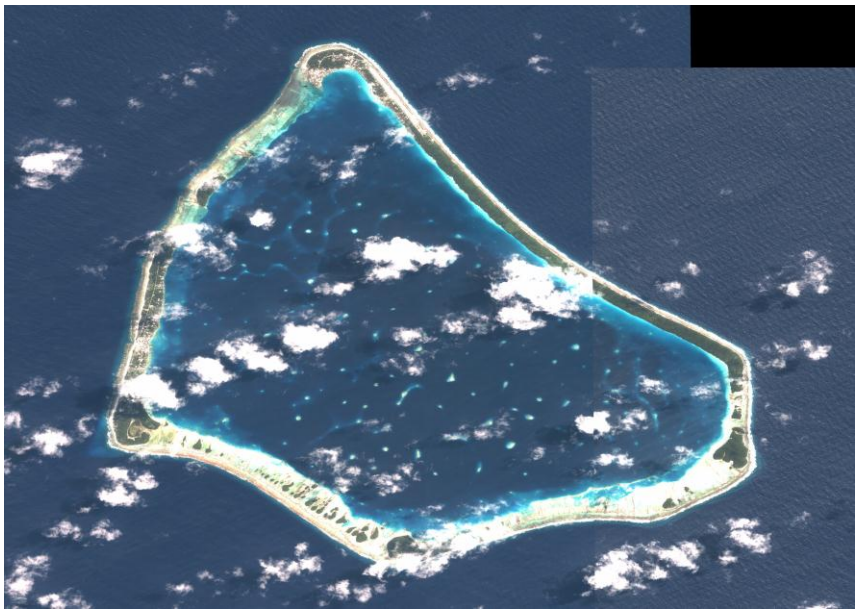
WATER QUALITY DATA REPORT
Manihiki

January – December 2008



June 2009

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Annual Report 2008

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Contents

1. Introduction

Manihiki lagoon, located in the northern group of the Cook Islands (10°25'S, 161°02'W), was designated as a fishery in 1992[i]. The lagoon is known for its abundant natural stocks of black-lip pearl oysters (*Pinctada margaritifera)*. Historically the oysters were harvested for their mother of pearl shell, however since the mid-1980's this oyster has been cultured for the production of black pearls. Manihiki lagoon now accounts for about 95% of pearl production in the Cook Islands, hence a significant pearl aquaculture industry.

Previous water testing included deploying a lagoon environmental monitoring buoy funded by Pacific Islands Applied Geoscience Commission (SOPAC) in Manihiki lagoon in October 2003. The buoy collected water quality data that included wind speed and direction, barometric pressure, dissolved oxygen, chlorophyll *a*, pH, air and sea temperatures, salinity and spectroradiance-UV-B in the marine environment. However, in July 2005, the buoy was removed from the lagoon for major maintenance work and sensor calibration.

The present water quality monitoring program was started in September 2004 to provide more information for the pearl farmers on the potential for disease occurrences in the oysters and the general health of the lagoon. The measurement of physical parameters, nutrients, chlorophyll *a* and bacteria especially Enterococci and *Vibrio,* was undertaken as part of this water quality monitoring program.

[1] [i] Section Three of the Marine Resources Act 1989 (the Act) provides that the Executive Council may, on the recommendation of the Minister, by Order, declare an area for aquaculture as a designated fishery (Aquaculture Management Area), where having regard to scientific, economic, environmental and other relevant considerations, it is determined that aquaculture in such an area:

a. is important to the national interest and to the interest of the Cook Island nationals on the island or islands involved;
b. requires management measures for effective conservation and optimum utilisation of the resource.

The weather in Manihiki has two distinct seasons which are the dry season beginning in April/May to September/October and the rainy season between November and March also known as the cyclone season. The daily weather in Manihiki is highly variable and can change quickly. The measurement of basic physical and chemical parameters (Temperature, pH and Salinity) is important for establishing long term changes in water quality of the lagoon. The data collected will assist in the assessment of the carrying capacity of the lagoon with respect to the health and food supply for pearl aquaculture under varying environmental conditions. Temperature influences aquatic plants, animals and water chemistry. Salinity varies little in most marine environments and saltwater is normally between 34ppt and 36ppt in areas away from freshwater influences (Smith 2004a & 2004b).

Mosely et al. (2004) in water quality guidelines developed for Pacific Countries suggest that pH should be between 8.0 and 8.4 in lagoon type environments. Smith 2004a also suggests that in areas of rapid plant growth or in warm productive areas pH typically is around 8.5. The Department of Health, Clean Water Branch Hawaii (1994) pH standard for open coastal waters is between 7.6 and 8.6 and can be as low as 7.0 in areas influenced by freshwater input. All parameters measured are indicative of lagoon water quality and will provide a baseline for water quality of Manihiki lagoon.

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). The ANZECC guideline values for streams or lowland rivers that are a cause for concern in Australia tropical areas based on measured values are 10µg/L for nitrate (NO_3-N) and ammonia (NH_4-N), and 4µg/L for DRP (ANZECC 2000).

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 and 4-5 mg/L Bell (1992) respectively.

Increased inorganic and organic materials entering lagoons are often associated with increases in bacteria numbers which can be disease causing organisms. Two types of bacteria are tested in Manihiki lagoon *Vibrio* spp. and Enterococci species. *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* which has 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). This guideline is also used for freshwater samples to evaluate the bacterial water quality of the streams as they flow directly into the lagoon and are likely to impact the bacterial water quality of the lagoon.

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 when samples were able to be air freighted to Rarotonga. Six marine sites were sampled (Table 1 and Figure 1). Water samples were collected using a Nansen bottle lowered down to 3 meters deep. For each site, a 2 litre (or 500mL plastic bottle depending on freight space) plastic bottle is rinsed before filling with the seawater sample (Hall et al., 2007), placed in a cool chilly bin, air freighted to Rarotonga and processed within nine hours.

2.2 Manihiki Marine Sampling Site and Map

Table 2. Manihiki lagoon sampling sites.

Location	Site Number	Latitude	Longitude
Takaniko	1	S10 26 2.76	W161 1 41.16
Rahea Raro	2	S10 26 10.68	W161 0 15.84
Moe Akaroro	3	S10 26 9.6	W160 58 29.28
Ngatoka e Hitu	4	S10 24 41.76	W161 1 5.16
Monitoring Buoy	5	S10 23 53.5	W160 59 57.84
Tukao Bay	6	S10 22 54.12	W161 0 9.36

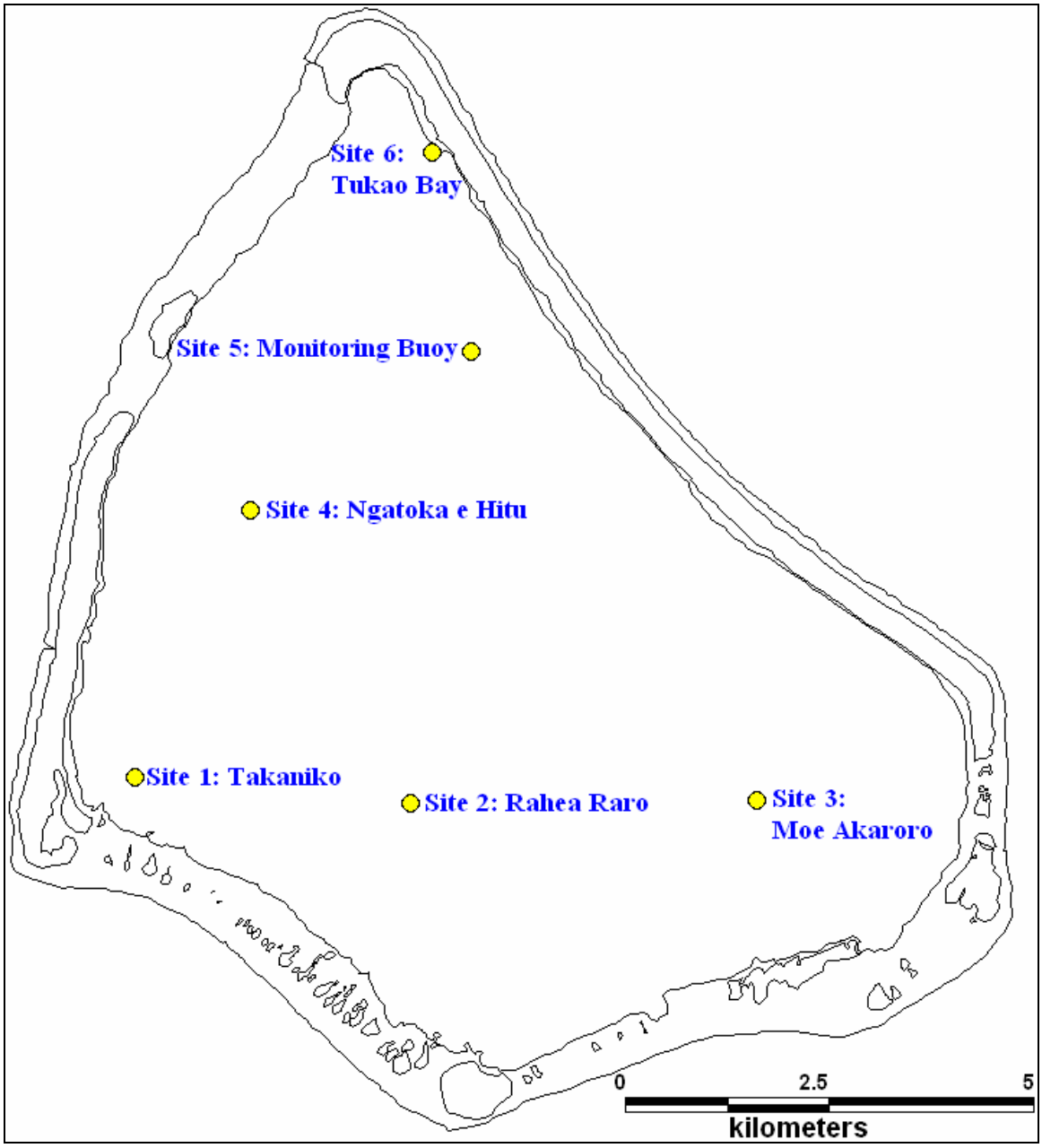

Figure 1: Manihiki Lagoon Water Quality Sampling Sites.

2.3 Physical Parameters

At each site temperature (ºC) is measured from a water sample collected at a 3m depth using a Eutech digital thermometer, pH, and salinity (‰) were measured at the MMR Laboratory in Rarotonga using a YSI 556 Probe. The probe is calibrated before use in the laboratory and the Eutech is calibrated every three months (Hall et al., 2007).

2.4 Nutrient

All water samples for 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 on ice in chilly bins 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 the chlorophyll *a* filter was frozen immediately. The frozen filters for chlorophyll *a* were then analyzed later by acetone extraction and fluorometry (APHA 1998) in the MMR laboratory (Hall et al., 2007). Total suspended solids analysis followed Hall et al. (2007).

2.6 Bacteria

Water samples collected for *Vibrio* spp. and Enterococci were analyzed in duplicate. Samples were analysed for Entrococci using the Membrane Filtration method and placed on Enterococci agar (Hall et al., 2007). The volumes filtered differ 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 37^0C for 24 hours (Hall et al., 2007)

2.7 Missing Data

There were no samples received for the months of January, August and December because of freight problems. In February and October no measurements were made for salinity and pH and from March to July the Eutech temperature data was deleted because of instrument error. The pH in July was deleted because it was too high even though instrument calibration was good and September and October was also deleted because of instrument error. The Suspended solids and VSS results for all sites in November were missing.

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 staffs of the Ministry of Marine Resources for editorial and the Manihiki Marine staff for their assistance in sample collecting. The Ministry of Marine Resources would also like to thank NZAid for all the funding support.

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5. Appendix

5.1 Manihiki Lagoon Water Quality Data

Location	Site Number	Date	Temp (ºC)	Salinity (ppt)	pH	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	Extracted Chl a (µg/L)	In Vivo Chl a (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (Count/100ml)	Vibrio Green (count/ml)	Vibrio Yellow (count/ml)
Takaniko	1	07-Feb-08	28.9	36.0	7.8	4	2	0.5		0.4	0.6	0.4	73	0	35
Takaniko	1	19-Feb-08	29.5			5	2	4		0.4	0.3	0.3	160	5	1290
Takaniko	1	06-Mar-08		35.4	7.6	5	2	2		0.3	0.3	0.3	21	5	10
Takaniko	1	15-Apr-08		35.7	7.9	2	7	0.5		0.6	0.3	0.3	38	5	70
Takaniko	1	27-May-08			7.9	0.5	15	3		0.5	0.7	0.3	32	0	60
Takaniko	1	10-Jun-08		36.0	7.1	2	0.5	2		0.5	0.3	0.3	26	0	0
Takaniko	1	08-Jul-08		35.9		5	0.5	0.5	0.6		2.0	0.3	3	10	0
Takaniko	1	23-Sep-08	24.7	36.1		1	6	6		0.5	1.5	2.0	26	0	10
Takaniko	1	15-Oct-08	28.6			2	4	0.5		0.2	0.3	0.3	350	0	0
Takaniko	1	04-Nov-08	29.3	35.3		3	9	2		0.4	1.8	1.8	21	0	5
Takaniko	1	18-Nov-08				4	7	17	0.5				0	0	0
Rahea Raro	2	07-Feb-08	28.7	36.0	7.9	5	3	0.5		0.5	1.0	0.8	73	0	10
Rahea Raro	2	19-Feb-08	29.3			6	2	1		0.3	0.3	1.6	28	0	160
Rahea Raro	2	06-Mar-08		35.8	7.6	6	2	2		0.3	0.3	0.3	38	20	20
Rahea Raro	2	15-Apr-08		35.7	7.8	0.5	6	4		0.4	0.3	0.3	29	0	5
Rahea Raro	2	27-May-08		33.8	7.9	3	5	4		0.3	0.3	0.3	9	0	0
Rahea Raro	2	10-Jun-08		36.0	7.5	4	0.5	3		0.5	0.3	0.3	19	5	0
Rahea Raro	2	08-Jul-08		36.2		5	0.5	0.5	0.4		1.4	0.5	25	0	10
Rahea Raro	2	23-Sep-08	25.2	36.0		1	5	5		0.9	1.0	0.5	16	0	0
Rahea Raro	2	15-Oct-08	28.3			5	13	0.5		0.3	0.3	1.2	645	0	2

Location	Site Number	Date	Temp (ºC)	Salinity (ppt)	pH	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	Extracted Chl a (µg/L)	In Vivo Chl a (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (Count/100ml)	Vibrio Green (count/ml)	Vibrio Yellow (count/ml)
Rahea Raro	2	04-Nov-08	28.9	35.3		4	9	0.5		0.2	0.8	0.8	19	0	0
Rahea Raro	2	18-Nov-08				2	7	16	0.3				0	0	0
Moe Akaroro	3	07-Feb-08	28.5	35.9	7.9	5	1	0.5		0.5	0.9	0.6	34	0	0
Moe Akaroro	3	19-Feb-08	29.2			5	1	1		0.3	0.3	0.3	11	0	85
Moe Akaroro	3	06-Mar-08		35.6	7.6	5	4	1		0.2	0.3	0.3	20	0	0
Moe Akaroro	3	15-Apr-08		35.4	7.8	1	4	2		0.4	0.3	0.3	75	0	0
Moe Akaroro	3	27-May-08		35.3	8.0	2	0.5	4		0.4	0.7	0.3	12	0	0
Moe Akaroro	3	10-Jun-08		36.0	7.6	1	3	1		0.8	0.3	0.3	10	0	0
Moe Akaroro	3	08-Jul-08		36.2		3	0.5	0.5	0.4		0.4	0.3	24	0	0
Moe Akaroro	3	23-Sep-08	24.2	36.0		1	7	6		0.9	0.5	1.5	14	0	0
Moe Akaroro	3	15-Oct-08	28.0			2	3	0.5		0.3	0.9	2.3	325	0	0
Moe Akaroro	3	04-Nov-08	28.6	35.4		19	6	1	0.3		1.6	0.4	158	55	0
Moe Akaroro	3	18-Nov-08				4	7	13		0.3			0	0	0
Ngatoka e Hitu	4	07-Feb-08	28.9	36.0	7.9	3	2	3		0.4	1.0	0.7	731	73	5
Ngatoka e Hitu	4	19-Feb-08	29.3			2	4	6		0.4	0.4	0.3	18	0	190
Ngatoka e Hitu	4	06-Mar-08		35.6	7.5	3	1	0.5		0.2	0.3	0.3	9	0	0
Ngatoka e Hitu	4	15-Apr-08		35.7	7.7	4	8	2		0.3	0.3	0.3	39	0	10
Ngatoka e Hitu	4	27-May-08		35.3	7.9	0.5	17	12		0.4	0.4	0.3	8	0	0
Ngatoka e Hitu	4	10-Jun-08		36.1	7.7	3	6	3		0.5	0.3	0.3	10	0	0
Ngatoka e Hitu	4	08-Jul-08		36.1		2	0.5	0.5	0.4		0.4	0.4	24	0	0
Ngatoka e Hitu	4	23-Sep-08	23.4	36.0		7	9	5		0.3	3.5	0.5	33	0	0
Ngatoka e Hitu	4	15-Oct-08	28.3			2	6	0.5		0.2	0.3	0.3	230	0	0
Ngatoka e Hitu	4	04-Nov-08	29.1	35.4		3	8	12	0.2		0.4	0.4	158	0	0
Ngatoka e Hitu	4	18-Nov-08				4	13	15		0.2			0	0	0

Location	Site Number	Date	Temp (ºC)	Salinity (ppt)	pH	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	Extracted Chl a (µg/L)	In Vivo Chl a (µg/L)	TSS (mg/L)	VSS (mg/L)	Enterococci (Count/100ml)	Vibrio Green (count/ml)	Vibrio Yellow (count/ml)
Monitoring Buoy	5	07-Feb-08	28.8	36.0	7.9	4	1	8		0.6	0.4	0.4	86	155	5
Monitoring Buoy	5	19-Feb-08	29.2			4	0.5	8		0.4	0.3	0.3	8	0	20
Monitoring Buoy	5	06-Mar-08		35.7	7.7	4	3	0.5		0.2	0.3	0.3	17	5	5
Monitoring Buoy	5	15-Apr-08		35.7	7.6	1	2	9		0.4	0.3	0.3	28	5	65
Monitoring Buoy	5	27-May-08		35.3	7.9	3	4	5		0.3	0.3	0.3	33	0	30
Monitoring Buoy	5	10-Jun-08		36.0	7.7	0.5	0.5	1		0.5	0.5	0.5	8	0	10
Monitoring Buoy	5	08-Jul-08		36.1		4	0.5	0.5	0.5		0.4	0.4	28	0	30
Monitoring Buoy	5	23-Sep-08	21.8	36.0		1	7	1		0.3	0.3	1.0	23	0	0
Monitoring Buoy	5	15-Oct-08	28.2			1	3	1		0.3	0.6	0.9	68	0	0
Monitoring Buoy	5	04-Nov-08	28.7	35.4		2	3	15		0.2	1.1	0.3	34	0	0
Monitoring Buoy	5	18-Nov-08				4	5	16	0.2				0	0	0
Tukao Bay	6	07-Feb-08	28.8	35.9	7.9	4	5	0.5		0.6	0.7	0.4	82	82	190
Tukao Bay	6	19-Feb-08	29.1			6	1	1		0.5	1.0	2.3	9	0	0
Tukao Bay	6	06-Mar-08		35.8	7.7	5	7	7		0.2	0.3	0.3	23	10	5
Tukao Bay	6	15-Apr-08		35.5	7.5	2	2	0.5		0.7	0.3	0.3	33	50	90
Tukao Bay	6	27-May-08		35.3	8.0	3	4	13		0.7	1.0	0.4	10	0	5
Tukao Bay	6	10-Jun-08		36.1	7.7	0.5	0.5	0.5		0.8	0.5	0.3	10	0	20
Tukao Bay	6	08-Jul-08		36.2		3	0.5	0.5	0.6		0.3	0.3	35	0	0
Tukao Bay	6	23-Sep-08	22.8	36.0		3	9	1		0.2	2.5	1.5	20	0	0
Tukao Bay	6	15-Oct-08	28.3			2	4	3		0.4	0.8	0.3	83	0	0
Tukao Bay	6	04-Nov-08	28.8	35.4		1	6	20		0.4	1.9	1.5	146	0	0
Tukao Bay	6	18-Nov-08				6	10	14	0.2				0	0	0