WATER QUALITY DATA REPORT
Penrhyn

January – December 2008

July 2009

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Annual Report 2008

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Contents

1. Introduction

Penrhyn also known as Tongareva is located at about 8.59'45" south latitude and 158.03' 33" west longtitude and is a coral atoll with 3 main passages. It has the largest lagoon in the Cook Islands with an area of 208km² compared to a land area of 9.8km² with a surrounding reef of 1.1km².

Previous water quality testing in Tongareva, were undertaken because of environmental concerns raised by the Tongareva residents regarding protection and management of the lagoon. The primary objective at the time was to establish a pearl culture industry using sound management practices to prevent detrimental environmental effects. The following physical (Temperature, DO, pH and salinity), chemical (chlorophyll a, orthophosphate, silicates, nitrate/nitrite nitrogen, ammonia and total dissolved phosphorus) and biological information were collected.

The present water quality monitoring program was started in January 2008 to provide information for the pearl farmers on the potential for disease occurrences in the oysters and the general health of the lagoon. The measurement of nutrients (dissolved inorganic nitrogen and dissolved reactive phosphorus) chlorophyll *a* and bacteria (enterococci and vibri*o* spp.) were undertaken as part of this water quality monitoring program.

All samples were processed in the Tongareva Marine Research Centre laboratory and temperature was measured in the field. The measurement of temperature is important for establishing long term trends and changes in the lagoon. Temperature influences aquatic plants, animals and water chemistry.

There are two distinct seasons in Tongareva which are the dry season beginning in May to November and the rainy season in November to April with January being the wettest month. Air temperature varies little throughout the year with December usually being the hottest month. The trade winds occur throughout the year but are particularly steady during May to November.

The prevailing winds are usually easterly, with occasional north and northwest winds between December and March.

Nutrients such as nitrate and phosphate which are naturally present in seawater are essential for the growth of phytoplankton and other algae which form the base of the food web. Elevated nutrients concentration can lead to an increase in algae and aquatic plants biomass which can have detrimental impacts on the coral reef health. The guidelines for nutrient concentrations for the protection of coral reef health are 14µg/L for dissolved inorganic nitrogen (DIN), which is made up of nitrate and ammonia (NO_3-N + NH_4-N), and 2.6µg/L for dissolved reactive phosphorus (DRP) (Bell 1992).

Chlorophyll *a* and total suspended solids measure phytoplankton biomass, inorganic and organic particulate material in the water respectively. Elevated concentrations of both have been shown to impact negatively on coral reef health above concentration of 0.5mg/L for chlorophyll a and 4-5 mg/L for total suspended solids Bell (1992).

Increased inorganic and organic materials entering lagoons is often associated with increases in bacteria numbers which can be disease causing organisms. Numbers of bacteria evaluated in the Tongareva lagoon were vibrio and enterococci. *Vibrio* spp. are a group of bacteria that naturally occur in seawater, survive well in warm water and are commonly found in bivalves, especially oysters and clams. *Vibrio* spp. infections of oysters have caused major disruptions to the pearl aquaculture production (Diggles and Hine 2001) in Manihiki, therefore monitoring this group of bacteria may provide an early warning of deteriorating water quality conditions for pearl aquaculture. There are no guidelines or standards for *Vibrio* spp. concentrations in relation to oyster health, however, *Vibrio* spp. can be broken down into glucose utilisers (yellow) and non-glucose utilisers (green) (Diggles and Maas 2003). The glucose utilisers include species such as *V. alginolyticus* and are not thought to be associated with disease outbreaks in aquaculture (Vandenberghe et al., 1999; Gomez-Gil et al., 2002; Irianto and Austin, 2002). The non-glucose

utilisers include *V. harveyi* have caused disease in the oysters in the past (Diggles and Hine 2001).

Enterococci bacteria are used to indicate the potential presence of human pathogens in marine and freshwater environment. Guidelines have been developed by the World Health Organisation (WHO) for contact recreation using Enterococci numbers (Table 1).

Table 1: WHO Standards for Bathing Water Quality (WHO 2001).

Category	Indicator Counts	Microbiological Assessment
A.	≤ 40 Enterococci / 100ml	Suitable for swimming
B.	≥ 41 to ≤ 200 Enterococci / 100ml	Suitable for swimming but requires surveillance
C.	≥ 201 to ≤ 500 Enterococci /100ml	Not suitable for swimming, requires assessment
D.	≥ 500 Enterococci / 100ml	Not suitable for swimming, public warnings

This report is a Data Report of the water quality sampling program in 2008.

2. Methods

2.1 Sampling

All the water quality parameters for the lagoon samples were measured fortnightly and samples were processed in the Tongareva Marine Research Centre laboratory (TMRC). Six marine sites were sampled (Table 1 and Figure 1). Water samples were collected 15-30cm below the surface of the lagoon, one 500ml bottle filled for microbiological analysis, one 2L bottle for other analyses and one 250ml nutrient bottle for total nitrogen and total phosphorus analysis (Hall et al., 2007), all samples were placed in a cool chilly bin and taken back to the laboratory for processing.

2.2 Penrhyn Marine Sampling Site and Map.

Table 2. Penrhyn lagoon sampling sites.

Location	Site Number	Latitude	Longitude
Paratea	1	S9° 0' 34.866	W201° 59' 8.106
Te Rakau	2	S8° 58' 3.2952	W202° 0' 50.2164
Nga Moenga Tangata	3	S8° 58' 16.6548	W201° 59' 8.4624
Turai I Tokerau	4	S8° 56' 21.5592	W201° 58' 52.7916
Moananui	5	S8° 56' 26.7504	W201° 56' 41.1432
Turahi	6	S8° 58' 37.5816	W201° 57' 14.4

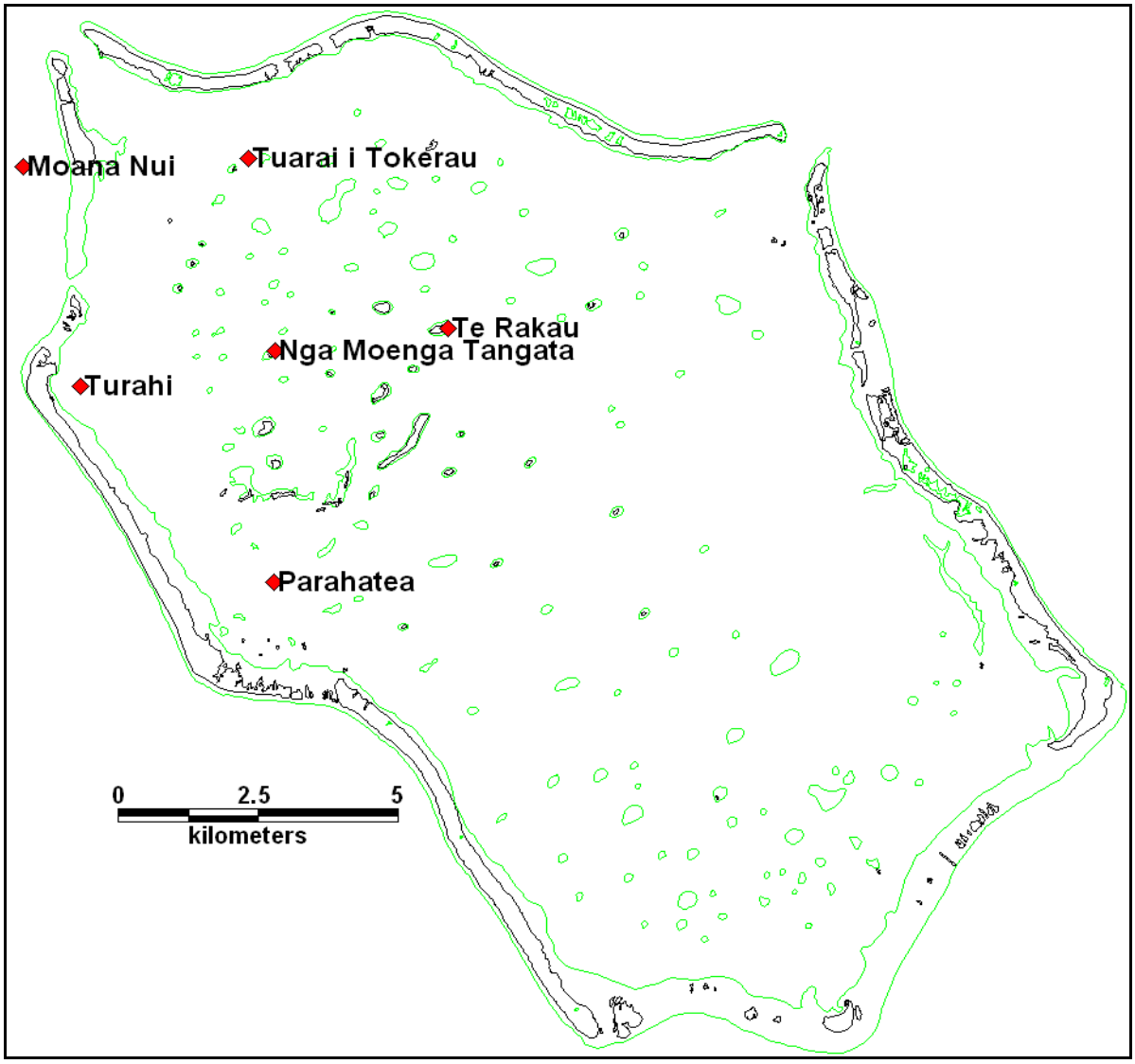

Figure 1: Penrhyn Lagoon Water Quality Sampling Sites.

2.3 Physical Parameters

At each site temperature (ºC) was measured from the boat using a Eutech digital thermometer just below the surface of the sea. The Eutech thermometer was calibrated every 3 months in the TMRC laboratory (Hall et al., 2007).

2.4 Nutrient

Total Nitrogen and Total Phosphorus samples were collected from the field cooled in a chilli bin till taken back to the TMRC lab and frozen. All water samples for dissolved nutrient analysis were filtered through a Whatman GF/F glass fibre filter into a 250ml acid washed plastic bottle. These samples were stored frozen until they were shipped or air freighted on ice in chilly bins to Rarotonga then on to National Institute of Water and Atmospheric Research Limited (NIWA) for analysis. All nutrient analysis was conducted using an Astoria Pacific autoanalyser 300 series with methods from the Astoria Pacific International Methods Manual (A 6/00). Nitrate was analysed by the cadmium column reduction method (Astoria 305-A177), DRP by the molybdenum blue method (Astoria 305-A204) and NH_4-N by the indophenol blue method (Astoria 305-A026).

2.5 Chlorophyll *a* and Suspended Solids

Samples for chlorophyll *a* and total suspended solids analysis of known volumes were filtered on to GF/F filters and both filters were frozen immediately in the TMRC laboratory. The frozen filters for chlorophyll *a* were shipped or air freighted on ice in chilly bins to Rarotonga and were then analyzed later by acetone extraction and fluorometry (APHA 1998) in the MMR laboratory (Hall et al., 2007). Total suspended solids analysis were done using Hall et al., (2007).

2.6 Bacteria

Water samples collected for *Vibrio* spp. and Enterococci were analyzed in duplicate. Samples were analysed for Enterococci using the Membrane Filtration method and placed on Enterococci agar (Hall et al., 2007; Hall et al., 2007). The volumes filtered differed depending on how clean the water was and on previous results (Hall et al., 2007). *Vibrio* spp. was analysed using spread plating on TCBS agar (Oxoid). Three

dilutions of each sample were used - direct sample (0.1ml), $10^{-1}$and 10^{-3} and were plated in duplicate on TCBS (Oxoid). Both Enterococci and *Vibrio* spp. plates were incubated at 37^{0}C for 24 hours (Hall et al., 2007; Hall et al., 2007)

2.7 Missing Data

No samples at all were collected from the 25th August to the 6th October because no filters were available for sample processing and shipping to Tongareva were scarce. Temperature was not measured in January. Chlorophyll *a* filters for the 2nd December were left behind in the freezer at TMRC laboratory and no nutrient samples were received by NIWA for the 25th of March. Suspended solid filters were missing for the 13th February. No vibrio results for the 1st July and 12th August because no agar and from October to November no pressure cooker.

3. Acknowledgments

We thank Drs Julie Hall and Els Maas for both technical advice and editorial comments and ongoing support, Mike Crump and his team at NIWA for their technical support, and the Inshore staffs of the Ministry of Marine Resources for processing, editorial and the Tongareva Marine Research Centre staff also for collecting and processing the samples. The Ministry of Marine Resources would also like to thank NZAid for all the funding support.

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5. Appendix

5.1 Penrhyn Lagoon Water Quality Data.

Location	Site Number	Date	Temperature (˚C)	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	Chl a (µg/L) Extraction	TSS (mg/L)	VSS (mg/L)	Enterococci (Count/100ml)	Vibrio green (count/mL)	Vibrio yellow (count/mL)
Parahatea	1	29-Jan-08		5	4	2	0.5	12.8	1.9	0	0	0
Parahatea	1	13-Feb-08	28.6	4	0.5	3	0.5	0.9	0.3	0	0	5
Parahatea	1	27-Feb-08	29	6	2	0.5	0.7	0.3	0.3	0	0	0
Parahatea	1	11-Mar-08	28.6	3	3	3	0.3	0.4	0.4	0	0	0
Parahatea	1	25-Mar-08	29.3	3	2	0.5	0.6	0.5	0.5	0	0	0
Parahatea	1	08-Apr-08	28.8	0.5	1	0.5	0.7	0.3	0.1	0	0	20
Parahatea	1	22-Apr-08	29	6	10	9	0.2	0.8	0.8	0	0	0
Parahatea	1	06-May-08	29	3	2	1	0.7	0.4	0.1	7	0	5
Parahatea	1	20-May-08	28.8	1	5	1	0.8	0.4	0.4	4	0	5
Parahatea	1	03-Jun-08	28.8	4	5	3	0.7	0.3	0.0	0	0	0
Parahatea	1	17-Jun-08	28.4	5	8	10	0.3	0.5	0.2	5	5	5
Parahatea	1	01-Jul-08	27.9	5	4	2	2.2	0.3	0.7	19		
Parahatea	1	15-Jul-08	28.4	9	6	30	0.2	0.5	0.5	1	0	5
Parahatea	1	29-Jul-08	27.8	7	12	11	0.5	0.3	0.3	2	0	5
Parahatea	1	12-Aug-08	27.6	5	6	11	0.1	0.3	0.3	3		
Parahatea	1	Sept										
Parahatea	1	21-Oct-08	28.6	4	5	4	1.1	0.8	0.0			
Parahatea	1	04-Nov-08	29.2	4	2	8	0.9	0.3	0.4			

Location	Site Number	Date	Temperature (˚C)	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	Chl a (µg/L) Extraction	TSS (mg/L)	VSS (mg/L)	Enterococci (Count/100ml)	Vibrio green (count/mL)	Vibrio yellow (count/mL)
Parahatea	1	18-Nov-08	28.9	4	8	11	0.9	0.6	0.6			
Parahatea	1	02-Dec-08	28.9	5	2	17		0.5	0.5			
Parahatea	1	16-Dec-08	28.6	3	3	3	0.7	1.2	0.5			
Te Rakau	2	29-Jan-08		2	2	0.5	0.2	0.4	0.2	0	0	0
Te Rakau	2	13-Feb-08	28.7	7	0.5	3	0.3	0.4	0.4	0	0	5
Te Rakau	2	27-Feb-08	28.8	7	5	0.5	0.1	0.3	0.2	0	0	0
Te Rakau	2	11-Mar-08	28.8	2	0.5	0.5	0.2	0.3	0.1	0	0	0
Te Rakau	2	25-Mar-08	29.1				0.1	0.5	0.2	0	0	0
Te Rakau	2	08-Apr-08	29	1	3	0.5	0.3	0.3	0.1	0	0	0
Te Rakau	2	22-Apr-08	29.2	3	8	2	0.4	0.8	0.3	0	0	0
Te Rakau	2	06-May-08	28.6	0.5	5	0.5	0.8	0.3	0.3	13	0	0
Te Rakau	2	20-May-08	28.6	0.5	1	0.5	0.2	0.3	0.3	0	0	0
Te Rakau	2	03-Jun-08	28.6	0.5	6	2	1.3	0.3	0.0	0	5	0
Te Rakau	2	17-Jun-08	28.6	3	4	3	0.4	0.3	0.6	0	0	0
Te Rakau	2	01-Jul-08	28.6	4	27	1	0.2	0.3	0.1	37		
Te Rakau	2	15-Jul-08	28.6	3	5	0.5	0.3	0.8	0.8	0	0	0
Te Rakau	2	29-Jul-08	27.6	5	10	3	0.4	0.3	0.3	1	5	0
Te Rakau	2	12-Aug-08	27.7	3	6	3	0.5	0.3	0.0	2		
Te Rakau	2	Sept										
Te Rakau	2	21-Oct-08	28.6	3	8	4	0.6	0.8	0.2			
Te Rakau	2	04-Nov-08	29.1	5	3	14	0.2	0.3	0.3			
Te Rakau	2	18-Nov-08	29	3	2	11	0.3	0.3	0.0			
Te Rakau	2	02-Dec-08	28.6	4	2	11		0.3	0.3			
Te Rakau	2	16-Dec-08	28.2	3	5	4	0.5	0.6	0.4			

Location	Site Number	Date	Temperature (˚C)	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	Chl a (µg/L) Extraction	TSS (mg/L)	VSS (mg/L)	Enterococci (Count/100ml)	Vibrio green (count/mL)	Vibrio yellow (count/mL)
Nga Moenga Tangata	3	29-Jan-08		4	7	0.5	0.2	0.3	0.3	0	0	0
Nga Moenga Tangata	3	13-Feb-08	28.7	5	0.5	0.5	0.4	0.8	0.0	0	0	5
Nga Moenga Tangata	3	27-Feb-08	29	3	0.5	0.5	0.9	0.3	0.3	0	0	0
Nga Moenga Tangata	3	11-Mar-08	28.8	2	5	0.5	0.4	0.3	0.3	0	10	20
Nga Moenga Tangata	3	25-Mar-08	29.2	4	7	2	0.3	0.3	0.2	0	5	0
Nga Moenga Tangata	3	08-Apr-08	29.2	2	7	2	0.4	0.3	0.2	0	0	0
Nga Moenga Tangata	3	22-Apr-08	29	4	7	4	0.3	0.3	0.0	0	0	5
Nga Moenga Tangata	3	06-May-08	28.6	0.5	0.5	0.5	0.8	0.3	0.3	0	5	0
Nga Moenga Tangata	3	20-May-08	28.8	0.5	0.5	0.5	0.5	0.3	0.3	0	0	0
Nga Moenga Tangata	3	03-Jun-08	28.8	2	6	2	0.6	1.0	0.0	0	10	0
Nga Moenga Tangata	3	17-Jun-08	28.4	0.5	6	3	0.5	0.4	0.4	0	0	0
Nga Moenga Tangata	3	01-Jul-08	28.4	6	7	2	0.2	0.3	0.9	31		
Nga	3	15-Jul-08	28.4	3	5	2	0.4	0.5	0.2	0	0	0

Moenga Tangata												
Location	**Site Number**	**Date**	**Temperature (˚C)**	**DRP (µg/L)**	**NH4-N (µg/L)**	**NO3-N (µg/L)**	**Chl a (µg/L) Extraction**	**TSS (mg/L)**	**VSS (mg/L)**	**Enterococci (Count/100ml)**	**Vibrio green (count/mL)**	**Vibrio yellow (count/mL)**
Nga Moenga Tangata	3	29-Jul-08	28.2	5	10	7	0.3	0.3	0.3	0	5	10
Nga Moenga Tangata	3	12-Aug-08	27.8	5	8	3	0.5	0.3	0.3	0		
Nga Moenga Tangata	3	Sept										
Nga Moenga Tangata	3	21-Oct-08	28.5	4	3	3	0.6	0.3	0.3			
Nga Moenga Tangata	3	04-Nov-08	29.4	4	5	9	0.3	0.3	0.0			
Nga Moenga Tangata	3	18-Nov-08	29	4	1	11	1.1	1.2	0.4			
Nga Moenga Tangata	3	02-Dec-08	28.4	5	1	20		0.3	0.3			
Nga Moenga Tangata	3	16-Dec-08	28.2	1	2	3	1.6	0.5	0.2			
Tuarai I Tokerau	4	29-Jan-08		4	0.5	6	0.2	0.3	0.1	0	0	0
Tuarai I Tokerau	4	13-Feb-08	28.6	5	0.5	1	0.3	0.4	0.3	0	0	10
Tuarai I Tokerau	4	27-Feb-08	28.9	3	7	0.5	0.3	0.4	0.4	0	5	15
Tuarai I Tokerau	4	11-Mar-08	29	1	18	1	0.3	0.3	0.2	0	0	0
Tuarai I Tokerau	4	25-Mar-08	29.2	3	29	2	0.2	0.3	0.1	0	0	0
Tuarai I	4	08-Apr-08	29.1	4	2	1	0.2	0.3	0.2	0	0	0

Tokerau												
Location	**Site Number**	**Date**	**Temperature (˚C)**	**DRP (µg/L)**	**NH4-N (µg/L)**	**NO3-N (µg/L)**	**Chl a (µg/L) Extraction**	**TSS (mg/L)**	**VSS (mg/L)**	**Enterococci (Count/100ml)**	**Vibrio green (count/mL)**	**Vibrio yellow (count/mL)**
Tuarai I Tokerau	4	22-Apr-08	29.2	7	8	4	0.3	0.9	0.3	0	0	0
Tuarai I Tokerau	4	06-May-08	28.4	4	3	2	0.7	0.4	0.4	0	0	5
Tuarai I Tokerau	4	20-May-08	28.8	0.5	0.5	0.5	0.4	0.3	0.3	1	0	0
Tuarai I Tokerau	4	03-Jun-08	28.8	1	4	2	0.5	0.8	0.8	1	5	0
Tuarai I Tokerau	4	17-Jun-08	28.6	0.5	6	3	0.4	0.5	0.0	0	0	0
Tuarai I Tokerau	4	01-Jul-08	28.6	3	4	0.5	0.6	0.3	0.1	100		
Tuarai I Tokerau	4	15-Jul-08	28.6	3	14	3	0.4	0.4	0.2	0	0	15
Tuarai I Tokerau	4	29-Jul-08	28.1	4	6	5	0.3	0.3	0.3	0	0	0
Tuarai I Tokerau	4	12-Aug-08	27.8	5	6	5	0.1	0.3	0.3	0		
Tuarai I Tokerau	4	Sept										
Tuarai I Tokerau	4	21-Oct-08	28.5	3	6	4	0.4	0.3	0.2			
Tuarai I Tokerau	4	04-Nov-08	29.3	2	2	18	0.4	0.3	0.3			
Tuarai I Tokerau	4	18-Nov-08	29	1	4	12	0.5	0.4	0.4			
Tuarai I Tokerau	4	02-Dec-08	28.4	8	0.5	25		0.3	0.3			
Tuarai I Tokerau	4	16-Dec-08	28.4	4	3	8	0.7	2.4	0.6			
Moananui	5	29-Jan-08		6	5	14	0.2	0.3	0.3	0	0	0
Moananui	5	13-Feb-08	29	6	0.5	5	0.1			0	5	0
Moananui	5	27-Feb-08	28.7	4	10	0.5	0.1	0.3	0.1	0	5	0

Location	Site Number	Date	Temperature (˚C)	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	Chl a (µg/L) Extraction	TSS (mg/L)	VSS (mg/L)	Enterococci (Count/100ml)	Vibrio green (count/mL)	Vibrio yellow (count/mL)
Moananui	5	11-Mar-08	28.5	4	7	4	0.2	0.3	0.2	0	0	0
Moananui	5	25-Mar-08	28.9	3	8	4	0.3	0.3	0.2	0	0	0
Moananui	5	08-Apr-08	28.9	2	3	0.5	0.3	0.3	0.2	0	0	35
Moananui	5	22-Apr-08	28.8	4	4	3	0.2	0.4	0.4	0	0	5
Moananui	5	06-May-08	28.2	5	6	7	0.3	0.9	0.1	9	0	0
Moananui	5	20-May-08	27.8	6	0.5	8	0.3	0.3	0.3	5	5	5
Moananui	5	03-Jun-08	27.8	4	7	6	0.2	0.8	0.2	0	0	0
Moananui	5	17-Jun-08	27.5	7	5	19	0.1	0.4	0.4	0	0	0
Moananui	5	01-Jul-08	28.5	6	3	17	0.2	0.3	0.3	250		
Moananui	5	15-Jul-08	28.2	7	7	23	0.1	0.8	0.2	2	0	0
Moananui	5	29-Jul-08	28.2	5	8	15	0.1	0.3	0.3	1	0	0
Moananui	5	12-Aug-08	27.8	6	8	16	0.2	0.3	0.0	0		
Moananui	5	Sept										
Moananui	5	21-Oct-08	28.4	11	3	48	0.2	0.3	0.2			
Moananui	5	04-Nov-08	28.8	11	3	53	0.4	0.3	0.3			
Moananui	5	18-Nov-08	28.5	12	5	56	0.3	0.3	0.3			
Moananui	5	02-Dec-08	28.2	13	5	52		0.3	0.3			
Moananui	5	16-Dec-08	28	10	7	36		0.3	0.3			
Turahi	6	29-Jan-08		6	5	4	0.6	0.4	0.4	0	0	0
Turahi	6	13-Feb-08	29.2	6	9	5	0.2	0.8	0.8	0	0	10
Turahi	6	27-Feb-08	29.1	6	9	3	1.1	0.3	0.2	0	10	20
Turahi	6	11-Mar-08	28.9	2	3	0.5	0.5	0.3	0.3	0	0	0
Turahi	6	25-Mar-08	29.6	1	2	0.5	0.6	0.5	0.2	0	0	0
Turahi	6	08-Apr-08	29.3	2	8	0.5	1.1	0.5	0.4	0	5	10

Location	Site Number	Date	Temperature (˚C)	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	Chl a (µg/L) Extraction	TSS (mg/L)	VSS (mg/L)	Enterococci (Count/100ml)	Vibrio green (count/mL)	Vibrio yellow (count/mL)
Turahi	6	22-Apr-08	29.2	3	6	3	0.4	0.9	0.9	0	5	0
Turahi	6	06-May-08	29.2	2	2	0.5	0.5	0.7	0.5	5	0	10
Turahi	6	20-May-08	29	0.5	4	1	0.3	0.4	0.4	5	0	0
Turahi	6	03-Jun-08	29	0.5	5	3	1.0	0.3	0.3	2	5	15
Turahi	6	17-Jun-08	28.6	3	4	0.5	0.6	0.3	0.3	0	0	0
Turahi	6	01-Jul-08	28.2	5	5	4	1.8	0.3	1.0	36		
Turahi	6	15-Jul-08	28.4	2	10	3	0.4	0.4	0.7	0	0	40
Turahi	6	29-Jul-08	28.4	3	6	4	0.6	0.4	0.1	0	0	5
Turahi	6	12-Aug-08	27.9	4	7	6	0.6	0.4	0.0	0		
Turahi	6	Sept										
Turahi	6	21-Oct-08	28.9	3	0.5	9	0.6	0.8	0.0			
Turahi	6	04-Nov-08	29.6	3	3	13	0.5	0.3	0.3			
Turahi	6	18-Nov-08	29.1	1	0.5	11	1.0	0.8	0.6			
Turahi	6	02-Dec-08	28.6	8	6	33		0.6	0.3			
Turahi	6	16-Dec-08	28.4	4	5	12	1.9	1.3	1.0			