles, 23 August 2017*

6. Nutrients and chlorophyll *a*

6.1 Nitrogen

For the majority of sampling events, the nitrogen and phosphorus site means were below the relevant ANZECC guidelines (ANZECC & ARMCANZ, 2000) (Figures 12 to 17).

Occasional elevations above the guidelines were observed for total phosphorus (TP) and filterable reactive phosphate (FRP), in particular in October 2016 and August 2017 (Figure 18).

This coincided with catchment inflows from the Kalgan River and to a lesser extent the King River as evidenced by the lower salinity surface waters at the same time (see *Figure 11*).

The catchment water quality data will be analysed and reported also in 2018 for the calendar year 2017. Once analysed this dataset will inform us on the delivery of flow volumes, nutrient loads and instream concentrations from catchment tributaries.

The dominant form of nitrogen was total organic nitrogen, which was approximately 95 per cent of the total nitrogen. Nitrate inputs were evident at site AOH–6, again at the mouth of the Kalgan River (see Appendix C).

The bottom water site mean of ammonium at site AOH–5 was slightly higher than other sites. This site is a collection zone of seagrass wrack due to prevailing south-easterly winds (T. Calvert, personal comm.), therefore it may be a decomposition zone, accumulating organic matter and contributing nutrients to the water column.

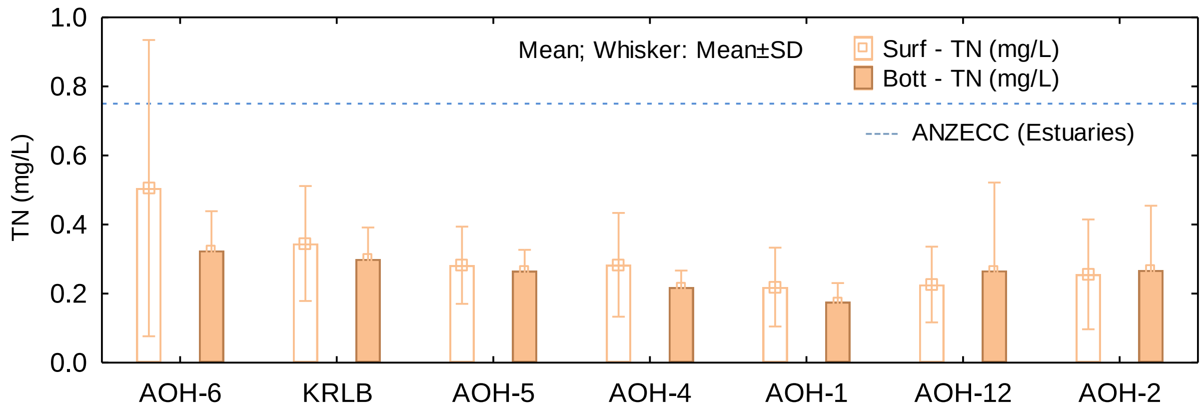

Figure 12 *Site mean and standard deviation of total nitrogen (mgL^{-1}) in surface and bottom waters*

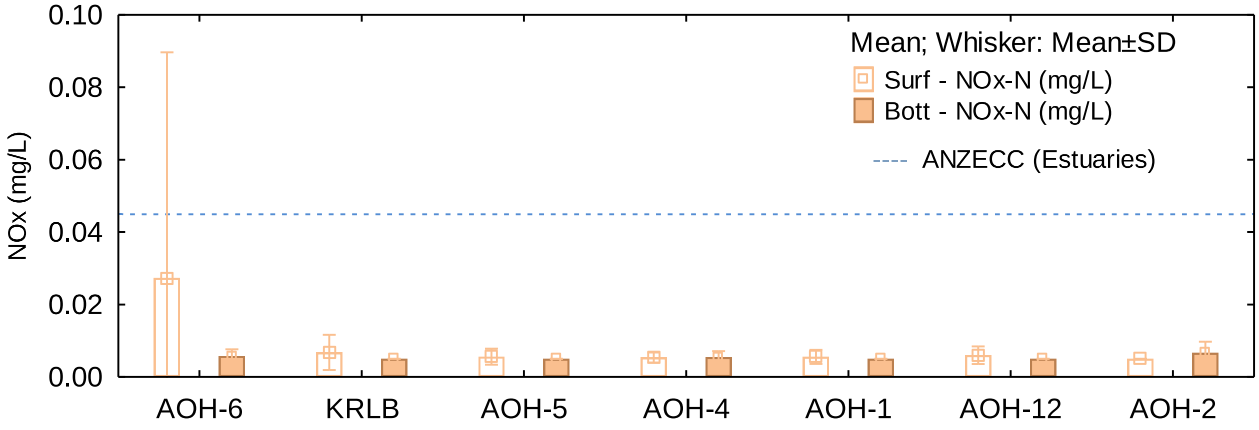

Figure 13 *Site mean and standard deviation of nitrate + nitrite (mgL^{-1}) in surface and bottom waters*

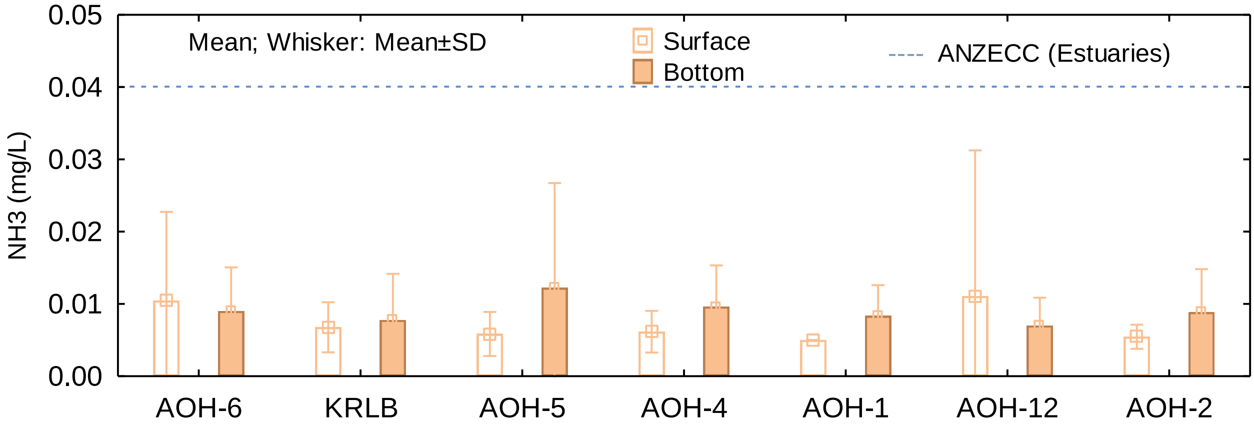

Figure 14 *Site mean and standard deviation of ammonium (mgL^{-1}) in surface and bottom waters*

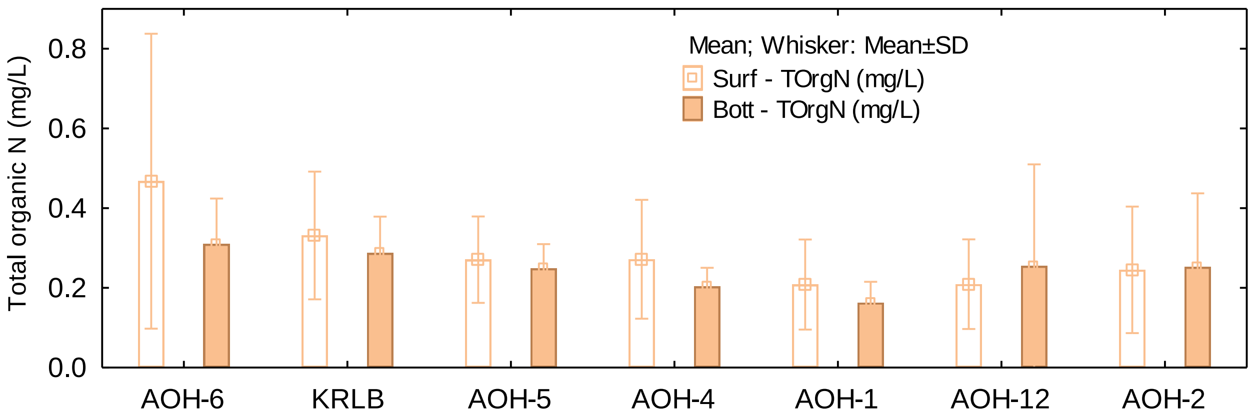

Figure 15 *Site means and standard deviations of total organic nitrogen (mgL^{-1}) in surface and bottom waters*

Note: There is no ANZECC guideline for Total Organic N.

6.2 Phosphorus

Some exceedances of FRP guideline in surface waters and not associated with anoxia indicate that the catchment is also the primary source of phosphate to the estuary.

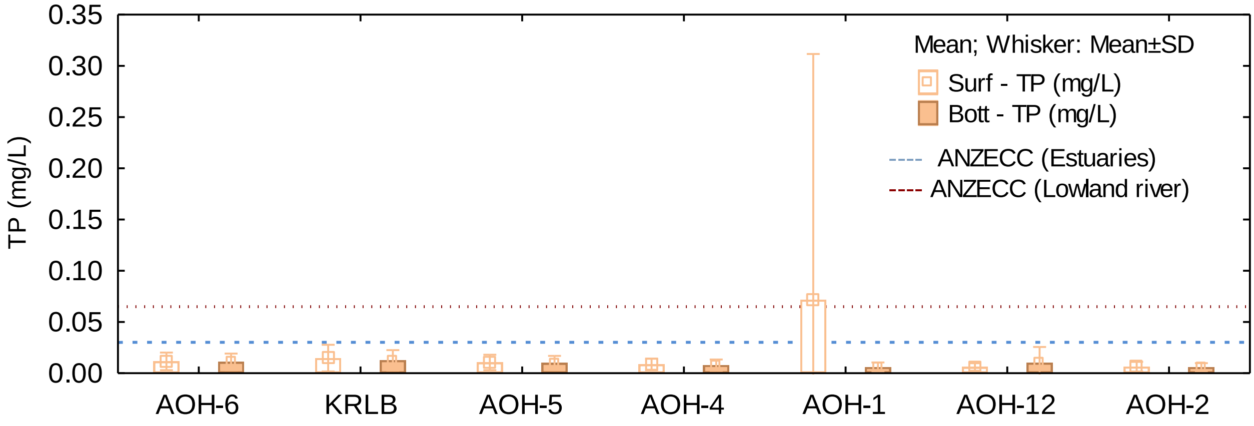

Figure 16 *Site mean and standard deviation of total phosphorus (mgL^{-1}) in surface and bottom waters*

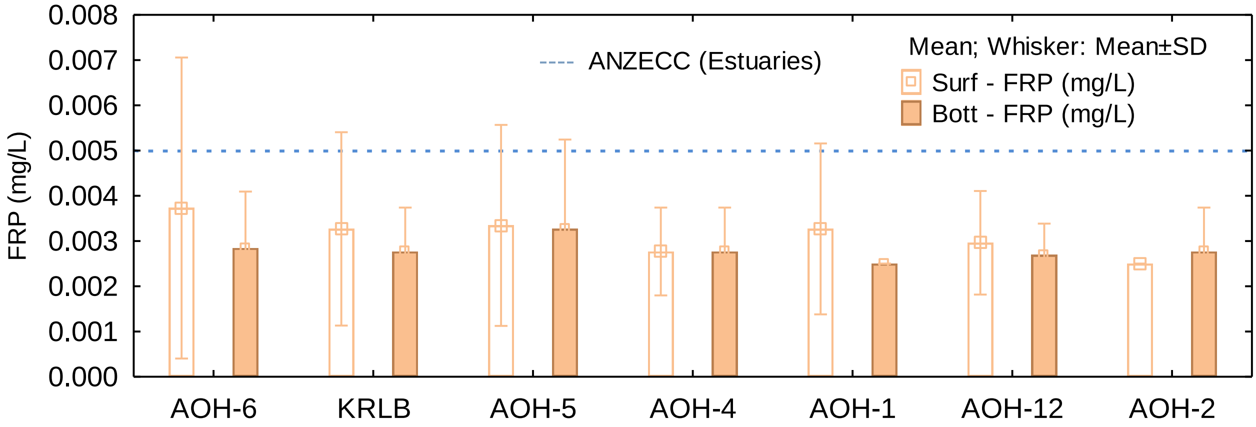

Figure 17 *Site mean and standard deviation of filtered soluble phosphate (mgL^{-1}) in surface and bottom waters*

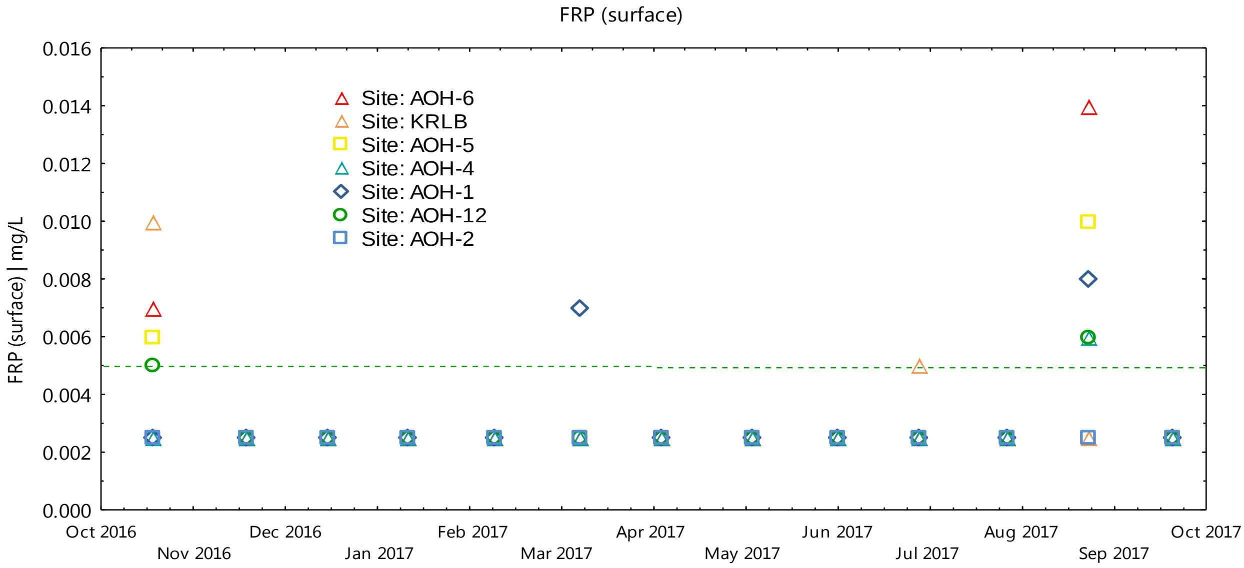

Figure 18 *Time series of filterable reactive phosphorus (FRP), all sites*

6.3 Chlorophyll

Site means of chlorophyll *a* concentrations in Oyster Harbour ranged from 1 to 3 micrograms per litre (µgL^{-1}) which were at or below the ANZECC guideline for south west estuaries of 3 µgL^{-1} (Figure 19).

The guideline was exceeded on a few occasions at the lower bridge of the King River and mouth of the Kalgan River mostly in summer and autumn and in the northern-most basin site, AOH–5, which recorded the maximum concentration of 10 µgL^{-1} in late August 2017 (see Appendix C). At site AOH–5, 30 per cent of the samples were above the ANZECC guideline.

These exceedances correlated with lower salinities and higher FRP concentrations. Filterable reactive phosphorus is a bioavailable form of phosphorus that promotes phytoplankton growth, and potentially fuelled the phytoplankton activity.

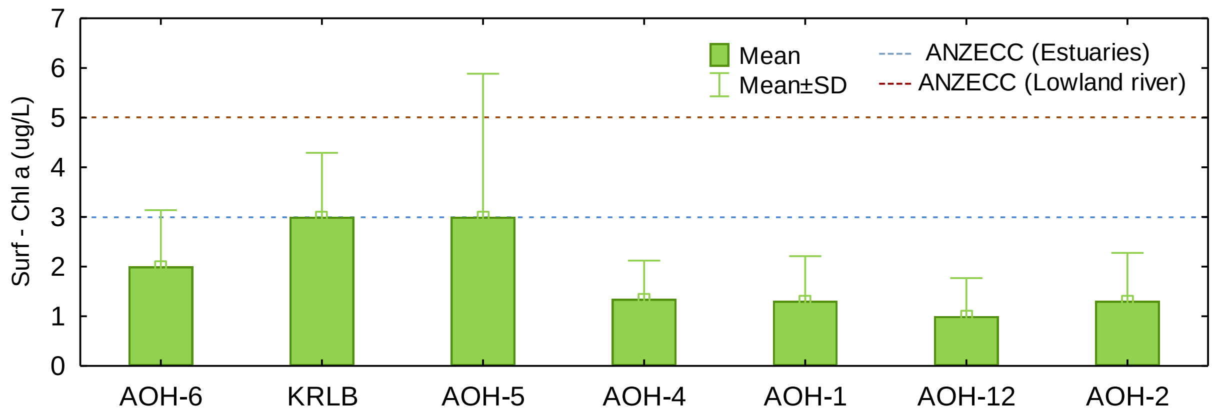

Figure 19 *Site means and standard deviations of chlorophyll a (mgL^{-1}) in surface waters*

A review of historical chlorophyll *a* data in estuarine waters by the former Department of Fisheries (Pearce *et al*, 2000) showed that 1978–79 Oyster Harbour means ranged from 0.57 to 3.74 μgL^{-1}, a decade later in 1987–88 they ranged from 0.28 to 0.77 μgL^{-1}.

These data suggest that the chlorophyll *a* concentrations decreased from 1978–79 to 1987–88 but have since increased in 2016–17 to similar concentrations observed in 1978–79. There is however insufficient data to validate this as a statistically significant trend.

These results suggest that catchment inputs are having a small impact on the water quality of Oyster Harbour and that the estuary is vulnerable to greater nutrient inputs.

To assist the recovery of habitats such as seagrass and oyster reefs, more proactive management of catchment land uses is needed to ensure water quality deterioration does not impede the restoration efforts.

7. Phytoplankton

Phytoplankton are microscopic single-celled algae and form the base of the food web in aquatic ecosystems. They contain chlorophyll, photosynthesise and globally they play an important role in capturing carbon from carbon dioxide in the atmosphere.

Taxonomically, phytoplankton are divided into a number of groups which have similar characteristics. When an ecosystem is unbalanced, phytoplankton populations can grow exponentially and/or the relative group composition can change. As a broad generalisation, dominance by the Diatom group tends to indicate good water quality or ecosystem health. Dominance by the Dinophyta or Cyanophyta groups is a signal of poor water quality and less desirable for a healthy and diverse food web. Certain species can produce toxins which are harmful to aquatic organisms, birds and/or humans.

Monthly phytoplankton samples were analysed taxonomically and counted for cell densities at three sites in Oyster Harbour.

In general, diatoms were the dominant taxonomic group from December 2016 to October 2017 (Figure 20). In October to November 2016, Chlorophyta was the dominant group.

Maximum cell densities of around 3000 to 3800 cells mL^{-1} occurred in summer and autumn and minimum densities were observed at the end of winter.

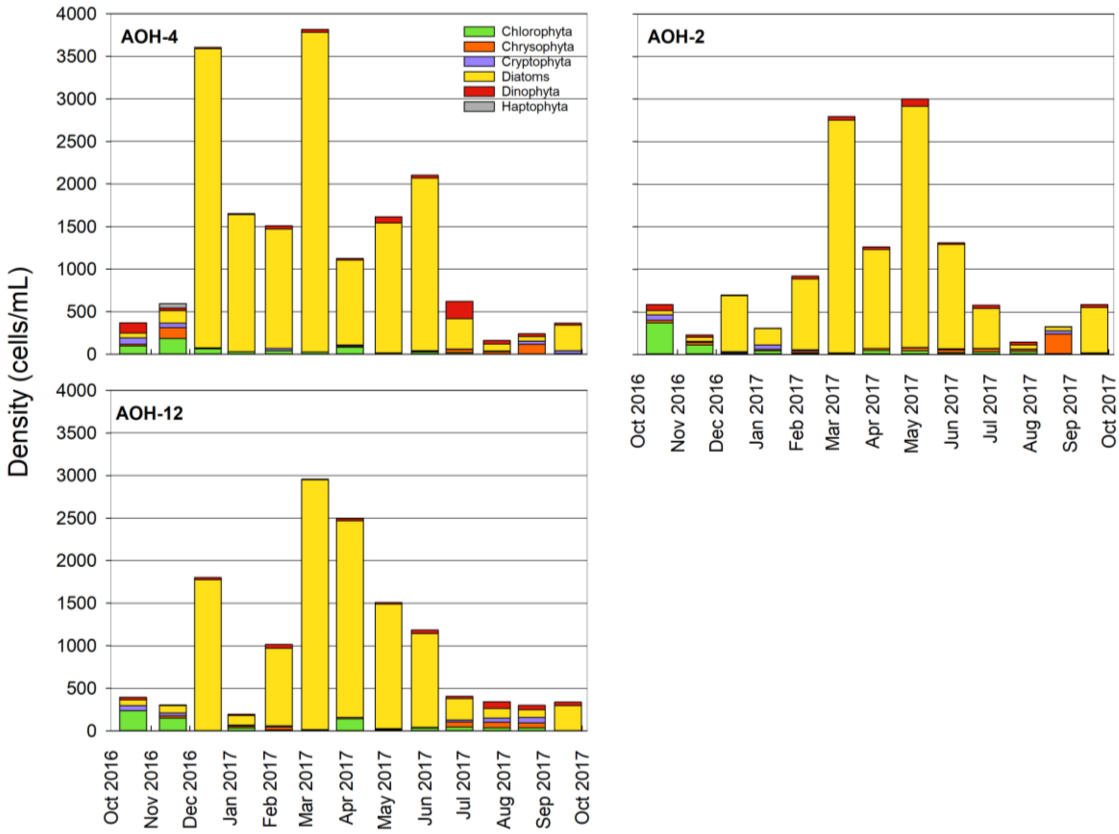

Figure 20 *Monthly phytoplankton group densities*

Note that these three sites are closest to the ocean entrance and are the sites with the lowest chlorophyll *a* concentrations. Consideration should be given to including phytoplankton surveillance of one of the monitoring sites closer to the freshwater inflows, such as AOH–5, which had the highest chlorophyll *a* concentrations.

Time series of each major group for each site are presented in Appendix D.

At the species level, *Chaetoceros spp* a planktonic diatom was dominant at all three sites.

7.1 Harmful algal species

Occasionally, some potentially harmful species were observed, *Gymnodinium-Karenia* complex, *Dinophysis acuminata* and *Psuedonitzschia,* mostly at very low cell densities (Table 2).

Note that the Western Australian Shellfish Quality Assurance Program (WASQAP, 2016) guideline for *Dinophysis acuminata* is 1 cell mL^{-1} and therefore this value was equalled or exceeded on four sampling events.

All other species were well below cell densities that are considered harmful.

Table 2 *Cell densities of potentially harmful algae*

Date	Site	Species	Group	Density cells/ml
18 Nov 16	AOH–2	Gymnodinium-*Karenia* complex	Dinophyta	6
18 Nov 16	AOH–4	*Dinophysis acuminata*	Dinophyta	1
18 Nov 16	AOH–4	Haptophyte spp	Haptophyta	50
10 Jan 17	AOH–12	*Dinophysis acuminata*	Dinophyta	1
08 Feb 17	AOH–2	*Karlodinium spp*	Dinophyta	3
08 Feb 17	AOH–4	*Karlodinium spp*	Dinophyta	10
08 Mar 17	AOH–2	*Prorocentrum mexicanum*	Dinophyta	8
04 Apr 17	AOH–2	*Prorocentrum mexicanum*	Dinophyta	1
04 May 17	AOH–2	*Dinophysis acuminata*	Dinophyta	1
04 May 17	AOH–4	*Dinophysis acuminata*	Dinophyta	5
04 May 17	AOH–4	*Prorocentrum minimum*	Dinophyta	5
01 Jun 17	AOH–12	*Pseudonitzschia spp*	Diatoms	33
01 Jun 17	AOH–4	*Prorocentrum minimum*	Dinophyta	16
28 Jun 17	AOH–12	*Pseudonitzschia spp*	Diatoms	10
28 Jun 17	AOH–2	*Prorocentrum minimum*	Dinophyta	13
28 Jun 17	AOH–2	*Pseudonitzschia spp*	Diatoms	6
28 Jun 17	AOH–4	*Prorocentrum minimum*	Dinophyta	144

8. Seagrass and macroalgae

Seagrass plays an important role in maintaining healthy water quality conditions and the restoration of seagrasses in Oyster Harbour has been underway over the last two decades. Although seagrass and macroalgae have not been directly monitored in the current monitoring period, the most recent seagrass density and species distributions are presented here as seagrass is key part of the ecosystem.

The most recent seagrass distribution and density maps recorded a total area of 5.6 square kilometres (km^2) of seagrass in Oyster Harbour in 2006 (Figure 21). The dominant species of seagrass recorded in the estuary was *P. australis,* which occurred over an area of 3.9 km^2, secondly by *P. sinuosa,* which covered an area of 3.1 km^2 (*Figure 22*). The combined total for *P. australis* and *P. sinuosa* (7 km^2) again includes 1.6 km^2 where these two species occurred together as mixed meadows. The total area of seagrass habitat created by these two species amounts to 5.4 km^2*. Ruppia* occurred over an area of 0.2 km^2.

Macroalgae was not observed as a dominant feature of the benthic habitat in Oyster Harbour in the 2006 survey.

Previous seagrass mapping studies in Princess Royal Harbour and Oyster Harbour identified a marked decrease in seagrass and macroalgae cover between 1962 and 1981–84. Over this 20 year period approximately 50 per cent of the total area of seagrass was lost in Oyster Harbour.

A successful seagrass restoration project has been underway since the 2000s (seagrassrestoration.net/oyster-harbour-wa/).

From 1984 to 2006 the Oyster Harbour seagrass coverage improved by nine per cent, but there was a decline in the density of the seagrass meadows across the estuary. In particular, a shift from the high (more than 75 per cent) density category to the lower seagrass density categories was observed.

Seagrasses in Oyster Harbour are vulnerable to the changes in water quality brought about by river flow from the King and Kalgan rivers, which is turbid and nutrient rich due to the influence of surrounding land uses. Reductions in light and sediment smothering are considered to be the main cause in the decline of seagrass density.

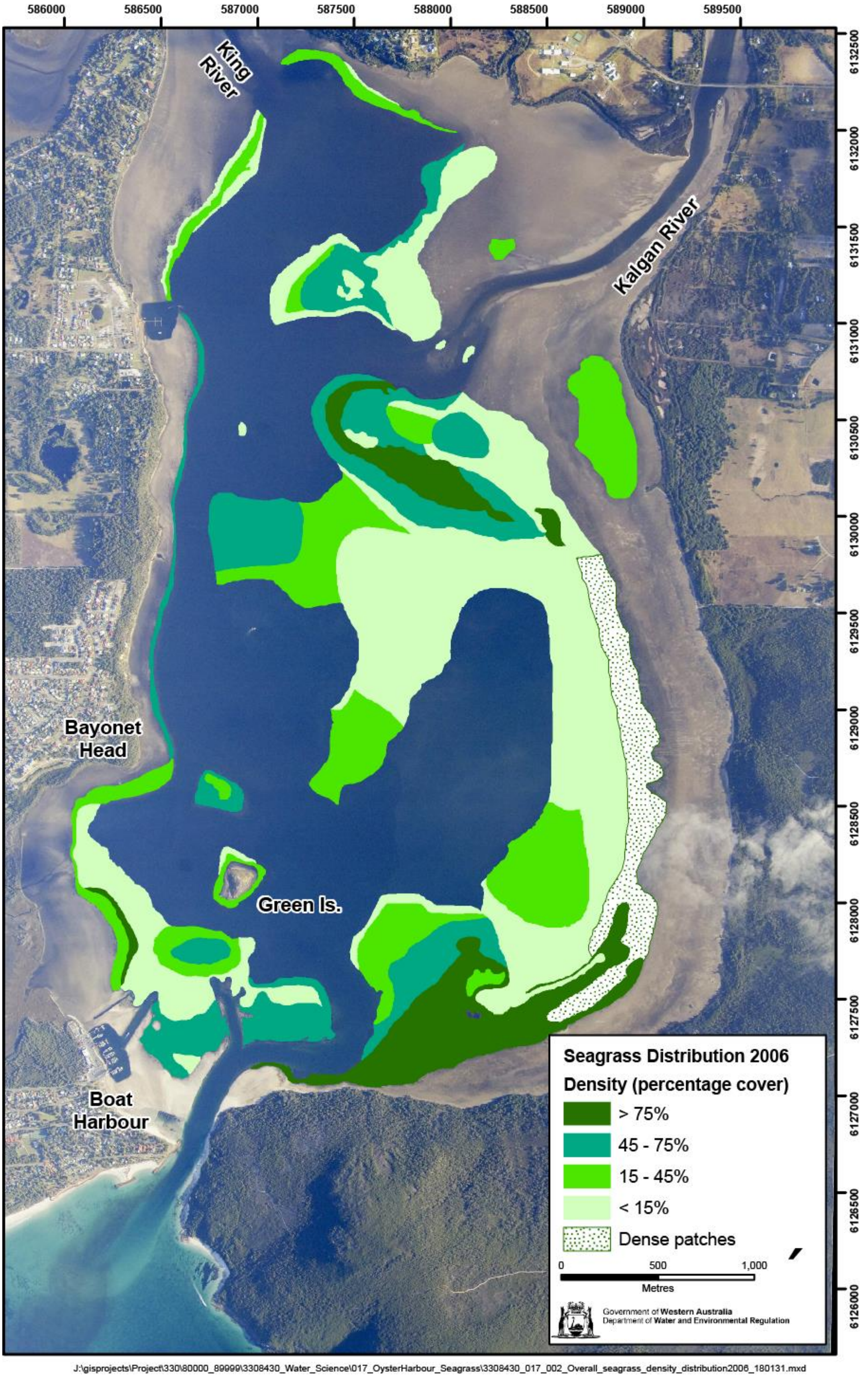

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Figure 21 *Seagrass distribution Oyster Harbour, Albany, March 2006*

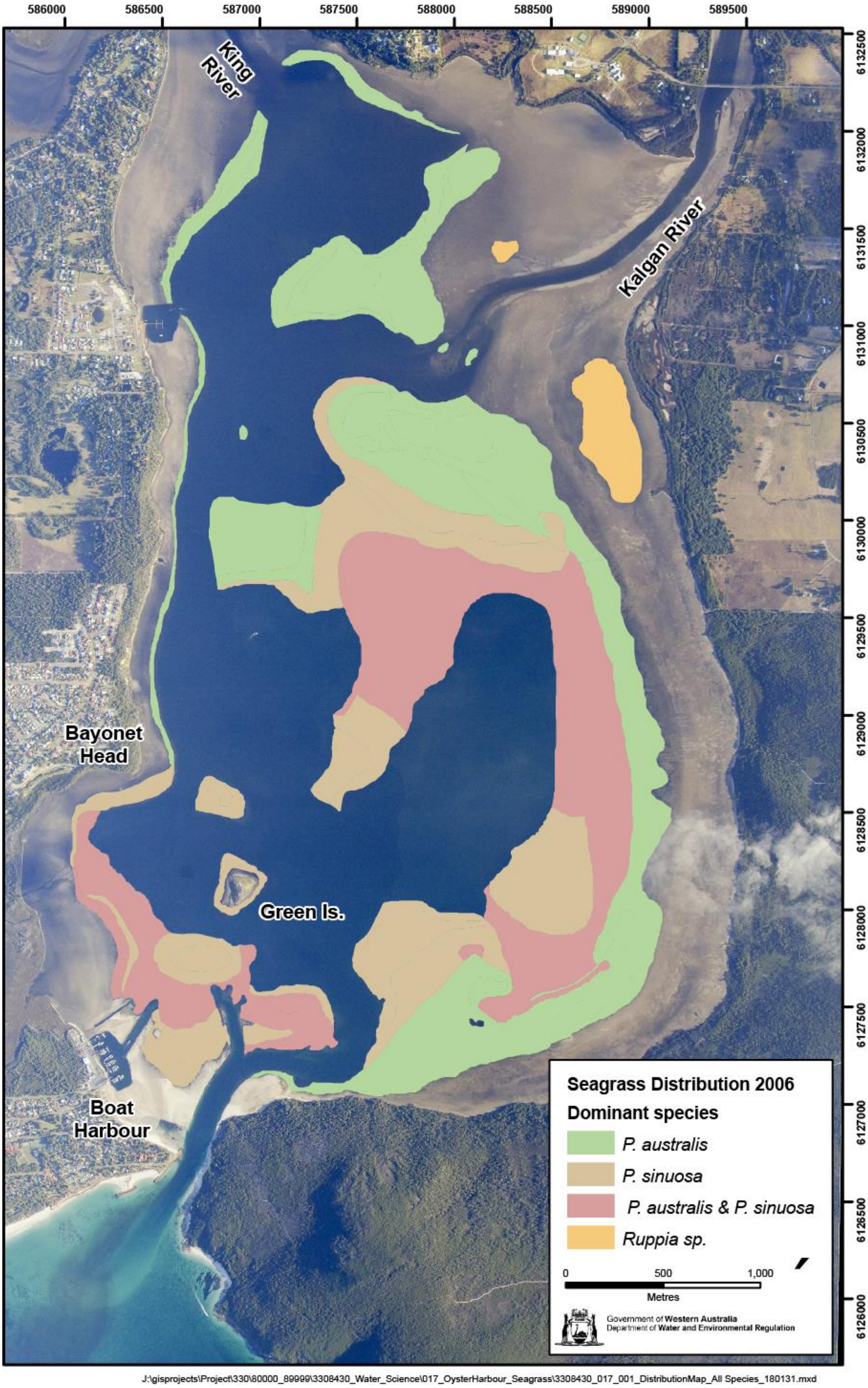


Figure 22 *Distribution of seagrass species in Oyster Harbour, Albany, March 2006*

9. Events

There were no notable algal bloom or fish kill events in Oyster Harbour for the 12 months, 1 October 2016 to 1 October 2017.

In September 2017, approximately 150 kilolitres of wastewater from the Albany wastewater treatment facility was discharged into Yakamia Creek. In the estuary, site AOH–12 is closest to Yakamia Creek. Examination of the site AOH–12 nutrient and chlorophyll *a* concentrations following the spill did not indicate any elevation in concentrations as they were comparable to other estuary sites. However, it should be noted that the frequency of the monthly sampling program would not necessarily pick up all nutrient spikes from such events.

Sewerage spills do carry nutrients, contaminants and pathogens such as *Escherichia coli*, however monitoring for the presence of non-nutrient contaminants is beyond the scope of the current monitoring program.

10. Conclusions and recommendations

Water quality indicators show Oyster Harbour to have good water quality status, free from symptoms of eutrophication. The waters are mostly marine, well-mixed and well-oxygenated. Nutrients and chlorophyll concentrations for the most part, were below ANZECC guidelines. The exceptions were during short periods of flow from the Kalgan River following the seasonal pattern of winter rainfall.

Phytoplankton densities, whilst low compared with other south west estuaries, were highest in summer and autumn. Diatoms were the dominant phytoplankton group. There were a few observations of harmful species that could impact shellfish harvesting, but these were generally in low concentrations.

Given the current hydrodynamic regime where the estuary is marine-dominated, the current monthly monitoring frequency is considered adequate.

The following recommendations are made to adjust the monitoring program –

- Include pathogen sampling at existing monitoring sites to provide baseline data on faecal contamination from stock and wastewater sources
- Include phytoplankton species identification and enumeration at site AOH-5 as this site had the highest chlorophyll *a* concentrations and it would provide better coverage of phytoplankton activity in the northern part of the Harbour.

Shortened forms

AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment Conservation Council
CO_2	Carbon dioxide
DO	Dissolved oxygen
DSP	Diarrhoeic shellfish poisoning
DWER	Department of Water and Environmental Regulation
FRP	Filterable reactive phosphorus
kL	Kilolitres
km^2	Square kilometres
m^3s^{-1}	Cubic metres per second
mgL^{-1}	Milligrams per litre
mL^{-1}	Millilitre
NH_3/NH_4	Ammonia/ammonium
NOx	Nitrate + nitrite
NSP	Neurologic shellfish poisoning
NTU	Nephelometric turbidity units
OHCG	Oyster Harbour Catchment Group
pH	Measure of acidity or alkalinity in water and sediments
ppt	Parts per thousand
REI	Regional Estuaries Initiative
Secchi	Secchi depth
TN	Total nitrogen
TP	Total phosphorus
μgL^{-1}	Micrograms per litre
WASQAP	Western Australian Shellfish Quality Assurance Program

Glossary

Acidity	The level of acid in water.
Ammonium	An important source of nitrogen to plants, particularly in low oxygen environments. Ammonium is a waste product of animals and enters waters either directly or as urea. It is a particularly important source of nutrients to phytoplankton.
Anoxic	A total decline in dissolved oxygen in the water column.
Anthropogenic	Caused by human beings.
ANZECC guidelines	Guidelines published by the Australian and New Zealand Environment Conservation Council for ecological and recreational water quality in marine and freshwater environments. It is a framework for conserving ambient water quality in rivers, estuaries, lakes and marine waters.
ANZECC guideline values	The ANZECC guideline values are intended to provide government, industry, consultants and community groups with a framework to maintain ambient water quality in rivers, lakes, estuaries and marine waters. The core concept is to manage water quality to protect environmental values. These values may include protection of aquatic ecosystems, drinking water, primary and secondary recreation, visual amenity, and agricultural water for irrigation, livestock and growing aquatic foods.
Aquatic macrophytes	Aquatic plants that can be seen with the naked eye, and grow submerged, emergent or floating within marine, estuarine and riverine environments, e.g. seagrasses.
Benthic	Relating to or occurring at the sea, estuary or lake bottom.
Catchment	The area of land that collects precipitation and drains via streams and rivers into estuaries and/or the ocean.
Chlorophyll	A plant pigment essential in photosynthesis. Chlorophyll *a*, *b*, and *c* are different forms of chlorophyll which absorb different wave lengths of light.
Chlorophytes	A group of algae characterised by green chloroplasts. They include unicellular phytoplankton and large leaf macroalgae.
Contaminant	A substance that has the potential to present a risk of harm to human or environmental health.
Cryptophytes	A group of phytoplankton, typically small in size with 2 flagella and without a skeleton (or shell).
Cyanobacteria	Also known as blue-green algae, these are a photosynthetic bacteria that occur as single cells or as colonies (which can form filaments). Some species are nitrogen-fixing, converting nitrogen from the air to form ammonia and nitrates/nitrites.
Diatom	Microscopic one-celled or colonic algae of the class Bacillaophycae, having cell walls of silica consisting of two interlocking symmetrical valves.
Dinoflagellate	Chiefly protozoans characteristically having two flagella and sculptured shell or pellicle that is formed from plates of cellulose deposited in membrane vesicles. They are one of the chief

	constituents of plankton. They include bioluminescent forms and forms that produce ‘red tides’.
Enumerated	To determine the number of.
Epiphytes	A plant that grows on another plant but is not parasitic.
Estuary	Partially enclosed coastal body of water, having an open connection with the ocean, where freshwater from inland is mixed with saltwater from the sea.
Eutrophication	Eutrophication is a deterioration of water quality caused by the excessive input of nutrients. It leads to overgrowth of aquatic plants, macroalgae and/or phytoplankton, and the ultimate decomposition of this plant growth leads to anoxia.
Filterable reactive phosphorus	Filterable reactive phosphorus is a bioavailable form of phosphorus that promotes phytoplankton growth.
Hydrodynamics	The flow and movement of water.
Hydrological cycle	Describes the cycle of water on and in the earth and atmosphere.
Hypoxic	Low in oxygen.
Inorganic dissolved nutrients	These include nitrate/nitrite, ammonium and soluble phosphate and are in forms most readily available to plants.
Invertebrates	An animal without a backbone, includes shellfish, worms.
Macroalgae	Photosynthetic plant-like organisms that can be seen with the naked eye. Macroalgae may be divided into the groupings: reds (rhodophytes), greens (chlorophytes), browns (phaeophytes) and blue-greens (cyanophytes). These divisions are primarily based on pigments in their tissues, which are also usually evident in their appearance.
Macrophyte	Rooted aquatic plants.
Nitrate/nitrite	A dissolved inorganic form of nitrogen. Often used in fertilisers and the source of nutrients in catchment runoff. It is also a byproduct of septic systems which can leach into groundwater.
Nutrient analytes	Chemical constituents of nutrient forms such as nitrogen and phosphorus.
Nutrients	Nutrients (nitrogen and phosphorus) are chemicals that are important for plants to survive and grow however, water quality is reduced by excess nutrients entering waterways.
Nutrient load	The amount of nutrient being deposited into the estuary. Calculated as median annual nutrient concentration x annual total flow volume.
Organic loading	The amount of organic matter or sediment being deposited into a specific area.
Organic matter	The collection of carbon-based compounds aquatic and terrestrial environments.
Pathogens	An infectious organism which can cause disease.

pH	pH is a measure of the relative acidity or alkalinity of water. It reflects the concentrations of hydrogen (H+) and hydroxide ions (OH-) in a water sample. Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity, while pH levels higher than 7 indicate increasingly basic solutions.
Photosynthesis	The biological process of plants which captures light energy and carbon dioxide and creates chemical energy for plant growth and metabolic processes.
Phytoplankton	Microscopic plants, usually single-celled.
Point source	An identifiable source of a substance, usually a contaminant, such as industrial discharges.
Salinity	The concentration of salt in water.
Seagrass wrack	Collection of dead or decaying seagrass leaves, usually on shorelines and associated with the odour of decomposition.
Sediment	Loose particles of sand, clay, silt and other substances that settle at the bottom of a body of water. Sediment can be derived from the erosion of soil or from the decomposition of plants and animals.
Stratification	The forming of water layers based on differences in salinity, oxygen or temperature.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape. In an estuary it also refers to the upper layer of the water column.
Taxonomically analysed	Identified as a taxonomic group.
Total nitrogen	The sum of all forms of nitrogen found in the water column. This includes particulate and dissolved forms of an inorganic and organic nature.
Total phosphorus	The sum of all forms of phosphorus found in the water column. This includes particulate and dissolved forms of an inorganic and organic nature.
Toxicity	The degree to which a substance or combination of substances is able to damage an exposed organism.
Tributaries	A river, stream or creek which flows into another larger river.
Turbidity	Opaqueness of water due to suspended particles in the water causing a reduction in the transmission of light. The units of measurement are NTU (nephelometric turbidity units).

Appendices

A. Water quality indicators – methods

Table 3 summarises the suite of nutrient analytes programmed for Oyster Harbour.

Nitrogen and phosphorous are nutrients critical for phytoplankton and higher plant growth and are thus routinely measured in estuaries. Total nitrogen and total phosphorous include all forms of nitrogen and phosphorus (particulate and dissolved, organic and inorganic), and are measured to determine the total nutrients in the estuary.

Dissolved forms of nitrogen and phosphorous such as ammonium, nitrate/nitrite and filterable phosphate are also measured. Dissolved nutrients are readily bioavailable to plants and phytoplankton for growth.

Also included in Table 1 are the limits of reporting (LOR) and the Australian and New Zealand Environment Conservation Council (ANZECC) Guideline concentration for each analyte (ANZECC & ARMCANZ, 2000).

- The “limit of reporting” or **reporting limit** means the concentration (or amount) of analyte that can be reported by a laboratory.
- The **ANZECC guideline values** are intended to provide government, industry, consultants and community groups with a framework to maintain ambient water quality in rivers, lakes, estuaries and marine waters. The core concept is to manage water quality to protect environmental values. These values may include protection of aquatic ecosystems, drinking water, primary and secondary recreation, visual amenity, and agricultural water for irrigation, livestock and growing aquatic foods.

The limit of reporting for each analyte should be equal or more sensitive than the guideline value in order to demonstrate the performance of any management measures to improve water quality (reduce nutrient inputs) in the receiving waterway.

Table 4 summarises the analysis methods for nutrients and biological parameters measured.

Table 3 *Nutrient suite and sampling rationale*

LOR is limit of reporting for an analyte determined by the analytical method and laboratory used for analysis.

Parameter	Description and sampling rationale	Limit of reporting (LOR) and ANZECC guideline
Total Nitrogen (TN)	TN includes all forms of nitrogen (particulate and dissolved), such as nitrate, nitrite, ammonia, and organic nitrogen. Measured to determine total nutrients (nitrogen) in the estuary.	**ANZECC guideline** 0.75 mgL^{-1} **LOR** 0.025 mgL^{-1}
Total Oxidised Nitrogen **(NO_x-N), or Nitrate (NO_3^-) + Nitrite (NO_2^-)**	NO_x-N (TON) is the sum of the nitrate (NO_3^-) and nitrite (NO_2^-) nitrogen concentrations in mg/L nitrogen. Nitrate and nitrite species can be determined separately. This is a dissolved form of nitrogen, readily available to phytoplankton and higher plants for growth. Surface NO_x can be a good indicator of nutrient/fertilizer inputs from the catchment, often closely related to flow volume.	**ANZECC guideline** 0.045 mgL^{-1} **LOR** 0.01 mgL^{-1}
Ammonium Nitrogen **(NH_3-N/NH_4-N)**	Ammonium and ammonia species are determined using the same analytical method. Analytically they are the same species. At pH 5-8, the species exists predominantly as ammonium (NH_4^+). This is a dissolved form of nitrogen, readily available to phytoplankton and higher plants for growth.	**ANZECC guideline** 0.04 mgL^{-1} **LOR** 0.01 mgL^{-1}
Total Phosphorous (TP)	TP includes all forms of phosphorus, organic and inorganic in particle or detritus, or in the bodies of aquatic organisms. Phosphorus occurs in natural waters and in wastewaters predominantly as phosphates (PO_4^{3-},pyro-, meta-, and other polyphosphates), and as organically bound phosphates. Measured to determine total phosphorus in the estuary.	**ANZECC guideline** 0.03 mgL^{-1} **LOR** 0.005 mgL^{-1}
Filterable Reactive Phosphorus (FRP)	Filterable Reactive Phosphorus (FRP) describes the dissolved phosphates. This is a dissolved form of phosphorus, readily available to phytoplankton and higher plants for growth.	**ANZECC guideline** 0.005 mgL^{-1} **LOR** 0.005 mgL^{-1}

Table 4 *Analysis method for nutrients and chlorophyll*

Parameter	Analysis Method
Total Nitrogen (TN)	The sample is mixed with potassium persulfate and sodium hydroxide and heated to 120°C for 30 minutes in an autoclave. The nitrogenous compounds in the sample are oxidised to nitrate. Total nitrogen is determined by analysing the nitrate in the digestate. Measurements are performed using the auto analyser. Persulphate digestion method 4500-N C (APHA 1998), and the Cadmium reduction method 4500-NO3- F (APHA 1998).
Total Oxidised Nitrogen **(NO_x-N), or Nitrate (NO_3^-) + Nitrite (NO_2^-)**	The method is based on the cadmium reduction method. The sample is passed through a column containing granulated copper-cadmium to reduce the nitrate to nitrite. The nitrite that was originally present and the reduced nitrate is determined by diazotizing with sulphanilamide and coupling with α-napthylenediamine dihydrochloride to form a highly coloured azo dye which is measured at 540 nm. Nitrite (NO_2-N) is determined using the same method omitting the copper-cadmium column. Nitrate (NO_3-N) is obtained by subtracting the nitrite result from the total organic nitrogen result. Cadmium reduction method 4500-NO3- F (APHA 1998).
Ammonium Nitrogen **(NH_3-N/NH_4-N)**	The method is based on a modified Berthelot reaction. Alkaline phenol and hypochlorite react with ammonia to form indophenol blue. The blue colour is intensified with sodium nitroprusside. The absorption is measured photometrically at 630 nm. Phenate method 4500-NH3 G (APHA 1998).
Total Phosphorous (TP)	The sample is mixed with potassium persulfate and sodium hydroxide and heated to 120°C for 30 minutes in an autoclave. The phosphorus compounds in the sample are oxidised to ortho-phosphate. Measurements are performed using the auto analyser. Persulphate digestion method 4500-P B.5 (APHA 1998), and Ascorbic Acid Colorimetric method 4500-P E (APHA 1998).
Filterable Reactive Phosphorus (FRP)	Ascorbic Acid Colorimetric method 4500-P (APHA 2017)
Chlorophyll (includes Chl a, b, c and Pheaeophytin)	Plankton from water is isolated by filtration and the pigments are extracted using aqueous acetone. The concentration of chlorophyll *a*, *b*, *c* and pheophtyin *a* in the extract is determined by measuring the optical density at compound specific wavelengths using a UV VIS spectrophotometer. Method: 10200 H(2) (APHA 1998).

Table 5 summarises the biological measures of water quality for Oyster Harbour.

Phytoplankton are a natural component of the estuaries ecology. Most species are favourable but some are harmful because they are either toxin producing or able to cause mechanical damage to other organisms.

Phytoplankton numbers can quickly increase in response to nutrient inputs. Phytoplankton densities (cell counts) and identifications (community composition) provide valuable information on phytoplankton population dynamics in the estuary.

Chlorophyll *a* is a pigment found in plant cells and is measured as a surrogate indicator of phytoplankton abundance and biomass (productivity).

Table 5 *Biological indicator (phytoplankton) sampling and rationale*

Parameter	Description and relevance	Unit/ Guideline
Phytoplankton	Phytoplankton are microscopic algae which can be used as an indicator of water quality. Different species of phytoplankton may develop blooms causing discolouration, odours, anoxic or toxic conditions.	**Units**: cells mL^{-1}
Chlorophyll (a, b, c and phaeophytin)	Chlorophyll a, b, c are pigments found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll a concentrations are an indicator of phytoplankton abundance and biomass. Phaeophytin is a common chlorophyll degradation product.	**ANZECC guideline** 3 μgL^{-1} (Chl *a*) **LOR** 1 μgL^{-1}

Table *6* summarises the physicochemical data collected from water column profiling in Oyster Harbour.

Profile data help us monitor natural phenomena such as stratification, river flows and tidal intrusion.

Table 6 *Physicochemical variables collected at each site*

Parameter	Description and relevance	Limit of reporting (LOR) and ANZECC guideline where available
Salinity and Conductivity	Salinity is the mass fractions of salts in the water column expressed as PSU (practical salinity units) which are based on water temperature and conductivity measurements. Salinity used to be expressed in parts per thousand (ppt). For oceanic seawater, ppt and PSU are very close. Salinity varies horizontally and vertically in the estuary and gives a measure of water movement and stratification.	Measured in the field using a calibrated EXO2 sonde **Units**: ppt and mS/cm

Parameter	Description and relevance	Limit of reporting (LOR) and ANZECC guideline where available
	Electrical conductivity (EC) measures a substance's ability to conduct an electric current. EC is to be measured and recorded *temperature compensated*. EC units are expressed in micro-siemens/cm (µS/cm) or milli-siemens (mS/cm) at 25°C 1000 EC = 1000 µS/cm = 640 ppm = 1 dS/m	
Temperature	Water temperature is a measure of heat content. Temperature is a vital indicator of the water column's ability to support growth and aquatic life. Water temperature regulates various biochemical reaction rates that influence water quality and also influence oxygen availability in the water column.	Measured in the field using a calibrated EXO2 sonde **Units**: °C
Dissolved Oxygen (DO)	Dissolved oxygen is the amount of gaseous oxygen (O_2) dissolved in the water. Dissolved oxygen is a good measure of the estuary's ability to support life. Values below 4 mg/L are considered unhealthy. Values below 2 mg/L can result in fish deaths.	Measured in the field using a calibrated Exo2 sonde **Units**: mg/L and % saturation **ANZECC guideline** 90-110% saturation
pH	pH is a measure of acidity or alkalinity of water on a log scale from 0 (extremely acidic) through 7 (neutral) to 14 (extremely alkaline). The pH of marine waters is close to 8.2, whereas most natural freshwaters have pH values in the range from 6.5 to 8.0.	Measured in the field using a calibrated Exo2 sonde **ANZECC guideline** 7.5-8.5
Turbidity	Turbidity is a measure of water clarity or murkiness. It is an estimate of the degree to which light is scattered and absorbed by molecules and particles. Turbidity is caused by suspended matter such as clay and silt (suspended sediment) and detritus and organisms (such as phytoplankton and zooplankton)	Measured *in situ* using a calibrated Exo2 sonde **Units:** Nephelometric turbidity units (NTU) **ANZECC guideline** 1-2 NTU

The measurements described in *Table 7* inform on the field conditions at the time of monitoring.

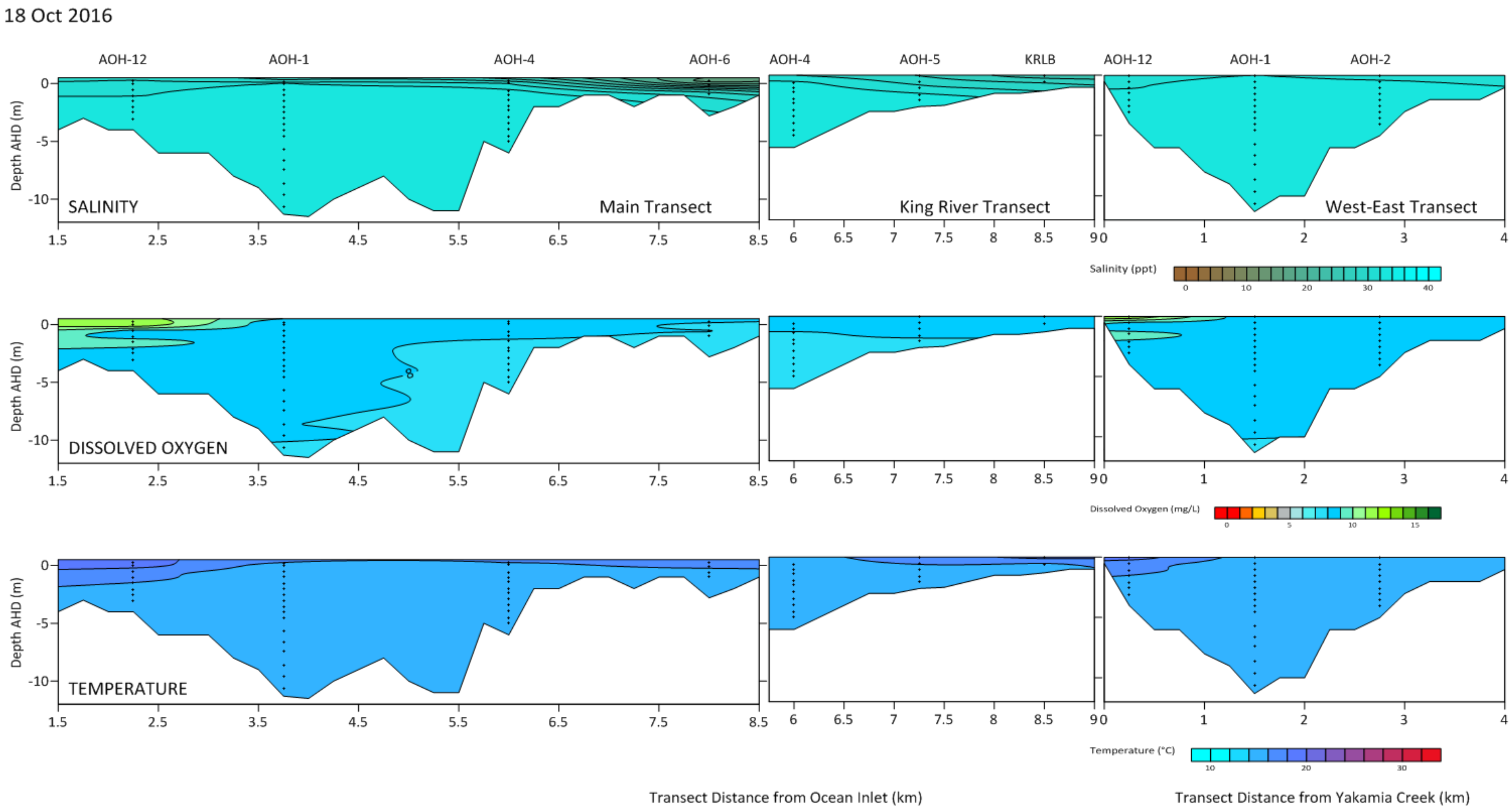
These are documented on *Field Observation Forms* and can be used to inform on any inconsistencies or peculiarities in the physical data collected at a particular site or on a particular day.

Table 7 *Other field observations*

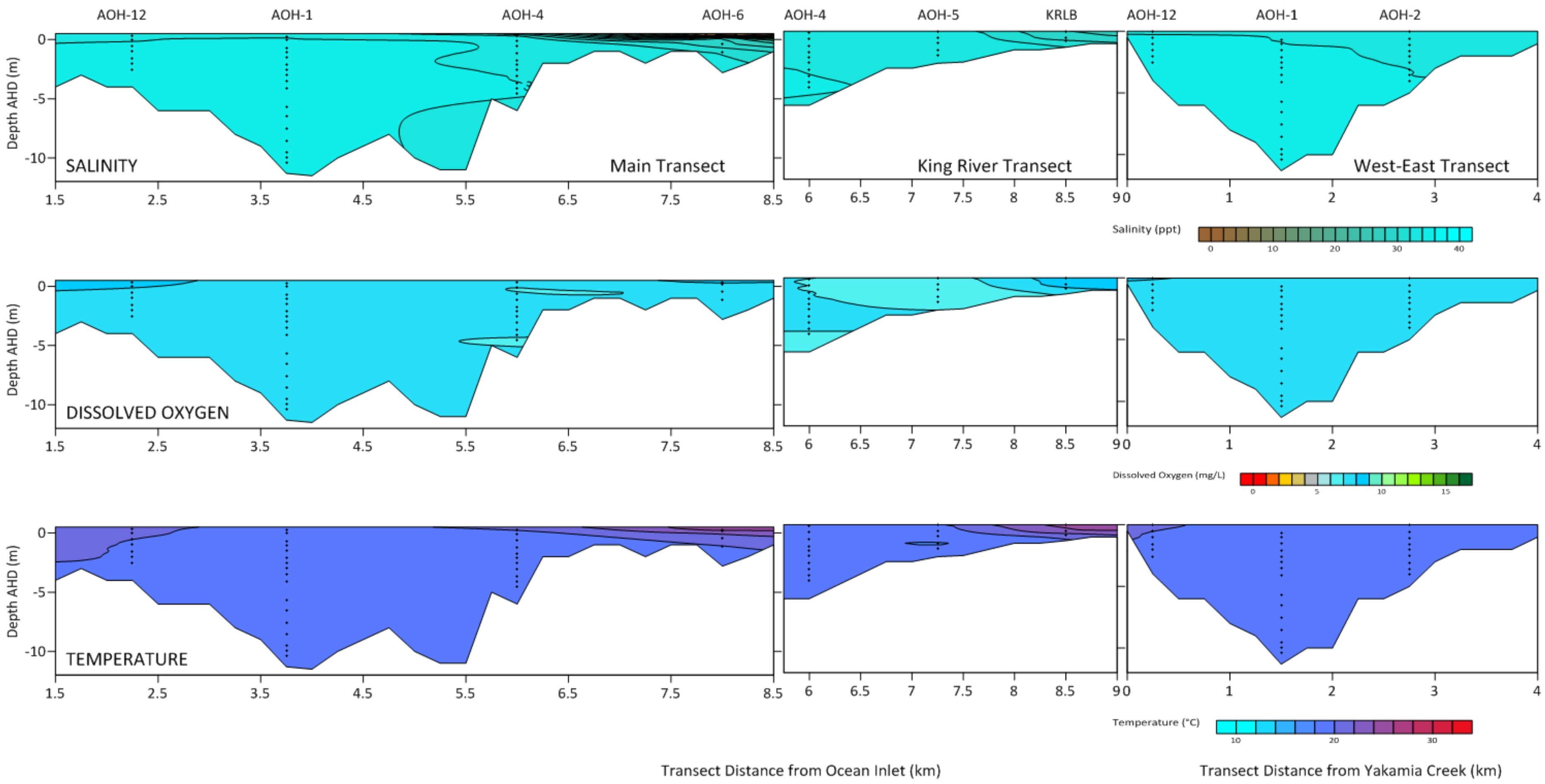
Parameter	Description and relevance	Unit where applicable
Secchi depth	Secchi depth is a measure of water transparency, providing an estimate of turbidity, measured using a Secchi disk.	Measured in the field using a 30 cm diameter Secchi disk. **Units**: m

Wind speed and Wind direction	Wind speed and direction may be useful for interpretation of water quality results as wind can influence waves, water mixing and aeration, location of scums etc.	Measured in the field using an anemometer and compass (or observed). **Units**: knots and degrees
Flow or Tide code	Ebbing, flooding or stationary tide is useful for interpretation of water quality results.	http://www.transport.wa.gov.au/imarine/tide-predictions.asp
Cloud cover	An estimate of the percentage of sky covered by cloud may be useful for interpretation of water quality results.	Observed in the field. **Units**: %

B. Surfer profiles



18 Nov 2016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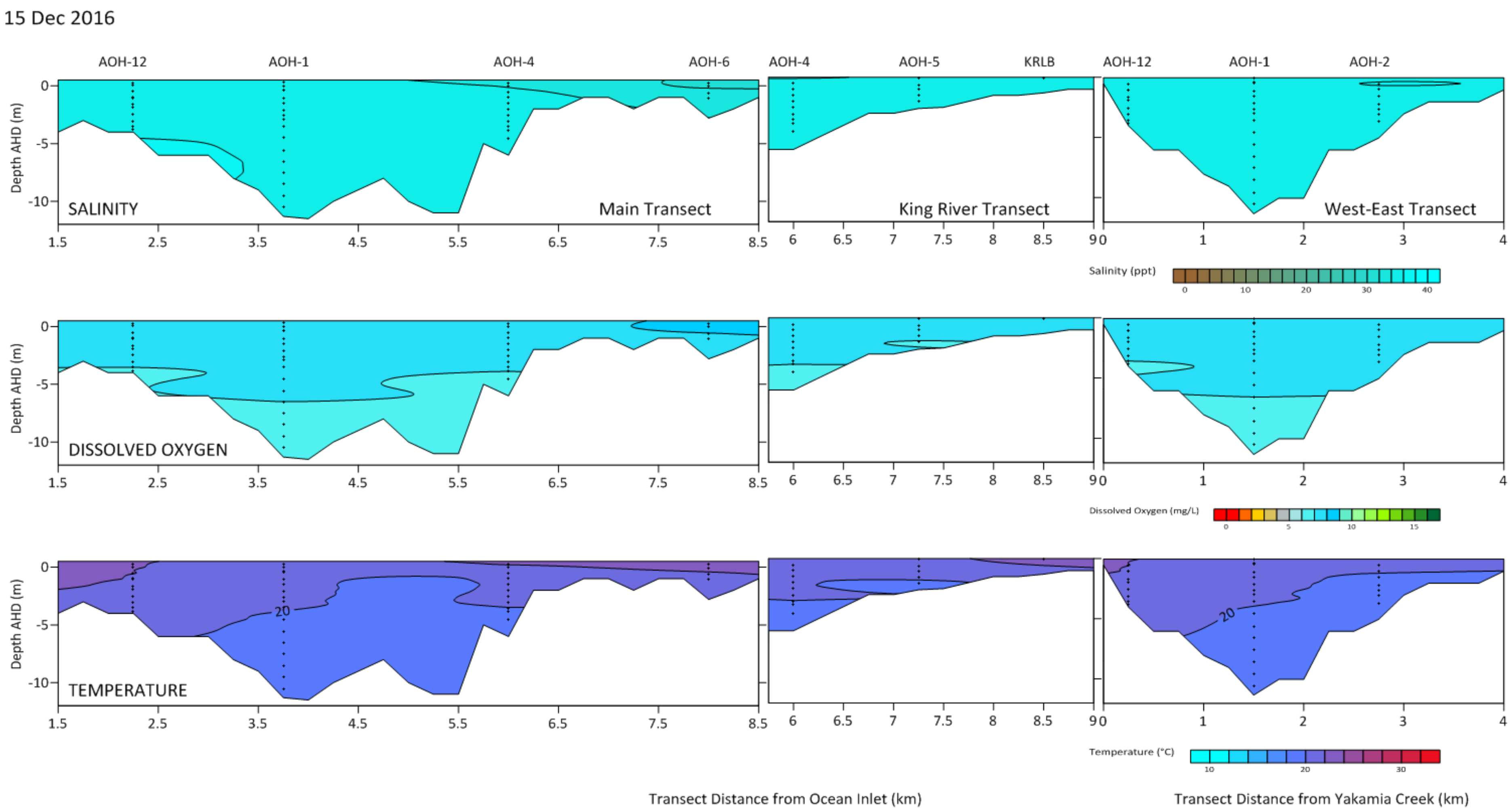
AOH-1
AOH-4
AOH-6
AOH-4
AOH-5
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)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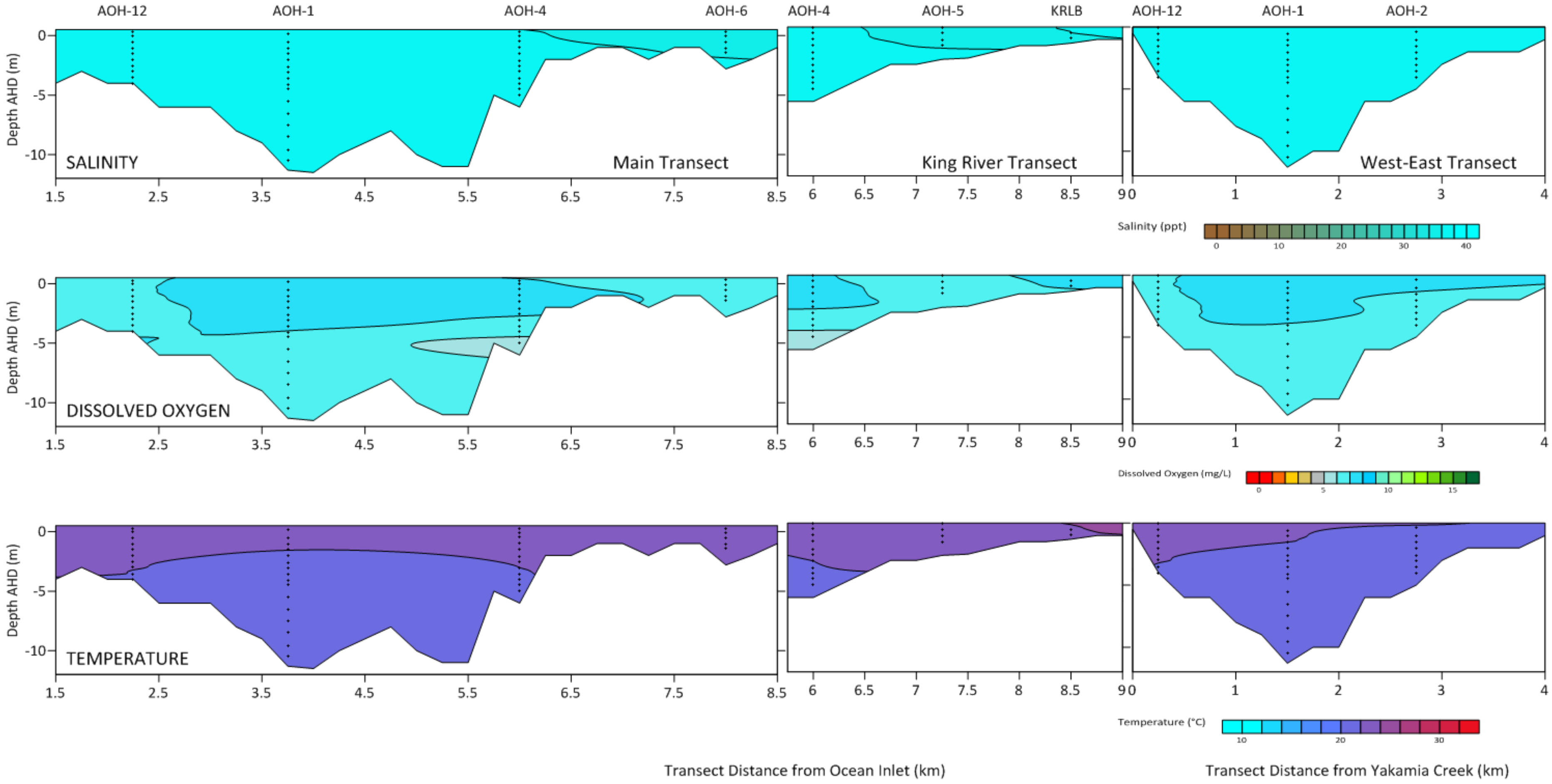
AOH-12
AOH-1
AOH-4
AOH-6
AOH-4
AOH-5
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

10 Jan 2017


AOH-12
AOH-1
AOH-4
AOH-6
AOH-4
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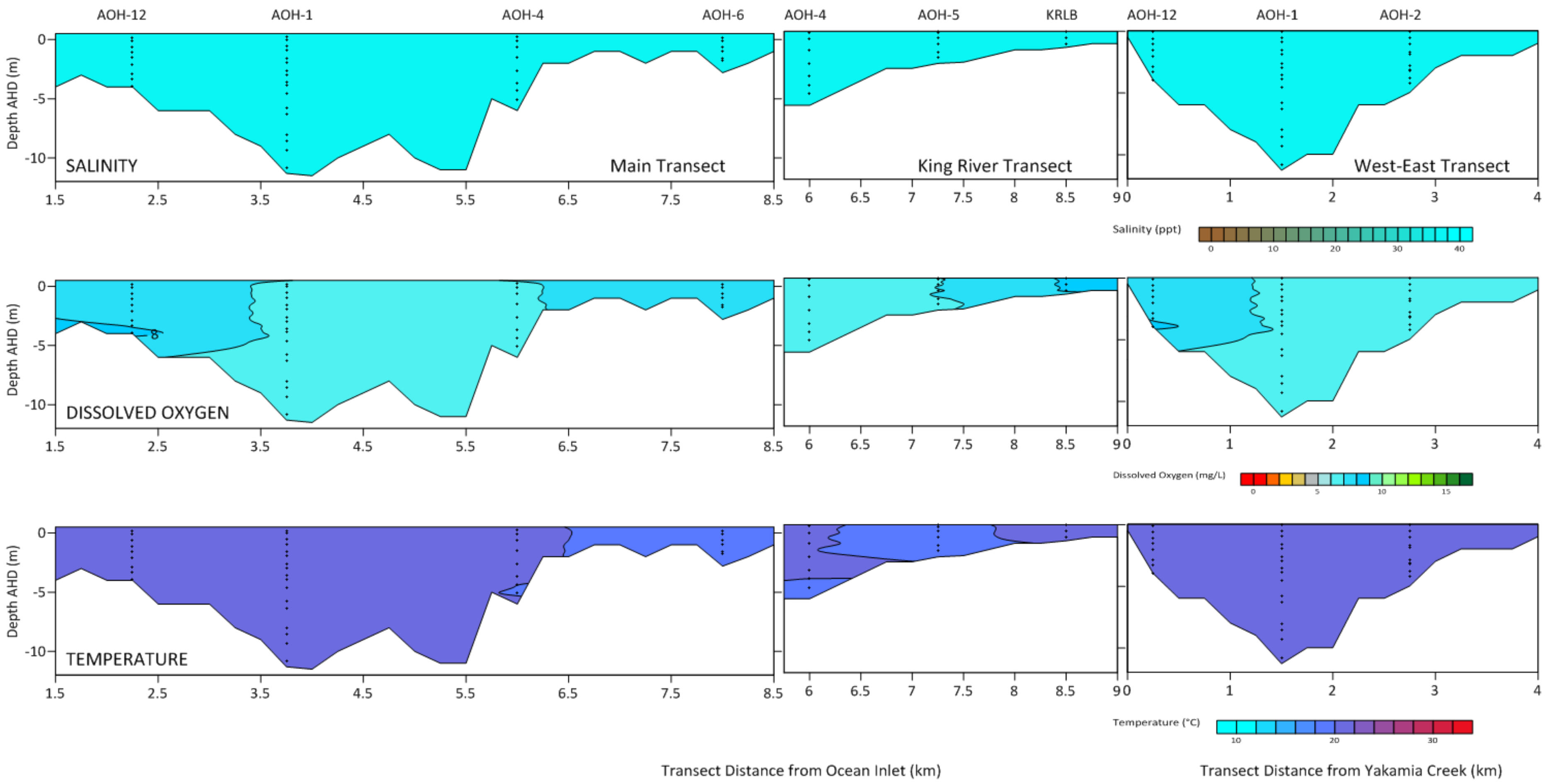
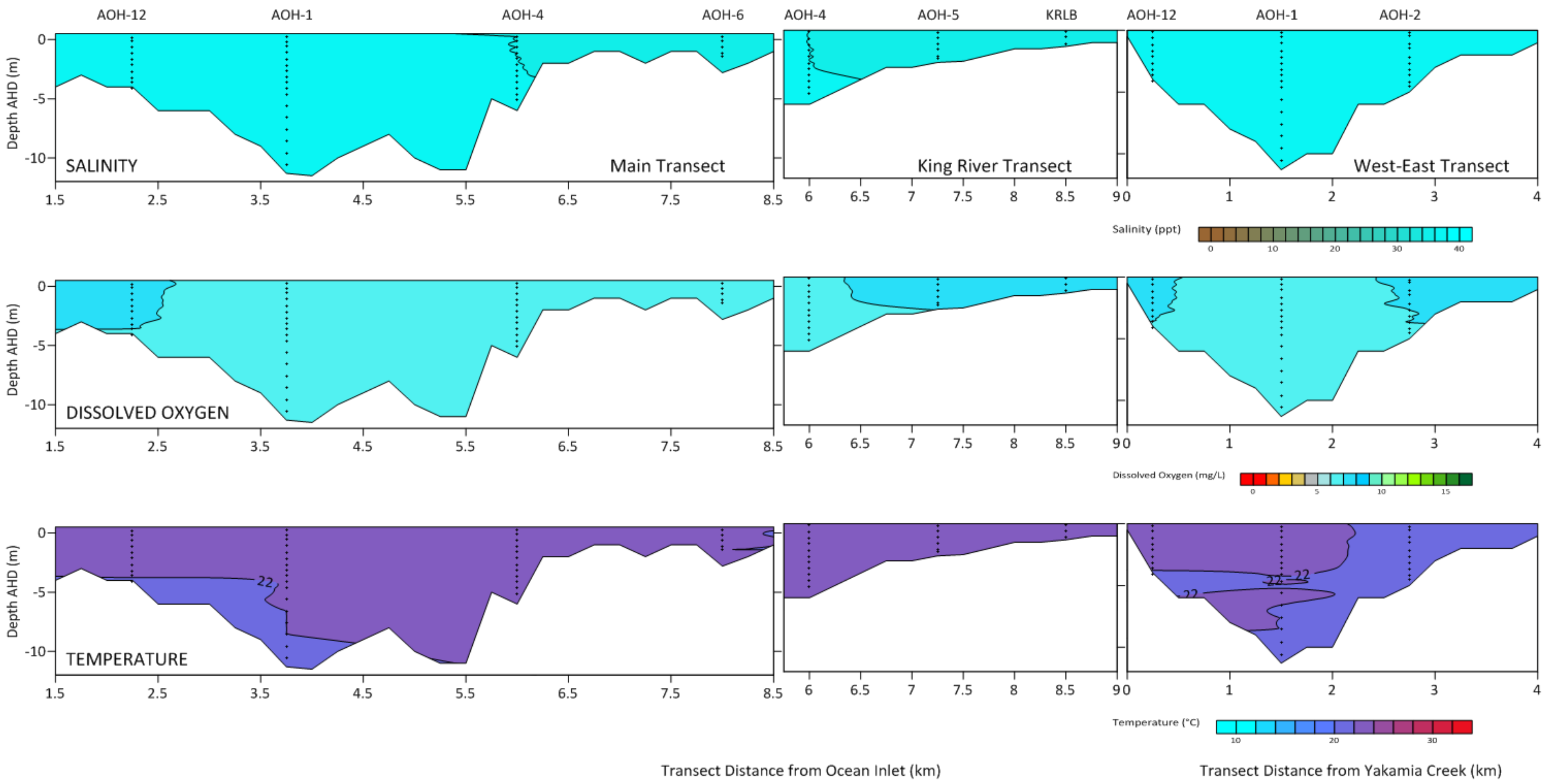
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

08 Feb 2017



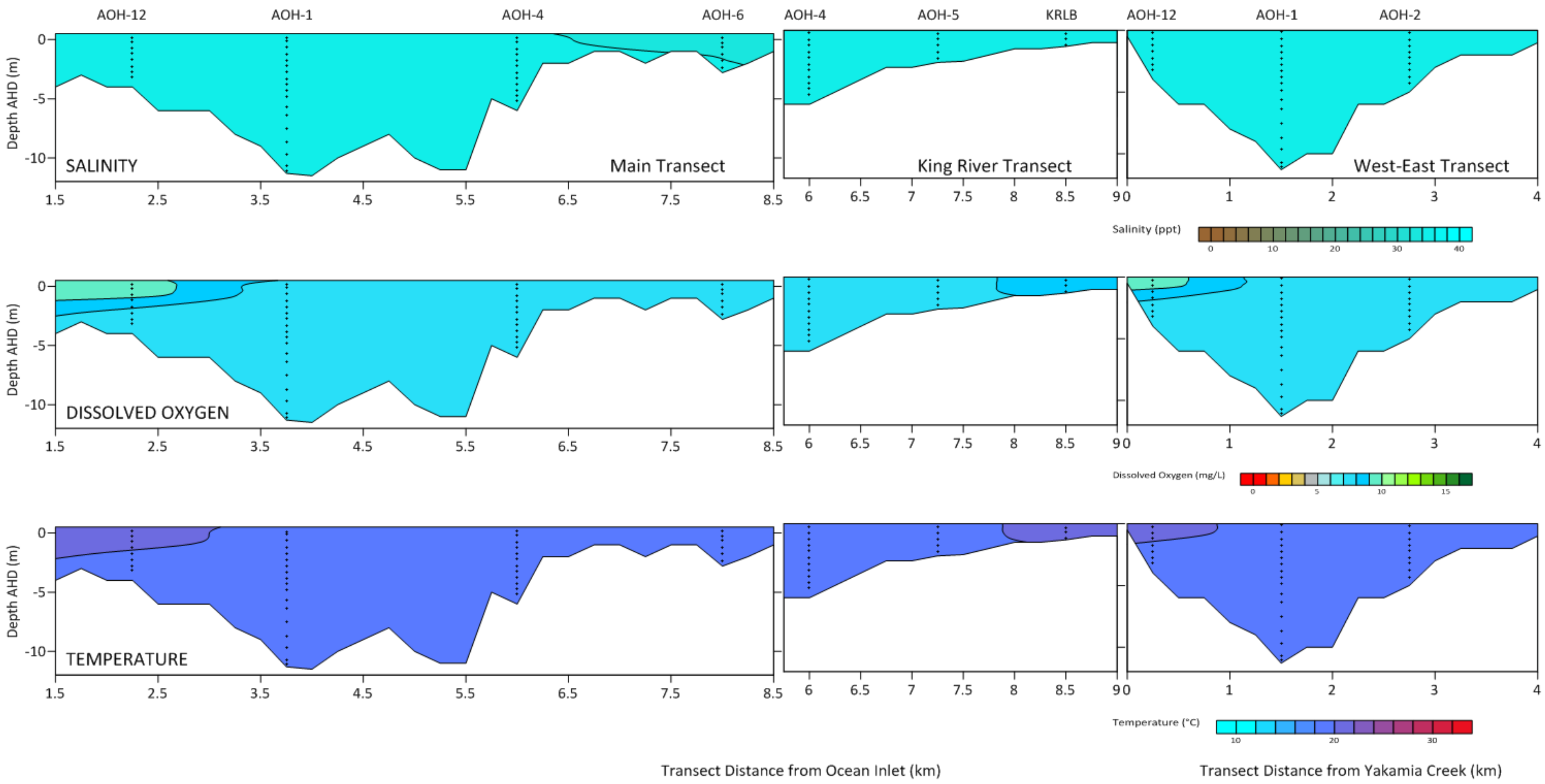
AOH-12
AOH-1
AOH-4
AOH-6
AOH-4
AOH-5
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

18 Mar 2017



AOH-12
AOH-1
AOH-4
AOH-6
AOH-4
AOH-5
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
22
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

04 Apr 2017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AOH-1
AOH-4
AOH-6
AOH-4
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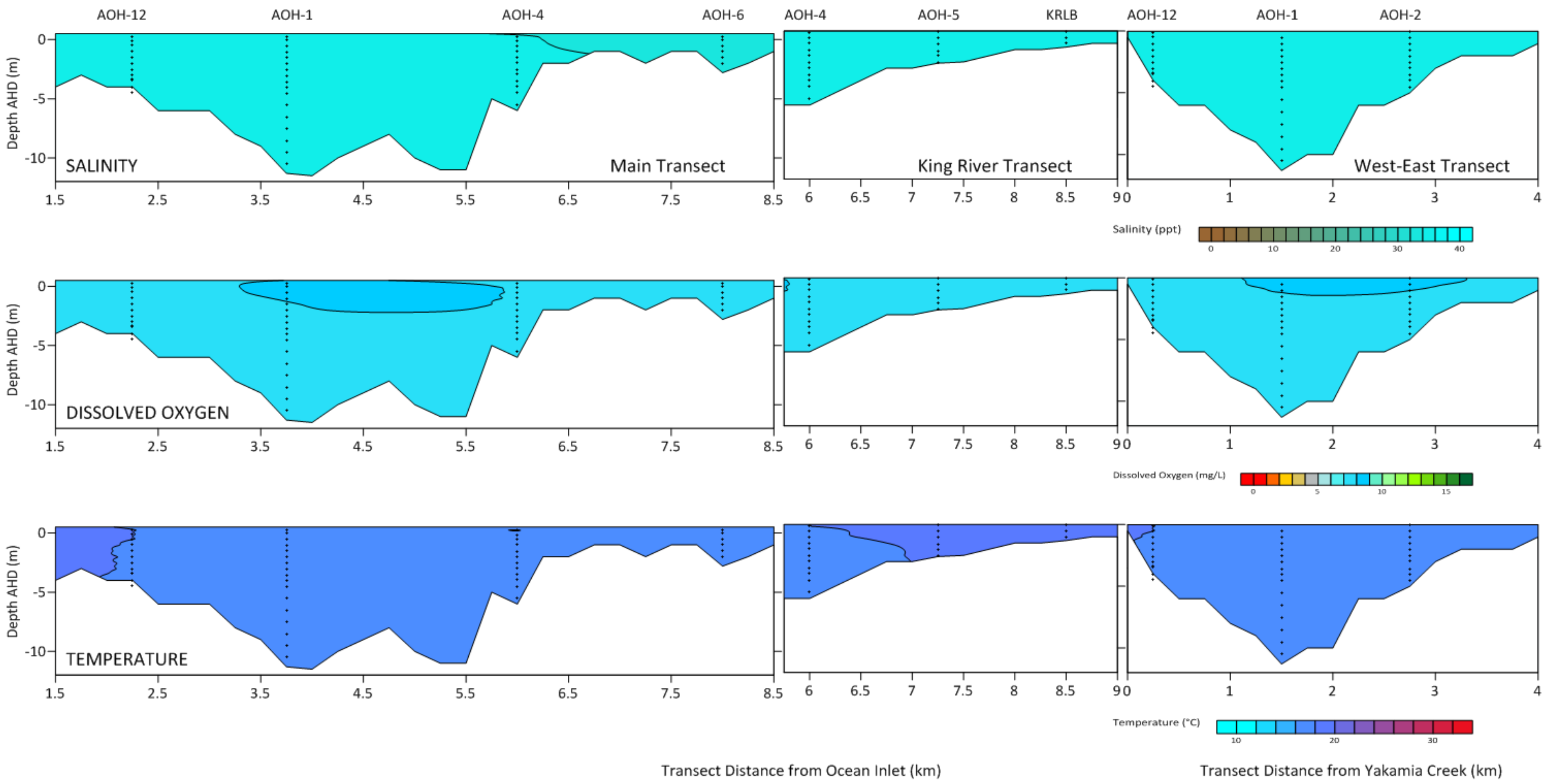
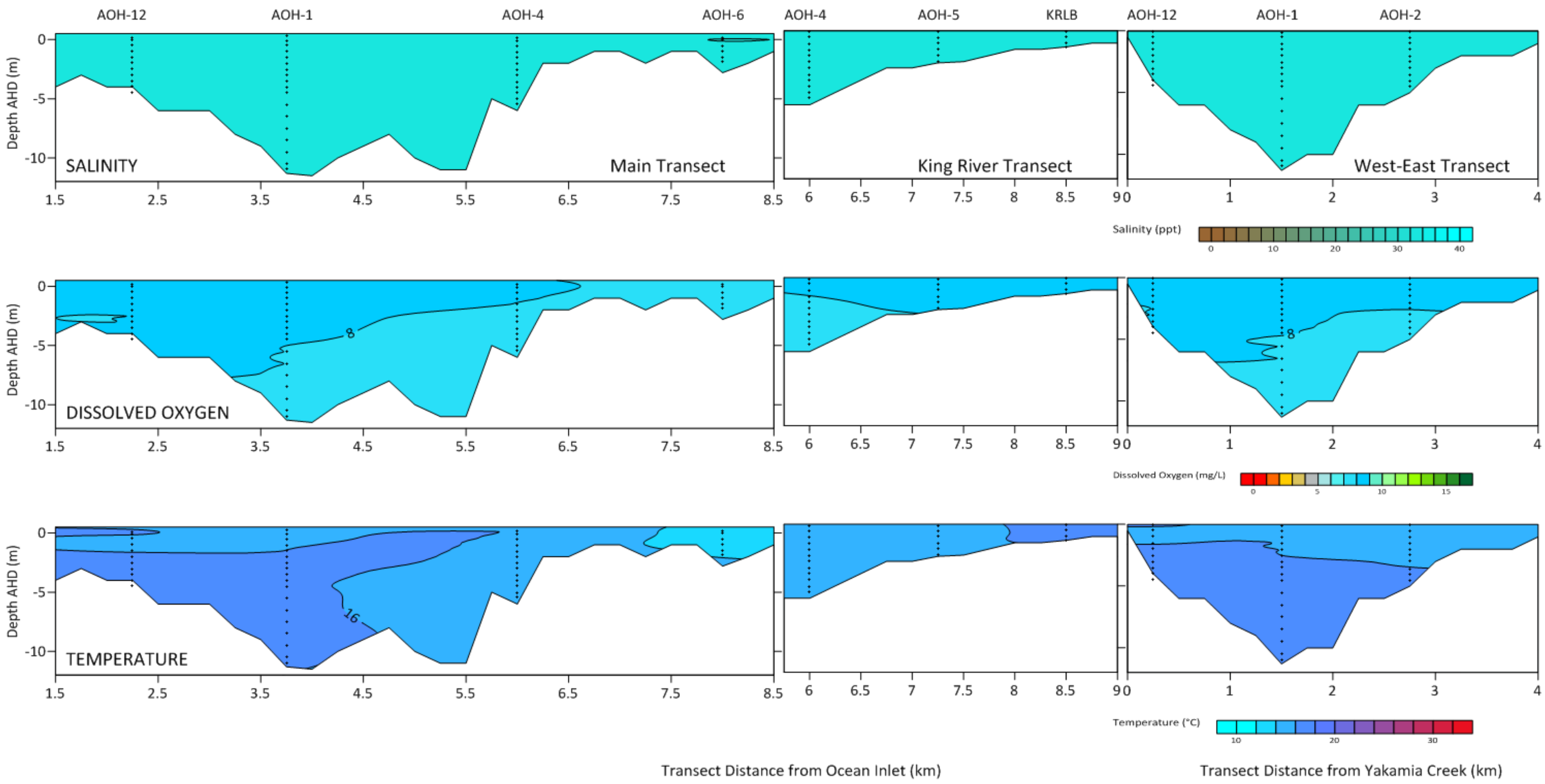
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
0
-5
-10
SALINITY
Main Transect
King River Transect
West-East Transect
1.5
2.5
3.5
4.5
5.5
6.5
7.5
8.5
6
6.5
7
7.5
8
8.5
9
0
1
2
3
4
Salinity (ppt)
0
10
20
30
40
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
0
5
10
15
TEMPERATURE
Temperature (°C)
10
20
30
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

04 May 2017

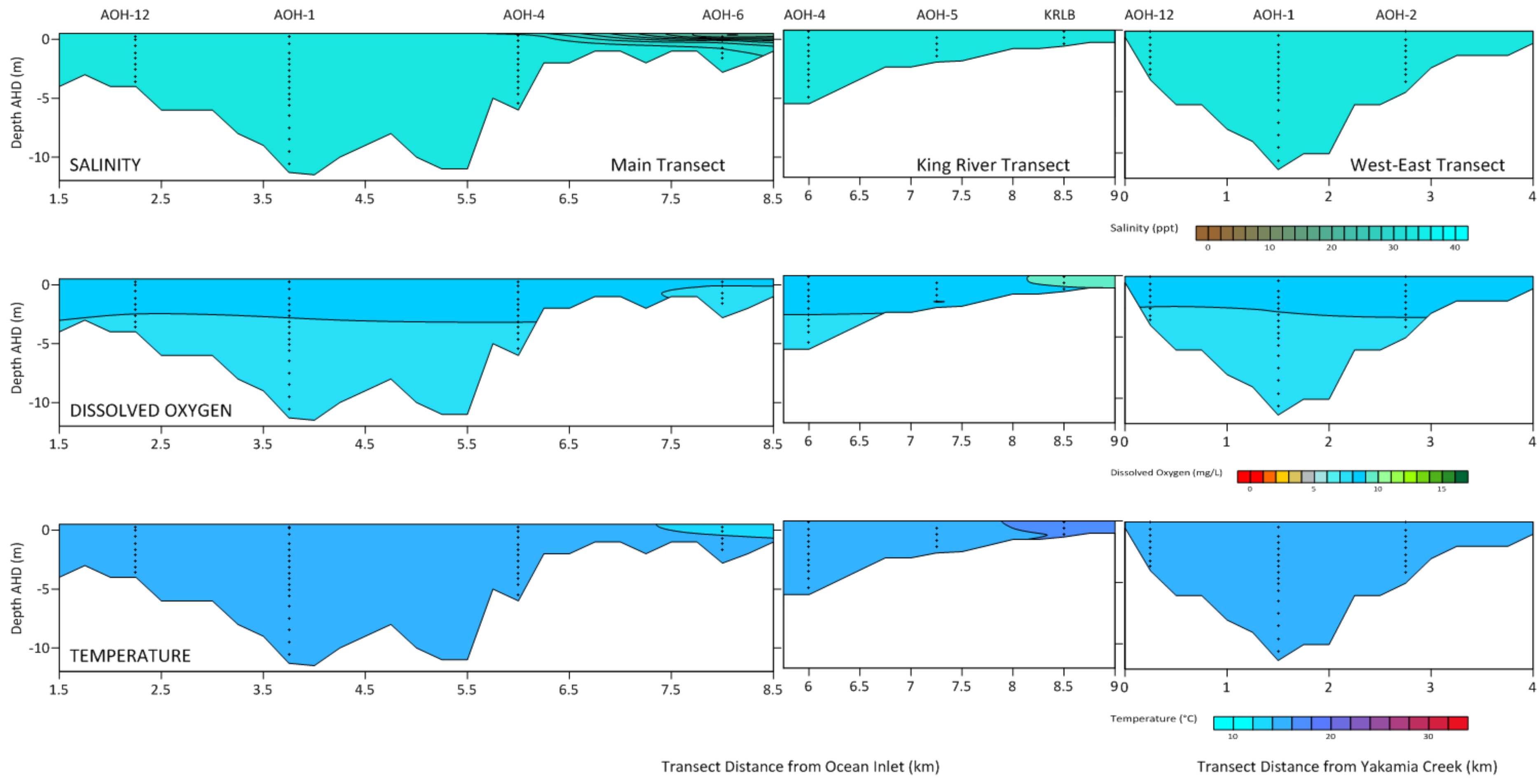


AOH-12
AOH-1
AOH-4
AOH-6
AOH-4
AOH-5
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

01 Jun 2017

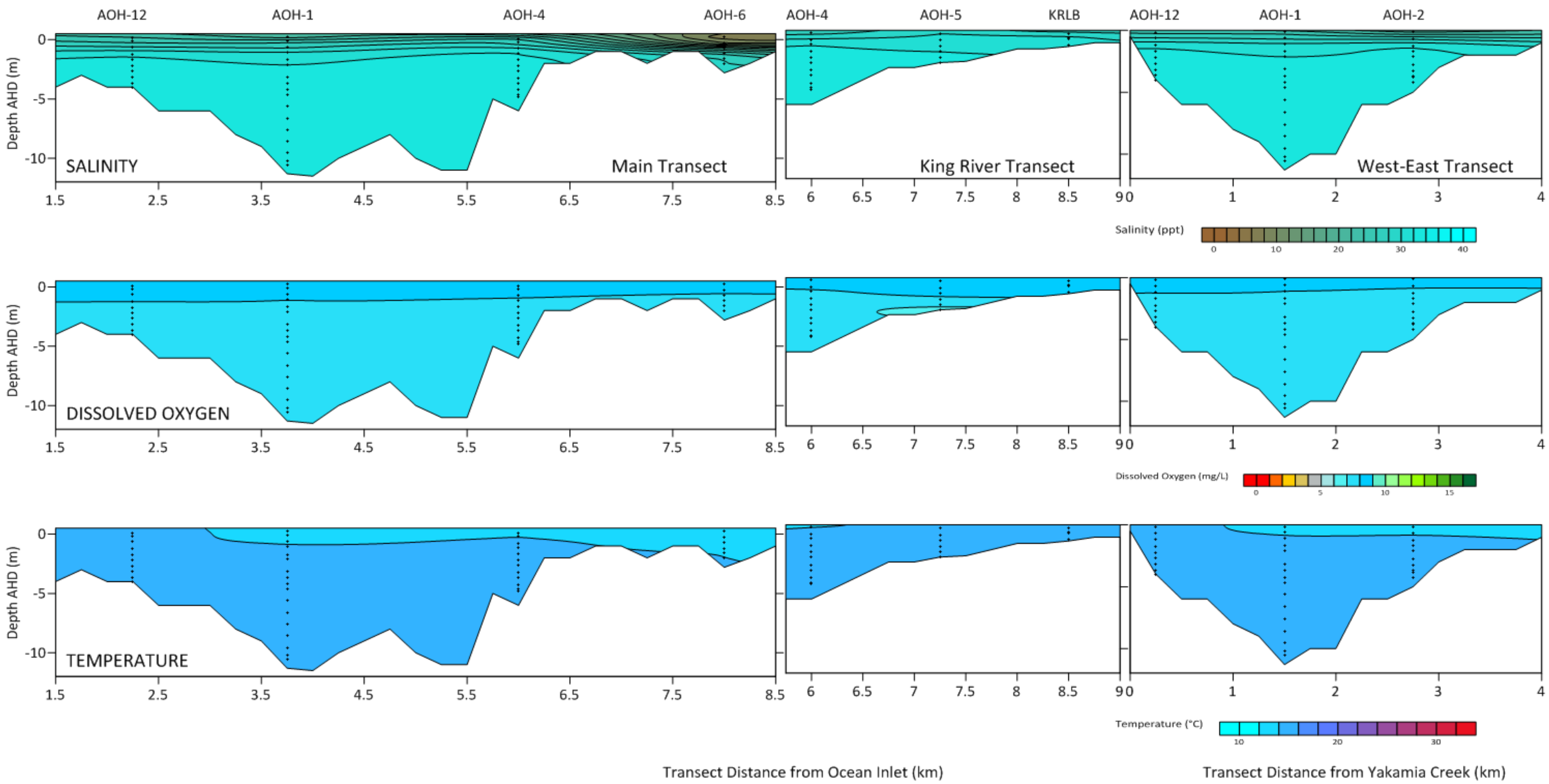

AOH-12
AOH-1
AOH-4
AOH-6
AOH-4
AOH-5
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

28 Jun 2017



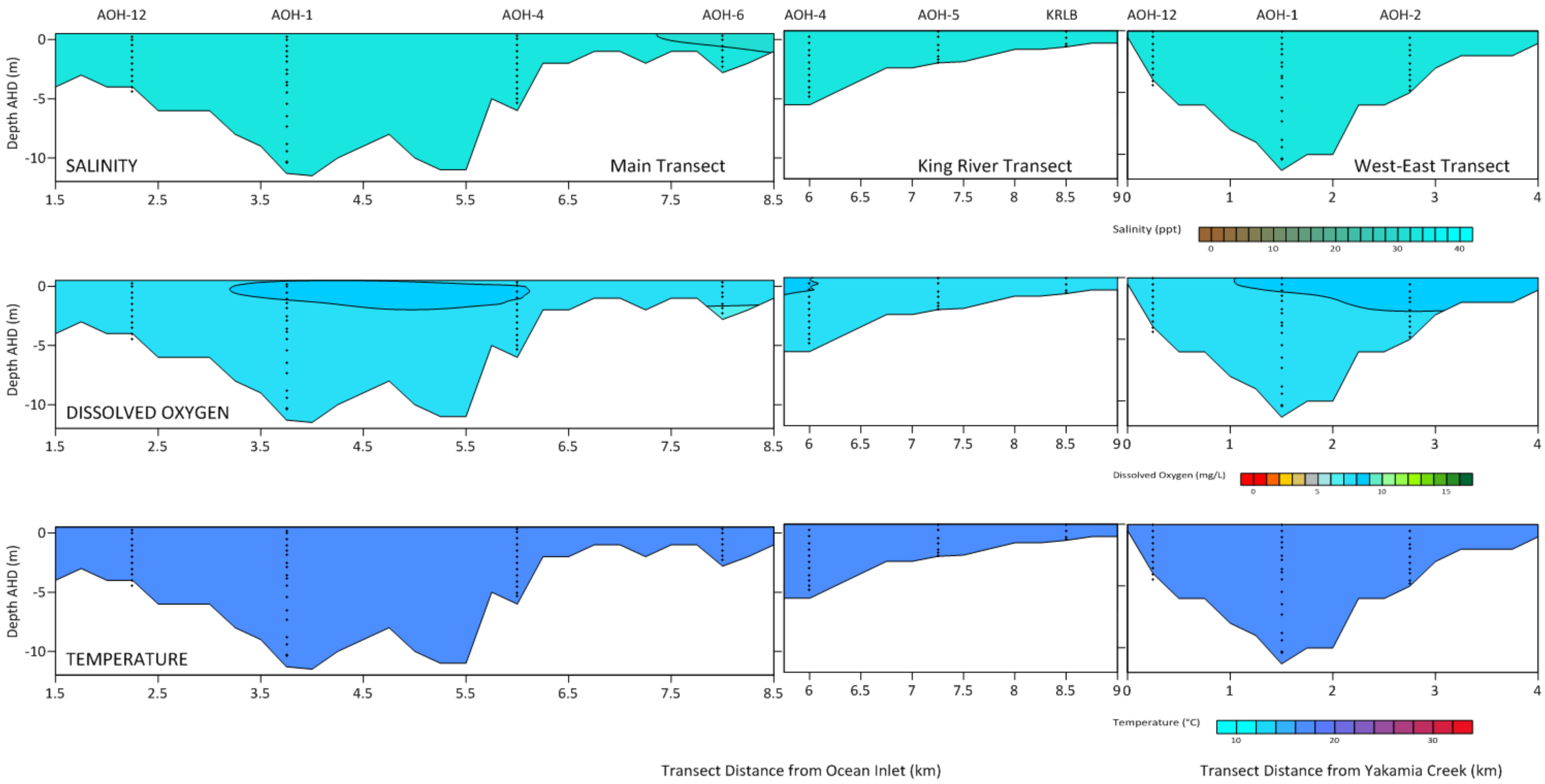
AOH-12
AOH-1
AOH-4
AOH-6
AOH-4
AOH-5
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

23 Aug 2017



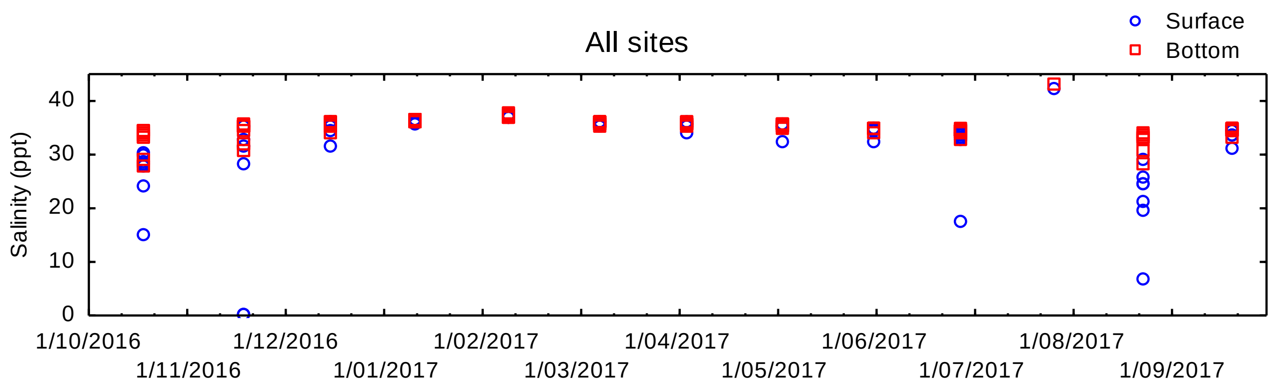
AOH-12
AOH-1
AOH-4
AOH-6
AOH-4
AOH-5
KRLB
AOH-12
AOH-1
AOH-2
Depth AHD (m)
SALINITY
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
DISSOLVED OXYGEN
Dissolved Oxygen (mg/L)
TEMPERATURE
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

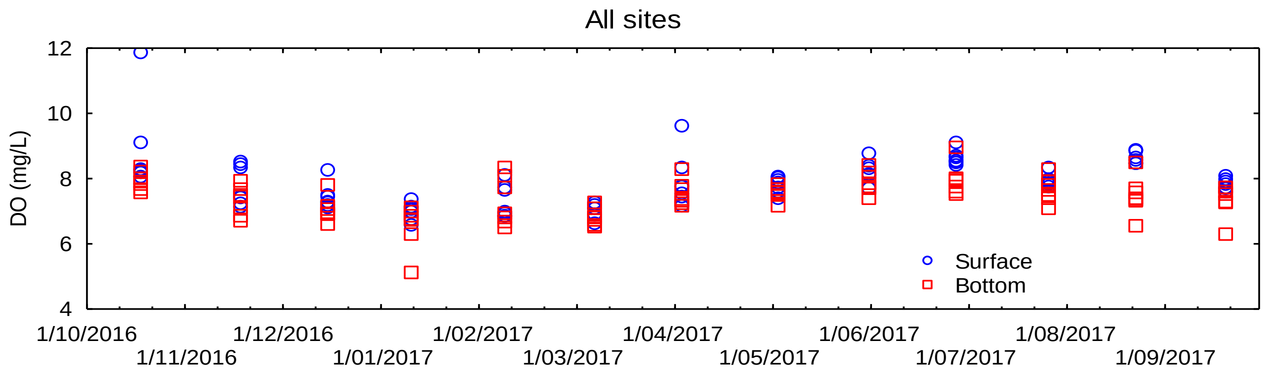
20 Sep 2017

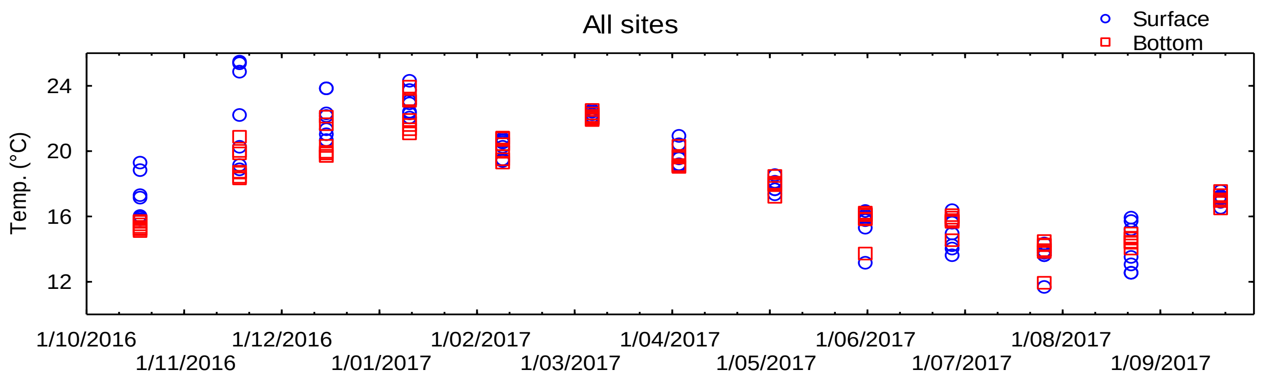


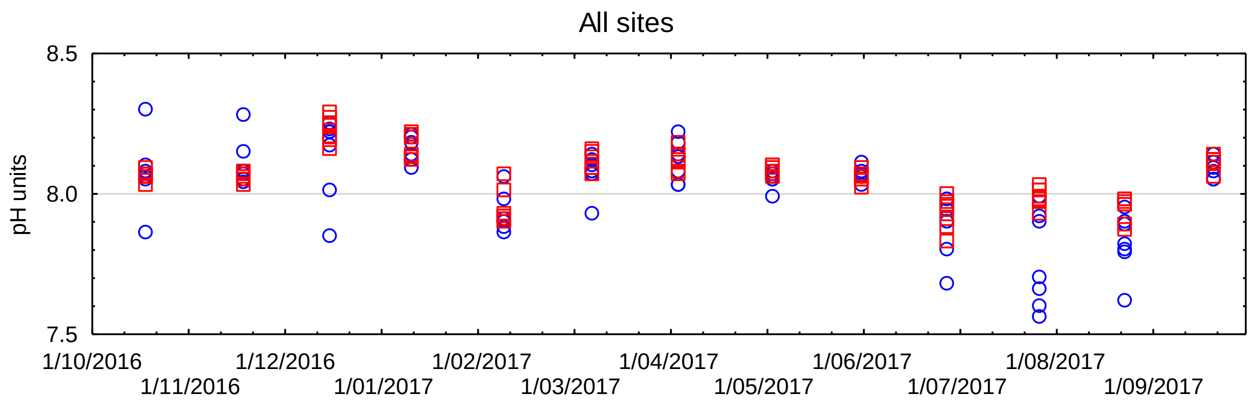
AOH-12
AOH-1
AOH-4
AOH-6
AOH-5
KRLB
AOH-2
Depth AHD (m)
SALINITY
DISSOLVED OXYGEN
TEMPERATURE
Main Transect
King River Transect
West-East Transect
Salinity (ppt)
Dissolved Oxygen (mg/L)
Temperature (°C)
Transect Distance from Ocean Inlet (km)
Transect Distance from Yakamia Creek (km)

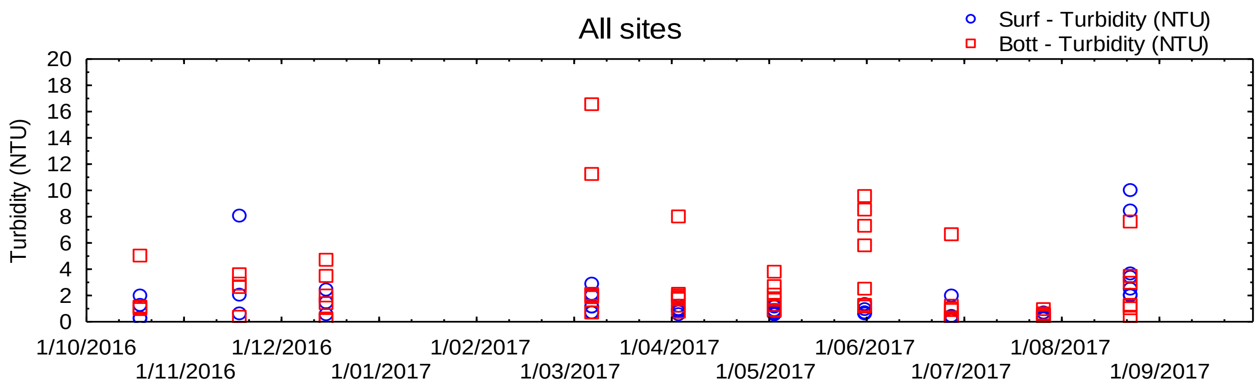
C. Water quality indicator time series

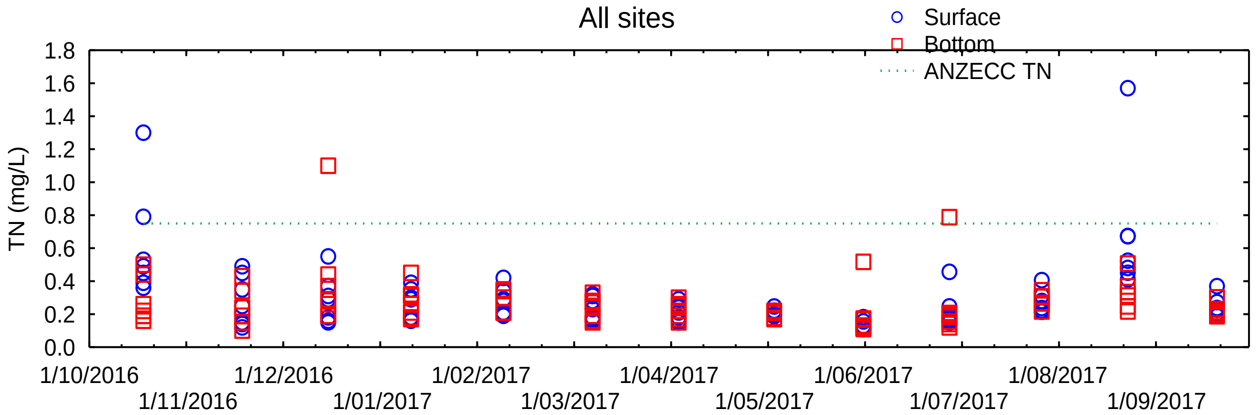


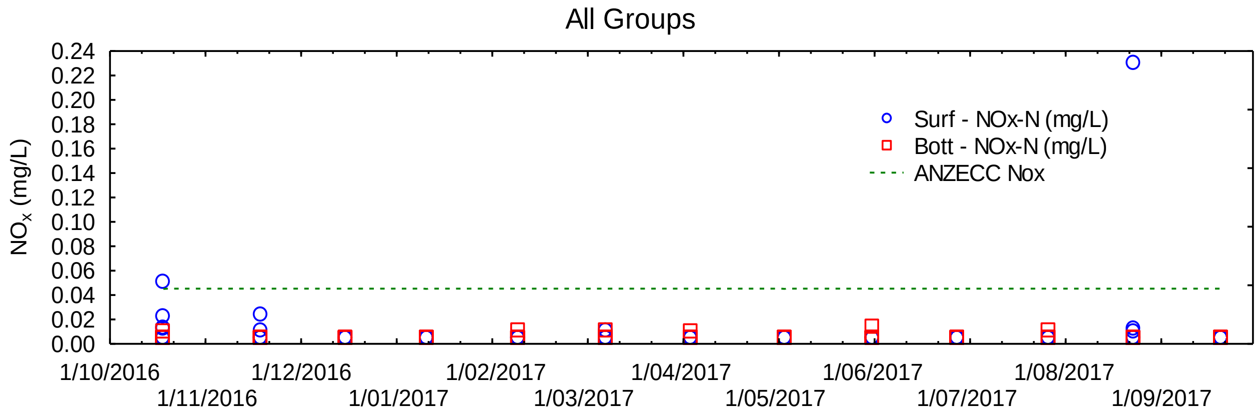


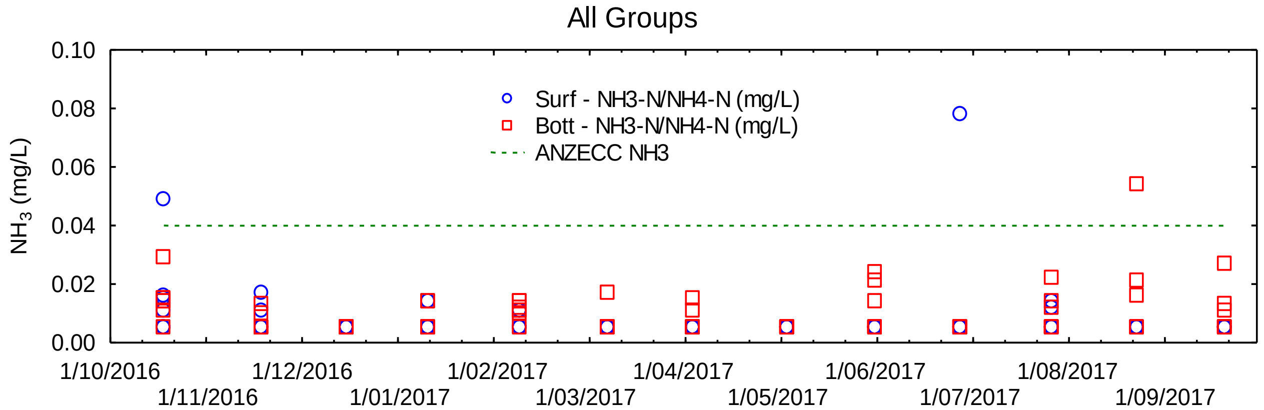


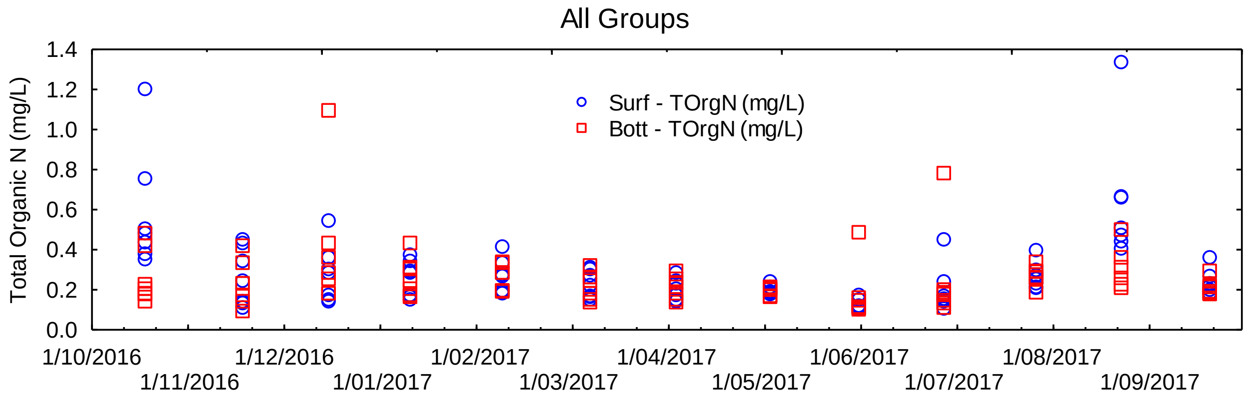


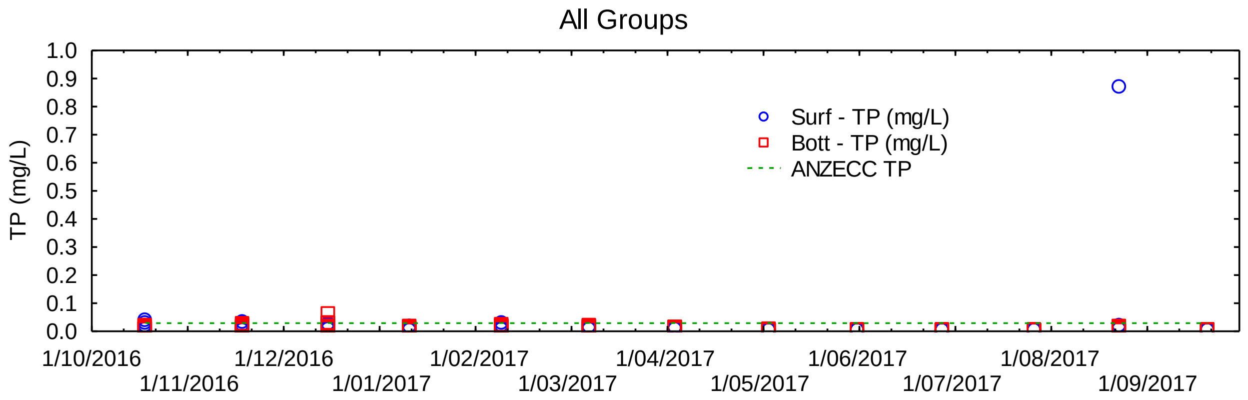

All sites
Surf - Turbidity (NTU)
Bott - Turbidity (NTU)
Turbidity (NTU)
20
18
16
14
12
10
8
6
4
2
0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

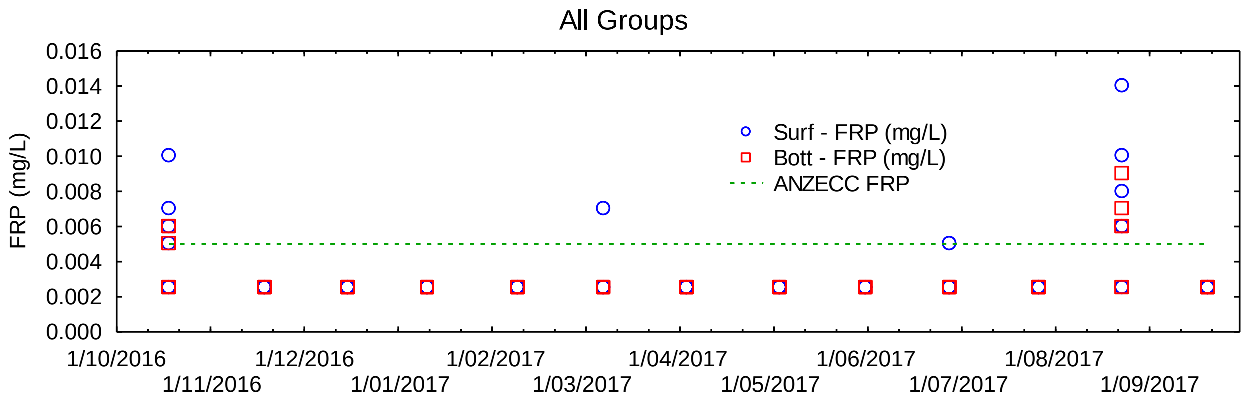

All sites
Surface
Bottom
ANZECC TN
TN (mg/L)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

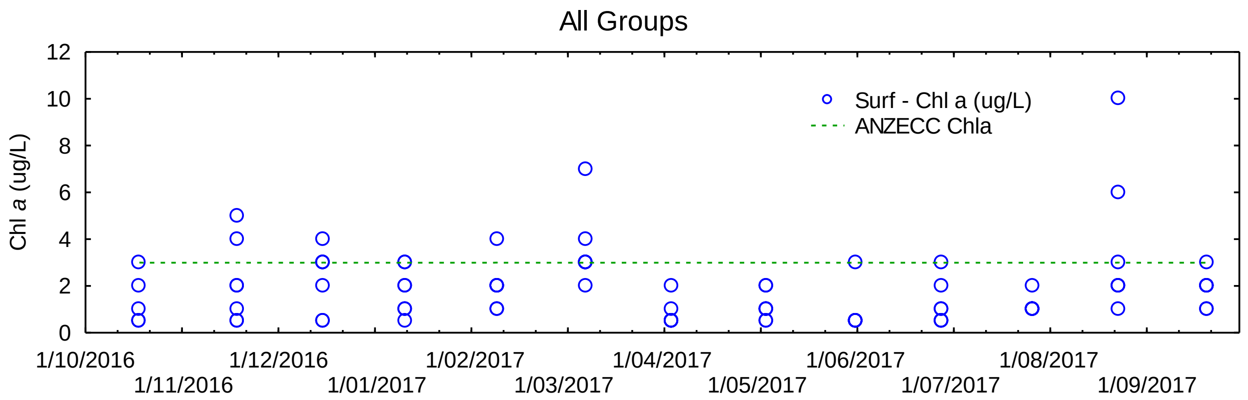

All Groups
Surf - NOx-N (mg/L)
Bott - NOx-N (mg/L)
ANZECC Nox
NO_x (mg/L)
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

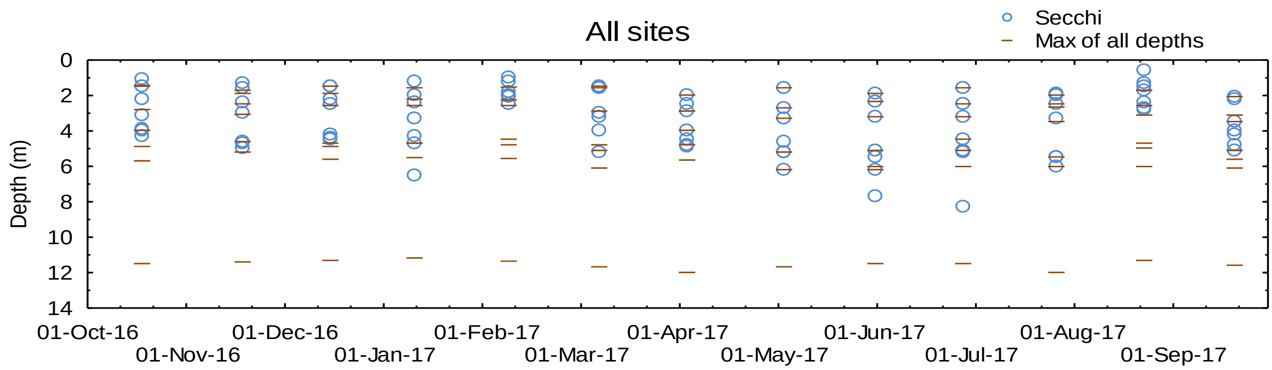

All Groups
Surf - NH3-N/NH4-N (mg/L)
Bott - NH3-N/NH4-N (mg/L)
ANZECC NH3
NH_3 (mg/L)
0.10
0.08
0.06
0.04
0.02
0.00
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

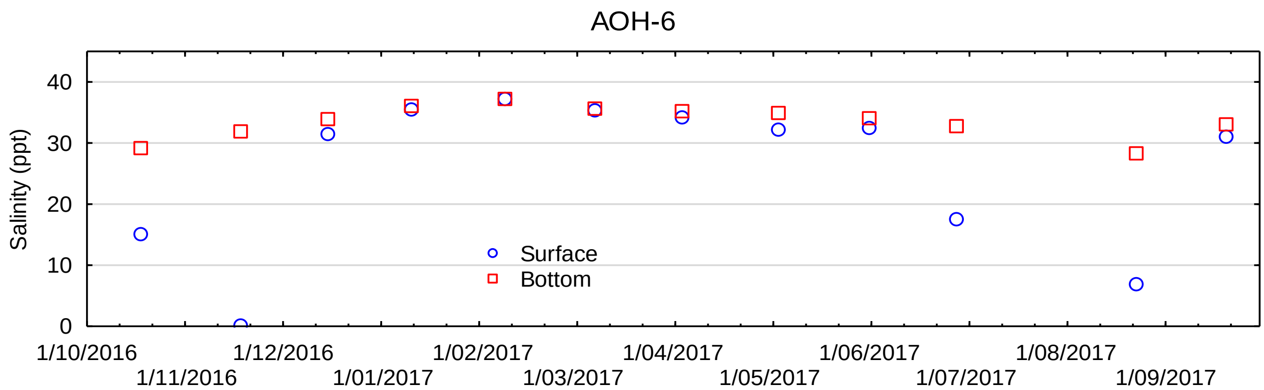

All Groups
Total Organic N (mg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Surf - TOrgN (mg/L)
Bott - TOrgN (mg/L)
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

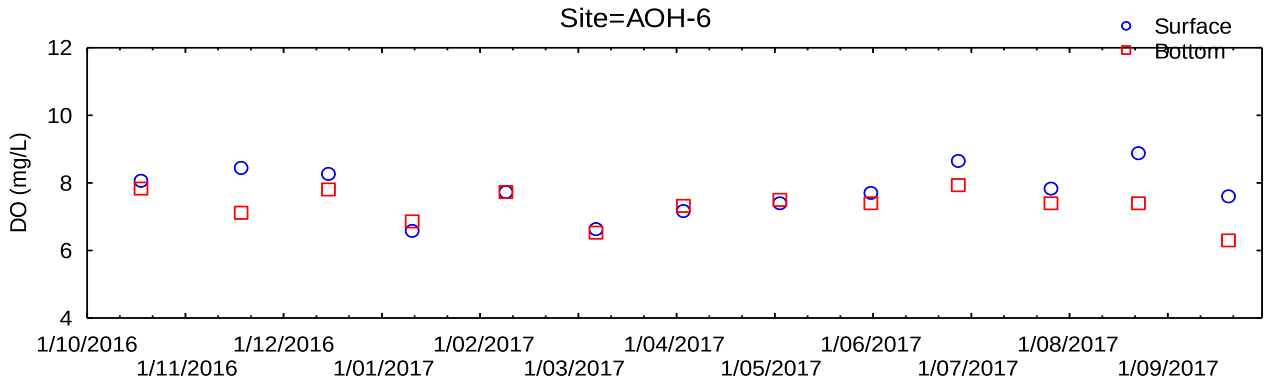

All Groups
TP (mg/L)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Surf - TP (mg/L)
Bott - TP (mg/L)
ANZECC TP
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

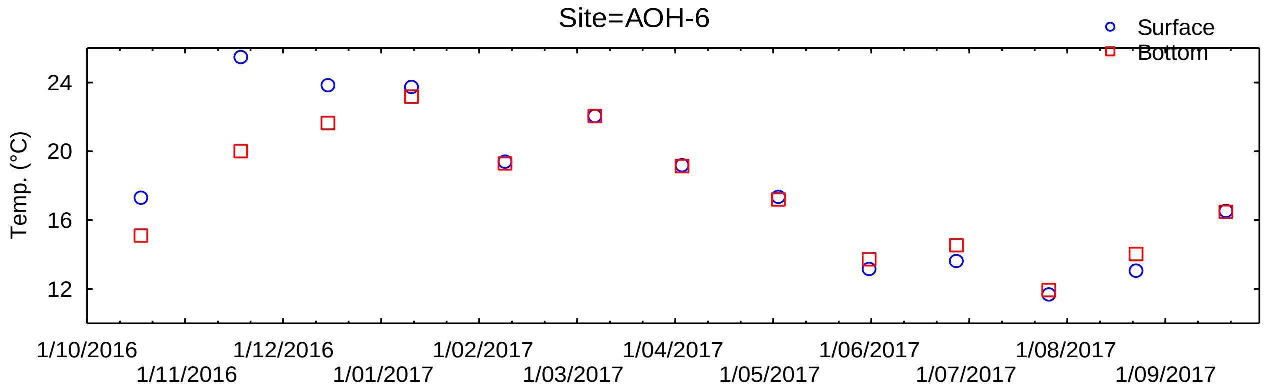

All Groups
FRP (mg/L)
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Surf - FRP (mg/L)
Bott - FRP (mg/L)
ANZECC FRP
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

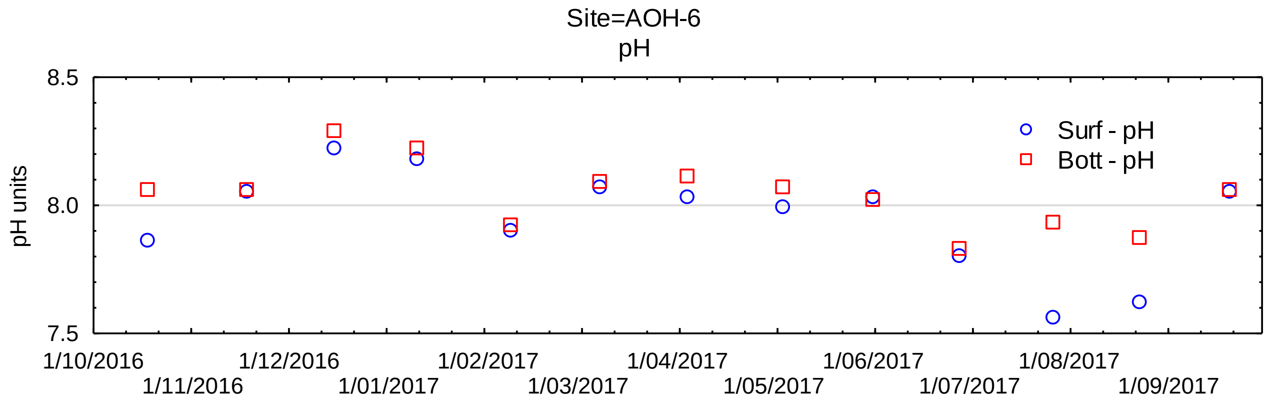

All Groups
Chl a (ug/L)
12
10
8
6
4
2
0
Surf - Chl a (ug/L)
ANZECC Chla
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

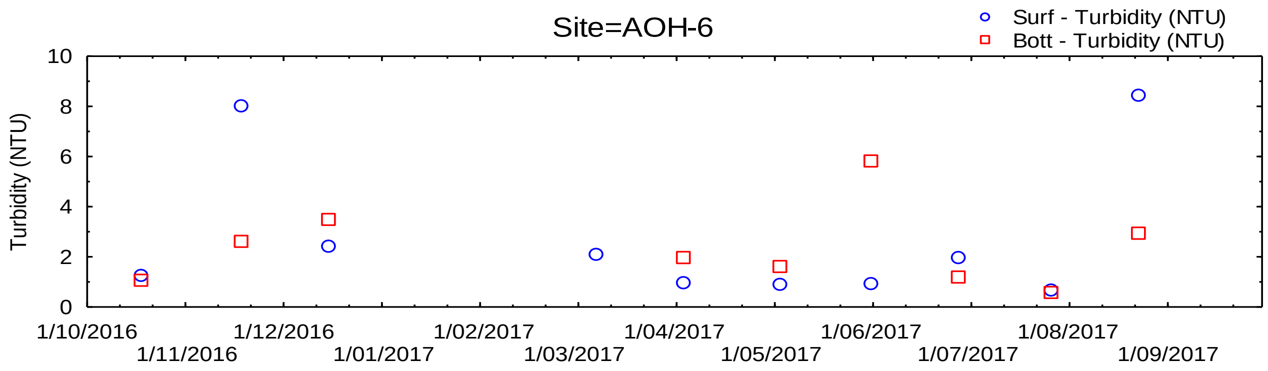

All sites
Secchi
Max of all depths
Depth (m)
0
2
4
6
8
10
12
14
01-Oct-16
01-Nov-16
01-Dec-16
01-Jan-17
01-Feb-17
01-Mar-17
01-Apr-17
01-May-17
01-Jun-17
01-Jul-17
01-Aug-17
01-Sep-17

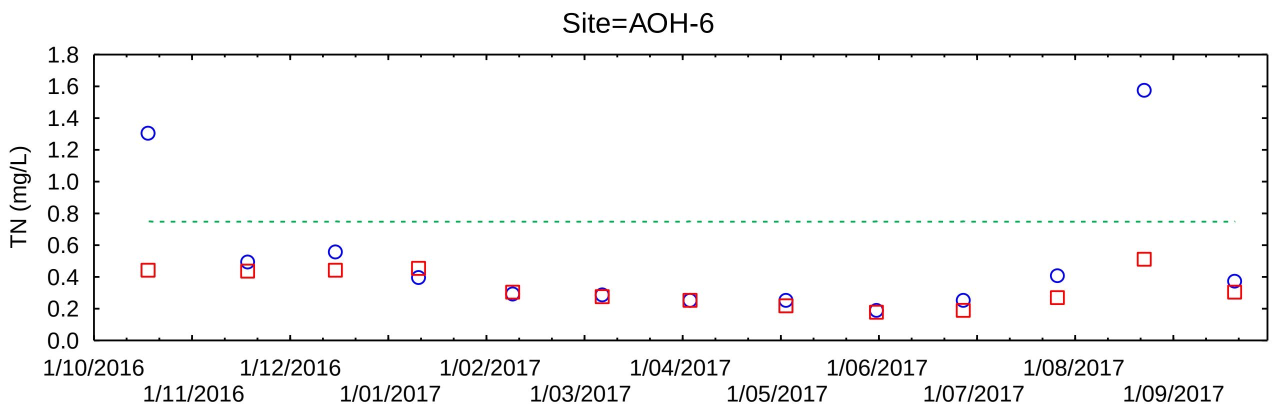

AOH-6
Salinity (ppt)
0
10
20
30
40
Surface
Bottom
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

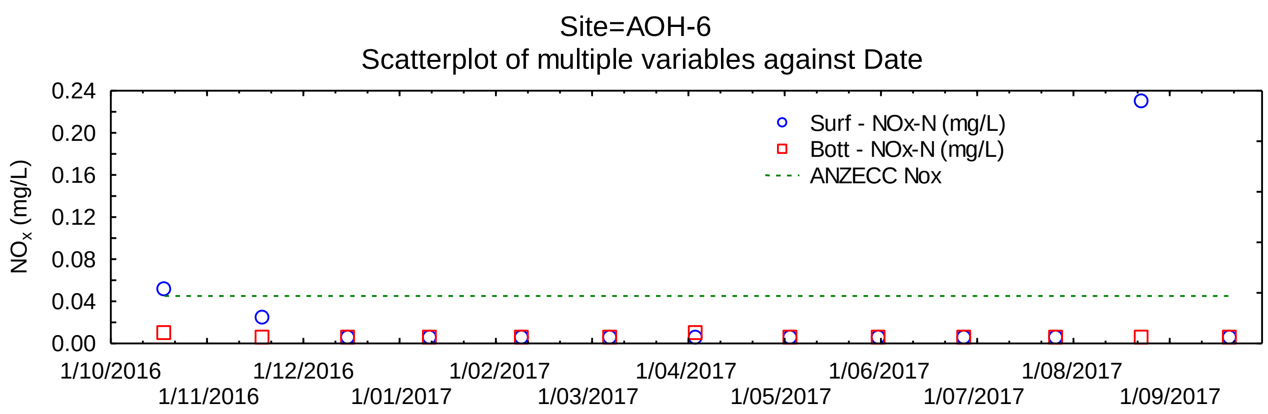

Site=AOH-6
Surface
Bottom
DO (mg/L)
4
6
8
10
12
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

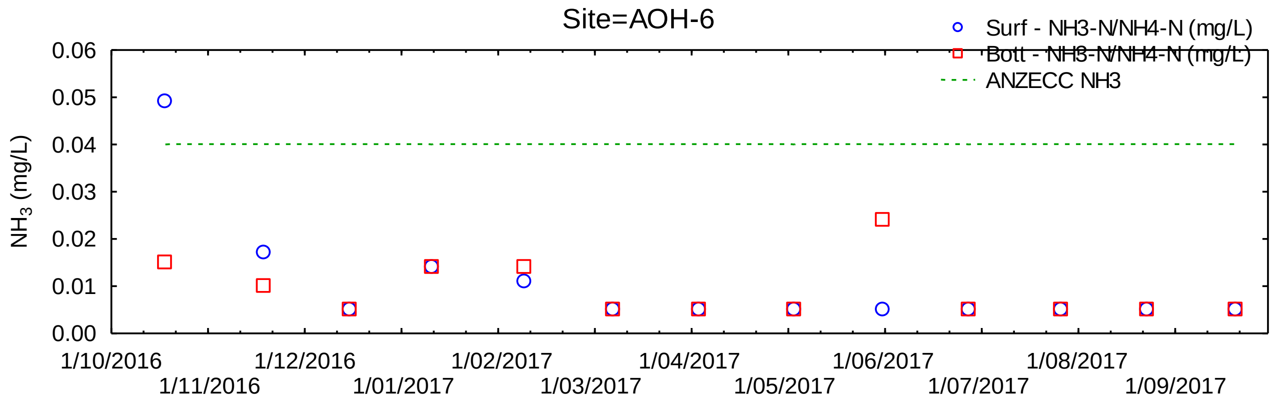

Site=AOH-6
Surface
Bottom
Temp. (°C)
12
16
20
24
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

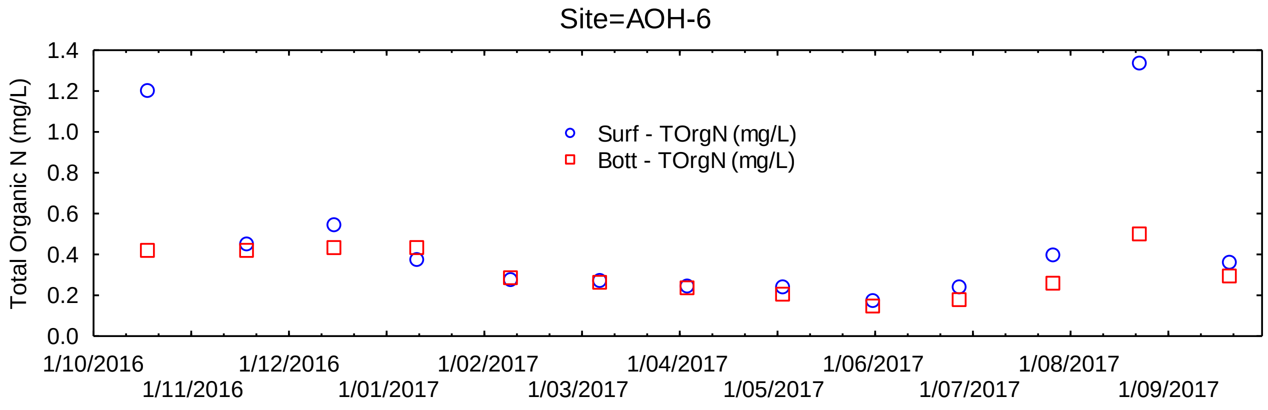

Site=AOH-6
pH
pH units
Surf - pH
Bott - pH
8.5
8.0
7.5
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

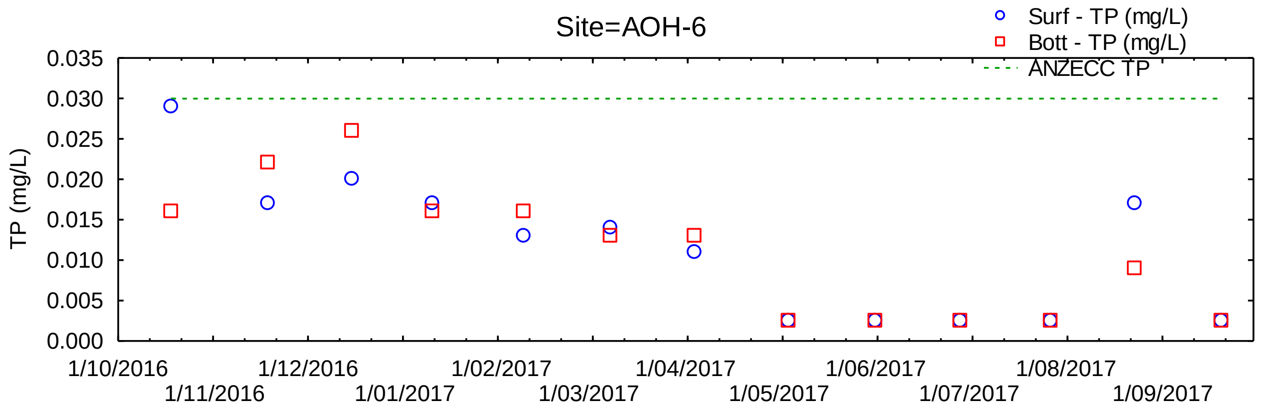

Site=AOH-6
Surf - Turbidity (NTU)
Bott - Turbidity (NTU)
Turbidity (NTU)
10
8
6
4
2
0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

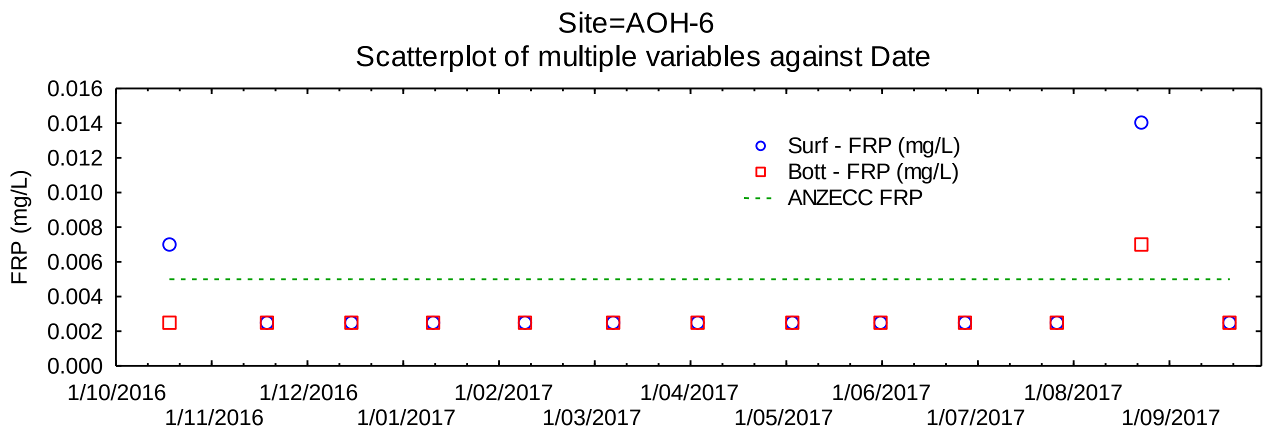

Site=AOH-6
TN (mg/L)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

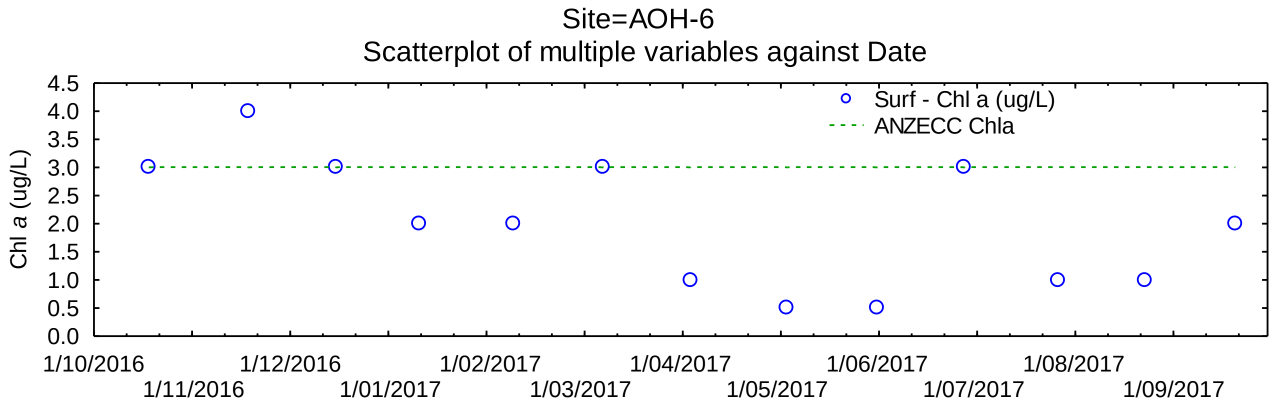

Site=AOH-6
Scatterplot of multiple variables against Date
Surf - NOx-N (mg/L)
Bott - NOx-N (mg/L)
ANZECC Nox
NOx (mg/L)
0.24
0.20
0.16
0.12
0.08
0.04
0.00
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

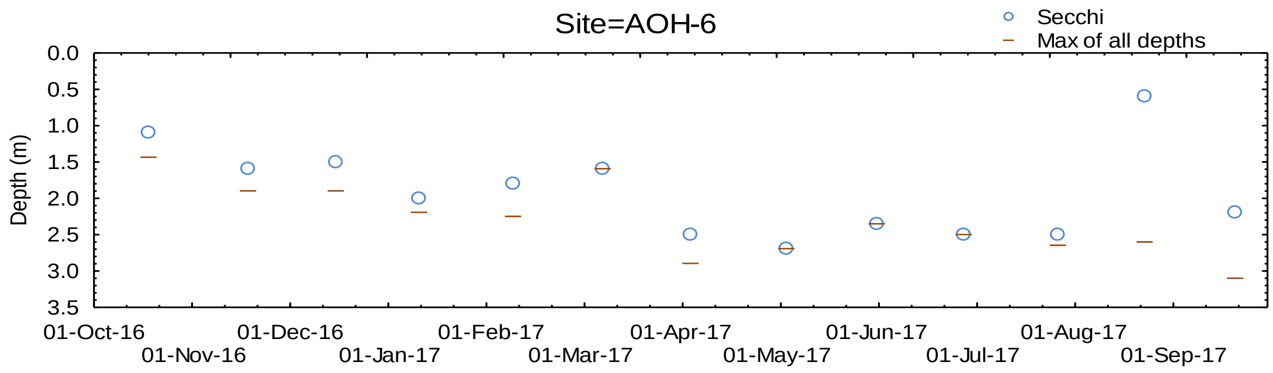

Site=AOH-6
Surf - NH3-N/NH4-N (mg/L)
Bott - NH3-N/NH4-N (mg/L)
ANZECC NH3
NH3 (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

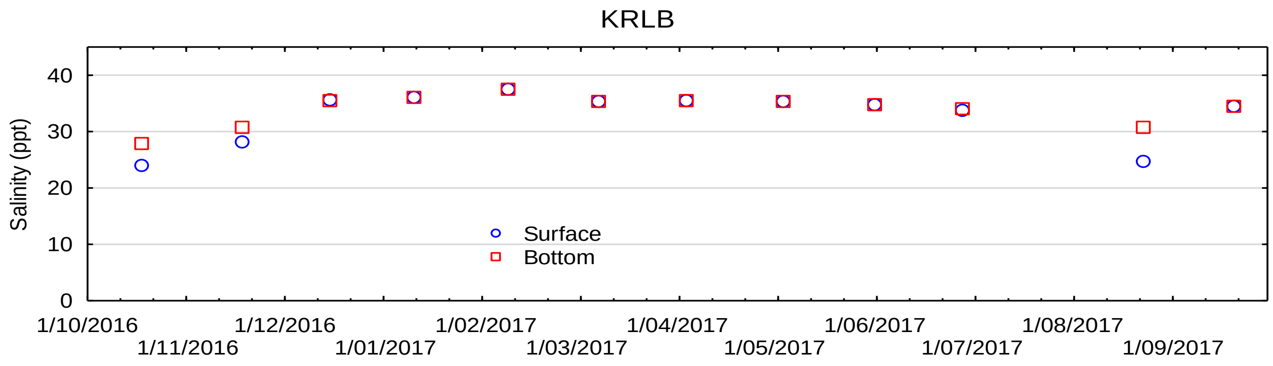

Site=AOH-6
Surf - TOrgN (mg/L)
Bott - TOrgN (mg/L)
Total Organic N (mg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

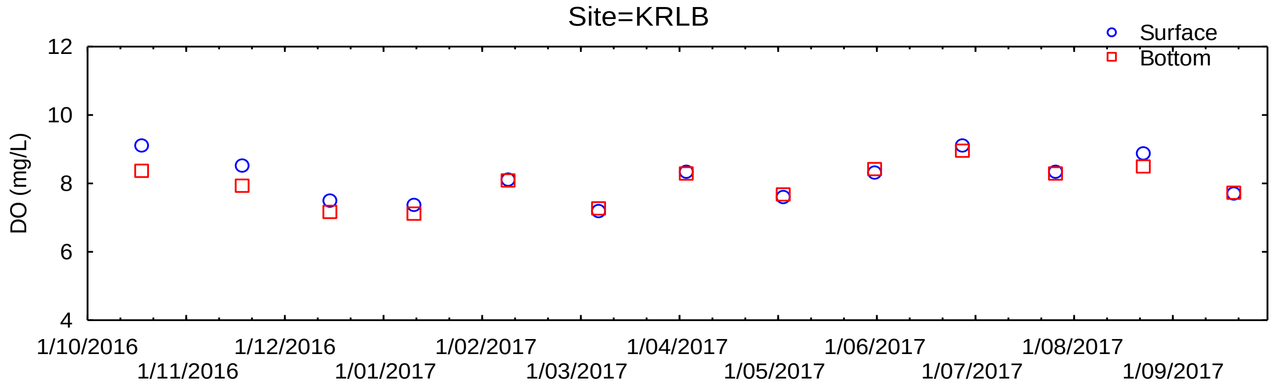

Site=AOH-6
Surf - TP (mg/L)
Bott - TP (mg/L)
ANZECC TP
TP (mg/L)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

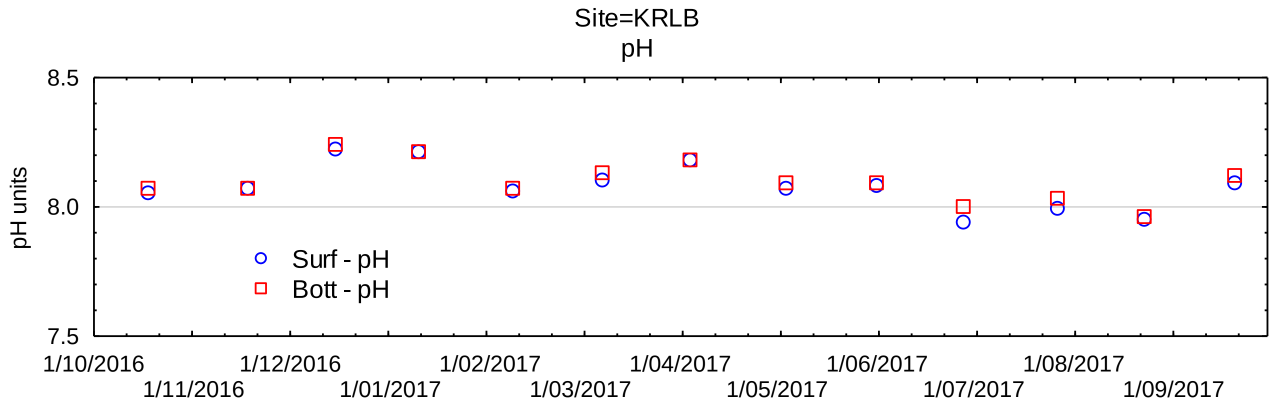

Site=AOH-6
Scatterplot of multiple variables against Date
Surf - FRP (mg/L)
Bott - FRP (mg/L)
ANZECC FRP
FRP (mg/L)
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

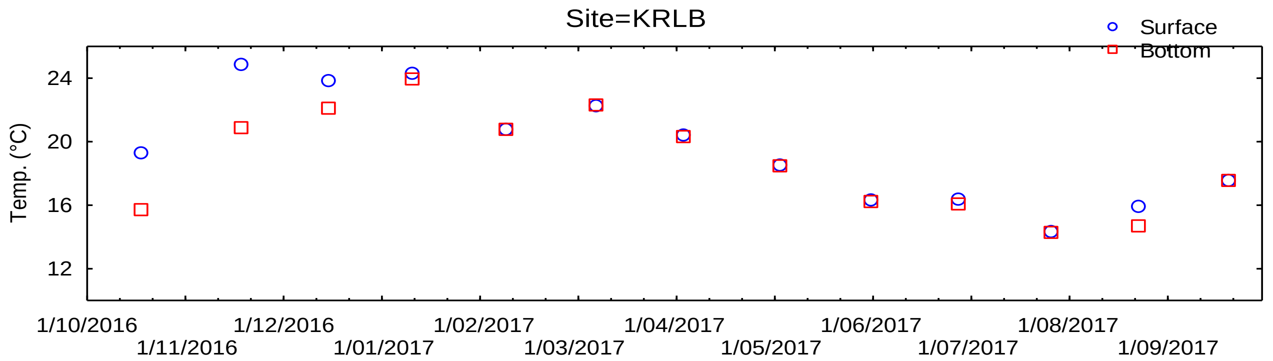

Site=AOH-6
Scatterplot of multiple variables against Date
Chl a (ug/L)
Surf - Chl a (ug/L)
ANZECC Chla
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
1/10/2016 1/11/2016 1/12/2016 1/01/2017 1/02/2017 1/03/2017 1/04/2017 1/05/2017 1/06/2017 1/07/2017 1/08/2017 1/09/2017

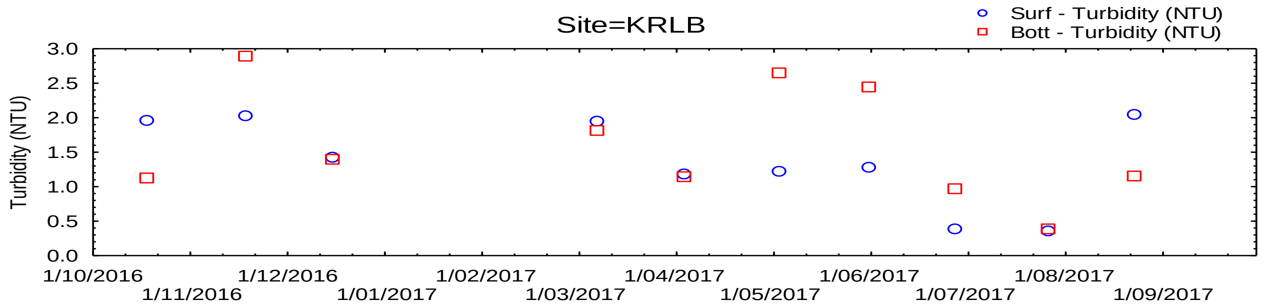

Site=AOH-6
Secchi
Max of all depths
Depth (m)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
01-Oct-16 01-Nov-16 01-Dec-16 01-Jan-17 01-Feb-17 01-Mar-17 01-Apr-17 01-May-17 01-Jun-17 01-Jul-17 01-Aug-17 01-Sep-17

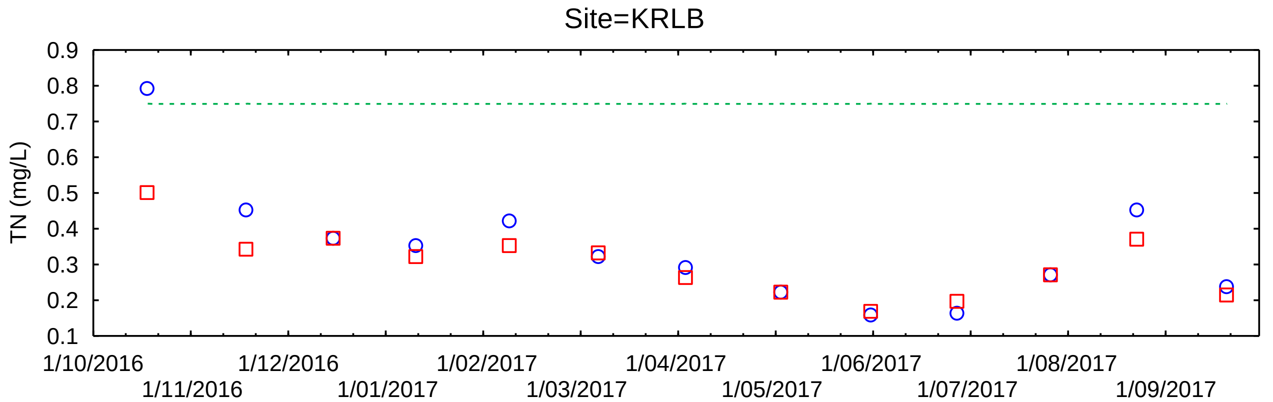

KRLB
Salinity (ppt)
Surface
Bottom
0 10 20 30 40
1/10/2016 1/11/2016 1/12/2016 1/01/2017 1/02/2017 1/03/2017 1/04/2017 1/05/2017 1/06/2017 1/07/2017 1/08/2017 1/09/2017

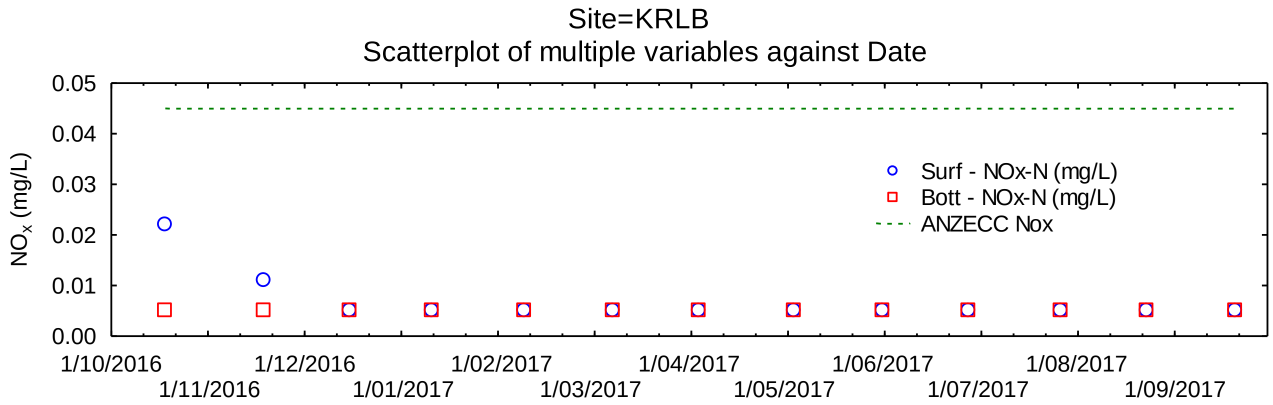

Site=KRLB
Surface
Bottom
DO (mg/L)
4 6 8 10 12
1/10/2016 1/11/2016 1/12/2016 1/01/2017 1/02/2017 1/03/2017 1/04/2017 1/05/2017 1/06/2017 1/07/2017 1/08/2017 1/09/2017

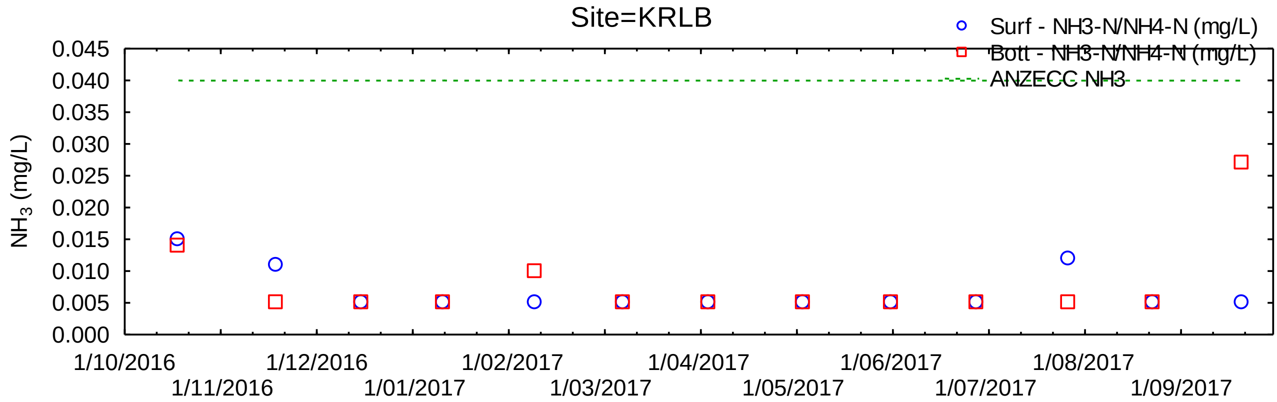

Site=KRLB
pH
pH units
8.5
8.0
7.5
Surf - pH
Bott - pH
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

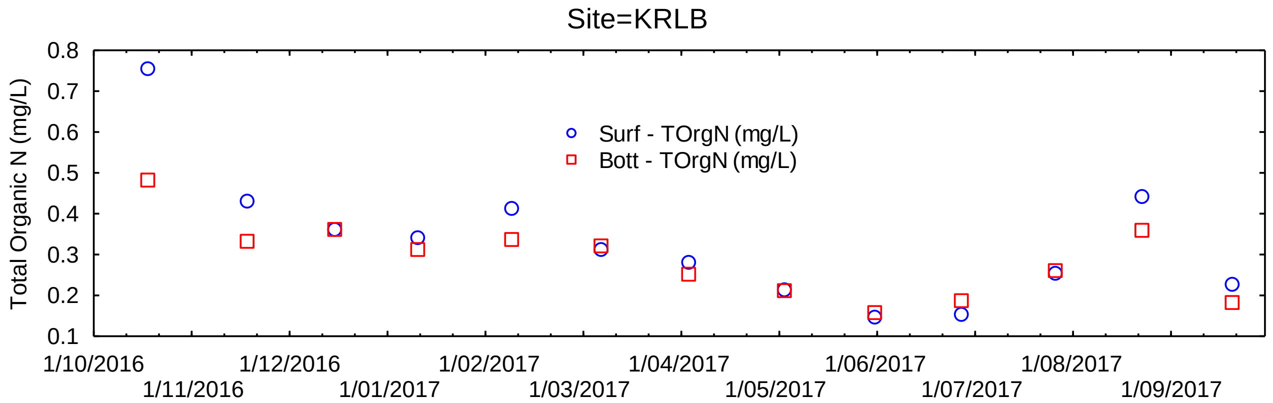

Site=KRLB
Surface
Bottom
Temp. (°C)
24
20
16
12
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

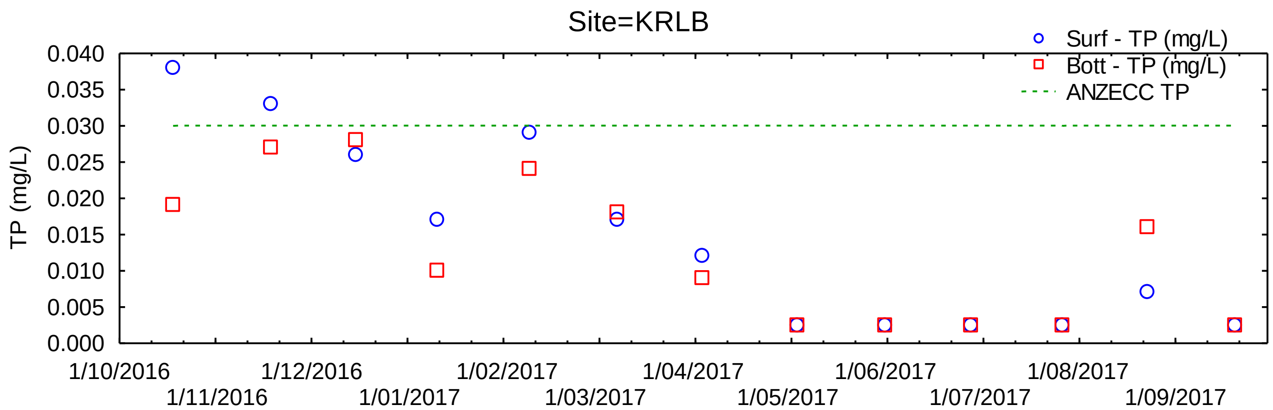

Site=KRLB
Surf - Turbidity (NTU)
Bott - Turbidity (NTU)
Turbidity (NTU)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

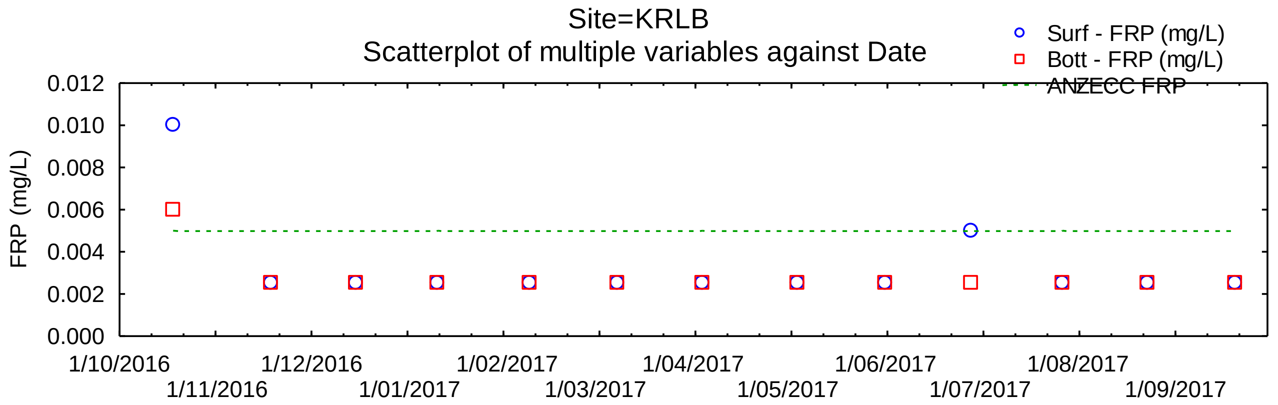

Site=KRLB
TN (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=KRLB
Scatterplot of multiple variables against Date
NOx (mg/L)
Surf - NOx-N (mg/L)
Bott - NOx-N (mg/L)
ANZECC Nox
0.05
0.04
0.03
0.02
0.01
0.00
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

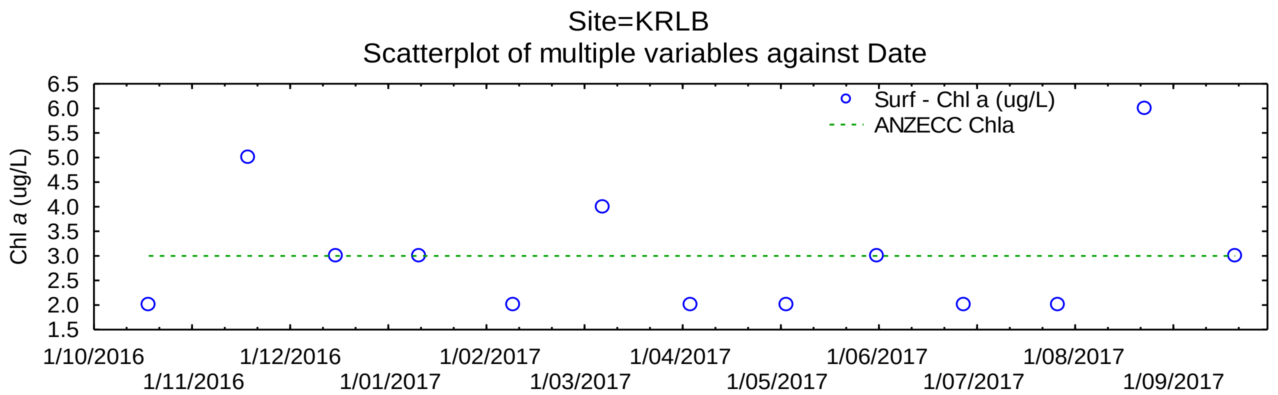

Site=KRLB
NH3 (mg/L)
Surf - NH3-N/NH4-N (mg/L)
Bott - NH3-N/NH4-N (mg/L)
ANZECC NH3
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=KRLB
Total Organic N (mg/L)
Surf - TOrgN (mg/L)
Bott - TOrgN (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

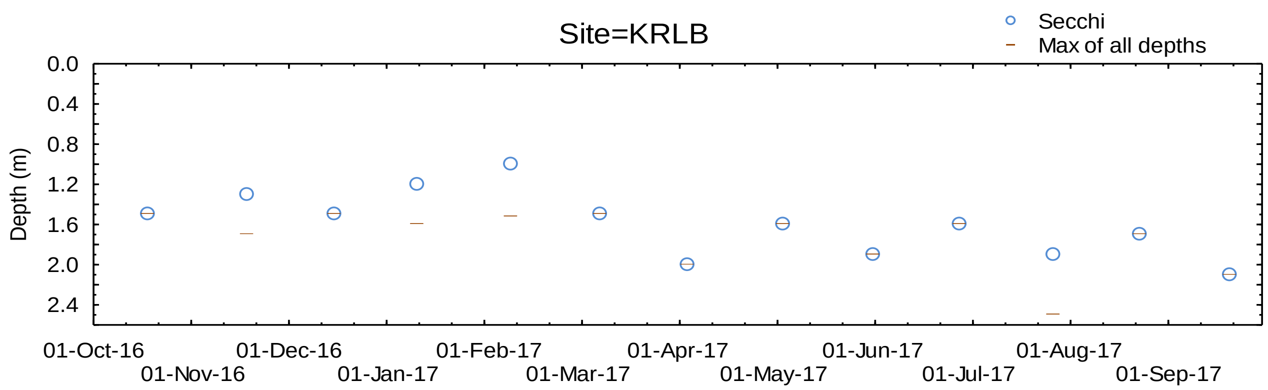

Site=KRLB
TP (mg/L)
Surf - TP (mg/L)
Bott - TP (mg/L)
ANZECC TP
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017



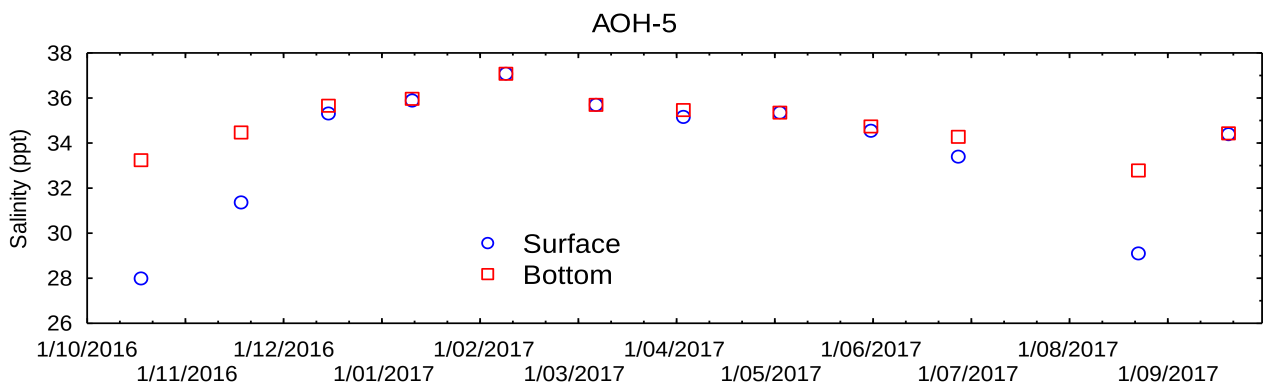
Site=KRLB
Scatterplot of multiple variables against Date
Surf - FRP (mg/L)
Bott - FRP (mg/L)
ANZECC FRP
FRP (mg/L)
0.012
0.010
0.008
0.006
0.004
0.002
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017



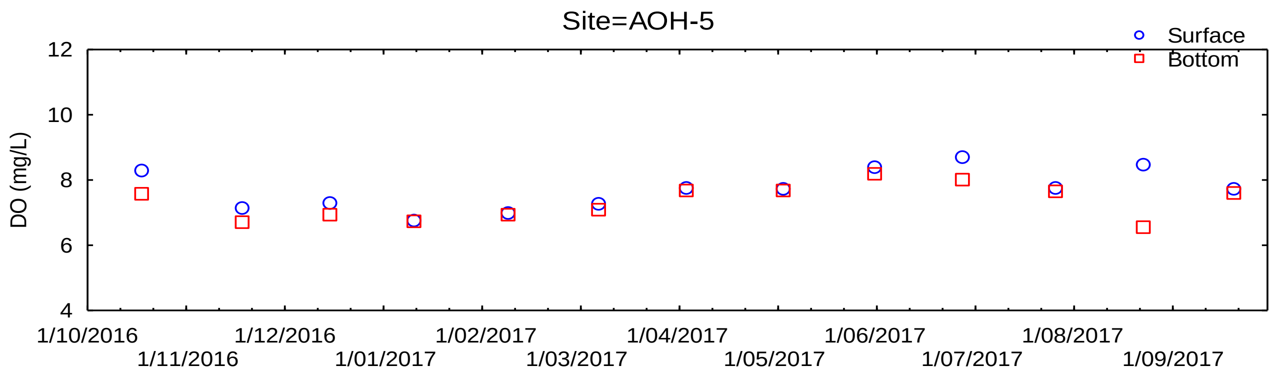
Site=KRLB
Scatterplot of multiple variables against Date
Surf - Chl a (ug/L)
ANZECC Chla
Chl a (ug/L)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

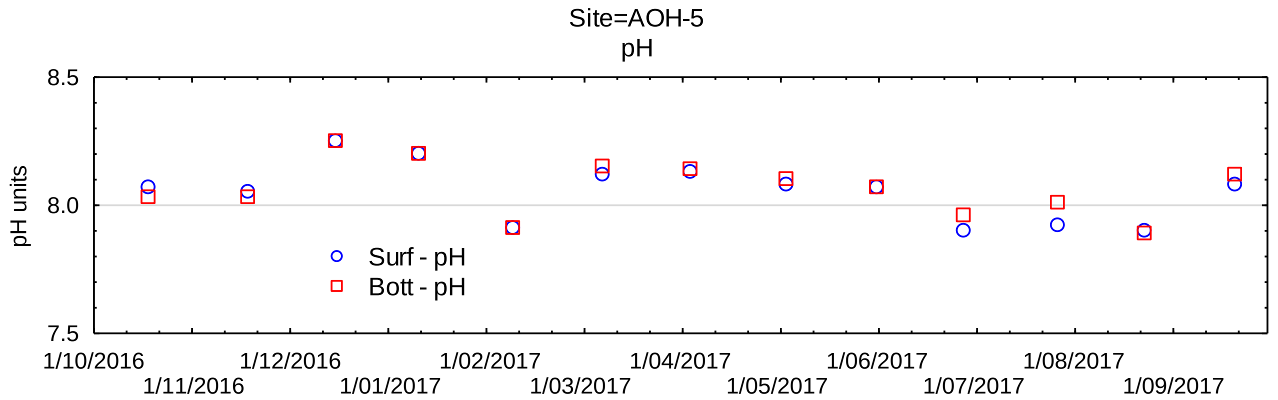


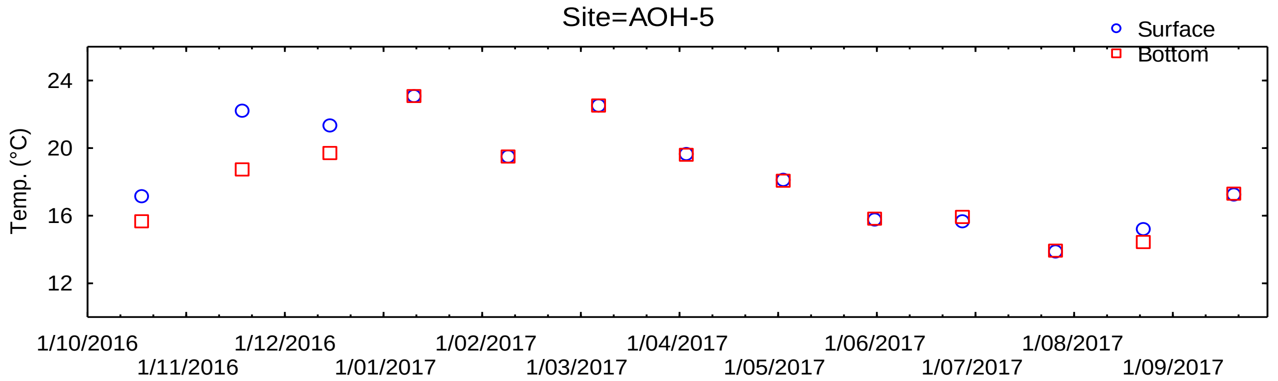
Site=KRLB
Secchi
Max of all depths
Depth (m)
0.0
0.4
0.8
1.2
1.6
2.0
2.4
01-Oct-16
01-Nov-16
01-Dec-16
01-Jan-17
01-Feb-17
01-Mar-17
01-Apr-17
01-May-17
01-Jun-17
01-Jul-17
01-Aug-17
01-Sep-17

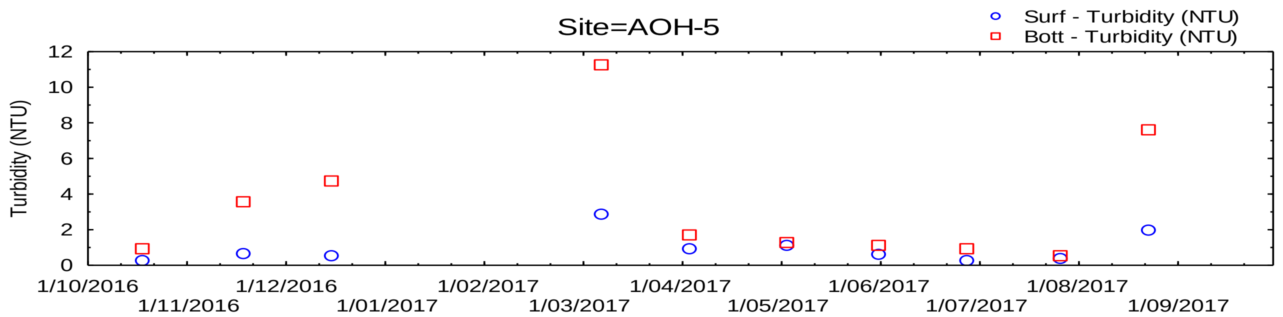


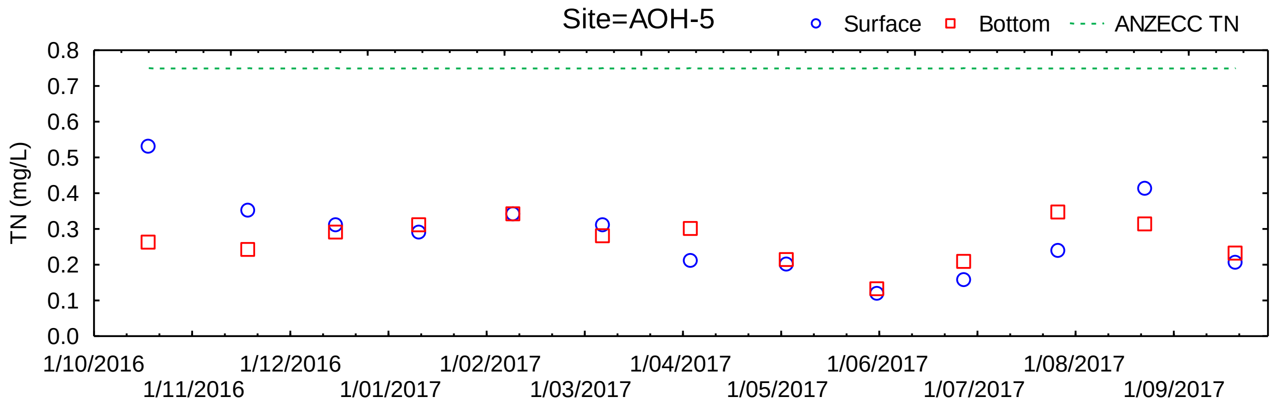
AOH-5
Salinity (ppt)
38
36
34
32
30
28
26
Surface
Bottom
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=AOH-5
Surface
Bottom
DO (mg/L)
12
10
8
6
4
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

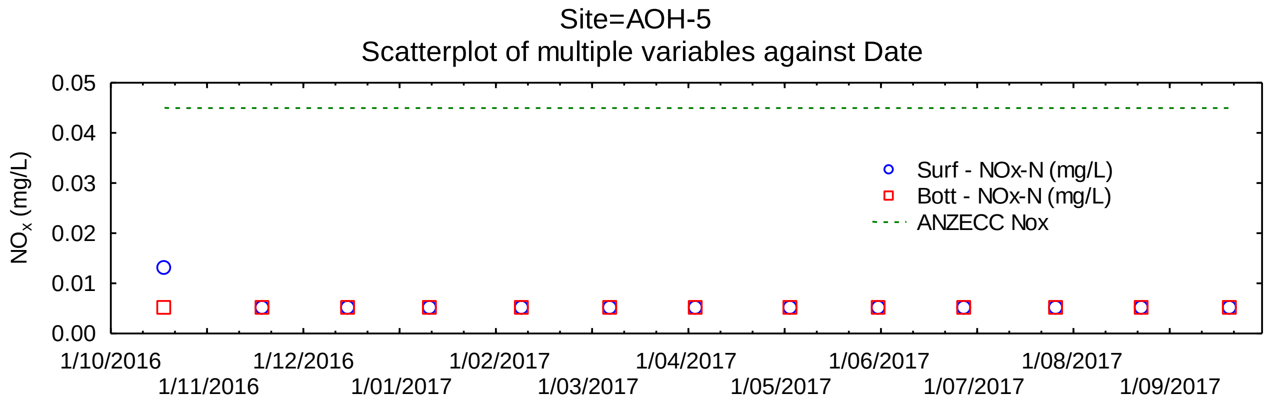

Site=AOH-5
pH
pH units
8.5
8.0
7.5
Surf - pH
Bott - pH
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=AOH-5
Surface
Bottom
Temp. (°C)
24
20
16
12
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

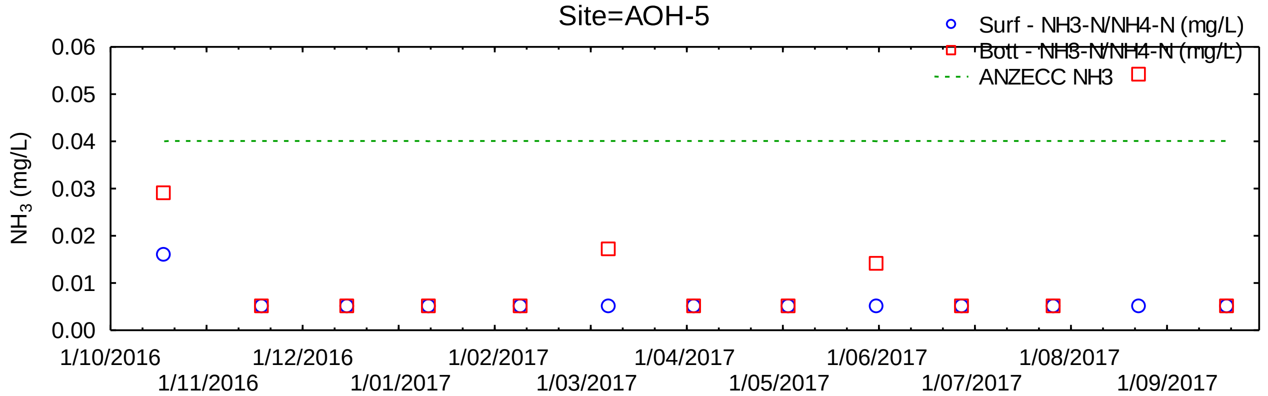

Site=AOH-5
Surf - Turbidity (NTU)
Bott - Turbidity (NTU)
Turbidity (NTU)
12
10
8
6
4
2
0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017



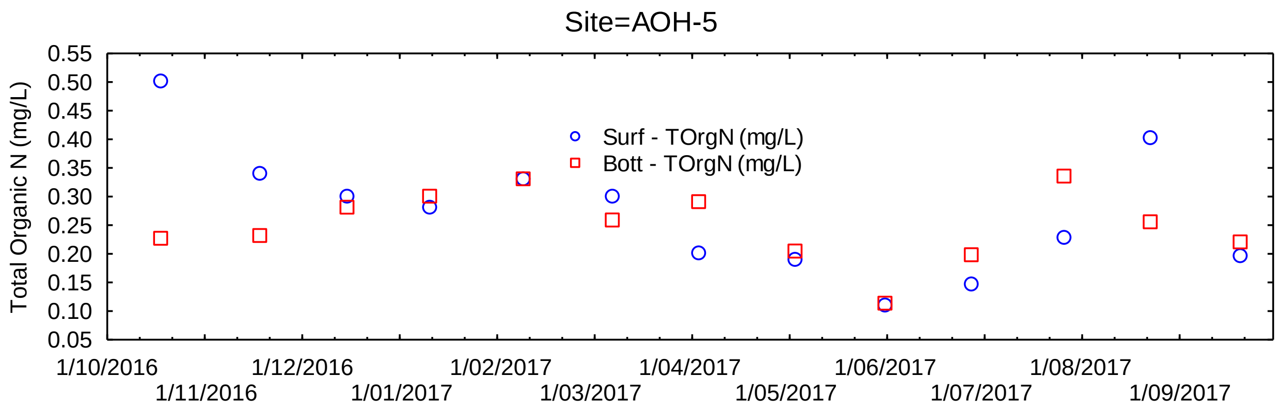
Site=AOH-5
Surface
Bottom
ANZECC TN
TN (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017



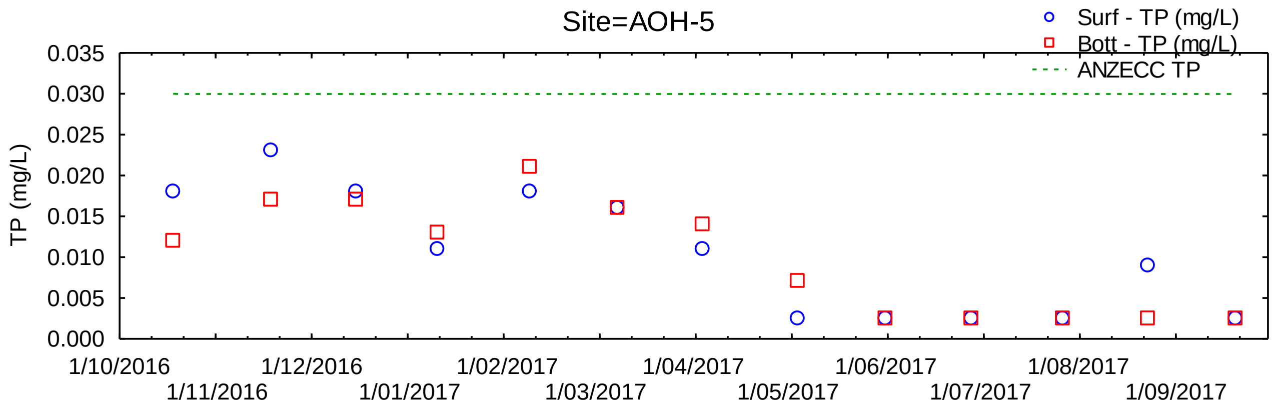
Site=AOH-5
Scatterplot of multiple variables against Date
Surf - NOx-N (mg/L)
Bott - NOx-N (mg/L)
ANZECC Nox
NOx (mg/L)
0.00
0.01
0.02
0.03
0.04
0.05
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

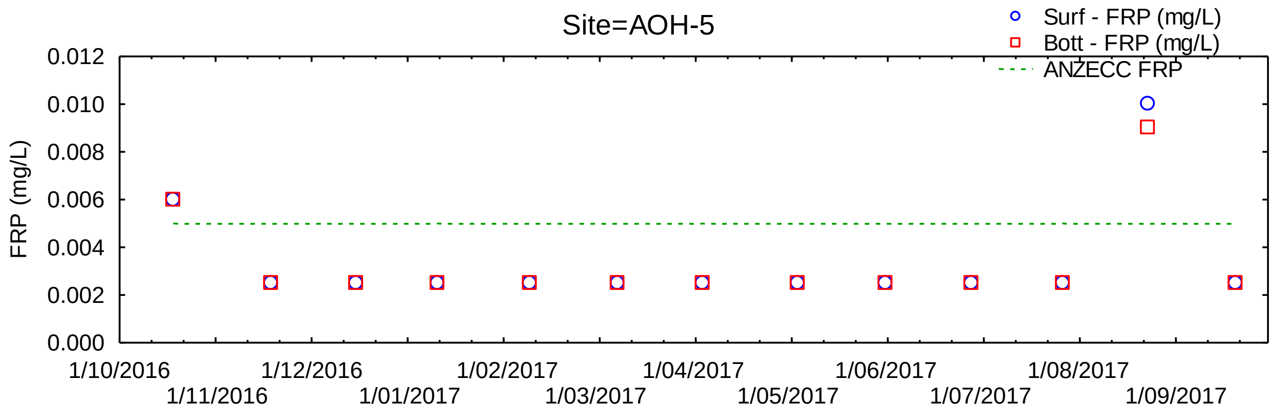


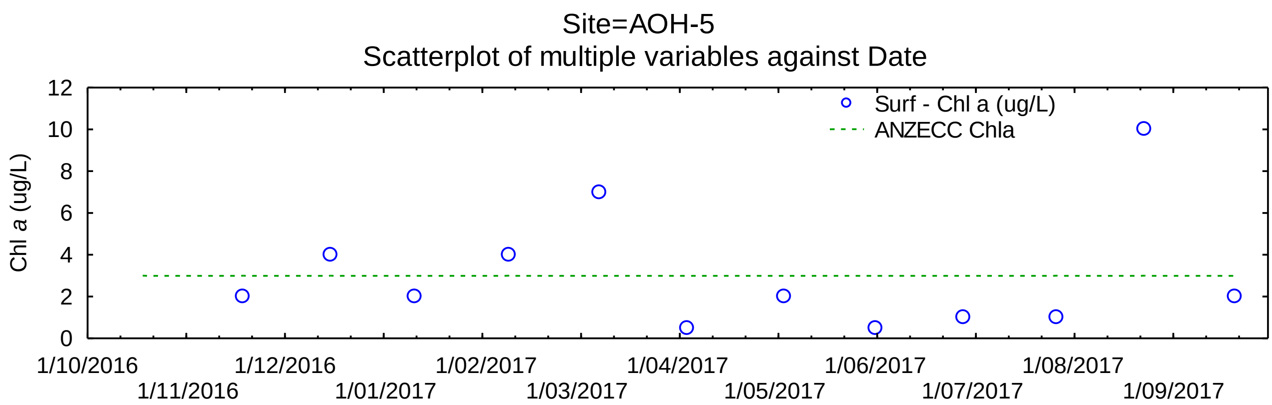
Site=AOH-5
Surf - NH3-N/NH4-N (mg/L)
Bott - NH3-N/NH4-N (mg/L)
ANZECC NH3
NH3 (mg/L)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

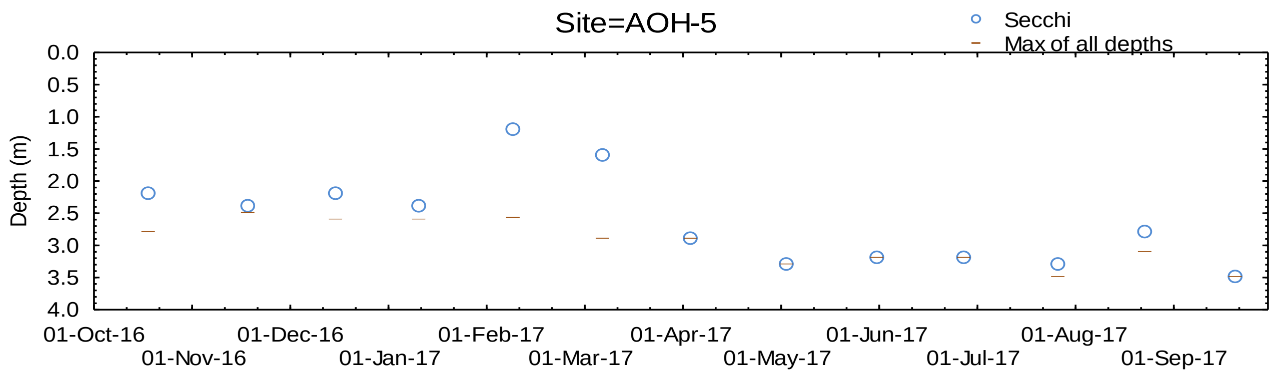


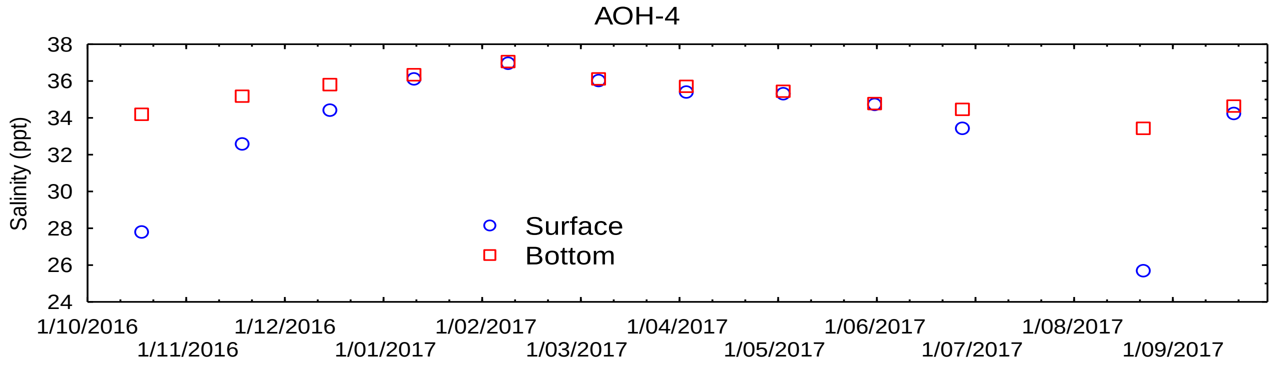
Site=AOH-5
Surf - TOrgN (mg/L)
Bott - TOrgN (mg/L)
Total Organic N (mg/L)
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=AOH-5
Surf - TP (mg/L)
Bott - TP (mg/L)
ANZECC TP
TP (mg/L)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

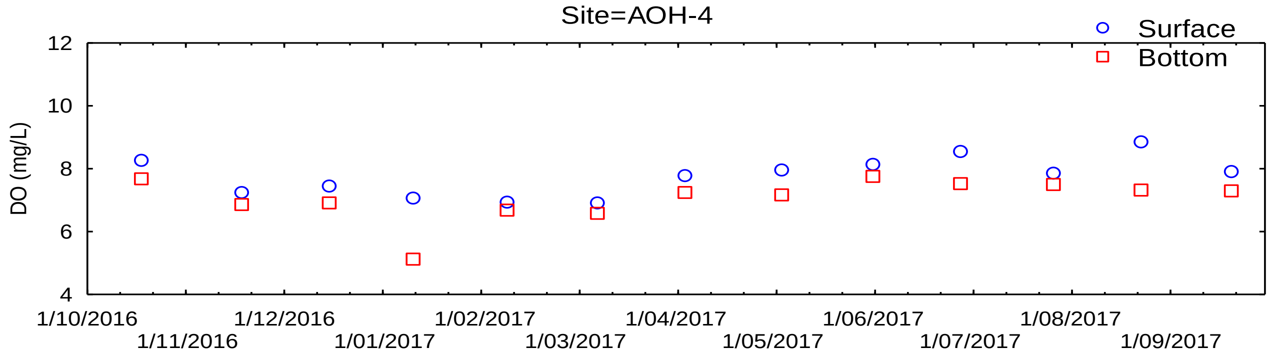

Site=AOH-5
Surf - FRP (mg/L)
Bott - FRP (mg/L)
ANZECC FRP
FRP (mg/L)
0.012
0.010
0.008
0.006
0.004
0.002
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=AOH-5
Scatterplot of multiple variables against Date
Surf - Chl a (ug/L)
ANZECC Chla
Chl a (ug/L)
12
10
8
6
4
2
0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

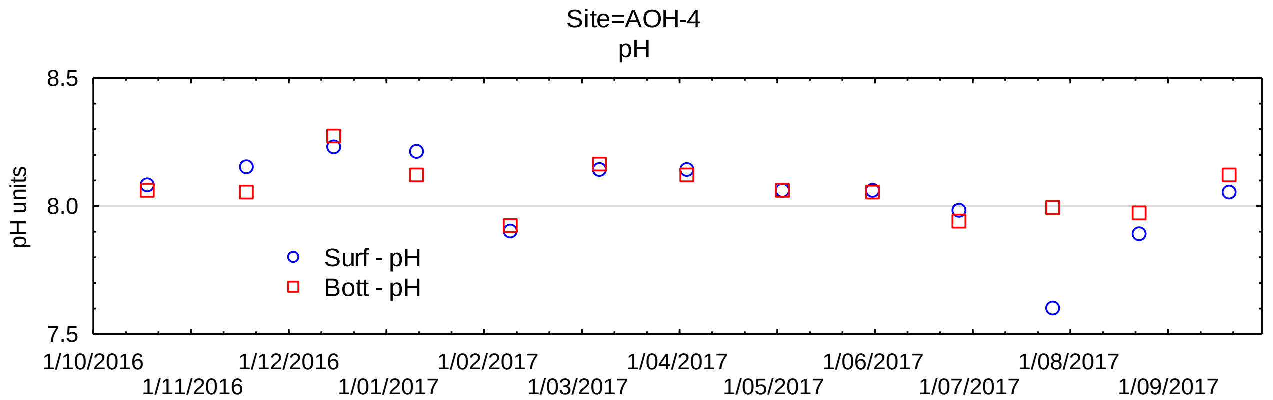

Site=AOH-5
Secchi
Max of all depths
Depth (m)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
01-Oct-16
01-Nov-16
01-Dec-16
01-Jan-17
01-Feb-17
01-Mar-17
01-Apr-17
01-May-17
01-Jun-17
01-Jul-17
01-Aug-17
01-Sep-17



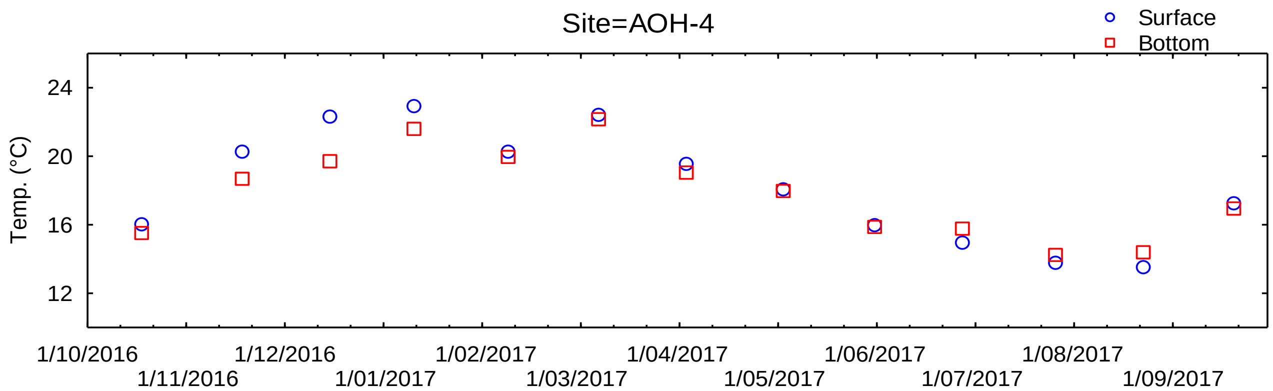
AOH-4
Salinity (ppt)
38
36
34
32
30
28
26
24
Surface
Bottom
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017



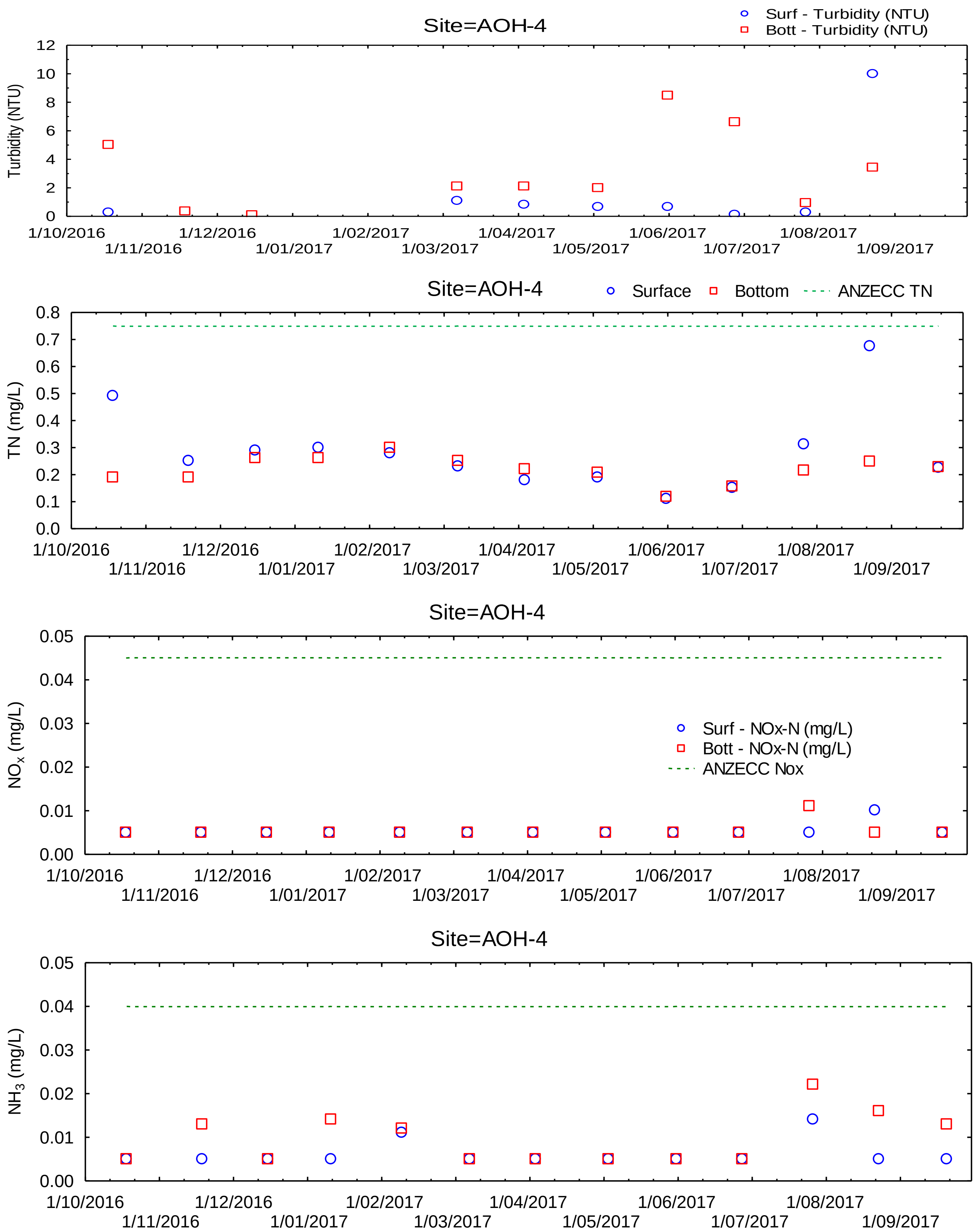
Site=AOH-4
Surface
Bottom
DO (mg/L)
12
10
8
6
4
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

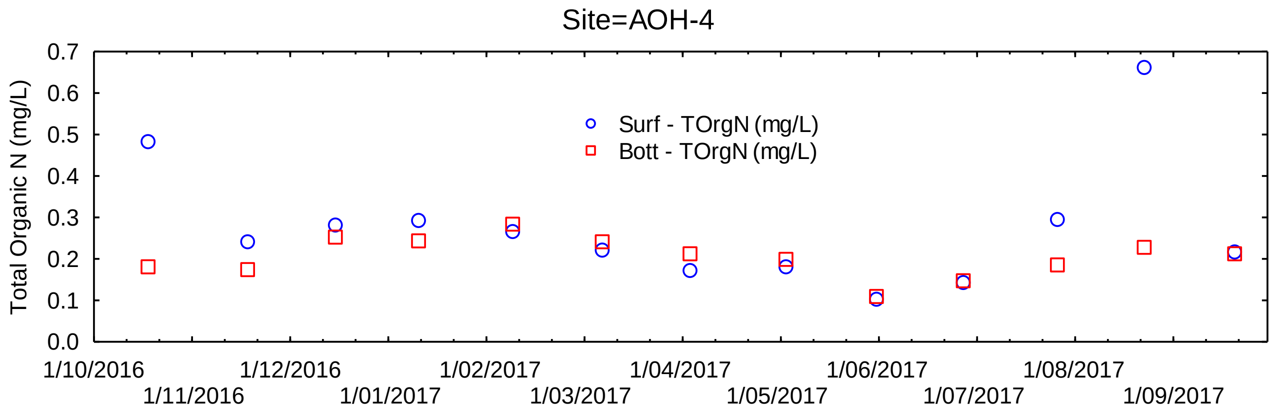


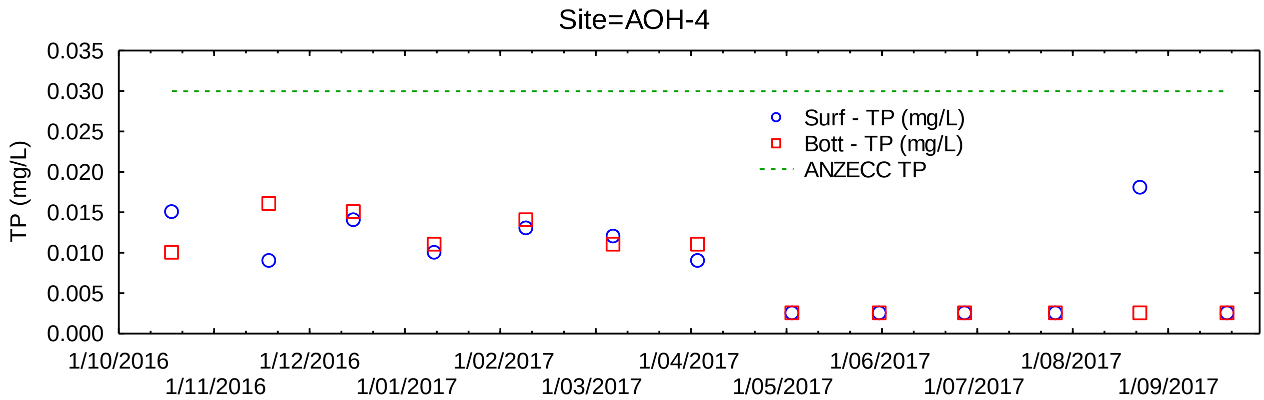
Site=AOH-4
pH
pH units
8.5
8.0
7.5
Surf - pH
Bott - pH
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

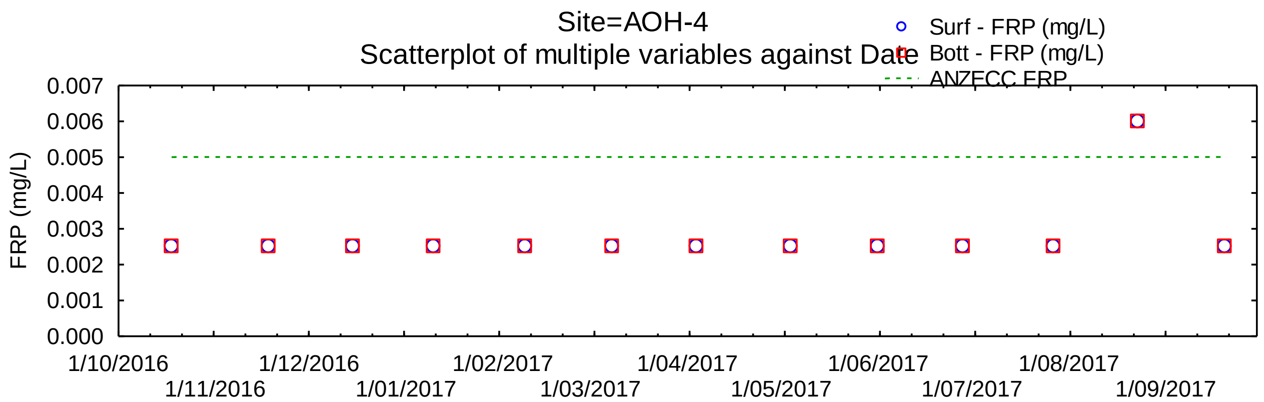


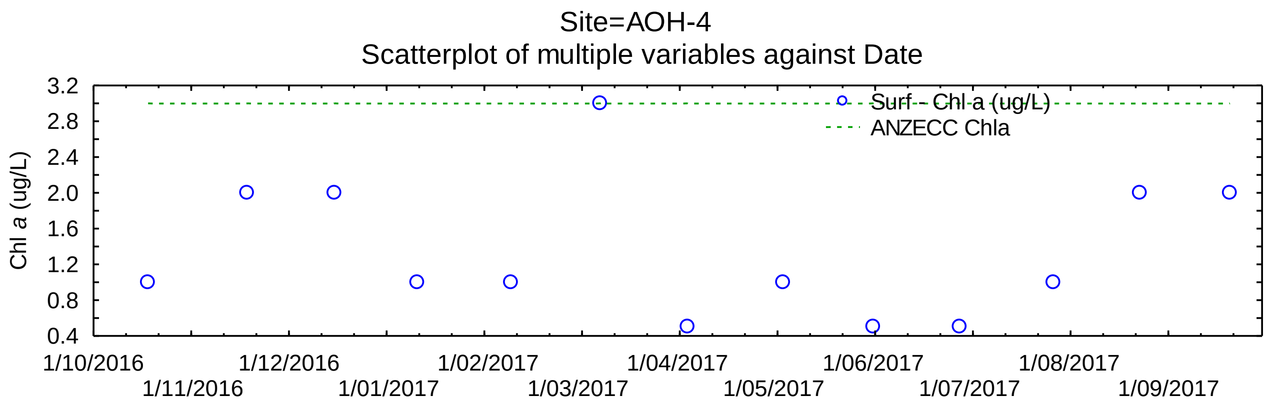
Site=AOH-4
Surface
Bottom
Temp. (°C)
24
20
16
12
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

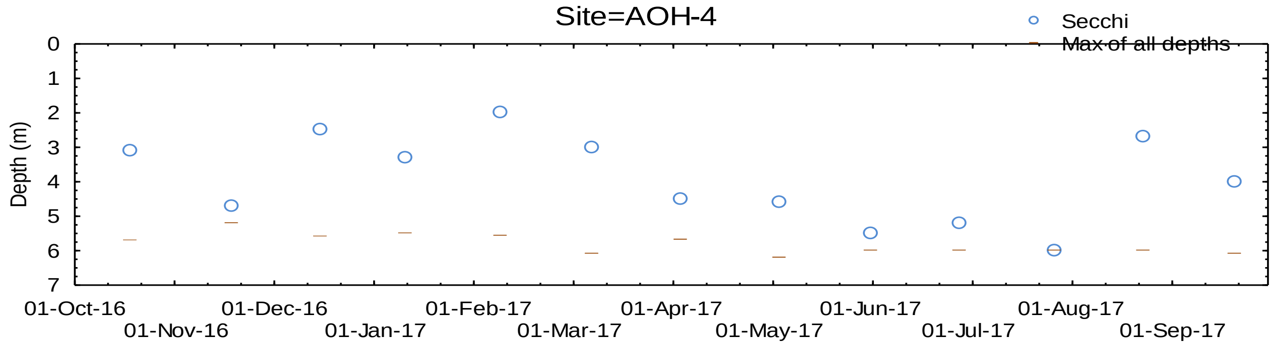

Site=AOH-4
Surf - Turbidity (NTU)
Bott - Turbidity (NTU)
Turbidity (NTU)
Site=AOH-4
Surface
Bottom
ANZECC TN
TN (mg/L)
Site=AOH-4
Surf - NOx-N (mg/L)
Bott - NOx-N (mg/L)
ANZECC Nox
NO_x (mg/L)
Site=AOH-4
NH_3 (mg/L)

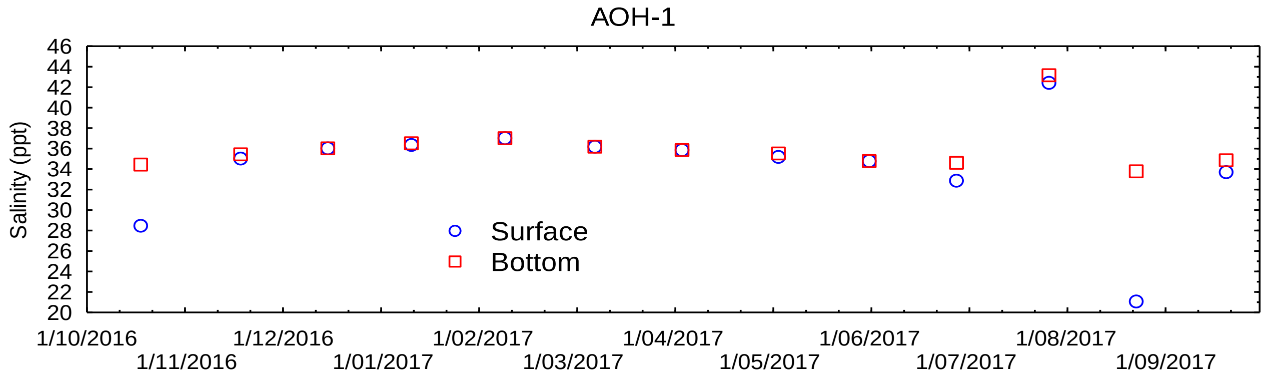

Site=AOH-4
Surf - TOrgN (mg/L)
Bott - TOrgN (mg/L)
Total Organic N (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

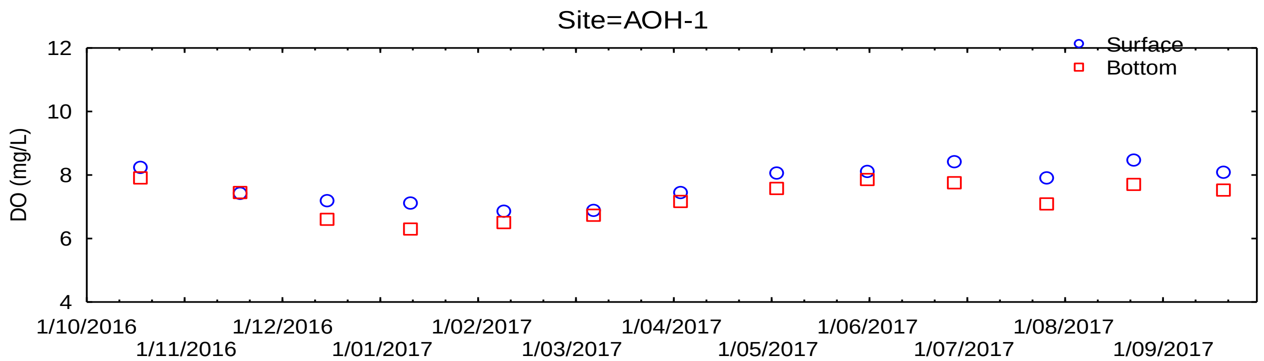

Site=AOH-4
Surf - TP (mg/L)
Bott - TP (mg/L)
ANZECC TP
TP (mg/L)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

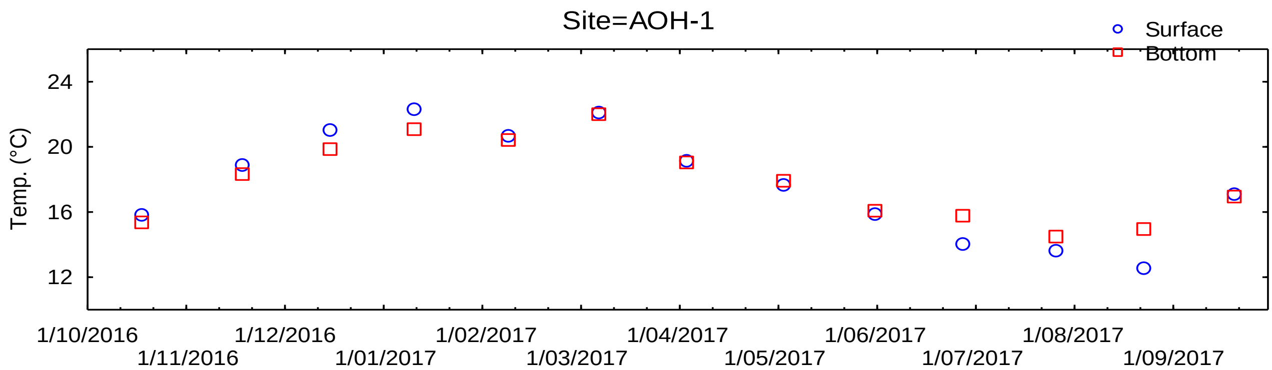

Site=AOH-4
Scatterplot of multiple variables against Date
Surf - FRP (mg/L)
Bott - FRP (mg/L)
ANZECC FRP
FRP (mg/L)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

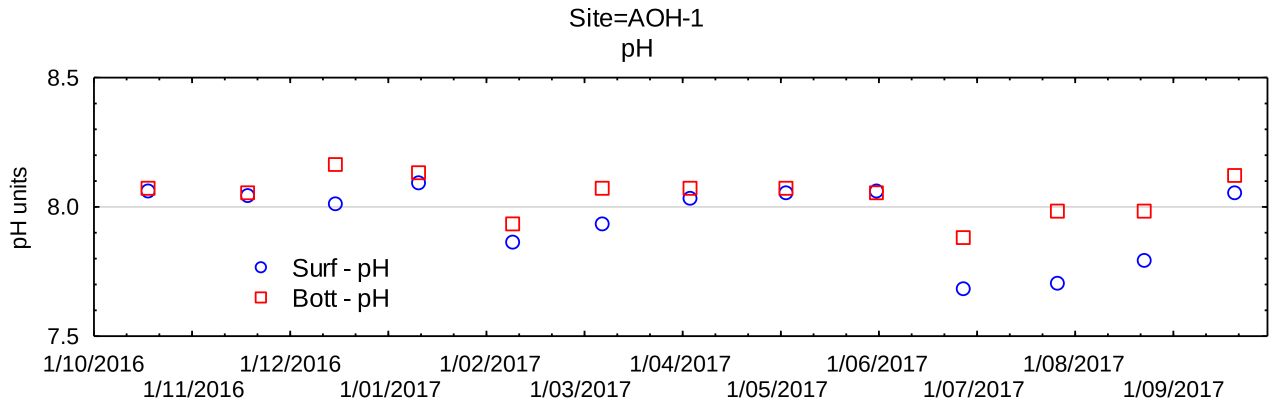

Site=AOH-4
Scatterplot of multiple variables against Date
Surf - Chl a (ug/L)
ANZECC Chla
Chl a (ug/L)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

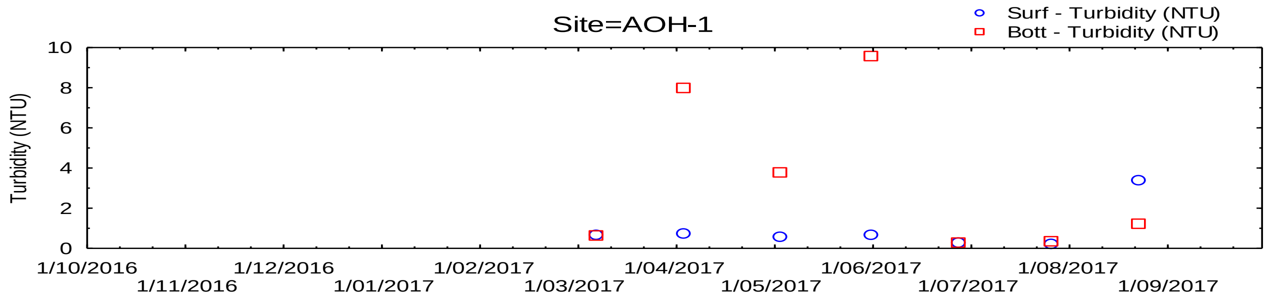

Site=AOH-4
Secchi
Max of all depths
Depth (m)
0
1
2
3
4
5
6
7
01-Oct-16
01-Nov-16
01-Dec-16
01-Jan-17
01-Feb-17
01-Mar-17
01-Apr-17
01-May-17
01-Jun-17
01-Jul-17
01-Aug-17
01-Sep-17

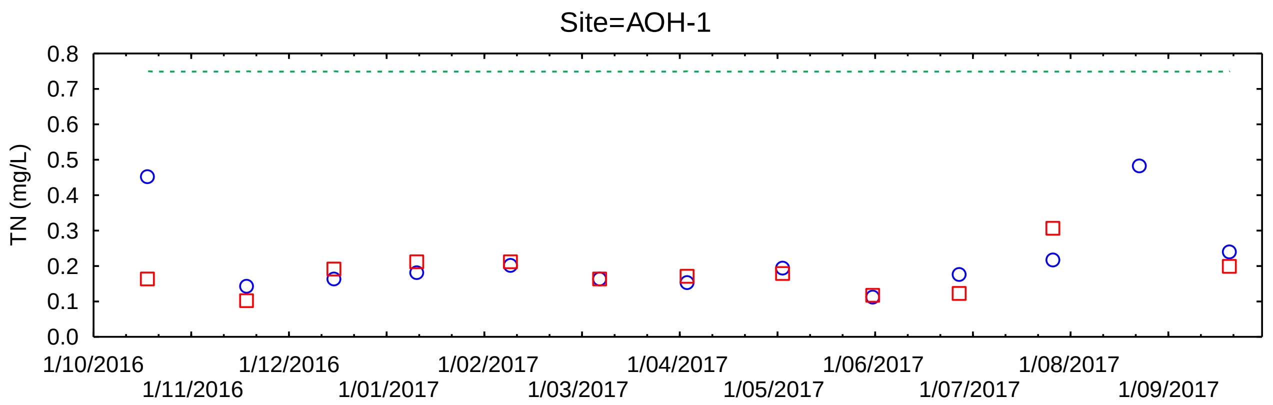

AOH-1
Salinity (ppt)
46
44
42
40
38
36
34
32
30
28
26
24
22
20
Surface
Bottom
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

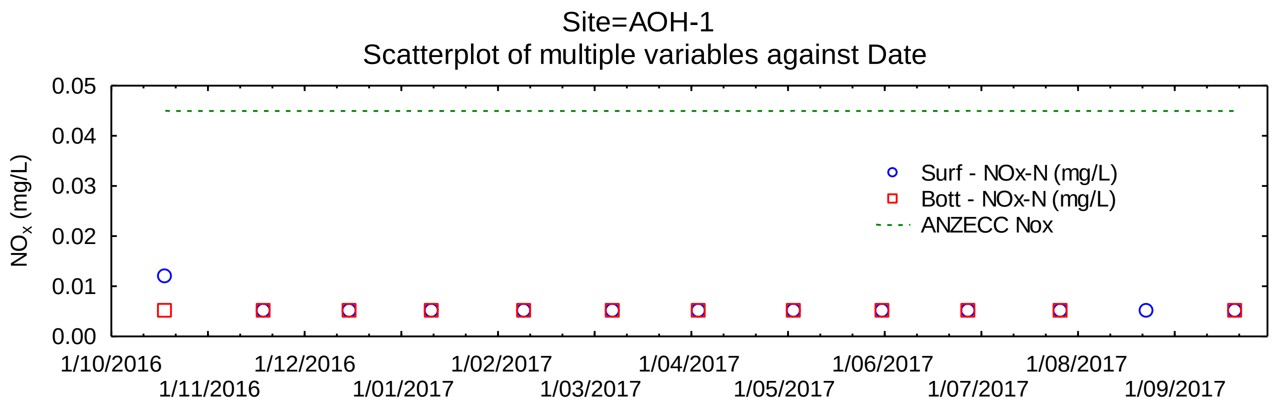

Site=AOH-1
Surface
Bottom
DO (mg/L)
12
10
8
6
4
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

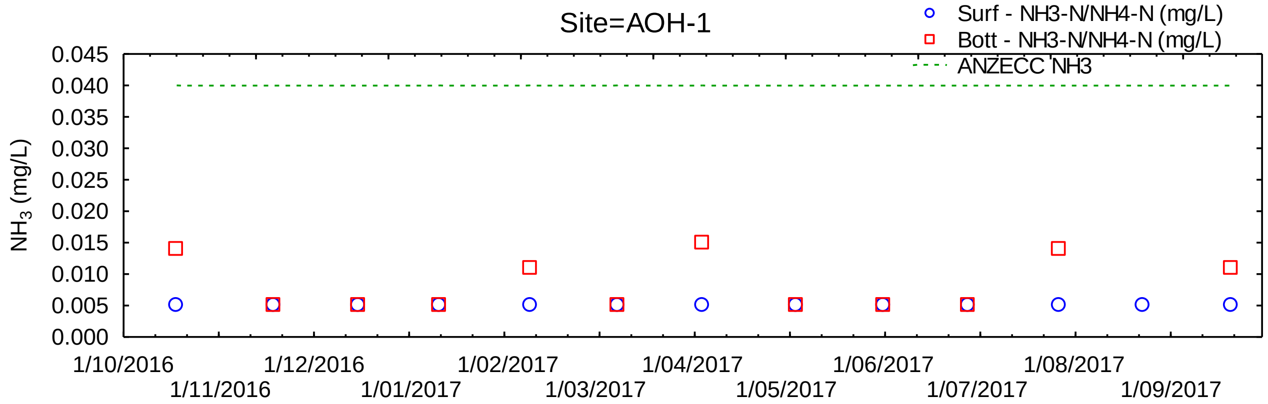

Site=AOH-1
Surface
Bottom
Temp. (°C)
24
20
16
12
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

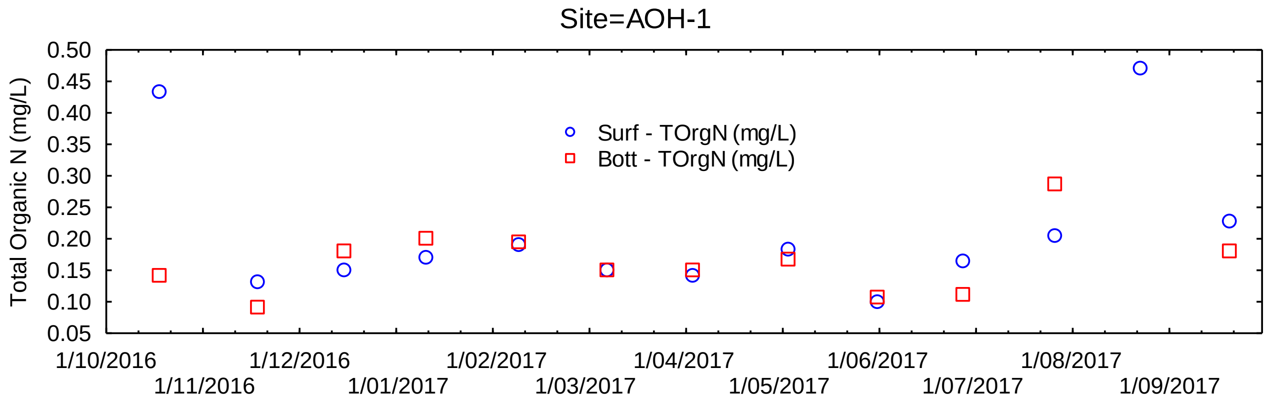

Site=AOH-1
pH
pH units
Surf - pH
Bott - pH
8.5
8.0
7.5
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

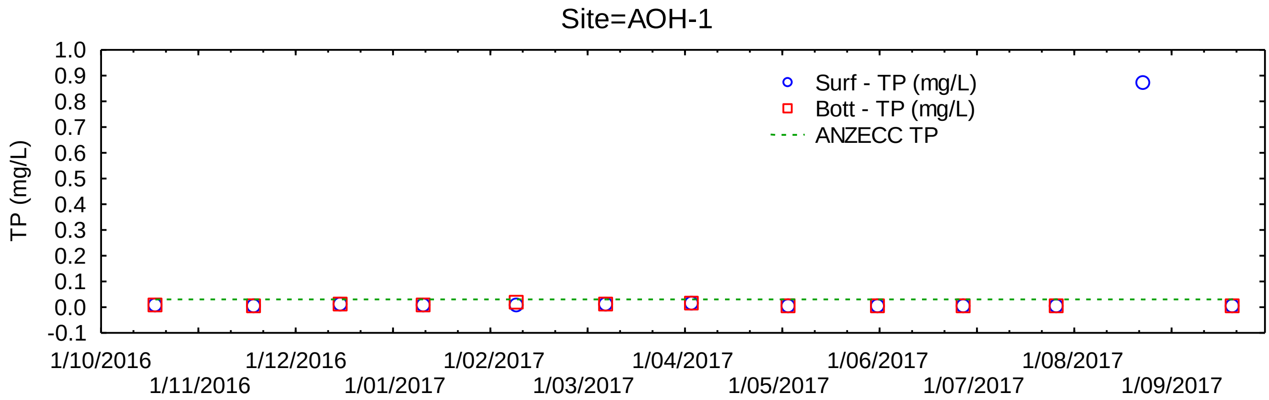

Site=AOH-1
Surf - Turbidity (NTU)
Bott - Turbidity (NTU)
Turbidity (NTU)
10
8
6
4
2
0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

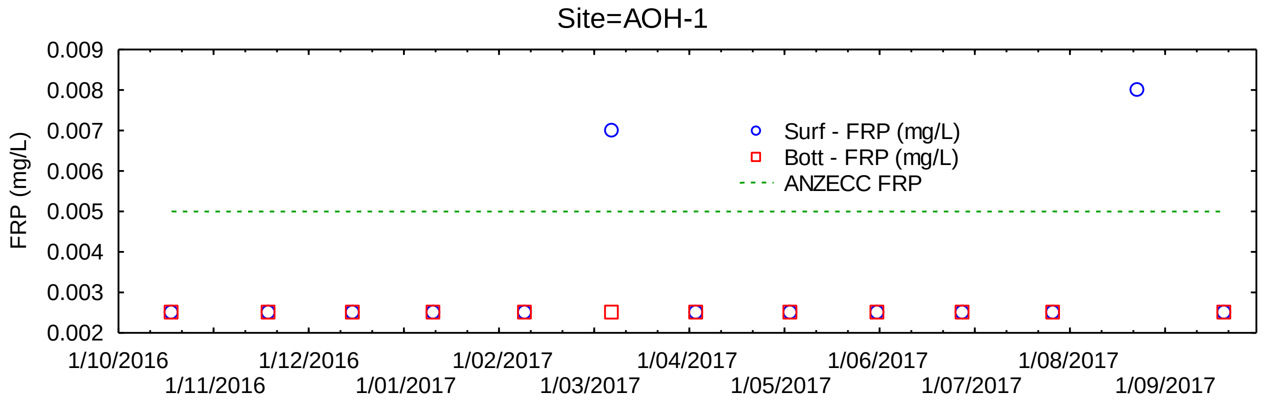

Site=AOH-1
TN (mg/L)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

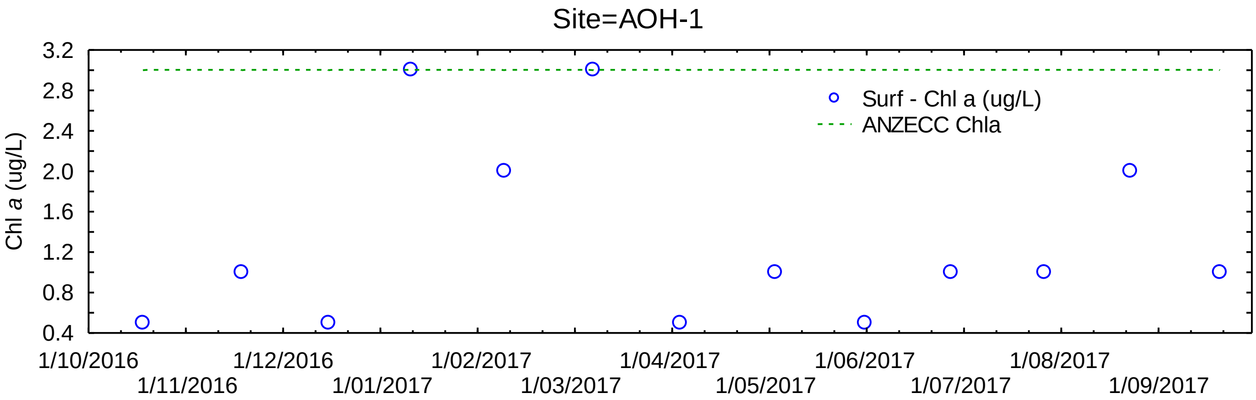

Site=AOH-1
Scatterplot of multiple variables against Date
NOx (mg/L)
Surf - NOx-N (mg/L)
Bott - NOx-N (mg/L)
ANZECC Nox
0.05
0.04
0.03
0.02
0.01
0.00
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

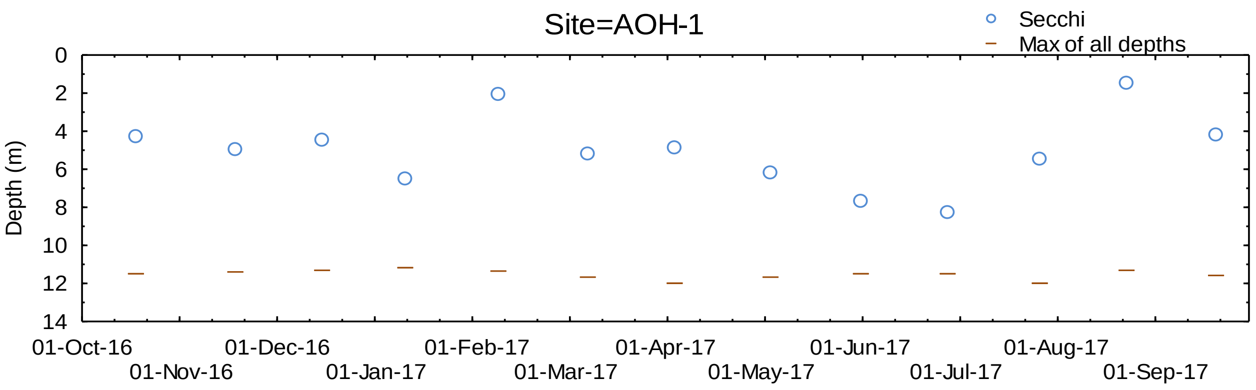

Site=AOH-1
Surf - NH3-N/NH4-N (mg/L)
Bott - NH3-N/NH4-N (mg/L)
ANZECC NH3
NH3 (mg/L)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

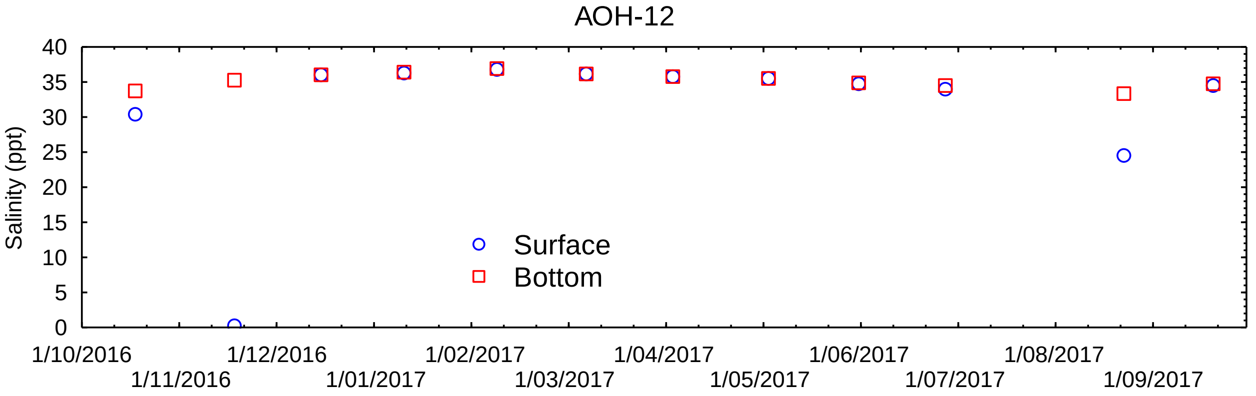

Site=AOH-1
Surf - TOrgN (mg/L)
Bott - TOrgN (mg/L)
Total Organic N (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

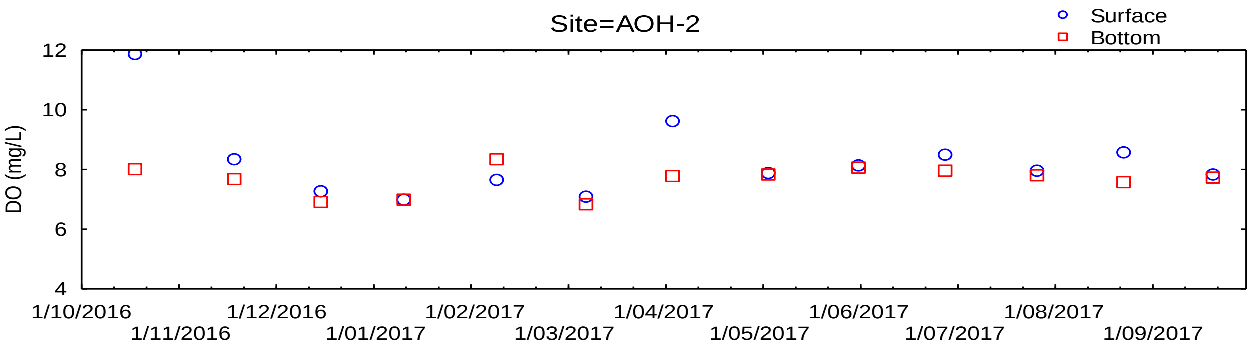

Site=AOH-1
Surf - TP (mg/L)
Bott - TP (mg/L)
ANZECC TP
TP (mg/L)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

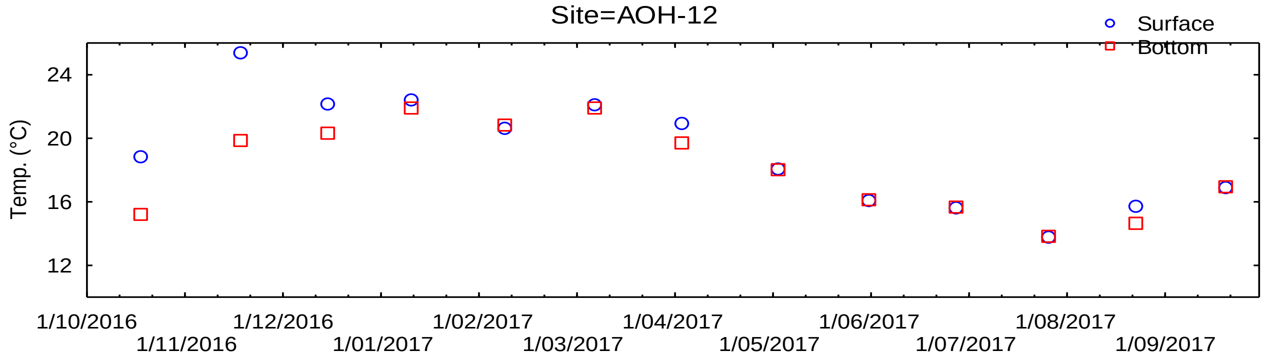

Site=AOH-1
Surf - FRP (mg/L)
Bott - FRP (mg/L)
ANZECC FRP
FRP (mg/L)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

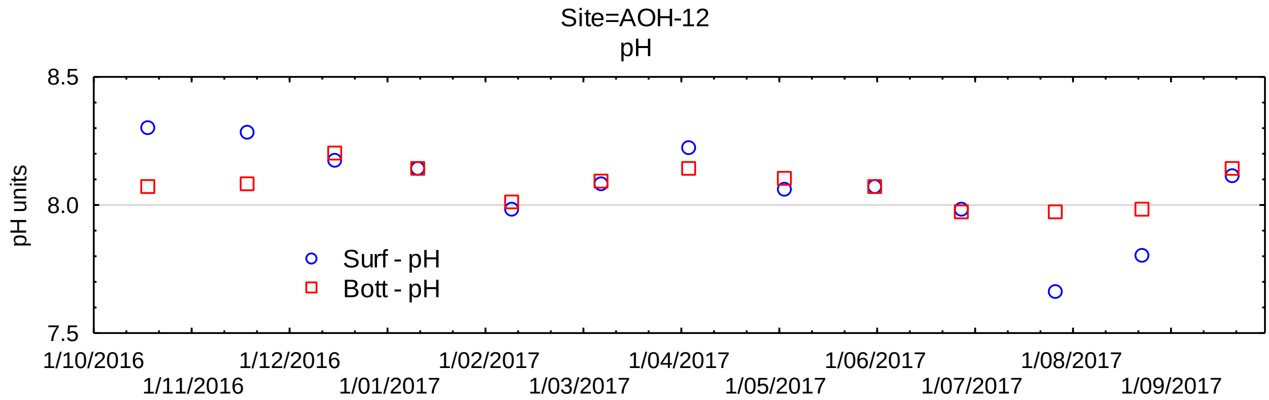

Site=AOH-1
Chl a (ug/L)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
Surf - Chl a (ug/L)
ANZECC Chla
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

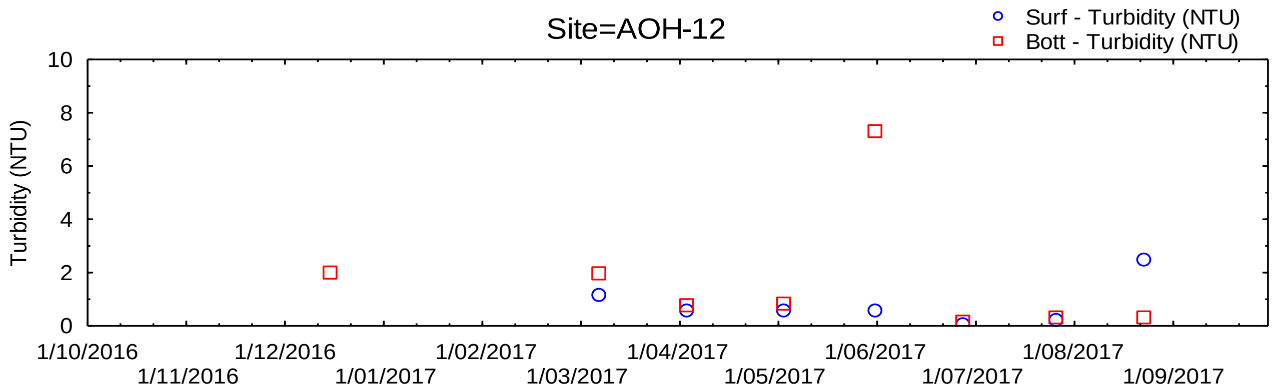

Site=AOH-1
Secchi
Max of all depths
Depth (m)
0
2
4
6
8
10
12
14
01-Oct-16
01-Nov-16
01-Dec-16
01-Jan-17
01-Feb-17
01-Mar-17
01-Apr-17
01-May-17
01-Jun-17
01-Jul-17
01-Aug-17
01-Sep-17

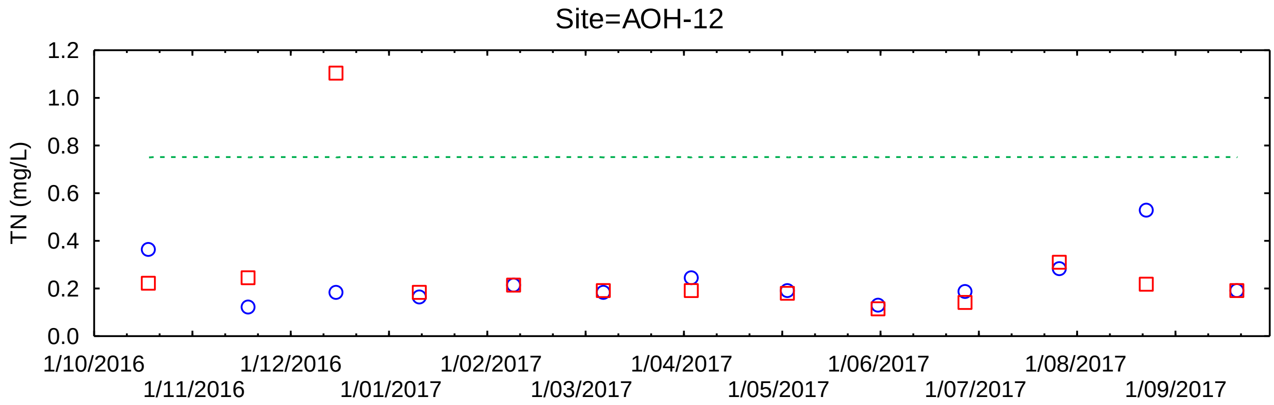

AOH-12
Salinity (ppt)
40
35
30
25
20
15
10
5
0
Surface
Bottom
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=AOH-2
Surface
Bottom
DO (mg/L)
12
10
8
6
4
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

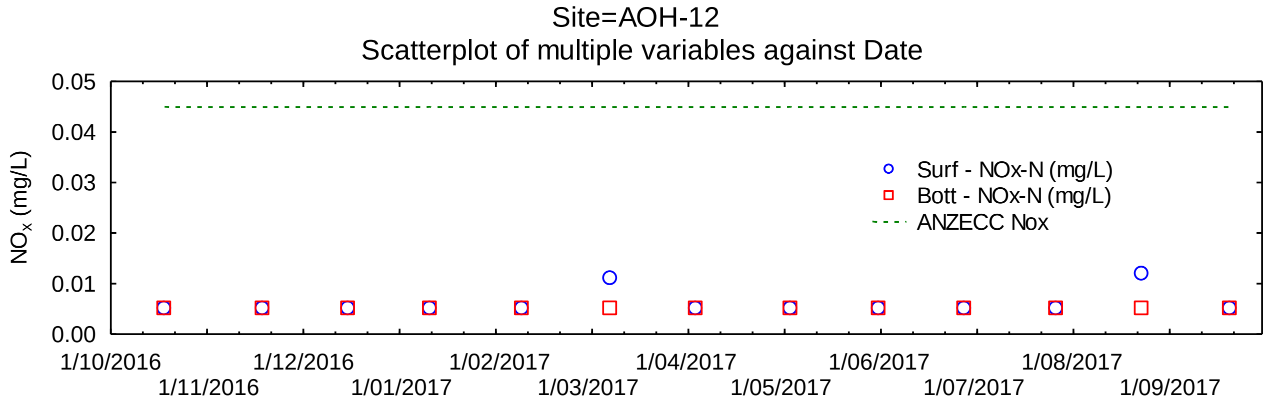

Site=AOH-12
Surface
Bottom
Temp. (°C)
24
20
16
12
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=AOH-12
pH
pH units
8.5
8.0
7.5
Surf - pH
Bott - pH
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

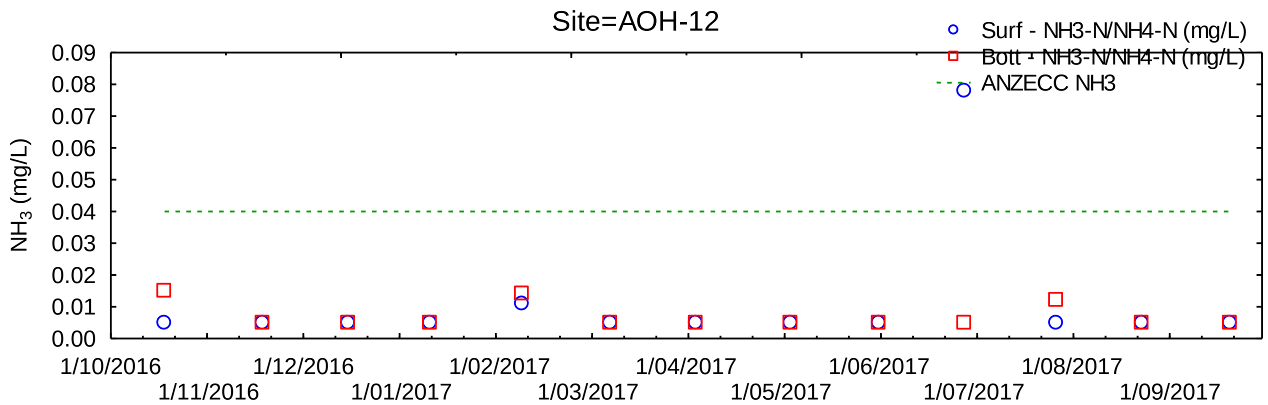

Site=AOH-12
Surf - Turbidity (NTU)
Bott - Turbidity (NTU)
Turbidity (NTU)
10
8
6
4
2
0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017



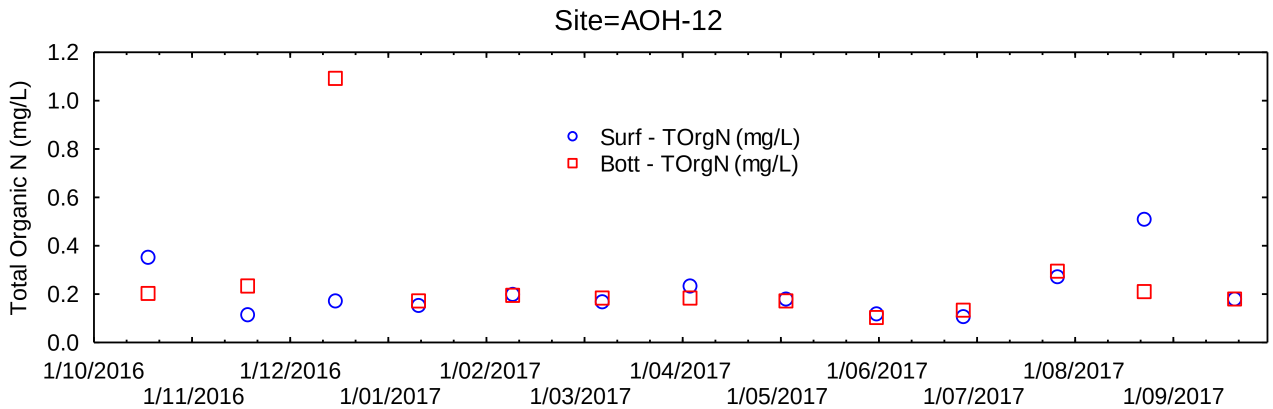
Site=AOH-12
TN (mg/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017



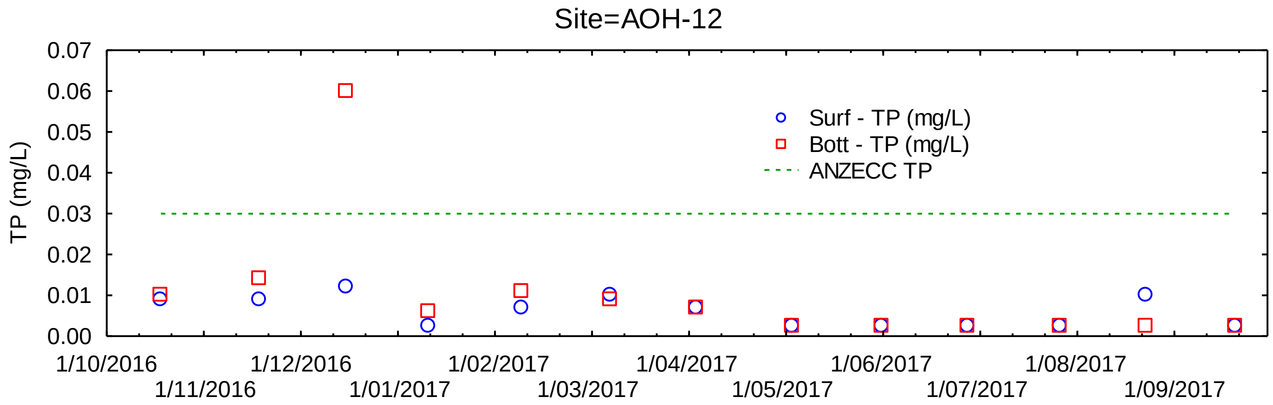
Site=AOH-12
Scatterplot of multiple variables against Date
NO_x (mg/L)
0.05
0.04
0.03
0.02
0.01
0.00
Surf - NOx-N (mg/L)
Bott - NOx-N (mg/L)
ANZECC Nox
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

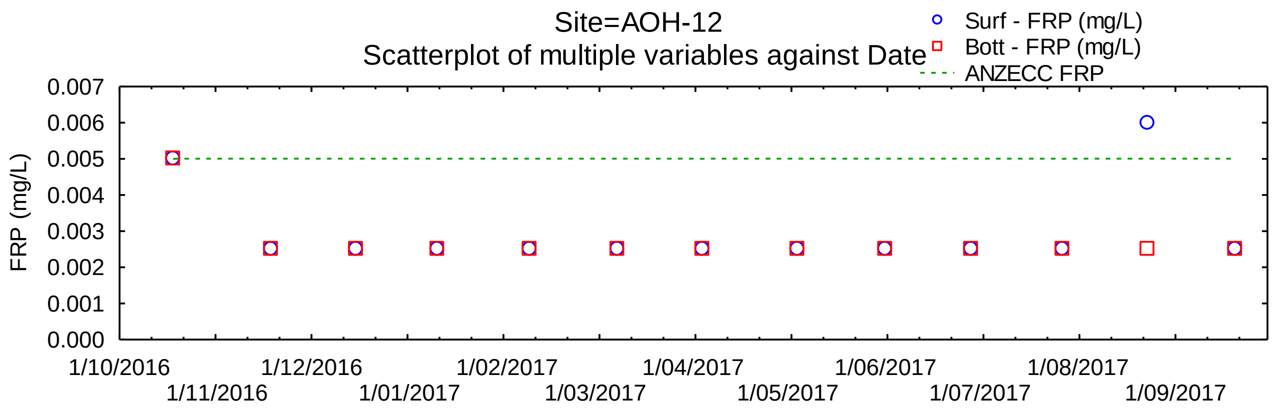


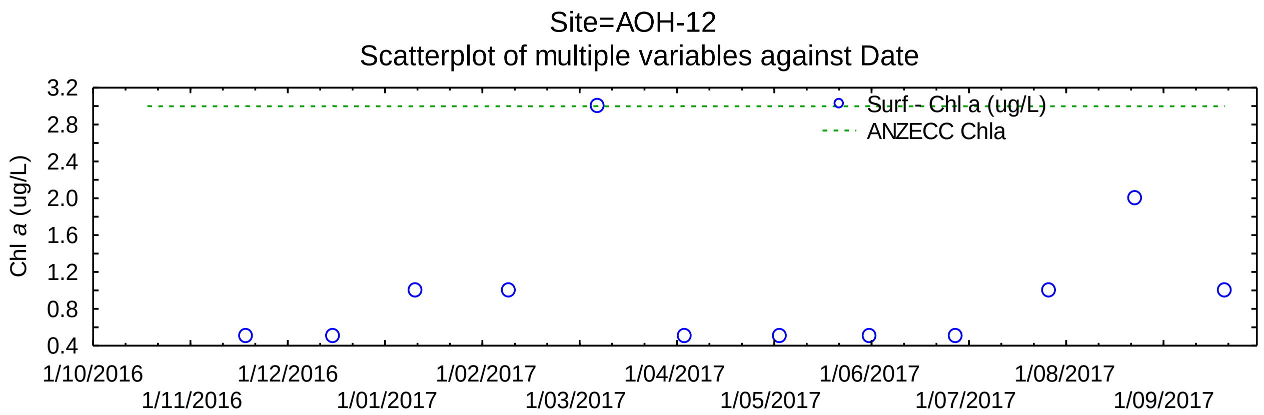
Site=AOH-12
NH_3 (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Surf - NH3-N/NH4-N (mg/L)
Bott - NH3-N/NH4-N (mg/L)
ANZECC NH3
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

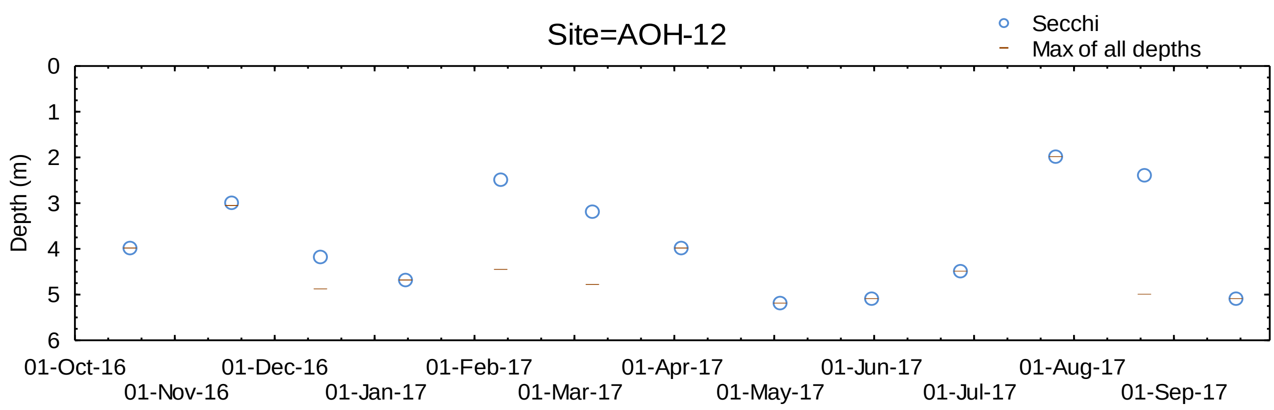


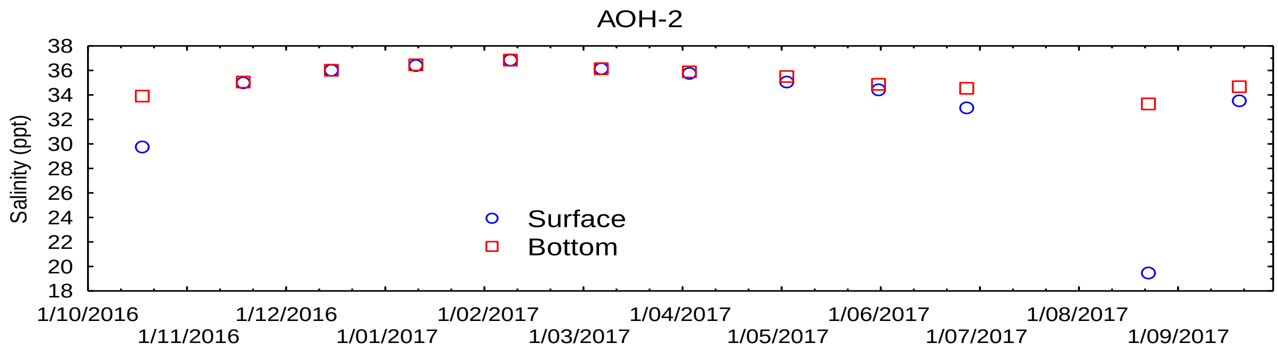
Site=AOH-12
Total Organic N (mg/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Surf - TOrgN (mg/L)
Bott - TOrgN (mg/L)
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

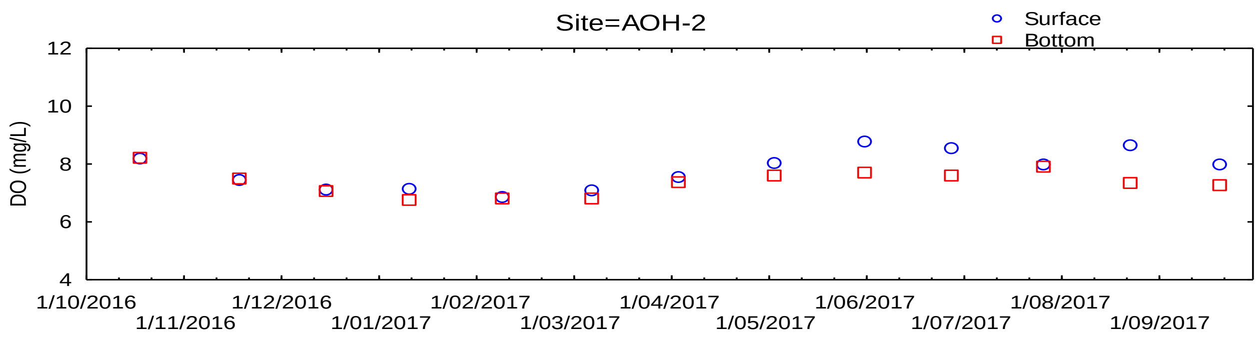

Site=AOH-12
TP (mg/L)
Surf - TP (mg/L)
Bott - TP (mg/L)
ANZECC TP
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

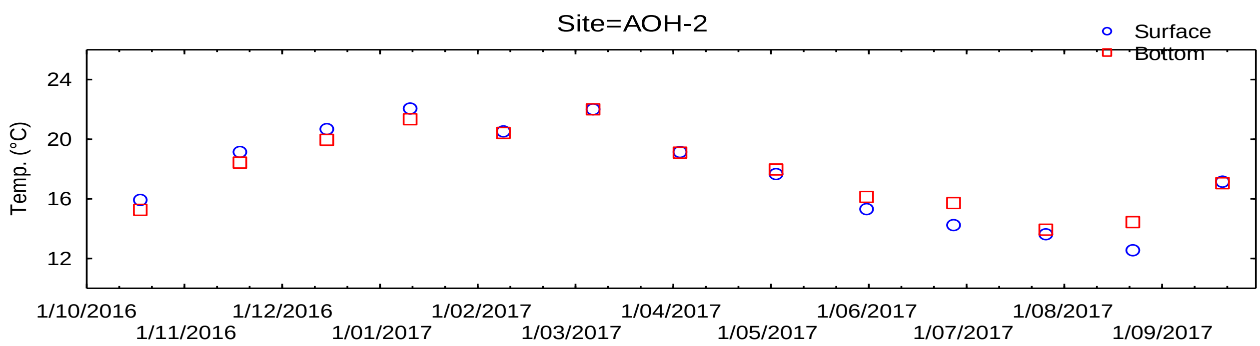

Site=AOH-12
Scatterplot of multiple variables against Date
FRP (mg/L)
Surf - FRP (mg/L)
Bott - FRP (mg/L)
ANZECC FRP
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

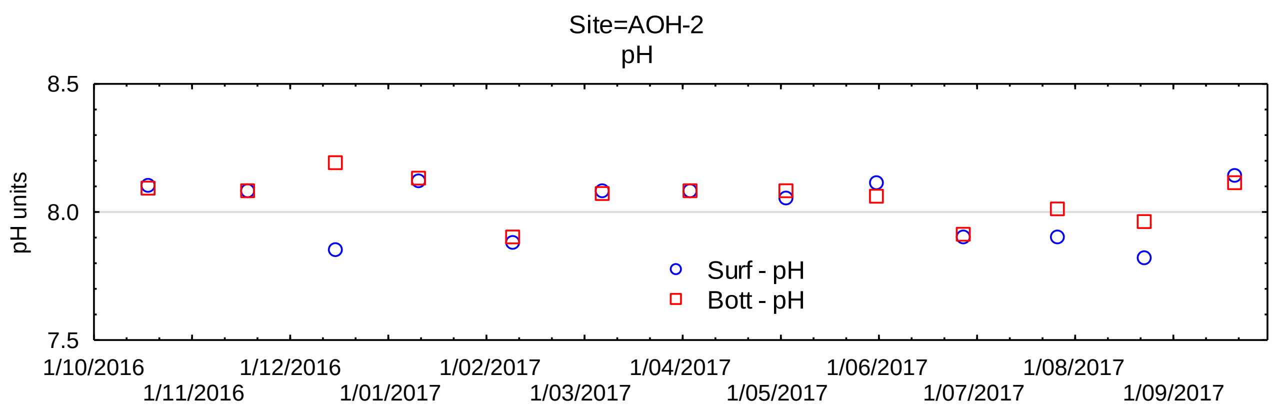

Site=AOH-12
Scatterplot of multiple variables against Date
Chl a (ug/L)
Surf - Chl a (ug/L)
ANZECC Chla
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

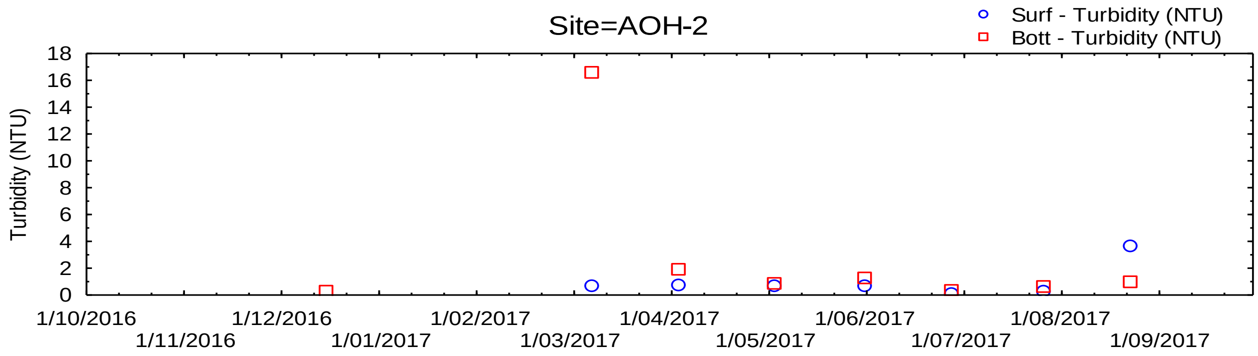

Site=AOH-12
Depth (m)
Secchi
Max of all depths
0
1
2
3
4
5
6
01-Oct-16
01-Nov-16
01-Dec-16
01-Jan-17
01-Feb-17
01-Mar-17
01-Apr-17
01-May-17
01-Jun-17
01-Jul-17
01-Aug-17
01-Sep-17

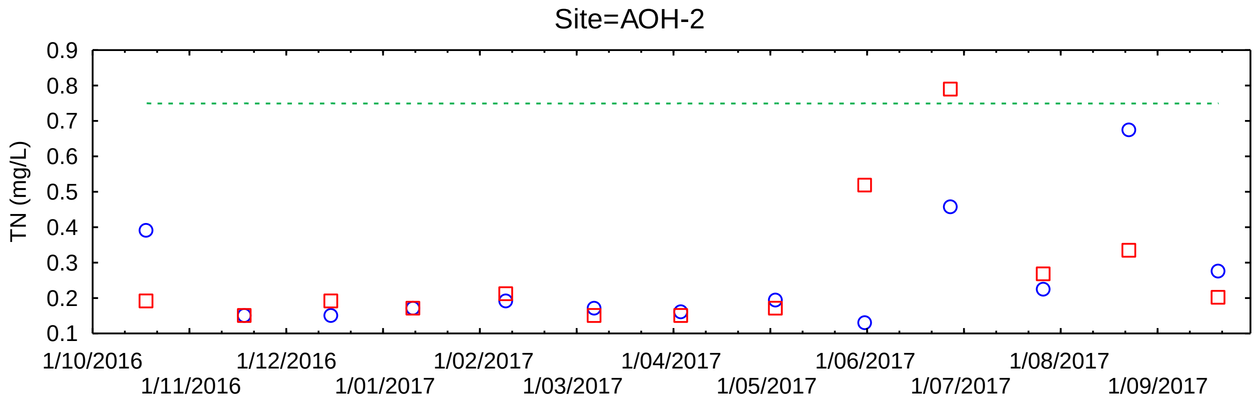

AOH-2
Salinity (ppt)
Surface
Bottom
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

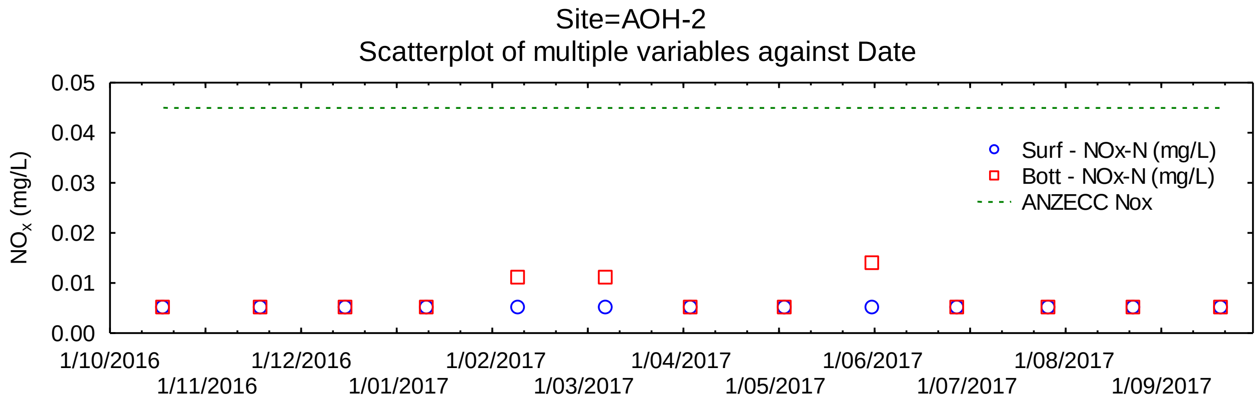

Site=AOH-2
Surface
Bottom
DO (mg/L)

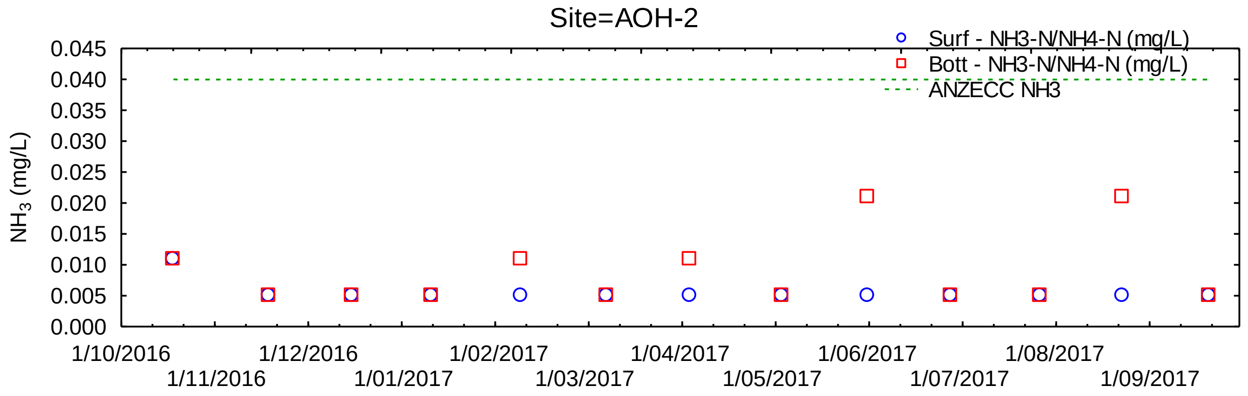

Site=AOH-2
Surface
Bottom
Temp. (°C)

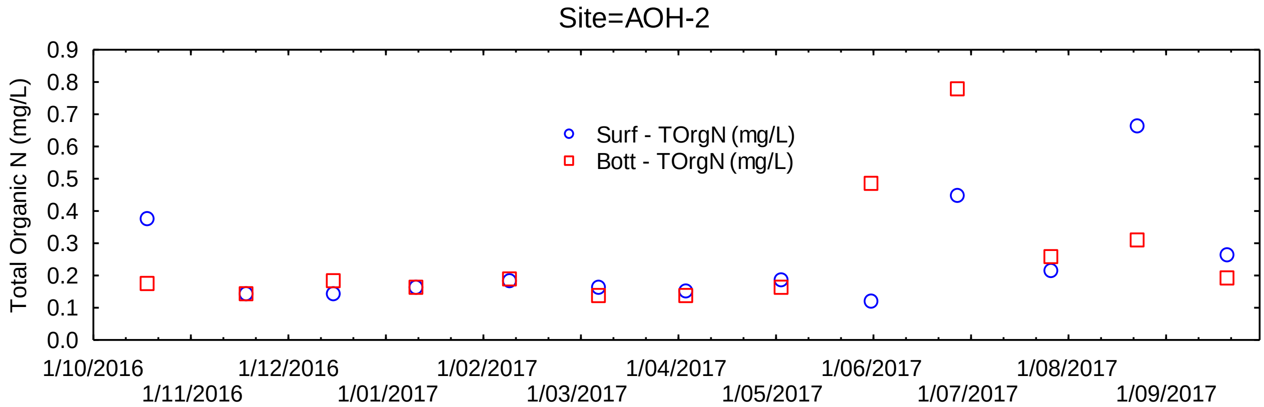

Site=AOH-2
pH
pH units
Surf - pH
Bott - pH

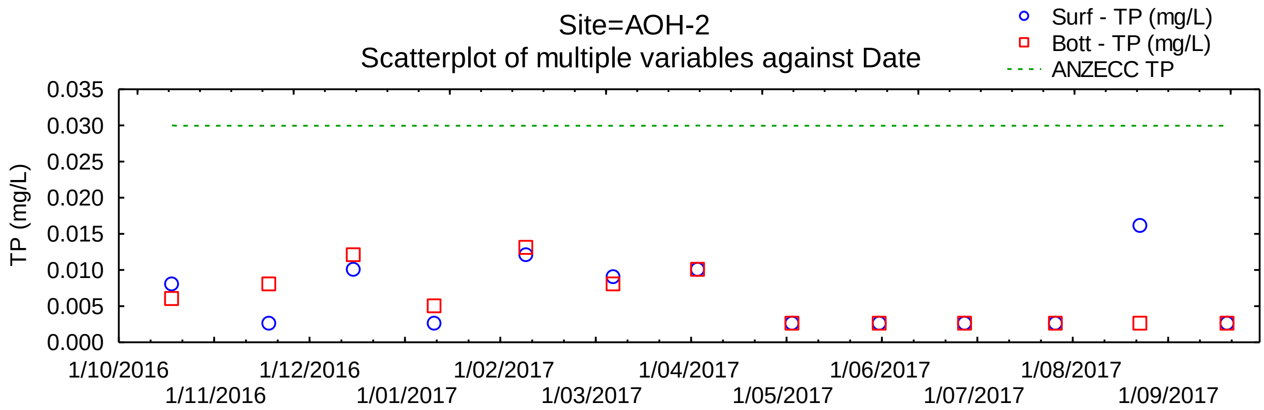

Site=AOH-2
Surf - Turbidity (NTU)
Bott - Turbidity (NTU)
Turbidity (NTU)
18
16
14
12
10
8
6
4
2
0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

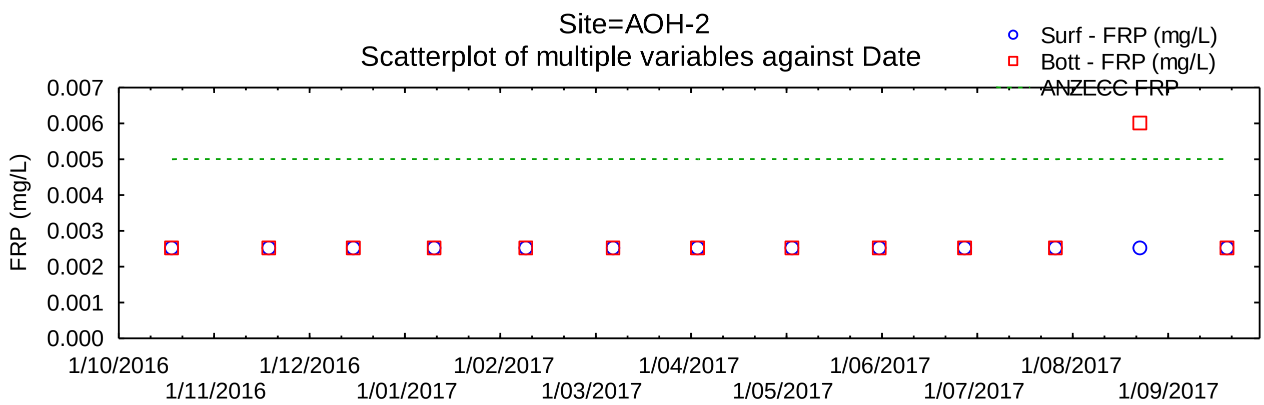

Site=AOH-2
TN (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

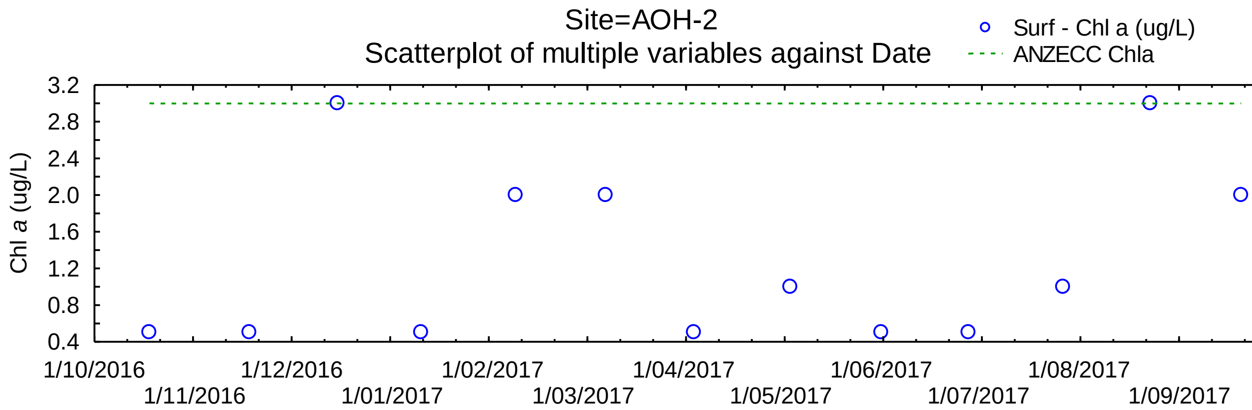

Site=AOH-2
Scatterplot of multiple variables against Date
Surf - NOx-N (mg/L)
Bott - NOx-N (mg/L)
ANZECC Nox
NOx (mg/L)
0.05
0.04
0.03
0.02
0.01
0.00
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

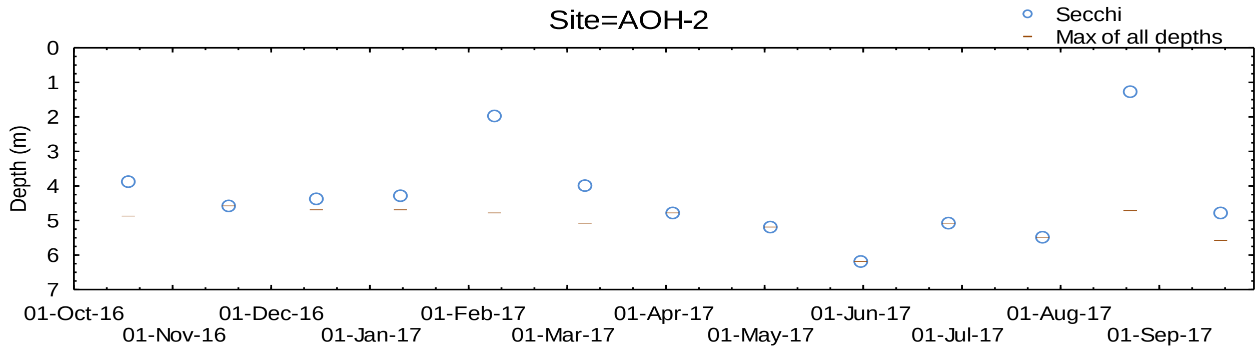

Site=AOH-2
Surf - NH3-N/NH4-N (mg/L)
Bott - NH3-N/NH4-N (mg/L)
ANZECC NH3
NH_3 (mg/L)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017


Site=AOH-2
Surf - TOrgN (mg/L)
Bott - TOrgN (mg/L)
Total Organic N (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

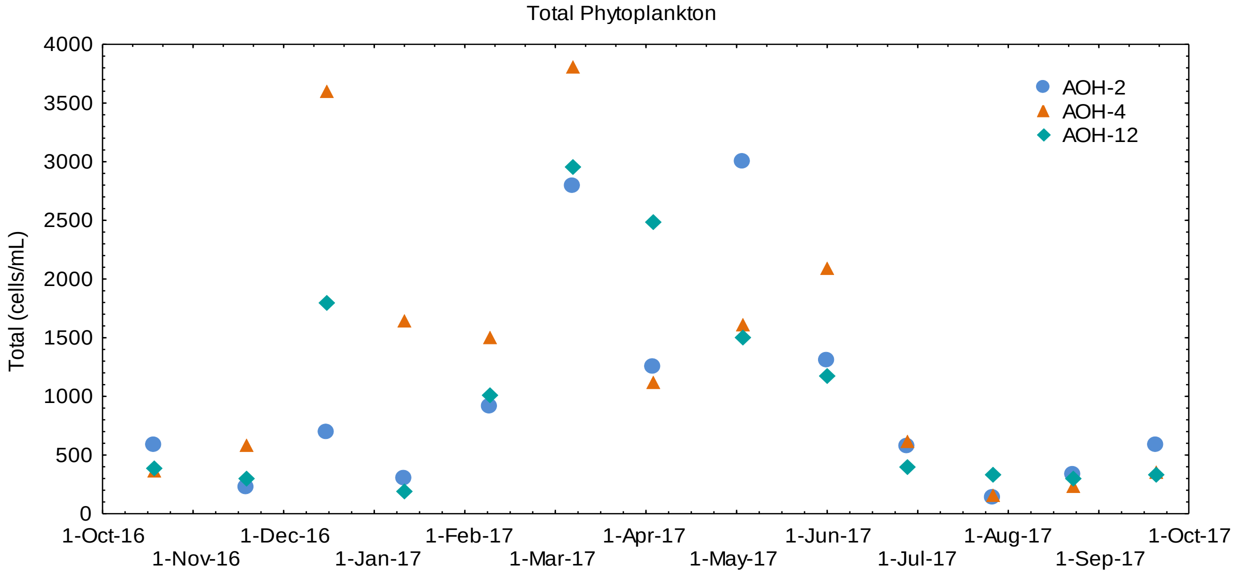

Site=AOH-2
Scatterplot of multiple variables against Date
Surf - TP (mg/L)
Bott - TP (mg/L)
ANZECC TP
TP (mg/L)
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

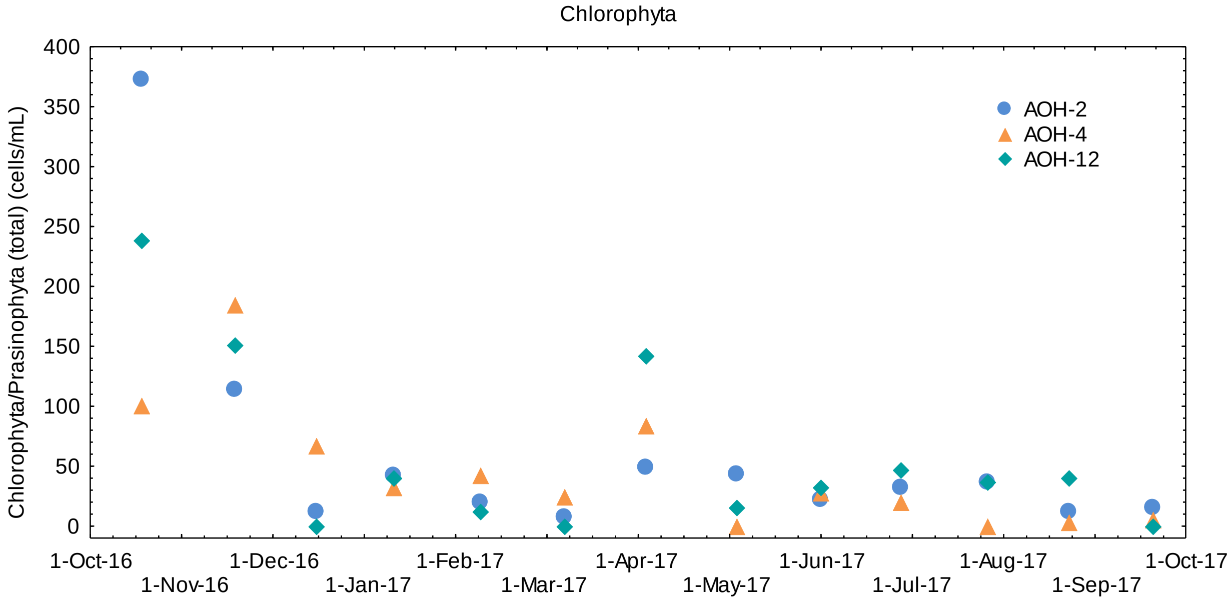

Site=AOH-2
Scatterplot of multiple variables against Date
Surf - FRP (mg/L)
Bott - FRP (mg/L)
ANZECC FRP
FRP (mg/L)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

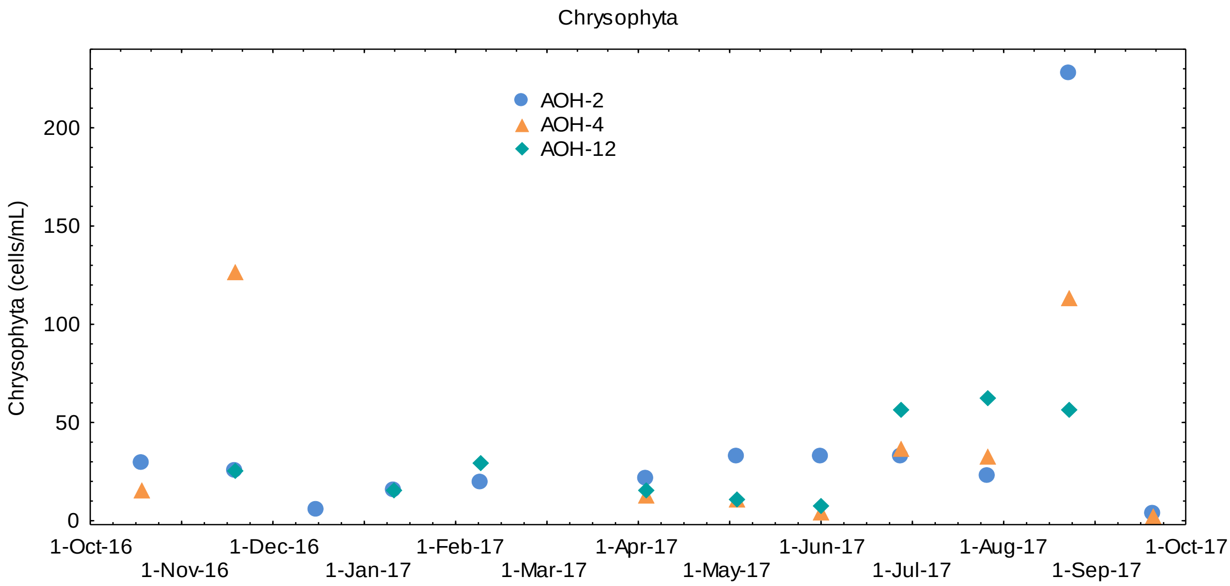

Site=AOH-2
Scatterplot of multiple variables against Date
Surf - Chl a (ug/L)
ANZECC Chla
Chl a (ug/L)
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
1/10/2016
1/11/2016
1/12/2016
1/01/2017
1/02/2017
1/03/2017
1/04/2017
1/05/2017
1/06/2017
1/07/2017
1/08/2017
1/09/2017

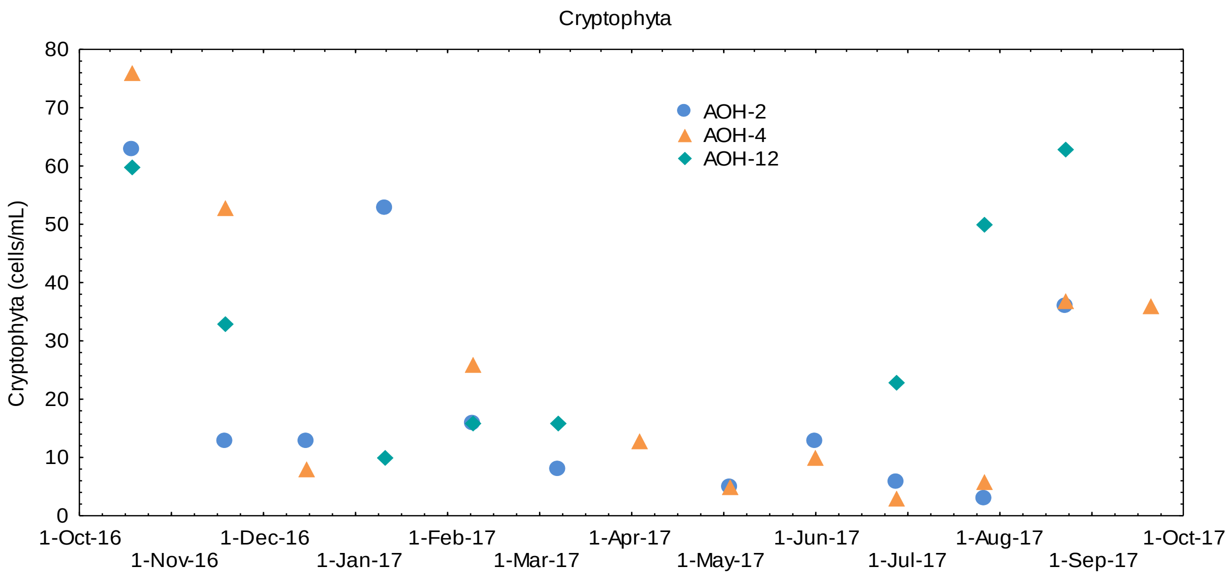

Site=AOH-2
Secchi
Max of all depths
Depth (m)
0
1
2
3
4
5
6
7
01-Oct-16
01-Nov-16
01-Dec-16
01-Jan-17
01-Feb-17
01-Mar-17
01-Apr-17
01-May-17
01-Jun-17
01-Jul-17
01-Aug-17
01-Sep-17

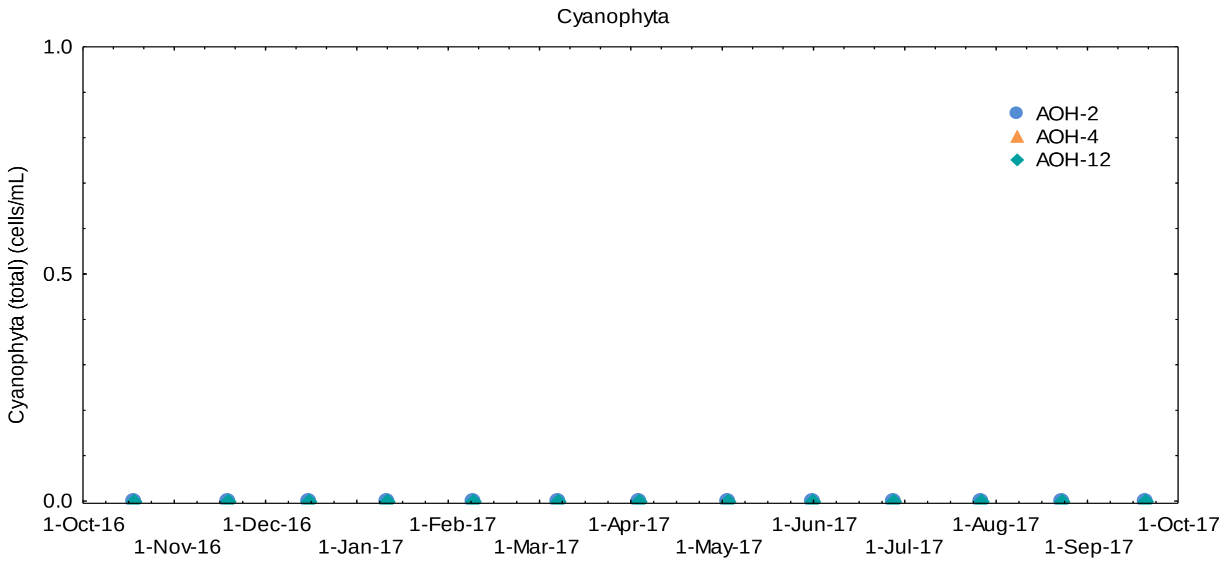
D. Phytoplankton group time series

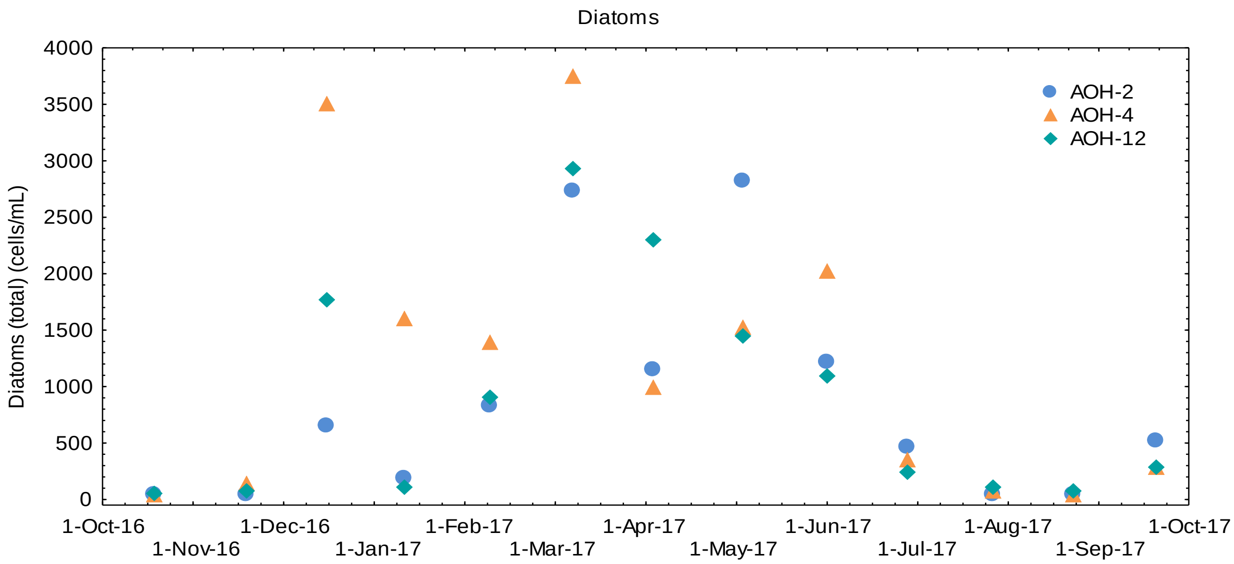


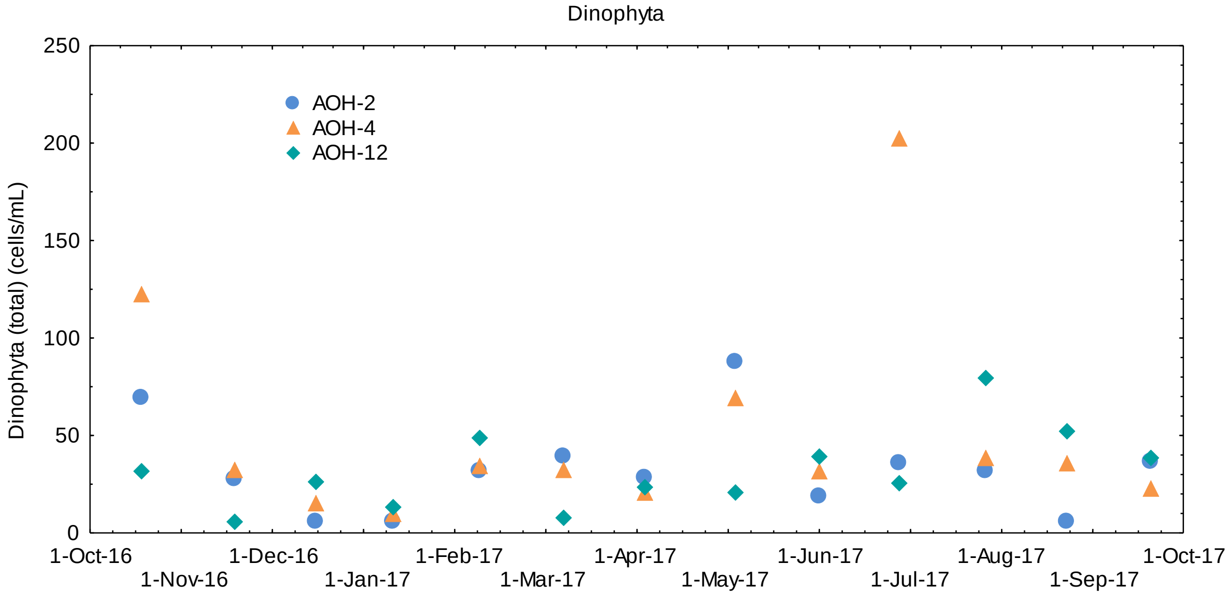



Chrysophyta
AOH-2
AOH-4
AOH-12
Chrysophyta (cells/mL)
200
150
100
50
0
1-Oct-16
1-Nov-16
1-Dec-16
1-Jan-17
1-Feb-17
1-Mar-17
1-Apr-17
1-May-17
1-Jun-17
1-Jul-17
1-Aug-17
1-Sep-17
1-Oct-17


Cryptophyta
AOH-2
AOH-4
AOH-12
Cryptophyta (cells/mL)
80
70
60
50
40
30
20
10
0
1-Oct-16
1-Nov-16
1-Dec-16
1-Jan-17
1-Feb-17
1-Mar-17
1-Apr-17
1-May-17
1-Jun-17
1-Jul-17
1-Aug-17
1-Sep-17
1-Oct-17


Cyanophyta
Cyanophyta (total) (cells/mL)
1.0
0.5
0.0
1-Oct-16
1-Nov-16
1-Dec-16
1-Jan-17
1-Feb-17
1-Mar-17
1-Apr-17
1-May-17
1-Jun-17
1-Jul-17
1-Aug-17
1-Sep-17
1-Oct-17
AOH-2
AOH-4
AOH-12


Diatoms
Diatoms (total) (cells/mL)
4000
3500
3000
2500
2000
1500
1000
500
0
1-Oct-16
1-Nov-16
1-Dec-16
1-Jan-17
1-Feb-17
1-Mar-17
1-Apr-17
1-May-17
1-Jun-17
1-Jul-17
1-Aug-17
1-Sep-17
1-Oct-17
AOH-2
AOH-4
AOH-12


Dinophyta
Dinophyta (total) (cells/mL)
250
200
150
100
50
0
AOH-2
AOH-4
AOH-12
1-Oct-16
1-Nov-16
1-Dec-16
1-Jan-17
1-Feb-17
1-Mar-17
1-Apr-17
1-May-17
1-Jun-17
1-Jul-17
1-Aug-17
1-Sep-17
1-Oct-17

References

ANZECC & ARMCANZ (2000). *Australian and New Zealand guidelines for fresh and marine water quality*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

APHA (1998). Standard Methods for the Examination of Water and Wastewater, 20th edn, American Public Health Association, Water Environment Federation, American Water Works Association, Washington, USA.

APHA (2017). Standard Methods for the Examination of Water and Wastewater, 23rd edn, American Public Health Association, Water Environment Federation, American Waterworks Association, Washington, USA.

Cambridge ML, Bastyan GR and Walker DI (2002) Recovery of *Posidonia* meadows in Oyster Harbour, southwestern Australia. Bulletin of Marine Science 71:1279–1289

EPA (1990a). *Estuaries of the Shire of Albany*. Estuarine studies series No. 8. Environmental Protection Authority Perth, Western Australia.

EPA (1990b) Albany Harbours Environmental Study (1988–1989). Environmental Protection Authority, Report No. 412, Perth, Western Australia, February 1990.

Pearce A, Helleren S and Marinelli M (2000) *Review of productivity levels of Western Australian coastal and estuarine waters for mariculture planning purposes.* Fisheries Research Report No. 123, 2000.

SCNRM (2017) *Bringing shellfish reefs back to Oyster Harbour*. Available at https://southcoastnrm.com.au/item/bringing-shellfish-reefs-back-to-oyster-harbour [Accessed 30 November 2017]

Warnock, B. and Cook, P.A. (2015). Historical abundance and distribution of the native flat oyster, *Ostrea angasi*, in the Great Southern region of Western Australia. Centre of Excellence in Natural Resource Management, University of Western Australia.

Western Australian Shellfish Quality Assurance Program (WASQAP) (2016). Marine Biotoxin Monitoring Management Plan 2016. Western Australian Department of Health, Perth.

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