26 May 2021

Alison Johnstone
Silver Fern Farms Ltd
PO Box 283
Christchurch 8140

ID: 2145

Dear Ali

Recent data for the Pareora discharge

This letter is in response to your request of 23 April 2021 for a comment on whether the water-quality monitoring data collected in the mixing zone of the Pareora outfall since our original report are consistent with the conclusions of that report[1].

The conclusions, based on data from August 2013 to August 2016, were that:

> [c]*onsent monitoring did not indicate any effect of the Pareora outfall on pH, salinity, colour or concentrations of total suspended solids, total phosphorus, total nitrogen, chlorophyll-a or dissolved oxygen in the mixing zone. Minor effects on temperature were observed within the mixing zone. Patchy or occasional effects of the outfall were evident for three nutrient classes: dissolved reactive phosphorus, ammoniacal-nitrogen, and total Kjeldahl nitrogen. Bacterial contamination was high, and clearly extended beyond the 1500 m limit of the mixing zone.*

In summary, I believe that these conclusions are generally supported by the more recent data (May-October 2017 to March-July 2020) for dissolved oxygen, salinity, oil and grease, total suspended solids, total phosphorus, dissolved reactive phosphorus, total nitrogen, ammoniacal nitrogen, chlorophyll-a, enterococci and faecal coliforms, as discussed below. Note that pH, colour, temperature and total Kjeldahl nitrogen were not included in the present review (see below).

Background

The present analysis was restricted to comparisons of box-and-whisker plots of the original and recent data for each variable because of the short timeframe for analysis. The plots show the median value (horizontal bar inside box), the inter-quartile range (IQR, upper and lower edge of box) and 1.5 × IQR (whiskers). I have attached the plots following this letter.

The original report noted that data on water colour (Hazen units) were very variable, confounding identification of any effects, and that pH did not vary among stations. Because of time limitations, these variables were omitted from the present review. The recent dataset

[1] Morrisey D, Floerl L, Newcombe E 2016. Silver Fern Farms Pareora outfall: mixing zone seawater quality. Prepared for Silver Fern Farms Ltd. Cawthron Report No. 2969. 52 p.

did not include values for temperature (only for differences in temperature between inside and at the boundary of the mixing zone) so this variable is also omitted. Total Kjeldahl nitrogen was also excluded because two other variables related to the nitrogen content of the discharge were already included.

Onshore data in both datasets were separated into those collected during northerly and southerly current flows. In the recent dataset, all offshore data were apparently collected during northerly current flow. Nearshore sites were sampled monthly in the original dataset, while offshore sites were only sampled in June 2015 and June 2016 and are not included in the box-and-whisker plots appended. The recent data were collected monthly.

Dissolved oxygen

Median and upper quartile values were slightly higher in the more recent data but, as in the original data, showed no change across the mixing zone. In both datasets there were some extremely high values (up to 193%), suggesting instrument error.

Salinity

Both inshore datasets showed a reduction in salinity at the southern end of the mixing zone during southerly and northerly flow, presumably due to fresh water from the Pareora River.

Oil and grease

Occasional high concentrations occurred at the outfall in both datasets, suggesting a local effect on water quality. Oil and grease concentrations were not higher at the down-current edge of the mixing zone and, therefore, any effect of the outfall does not appear to extend to the 1500-m limit. Recent offshore values were very low (apart from one outlier).

Total suspended solids

No effect of the discharge on suspended solids was apparent beyond the mixing zone in either the original or more recent data. Offshore concentrations of suspended solids were lower than at near-shore sampling stations, as expected where wave action in shallower water causes resuspension of seabed sediment.

Total phosphorus

Median and upper quartile values of the more recent inshore data were similar across all stations, but there were occasional high values at the outfall. Relatively high concentrations of total phosphorus were occasionally recorded in both datasets but were apparently not related to the outfall, as they occurred up-current of the outfall site. Offshore data were not higher at the outfall but (under northerly flow) were higher at the 500 m North and 1,500 m North stations.

Dissolved reactive phosphorus

Median and upper quartile values were similar among sites in the more recent inshore data, with occasional outlying high values at the outfall and one at the northern edge of the mixing zone under northerly flow. The recent offshore data showed an elevated range at the 500 m North site (under northerly flow) and, to a lesser extent, at the outfall. Conclusions are, therefore, similar to those from the original data.

Total nitrogen

There were no clear patterns across the mixing zone in either the original or more recent onshore datasets, with some relatively high values occurring up-current and down-current of the outfall. There was no clear pattern of difference in the offshore data either, with elevated values at the 500 m North and 1,500 m North stations (under northerly flow) but not at the outfall or 1,000 m North.

Ammoniacal nitrogen

Occasional peaks in ammoniacal nitrogen were observed in the original dataset and were possibly related to the outfall, but no clear pattern was apparent across the mixing zone. The recent data showed a higher upper quartile value at the outfall under southerly flow but there was no clear pattern under either flow direction that would indicate an effect of the outfall. The recent offshore data showed higher upper quartile values at the outfall and at 500 m North, but no effect at the northern boundary of the mixing zone.

Chlorophyll-*a*

Concentrations in the original dataset were generally low (< 0.01 g/m^3) and often below the limit of detection. No effect of the outfall was apparent. The more recent dataset was consistent with these observations.

Enterococci

A strong signal from the outfall was seen in concentrations of enterococci at and down-current of the outfall in the original dataset. High concentrations observed up-current of the outfall may be due to other sources of enterococci but, given the high concentrations associated with the outfall on some occasions, it is possible that these up-current peaks resulted from outfall-associated material returning to the mixing zone in tidally reversing currents. This patchiness up- and down-current of the outfall made it difficult to establish from the 2014–2016 data set whether enterococcal concentrations were elevated at the edge of the 1500-m mixing zone. The original report therefore included an analysis of an older dataset that indicated that enterococcal concentrations were higher at the down-current edge of the mixing zone. The more recent inshore and offshore data were consistent with this observation.

There was no clear correspondence between enterococcal concentrations at the boundaries of the mixing zone and the volume of discharge in the original data. In the more recent data, there was a correlation between the concentration of enterococci and volume at the northern boundary of the mixing zone (r = 0.22, p < 0.05) but not at the southern boundary (r = -0.02).

Faecal coliforms

Concentrations of faecal coliforms indicated that contamination extended beyond the edge of the mixing zone in the original dataset. Substantially elevated concentrations of faecal coliforms were frequently recorded up- and down-current of the outfall. While patchiness was apparent, faecal coliform concentrations were higher at the down-current boundary of the mixing zone than at the up-current boundary, indicating that the contamination extended beyond 1500 m of the outfall. The same conclusions can be drawn from the more recent

inshore and offshore datasets. The effect at the northerly boundary of the mixing zone was clear in the offshore data but not in the inshore data under northerly flow.

There was a broad correspondence between coliform concentrations at the boundaries of the mixing zone and discharge volume in the original data. In the more recent data, there was a correlation between the concentration of enterococci and volume at the northern boundary of the mixing zone ($r = 0.23$, $p < 0.05$) but not at the southern boundary ($r = -0.06$).

Notes on temperature difference

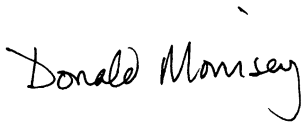
Median differences in the original dataset were all < 1 °C, indicating that temperatures generally returned to near ambient conditions by the time water reached the edge of the mixing zone. The median differences for the recent data were in the range 10–20 °C and the fact that these differences extended to 1.75 km from the outfall suggests that there were errors in measuring or recording these data. The obvious explanation is that the values reported are actual temperatures, rather than differences, but the presence of several values around zero indicates that this is not a complete explanation (sea-water temperatures of zero are extremely unlikely at this site). Due to these uncertainties, I have not considered this variable further.

Other comments

The more recent dataset contained anomalous values of several variables, suggesting measurement or recording error. The most obvious examples were removed for this analysis, but thorough grooming of the data was outside the project scope. I suggest that data be checked and groomed at the time they are entered into the database, and that instrument calibration should be checked regularly.

Yours sincerely

Scientist



Don Morrisey
Senior Coastal Scientist
Cawthron Institute

Reviewed by

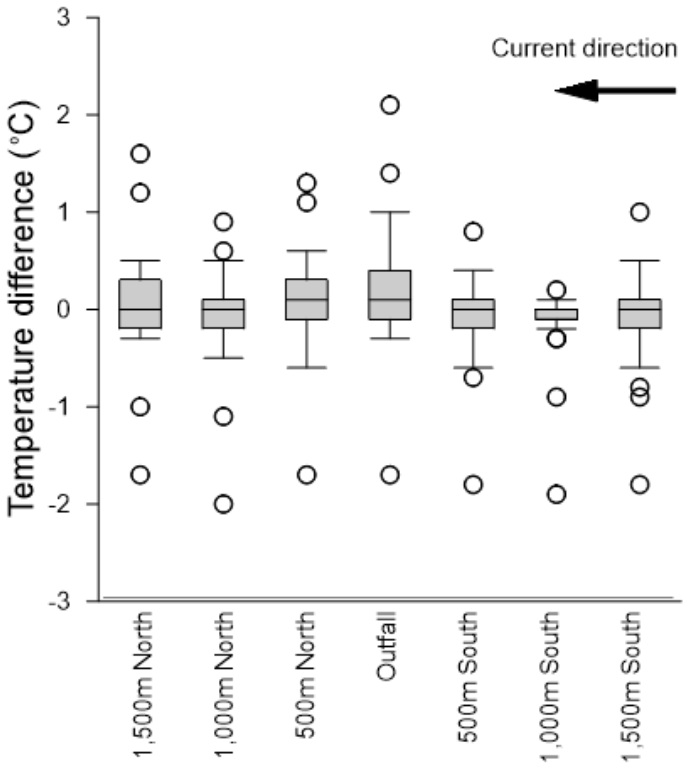
Emma Newcombe
Marine Ecologist
Cawthron Institute

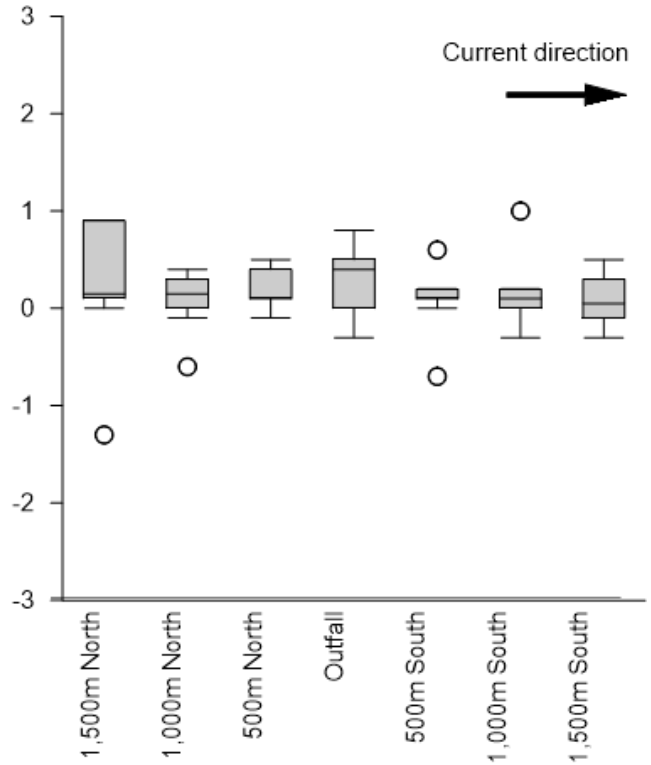
Combined plots of original (August 2013 to August 2016: upper plots) and more recent (May-October 2017 to March-July 2020) water-quality data from onshore and offshore sampling stations around the Pareora outfall

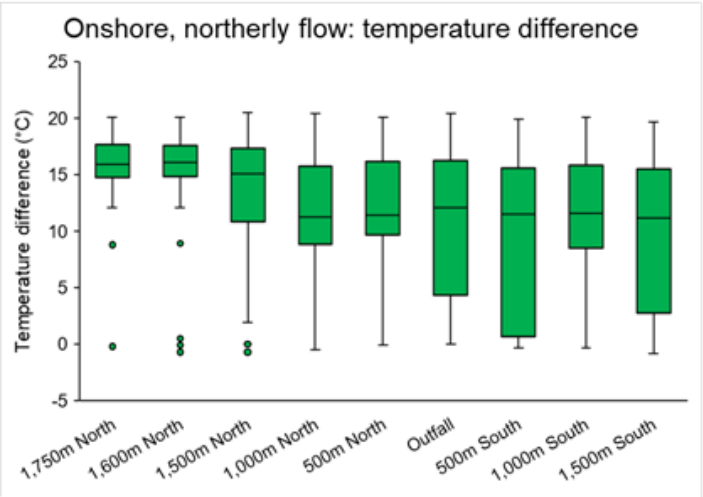
Upper pair of plots show the original onshore data under northerly (left-hand plot) and southerly current flow. Lower plots show the more recent onshore (green and red bars) and offshore (blue bars) data. All recent offshore data were collected under northerly current flow.

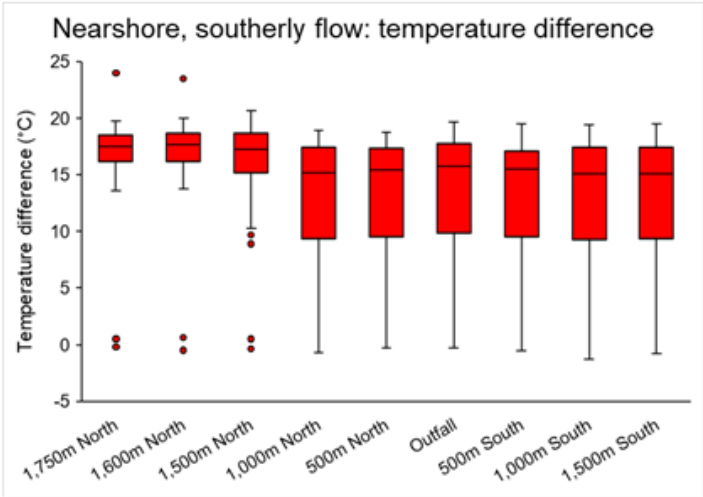
The plots of enterococci and faecal coliforms also show concentrations at the 1500 m North and 1500 m South stations and the daily volume of wastewater discharged for the period August 2016 to March 2021.

Temperature difference

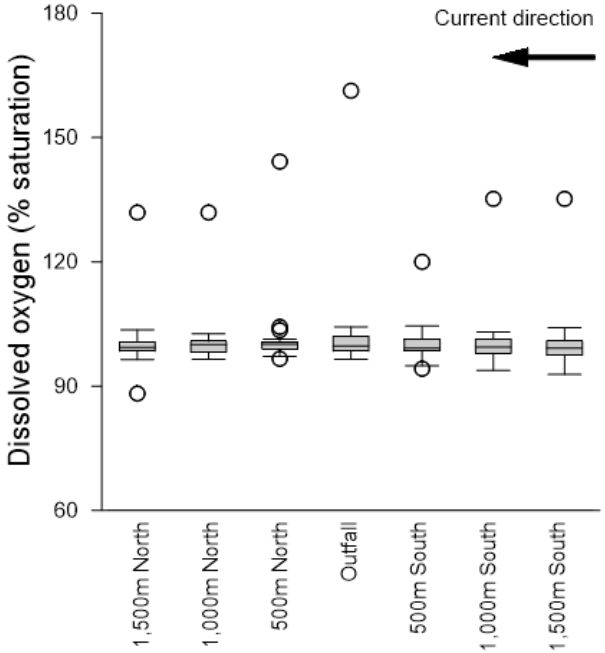


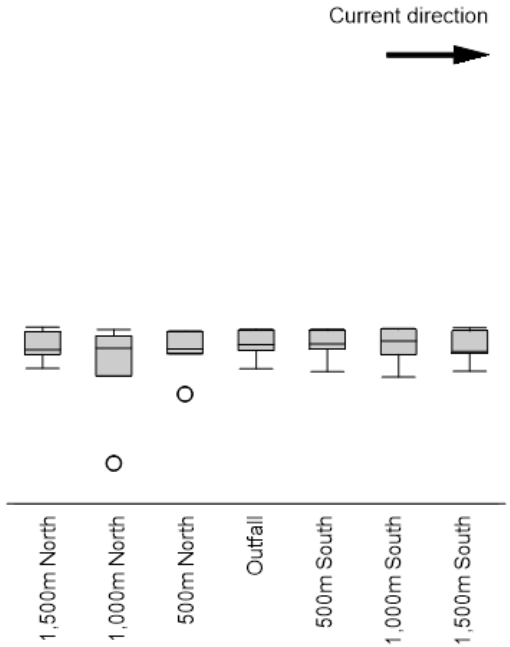


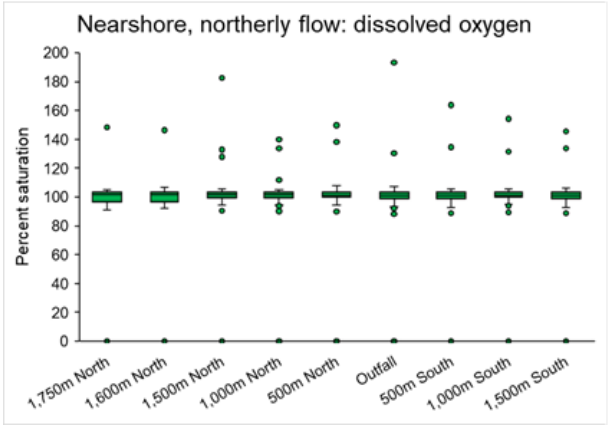


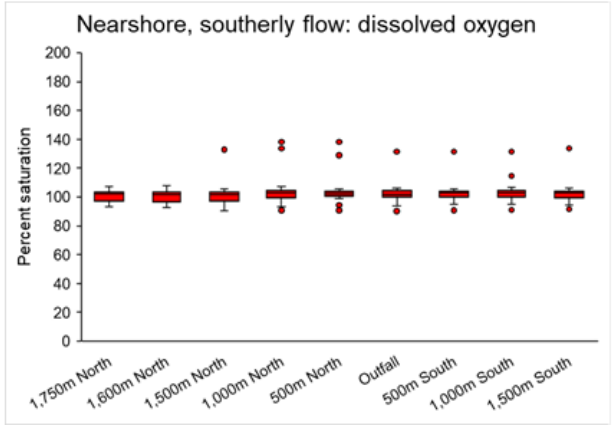


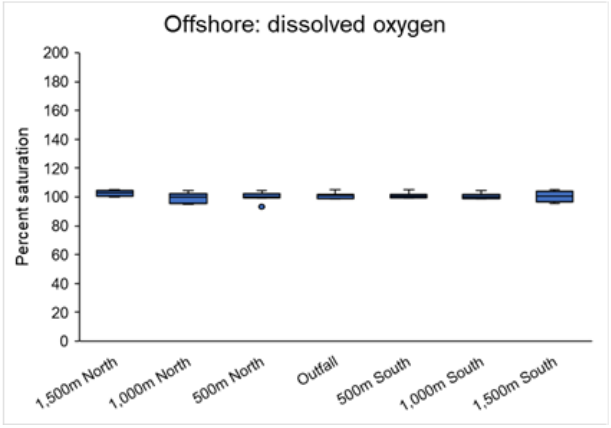
Dissolved oxygen



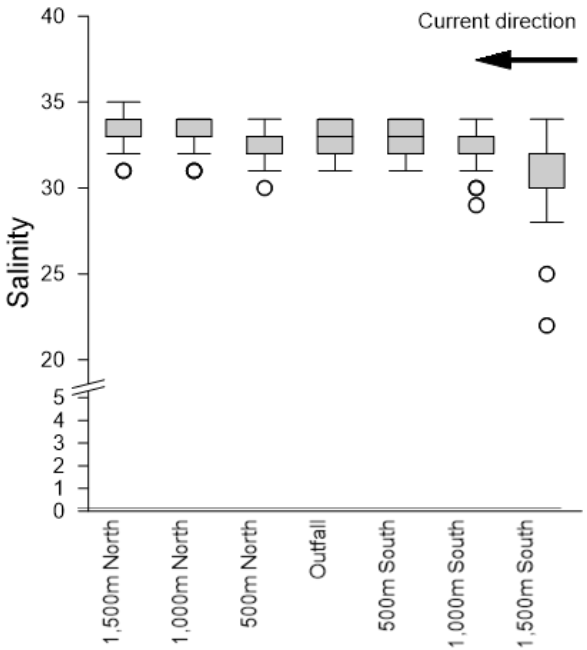








Salinity


Current direction
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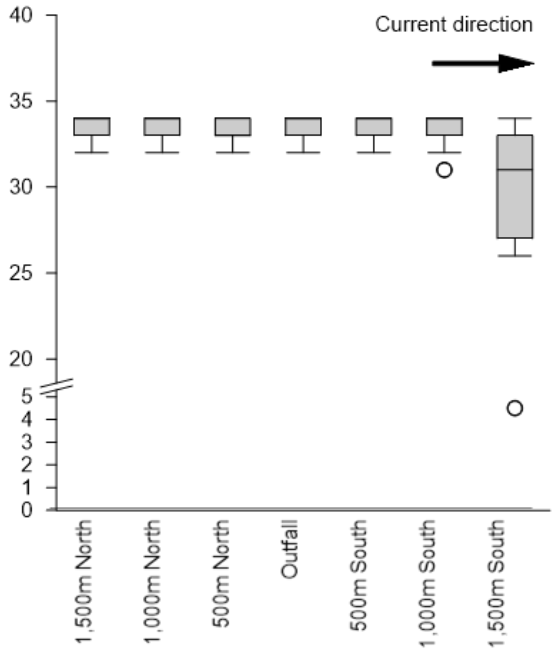
Current direction
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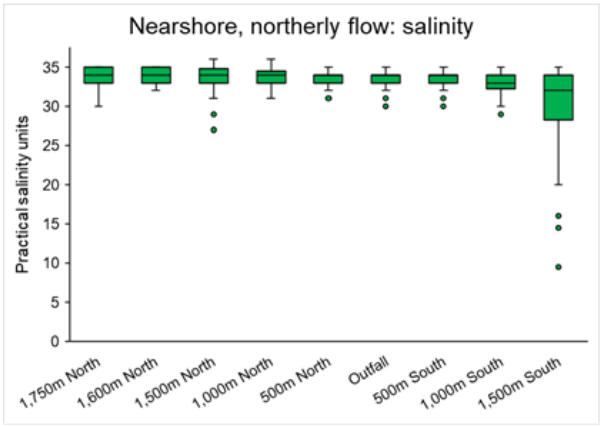
Nearshore, northerly flow: salinity
Practical salinity units
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Outfall
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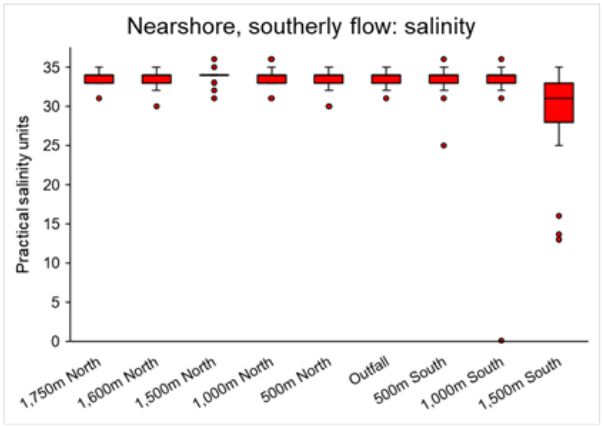
Nearshore, southerly flow: salinity
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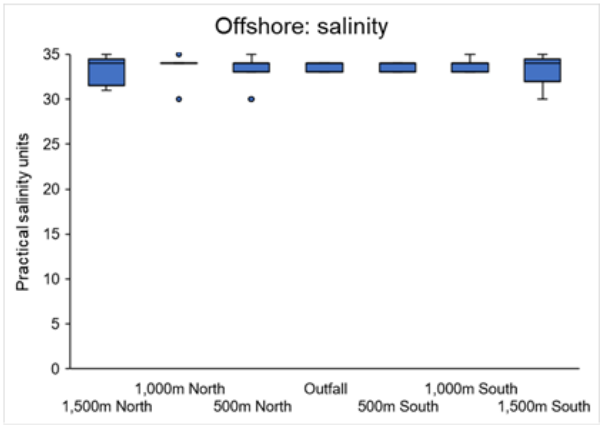
Offshore: salinity
Practical salinity units
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Outfall
500m North
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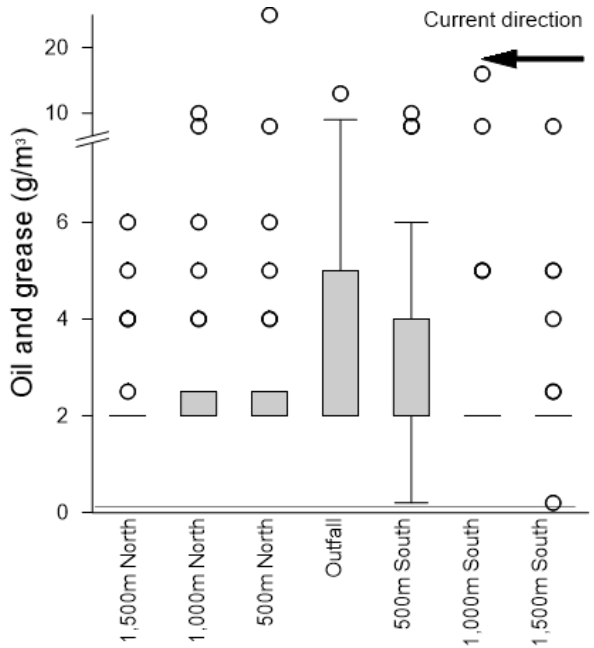
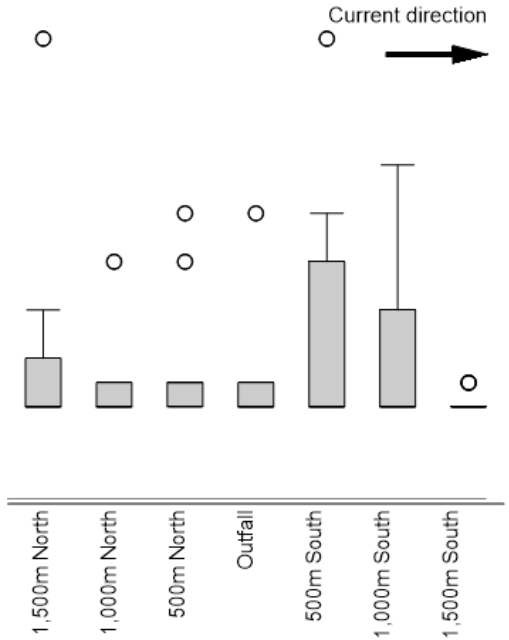
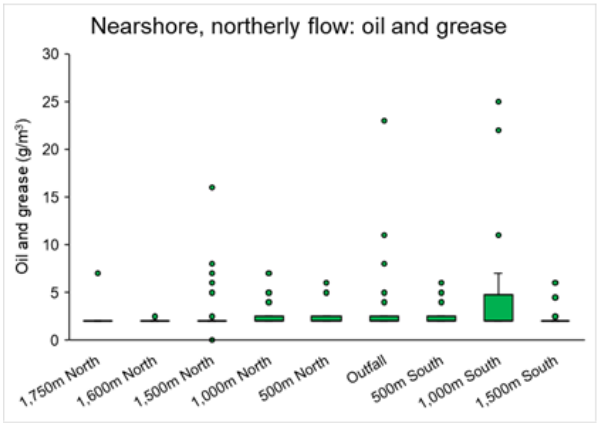
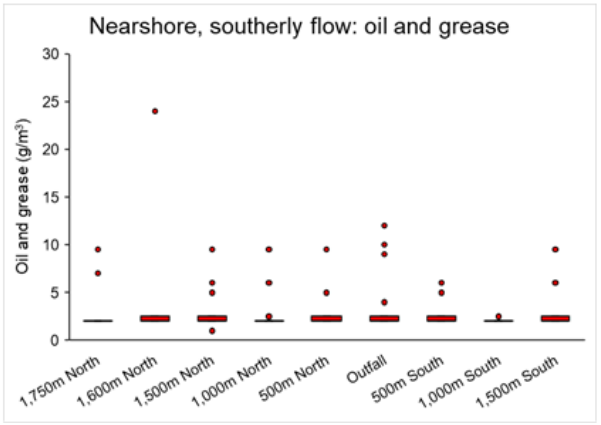
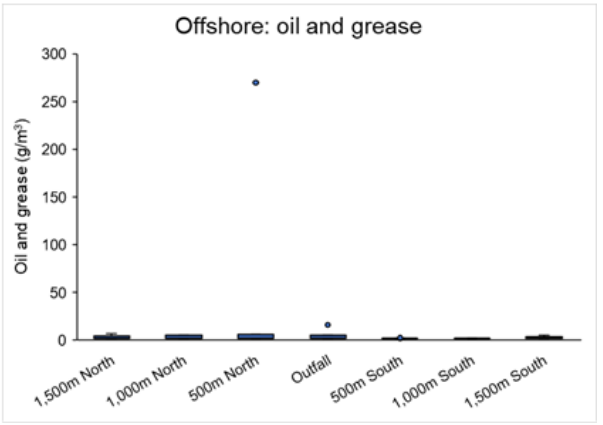
Oil and grease



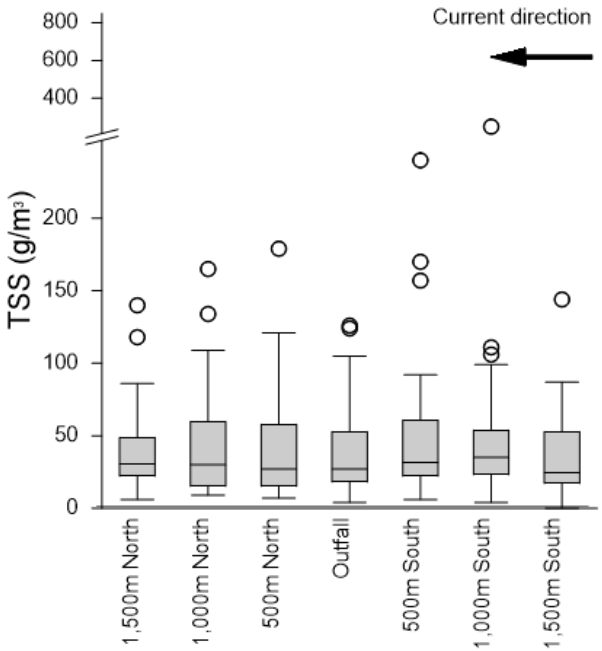


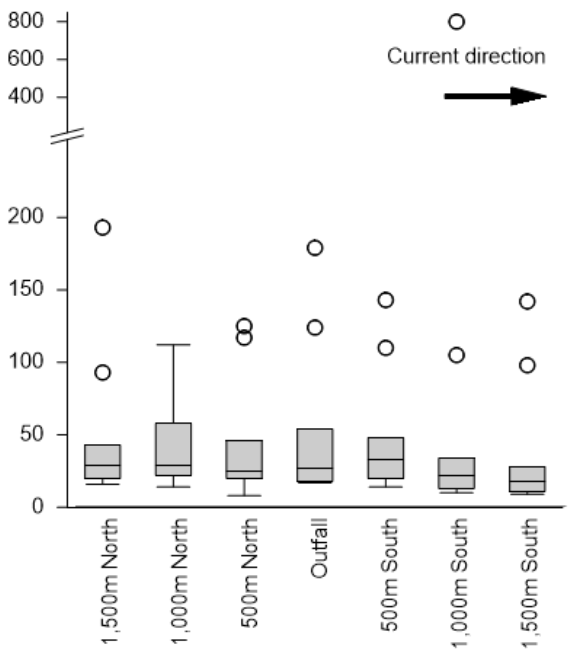


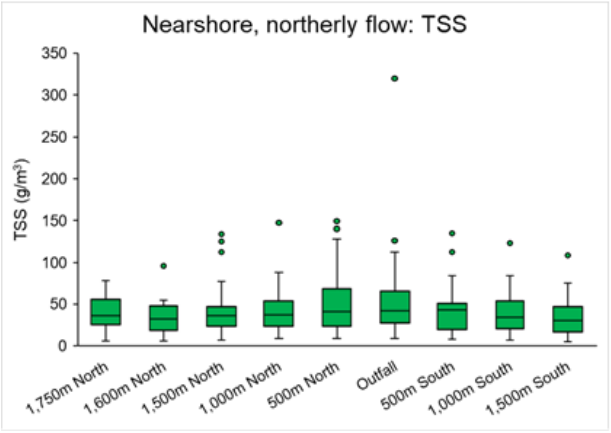


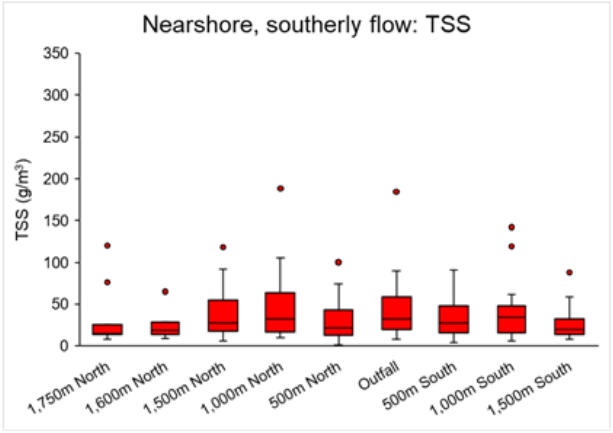


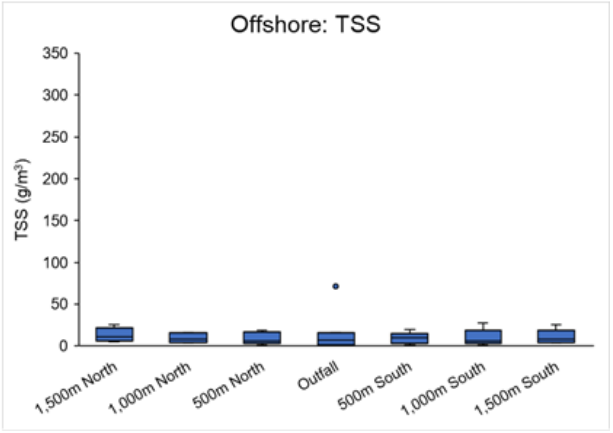
Total suspended solids



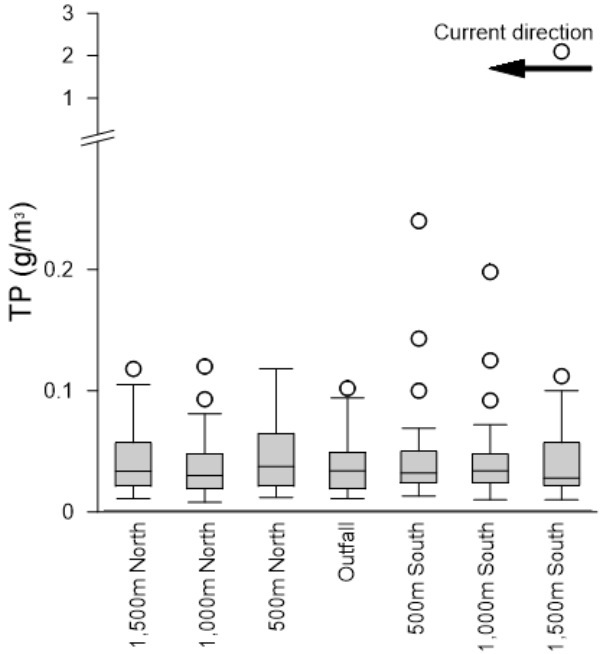


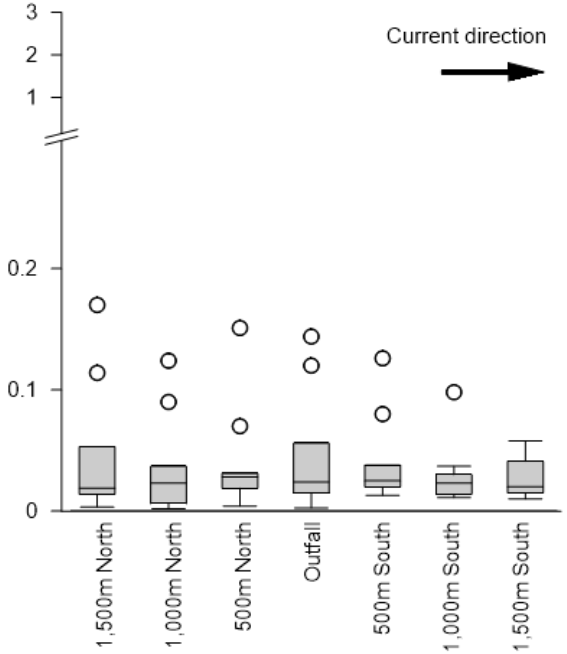


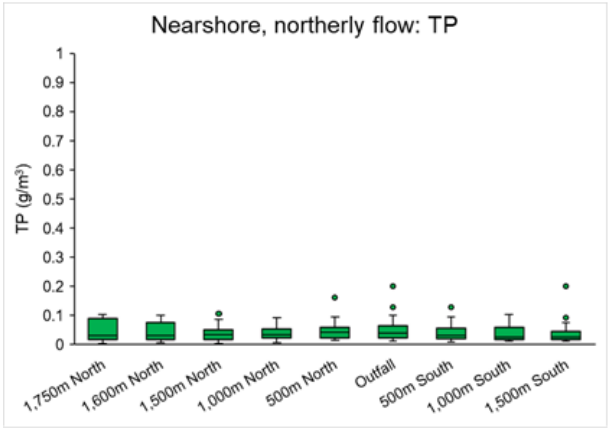


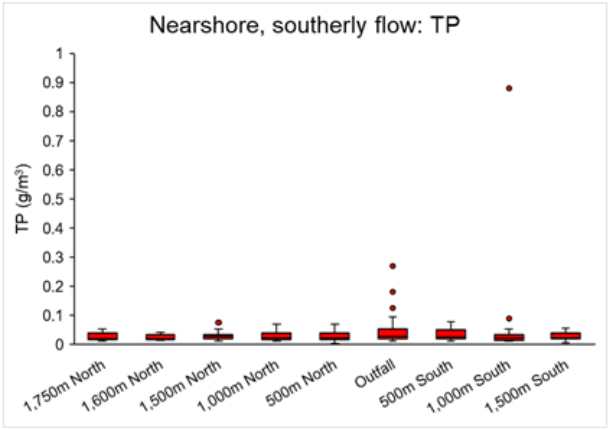


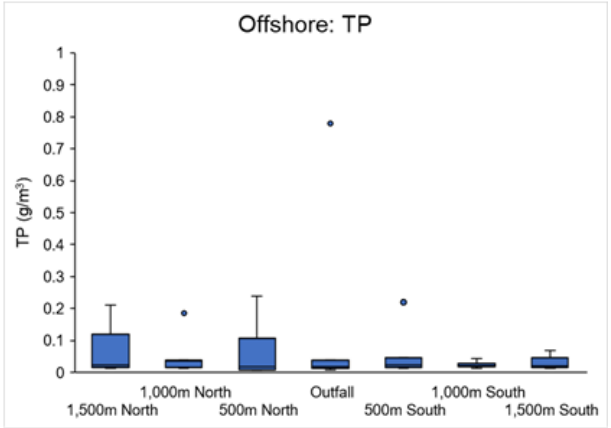
Total phosphorus



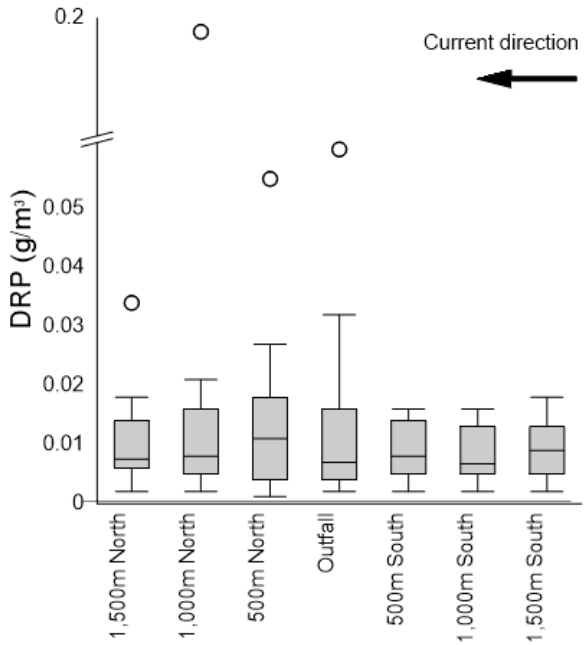


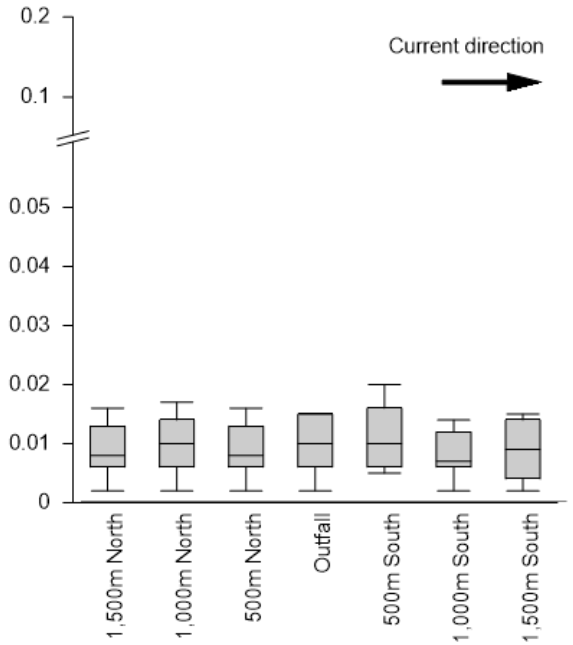


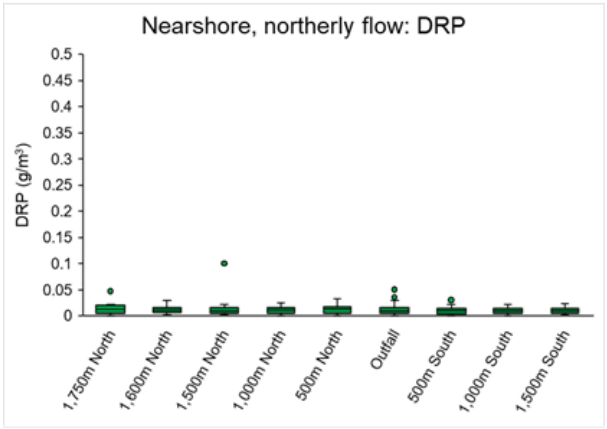


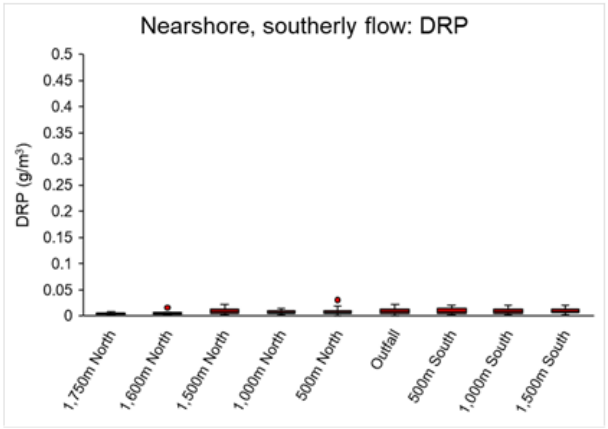


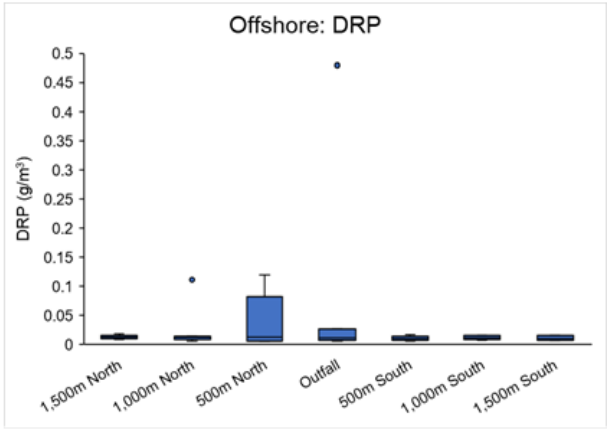
Dissolved reactive phosphorus



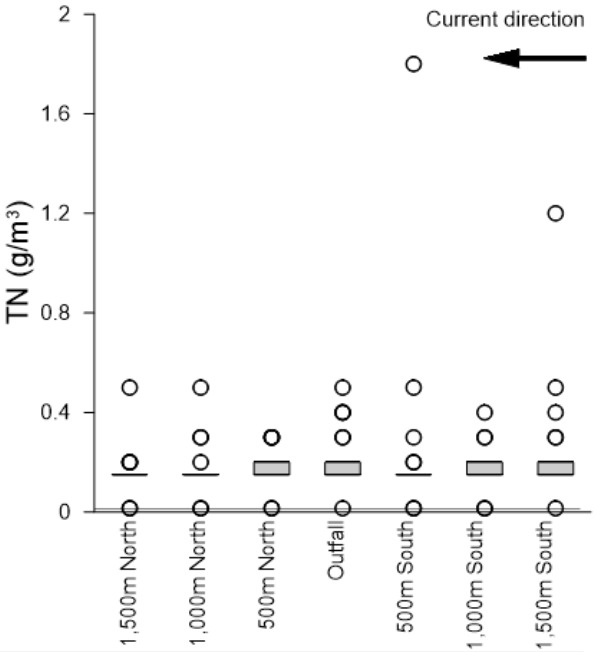


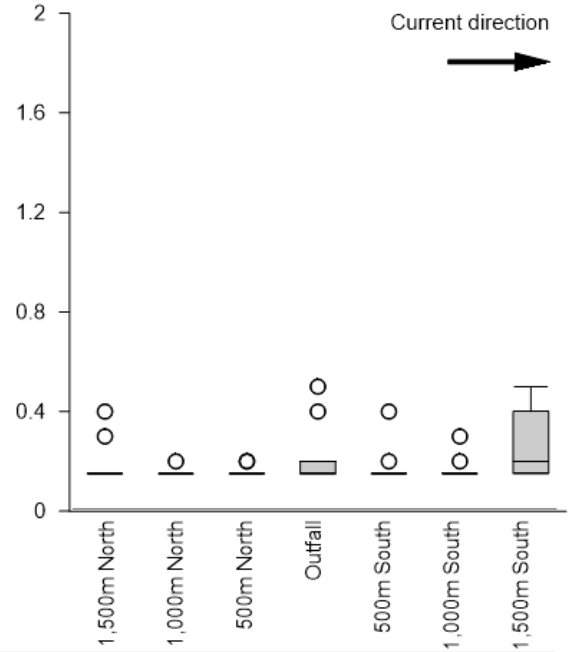


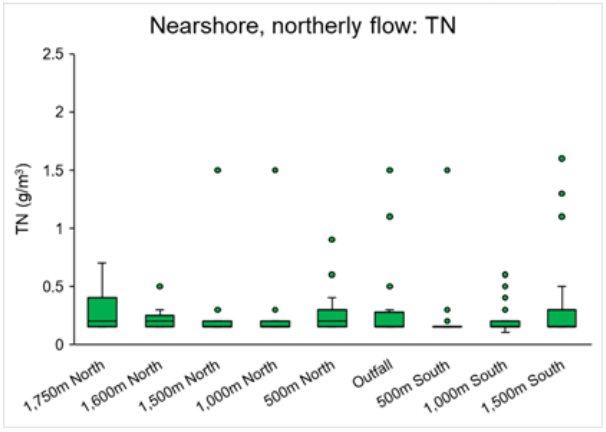


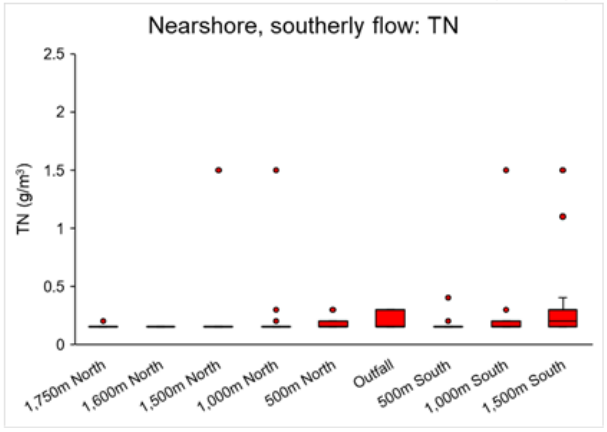


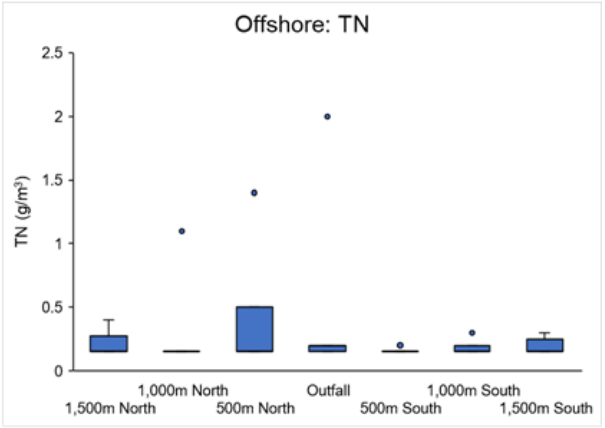
Total nitrogen



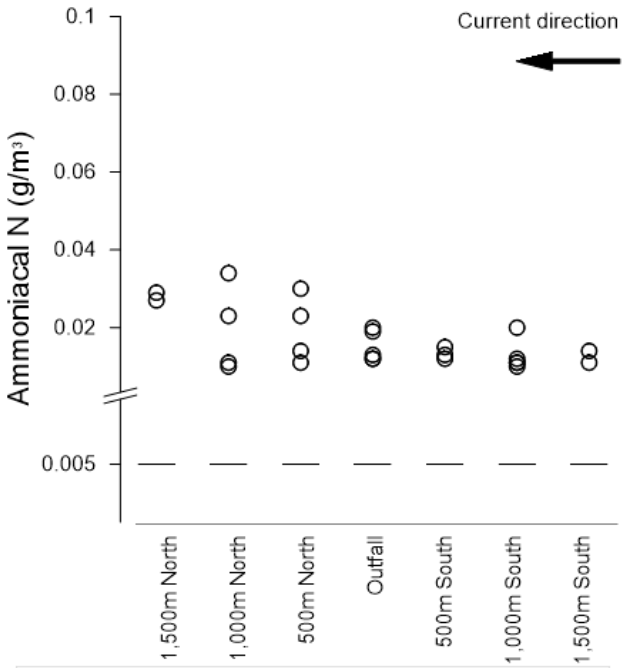


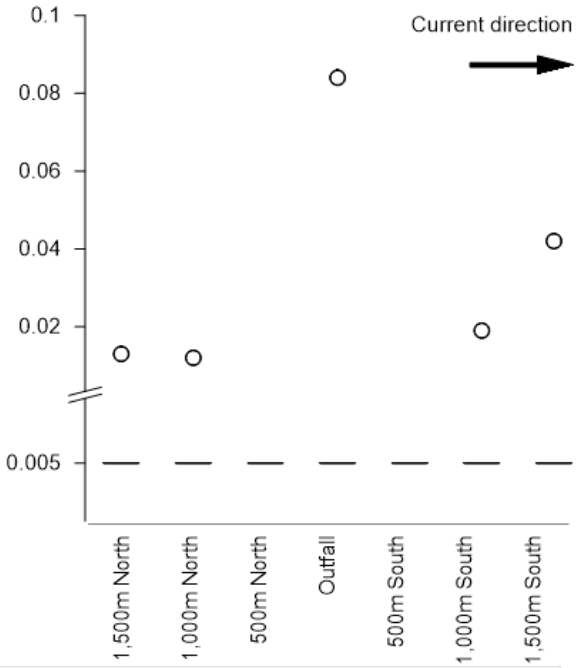


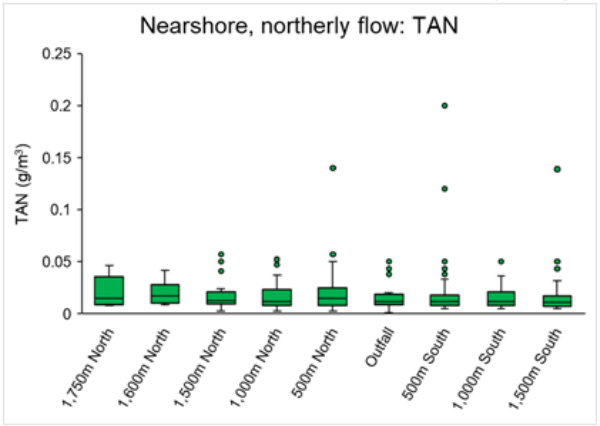


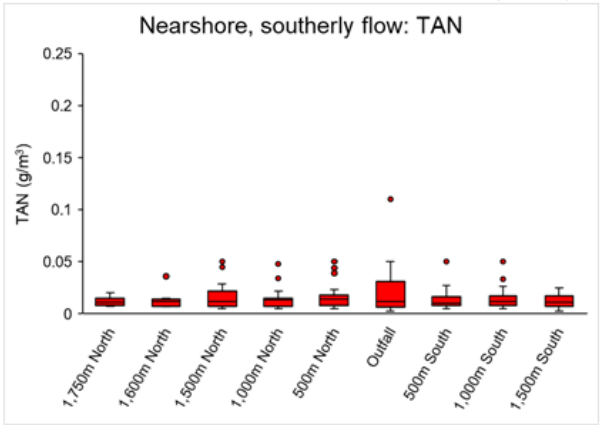


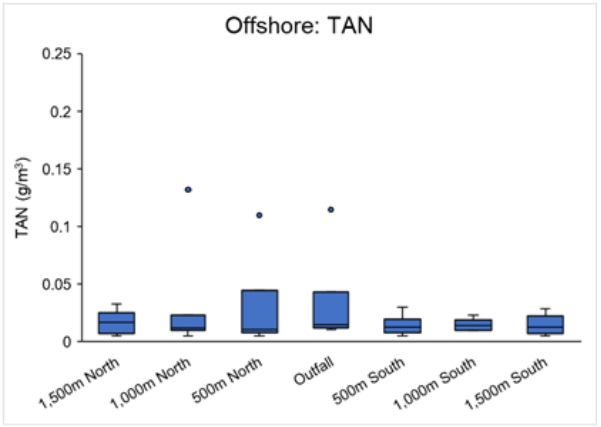
Ammoniacal nitrogen



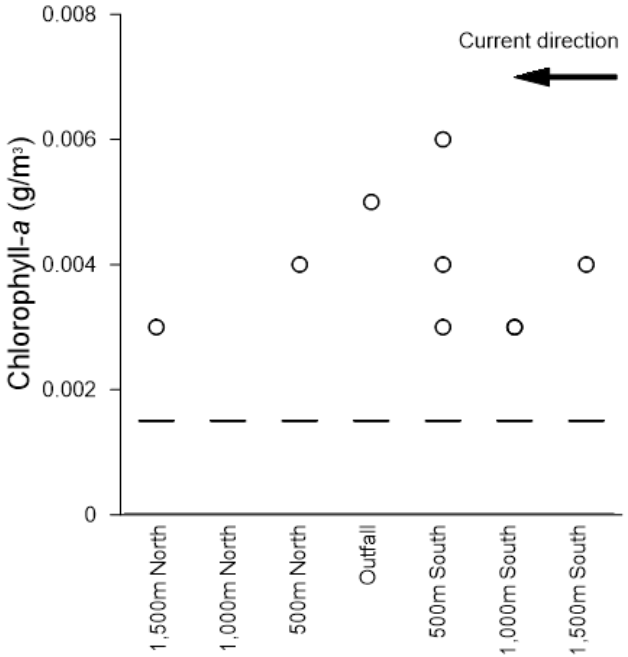


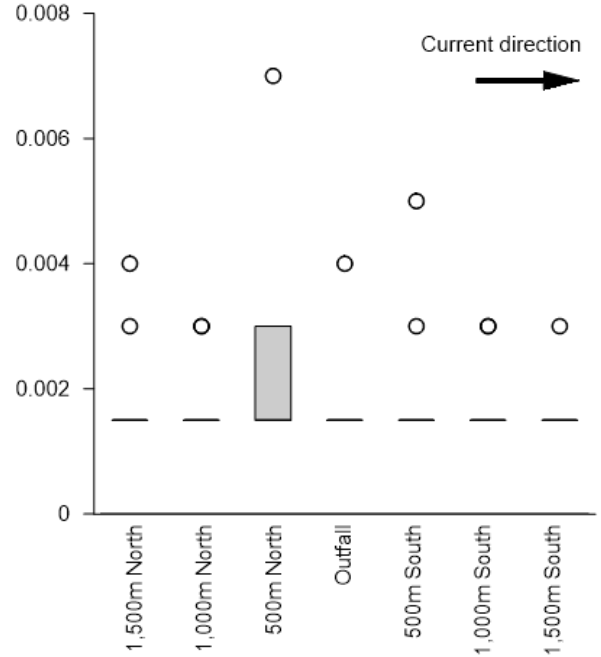


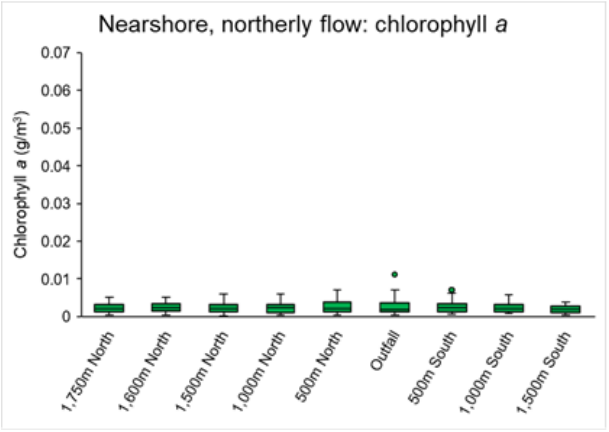


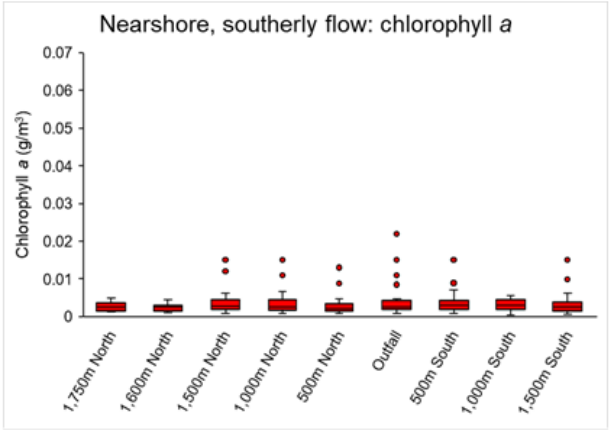


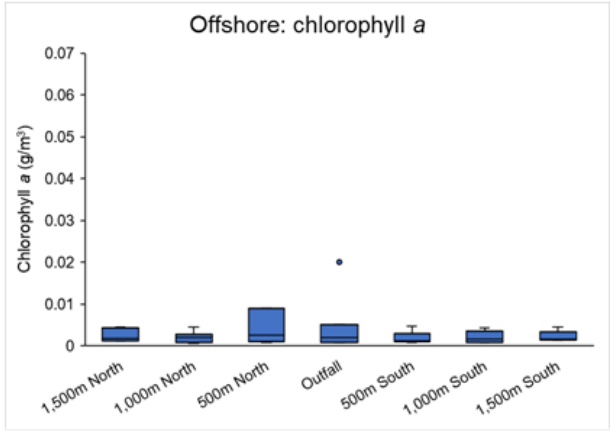
Chlorophyll-*a*



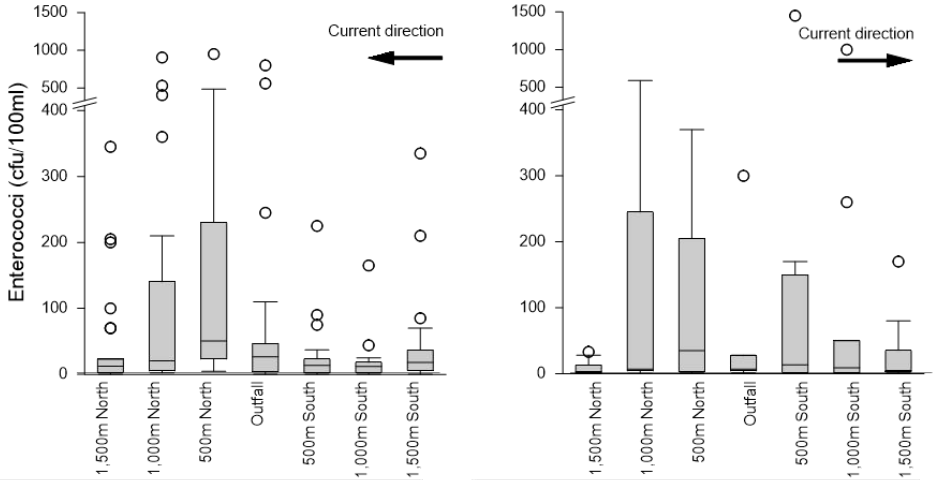


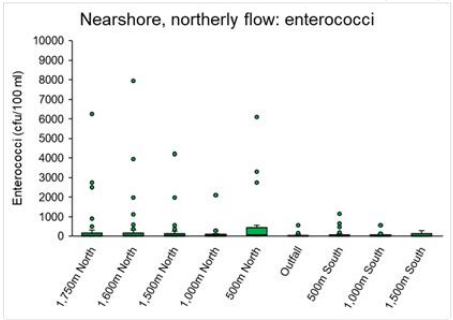


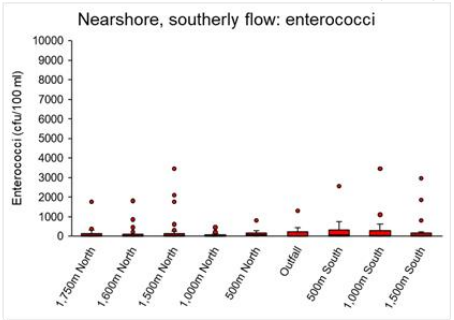


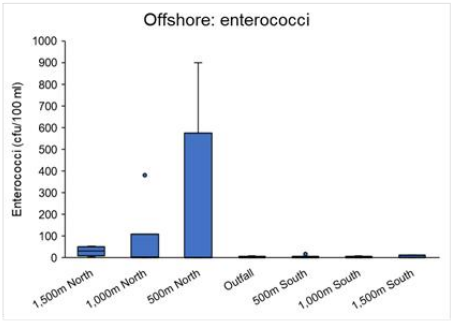


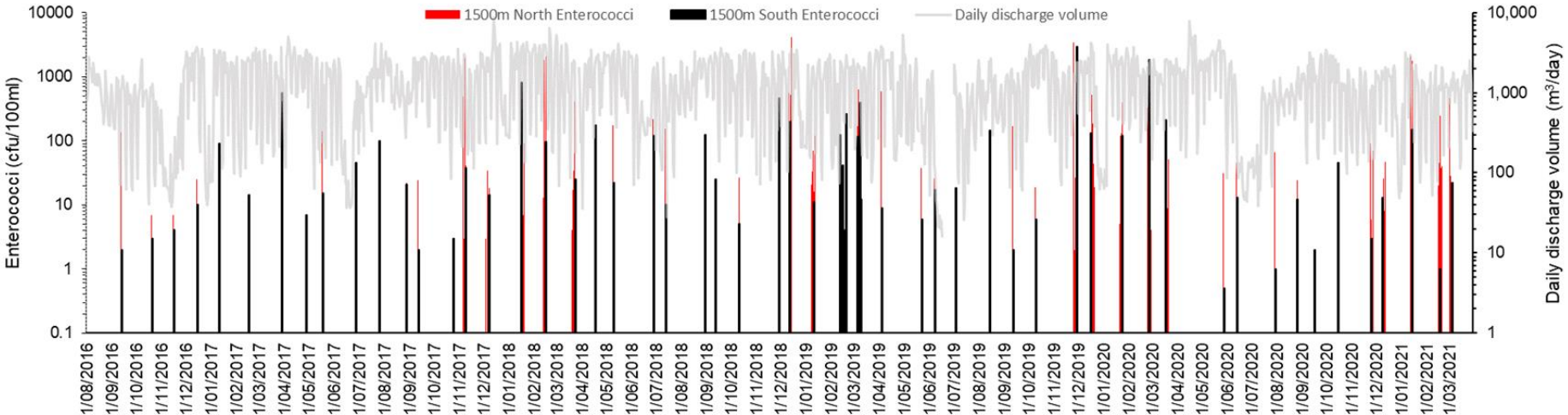
Enterococci











Faecal coliforms