Rarotonga water quality annual report 2006

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Executive Summary

The water quality programme was initiated in September 2004 and was modified and expanded in 2006. The monitoring programme was started to provide baseline water quality data for Rarotonga. Initially the Takitumu area was a concern because of the Syndrome that occurred in Titikaveka, which was a sickness that affected people who swam or spent time in the Titikaveka lagoon area at the end of 2003 and as a result got irritations in the eye, nose throat and skin irritations.

Samples were collected on a monthly basis from 14 lagoon sites and 8 streams. The water samples were analysed for nutrients, physical parameters, total suspended solids, chlorophyll *a* and bacteria. Nutrients, total suspended solids and chlorophyll *a* were sent to NIWA for analysis, the physical parameters were measured at each site and bacteria were analysed at the MMR lab.

The results show that the Ecotours site had the lowest lagoon water quality with concentration above those recommended for the protection of coral reefs for DRP, DIN, chlorophyll *a* and total suspended solids (Bell 1992) and DO concentrations were below the Clean Water Branch Hawaii (1994) recommendations. The Kent Hall and the Sheraton sites were also over the DRP and DIN guidelines concentrations. Totokoitu site had the best lagoon water quality where, DRP DIN, Chlorophyll *a* and total suspended solids were below the guidelines recommended for the protection of coral reefs. All of the sites were safe for swimming except for the East Airport Drain site which was over the WHO standards for contact recreation on two sampling occasions.

The Akapuao stream had the lowest water quality with the highest concentrations of ammonia, nitrate and also lower DO concentrations. The Enterococci numbers at all stream sites for all sampling occasions were in Category C and D which is not recommended for swimming by the WHO standards. The Totokoitu Stream had the highest water quality with lowest mean concentrations of ammonia, nitrate and total suspended solids concentrations.

The results from this report can be used to compare the state of water quality in the lagoon and streams with those in the past and can be used to evaluate future developments.

1. Introduction

Rarotonga is the capital of the Cook Islands and is rapidly developing, hence it is vital that the health of the lagoon is monitored and action is taken to protect the health of the lagoon, the reef and most importantly the human health. Human activities for example the domesticating of pigs, deforestation and farming of crops close to streams have been known to decrease the water quality both in the streams and in the lagoon. Having a water quality monitoring programme gives an indication of the state of the streams and the lagoons and if a low water quality is detected, human activities close to the streams can be investigated.

Rainfall can influence the health status of the lagoon and streams, and on Rarotonga the rainfall and weather patterns are variable between the wet and dry season. The dry season begins in April/May to September/October and the wet season begins in November and ends in March. During the dry season the prevailing wind direction is from the east and southeast shifting to the northeast during the rainy season with occasional tropical storms especially from the north west.

The measurement of basic physical and chemical parameters (temperature, dissolved oxygen, pH and salinity) is important for establishing long term changes in water quality. Temperature influences the occurrence and growth of aquatic plants, and animals. The solubility of dissolved oxygen (DO) is regulated by temperature however other factors also affect DO including water flow. In the water, DO is either absorbed directly from the atmosphere or is produced by algae by photosynthesis and is removed by respiration and decomposition of organic matter. The recommended minimum for DO is not less than 75% saturation for oceanic waters, embayments, open coastal waters and estuaries and not less than 80% for streams (Department of Health, Clean Water Branch Hawaii 1994). Salinity varies little in most marine environments and saltwater is normally between 34ppt and 36ppt (Smith 2004).

Mosely *et al* (2004) in water quality guidelines developed for Pacific Countries by SOPAC suggests that pH should be between 8.0 and 8.4 in lagoon type environments. 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.

Nutrients such as nitrate and phosphate are naturally present in seawater and are essential for the growth of phytoplankton and other algae, which form the base of the food web. The same two nutrients are used to determine the Redfield ratio which is the ratio of dissolved inorganic nitrogen to dissolved reactive phosphorus (DRP) and is used to indicate which nutrient nitrogen or phosphorous is limiting the growth of phytoplankton and macro algae (Hall *et al* 2006). Naturally occurring nutrient concentrations in the tropical Pacific Ocean are generally very low, as is productivity. The guidelines for nutrient concentrations for the protection of coral reef health are 14 µg/L for dissolved inorganic nitrogen (DIN), which is made up of nitrate and ammonia (NO_3-N + NH_4-N), and 2.6 µg/L for (DRP) (Bell 1992). When the Redfield ratio is more than 16, phosphorus is most likely to be the limiting nutrient and below 16, nitrogen is the limiting nutrient (Redfield 1958). The Australian and New Zealand Environment and Conservation Council guideline values for streams or lowland rivers that are a cause for concern in Australia tropical areas based on measured values are 10 µg/L for nitrate (NO_3) and ammonia (NH_4), and 4 µg/L for DRP (ANZECC 2000).

Chlorophyll *a* is used to measure phytoplankton biomass which increases when nutrient concentrations in the water column increase. Elevated chlorophyll *a* concentrations have been shown to impact on coral reef health (Bell 1992). Total suspended solids measures the inorganic and organic particulate material in the water column, like Chlorophyll *a*, elevated total suspended solids have been shown to impact negatively on coral reef health above concentration of 4-5 mg/L (Bell 1992).

The organic particulate material in the water especially of animal origin can be related to bacteria concentrations in the water; the higher the particulate material the higher the concentration of bacteria. Enterococci are a group of bacteria commonly used to indicate the potential presence of human pathogens in the marine and freshwater environment. Guidelines have been developed by the World Health Organisation (WHO) for contact recreation using Enterococci numbers in the marine environment (Table 1). In this report these guidelines have also been used for the number of bacteria that were found in the streams.

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 summarises the chlorophyll *a*, total suspended solids and nutrients analysis for the whole year in 2006 for the lagoon sites; Ecotours, Kent Hall, Totokoitu and Sheraton. All new streams and the lagoon sites sampled, starting from October were also analysed for nutrients. All stream and lagoon sites were sampled for physical parameters for the whole year. Samples were analysed for bacteria for all lagoon sites for the whole year except for Club Raro which started in October. The stream sites Paringaru, Akapuao, Totokoitu, and Rutaki were sampled for the whole year for bacteria, total suspended solids and nutrients. All new stream sites were sampled and analysed for bacteria and nutrients starting from October. The results are compared to the guidelines for the protection of coral reefs and the guidelines for swimming and overall findings are presented.

2. Methods

2.1 Sampling Sites and Sampling

Bacteria and physical parameters were sampled monthly for ten and eleven months respectively and Club Raro site was introduced in October 2006. Four lagoon sites (Site 5, (Ecotours), Site 7, (Kent Hall), Site 8, (Totokoitu Research Station) and Site 9 (Sheraton)) were sampled monthly for chlorophyll *a*, total suspended solids and nutrients and in October a further ten new lagoon sites were added to the water monitoring programme. Four new stream sites (Avana Mudflats, Betela, North Airport Drain and Avatiu) were added to the old stream sites and were sampled from October 2006. (Table 2 & 3).

2.2 Physical Parameters

At each site temperature (ºC), dissolved oxygen (DO), % saturation and concentration, pH, and salinity (‰) were measured using a YSI 556 Probe. The individual probes were calibrated before use in the field (Hall *et al.* 2006). Measurements were made at each site at the time of sampling (Hall *et al.* 2006).

2.3 Nutrients

All water samples for nutrient analysis were collected, stored on ice and processed within 8 hours. For nutrient analysis water samples 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 NIWA for analysis. All nutrient analysis were conducted using an Astoria Pacific autoanalyser 300 series with methods from the Astoria Pacific International Methods Manual (A 6/00). NO_3-N 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).

2.4 Chlorophyll *a* and Suspended Solids

Samples for chlorophyll *a* and total suspended solids analysis were collected stored, in the dark, on ice for a maximum of 8 hours. Known volumes of samples were filtered on to GF/F filters and frozen immediately. The frozen filters were shipped in liquid nitrogen to NIWA for analysis. For chlorophyll *a* the filters were analyzed by acetone extraction and fluorometry (APHA 1998). Total suspended solids analysis followed Hall *et al* (2006).

2.5 Bacteria

Water samples collected for Enterococci were stored on ice and were analysed within 8 hours after sample collection. Samples were analysed for Enterococci in duplicate using Membrane Filtration method and placed on Enterococci agar (Hall *et al*, 2006). The volumes filtered differed depending on how clean the water was and on previous results. (Hall *et al*, 2006). Enterococci plates were incubated at 37^0C for 24 hours (Hall *et al*, 2006)

Table 2: Rarotonga Lagoon sampling sites.

SITE NUMBER	LOCATION	LATITUDE	LONGITUDE
#1	TJ's	S21 12.308	W159 46.441
^2	Club Raro	S21 04.417	W159 45.304
#3	Pou'ara Ra'ui	S21 13.821	W159 43.842
#4	Avana Mudflat	S21 14.864	W159 43.730
~5	Eco Tours	S21 15.856	W159 44.089
#6	Tikioki Packing Shed	S21 16.314	W159 44.788
~7	Kent Hall	S21 16.195	W159 45.335
~8	Totokoitu Research Station	S21 15.976	W159 46.570
~9	Sheraton	S21 15.744	W159 47.851
#10	Kaena Restaurant	S21 15.401	W159 49.036
#11	Arorangi School	S21 13.903	W159 49.723
#12	Public Works	S21 13.149	W159 49.873
#13	Social Centre	S21 12.285	W159 49.205
#14	East Airport Drain	S21 11.932	W159 47.737

Keys:

Sites sampled for chlorophyll *a*, nutrients and total suspended solids starting from October 2006.

^ New site sampled for physical parameters and bacteria starting from October 2006

~ Sites sampled for all parameters for the whole year.

Table 3: Rarotonga Stream sampling sites.

SITE NUMBER	LOCATION	LATITUDE	LONGITUDE
*1	Avana	S21 14.794	W159 43.835
2	Paringaru	S21 15.838	W159 44.135
3	Akapuao	S21 16.274	W159 44.836
4	Totokoitu	S21 15.938	W159 46.535
5	Rutaki	S21 15.481	W159 48.442
*6	Betela	S21 14.739	W159 49.462
*7	North Airport Drain	S21 12.214	W159 49.043
*8	Avatiu	S21 12.342	W159 47.047

* Stream sites added in October 2006.

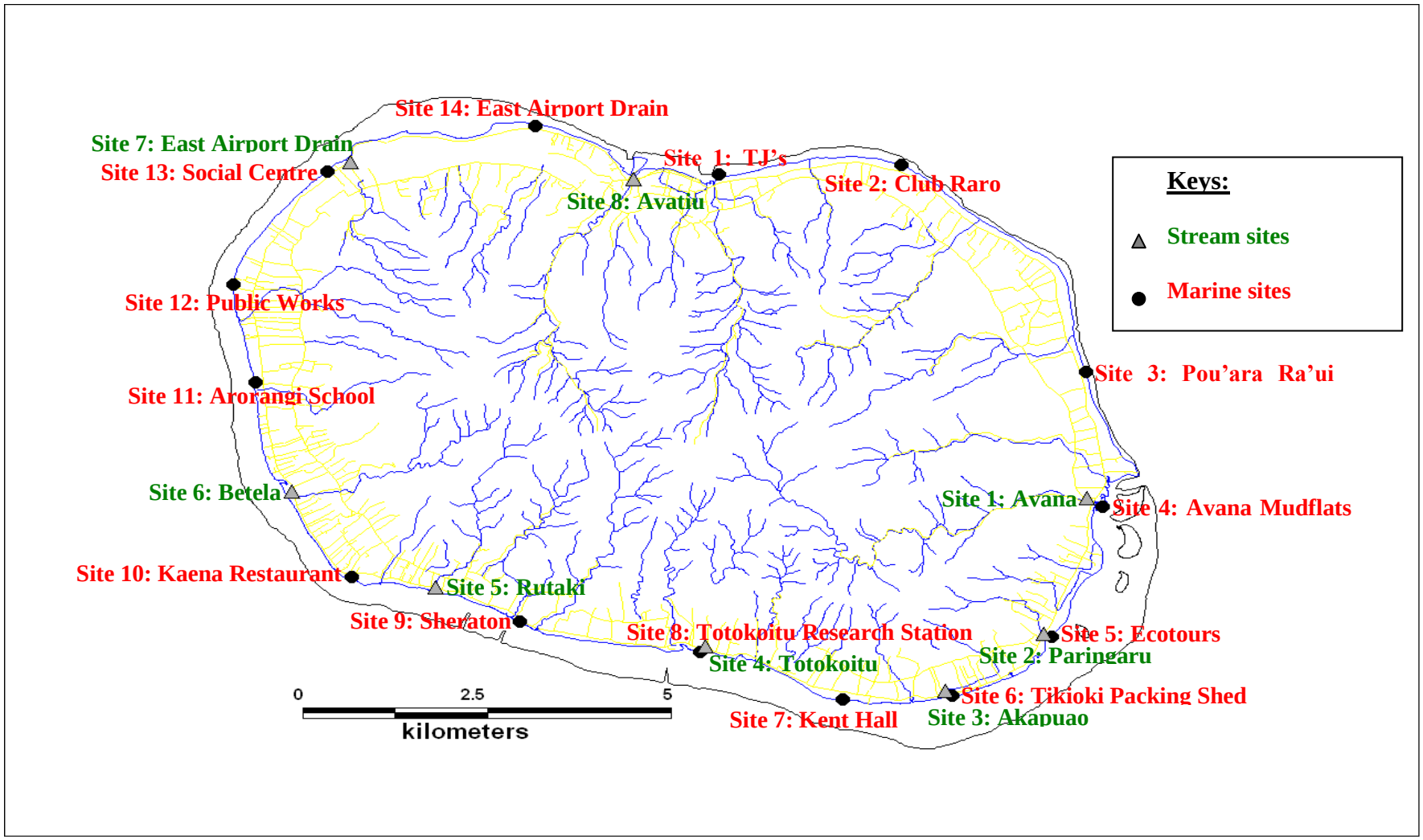

Figure 1. Lagoon and stream sites for Rarotonga.

3. Results

3.1 Physical Parameters

Lagoon

The water temperature in the lagoon has a strong seasonal variation with mean temperatures being high from November to May and low from June to October. The highest mean temperature occurred in March and the lowest in September (Fig.2). The lowest mean temperature was recorded at Club Raro (25.8±0.6ºC) and the highest at East Airport Drain (27.4±0.9ºC) (Appendix 3). The Club Raro site has a very narrow reef and consequently has a high oceanic influence. The East Airport Drain site is in a shallow area of the lagoon and is influenced by the freshwater input (salinity 33.3‰) from the airport drain. In 2006 the air and sea temperature trends are similar. The water temperature ranges between 21.1ºC at Avana Mudflats in September and 30.2ºC at Ecotours in November. The coolest mean air temperature in 2006 were 21.9±0.3 ºC in July and warmest at 27.2±0.2 ºC in April.

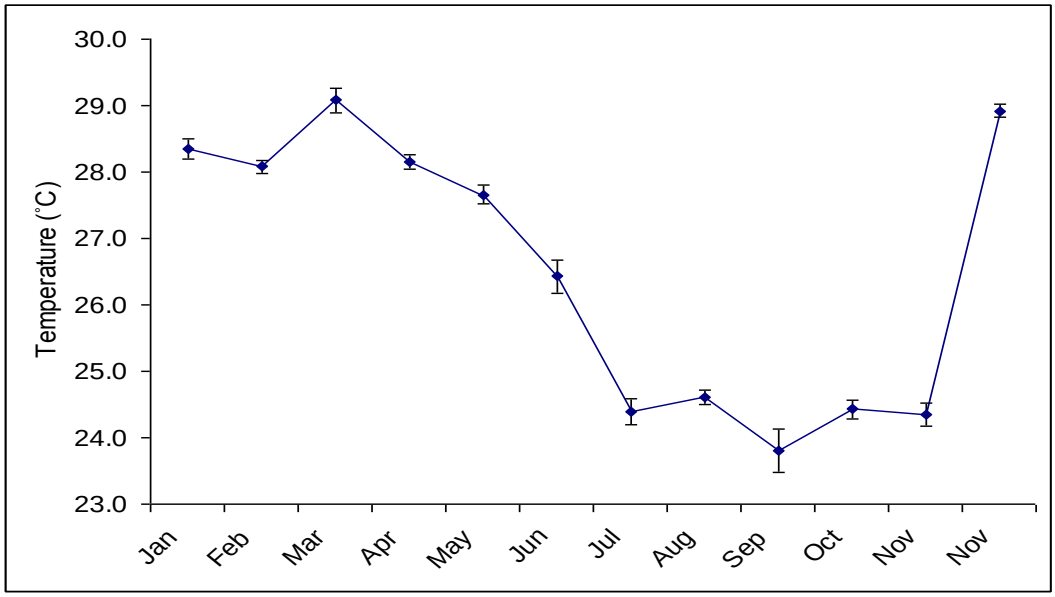

Figure 2. Lagoon annual average temperature for all sites (ºC) with standard errors in Rarotonga lagoon from January to November 2006.

The pH of the lagoon ranged from 7.6 at Club Raro in October to 8.2 at Avana Mudflats, Ecotours and Pou'ara Ra'ui in November (Appendix 3). The Club Raro pH was lower than the Pacific Region standard of 8.0-8.4 (Mosely *et al.* 2004) but consistent with the Global standard 7.8 (Pinet 1992).

Salinity ranged from 28.7‰ at Avana Mudflats in July to 39.1‰ at Social Centre in August (Appendix 3). The Avana Mudflats site is influenced by the stream inflow resulting in lower salinities at certain tides. East Airport Drain had the lowest mean salinity of 32.7±0.9‰ and Social Centre the highest at 36.2±0.4‰. Salinity (30-32‰) can be lower than expected where the sites are close to stream outflows and underground springs. The sites influenced by streams are Pou'ara Ra'ui, Avana Mudflats, Totokoitu Station, North Airport Drain, Ecotours and Kent Hall. The following sites Public Works, Arorangi School and Tikioki Packing Shed are influenced by underground springs. DO concentrations were measured in October 2006 and ranged from 5.0 mg/L (72%) at Ecotours to 7.2 mg/L (105.7%) at Pou'ara Ra'ui (Appendix 3).

Streams

The average temperatures in the streams have a seasonal trend with highest temperature in November and lowest in July (Fig.3). Temperatures in the streams ranged from 21.1ºC in July to 33.96ºC in November. Totokoitu stream had the lowest mean temperature at 23.8ºC and highest of 27.5ºC was at the North Airport Drain. The mean temperatures of the streams are similar with the exception of the North Airport Drain which showed consistently higher temperatures. The North Airport Drain collects runoff from residential areas as well as the airport and has a shallow flow over a concrete channel.

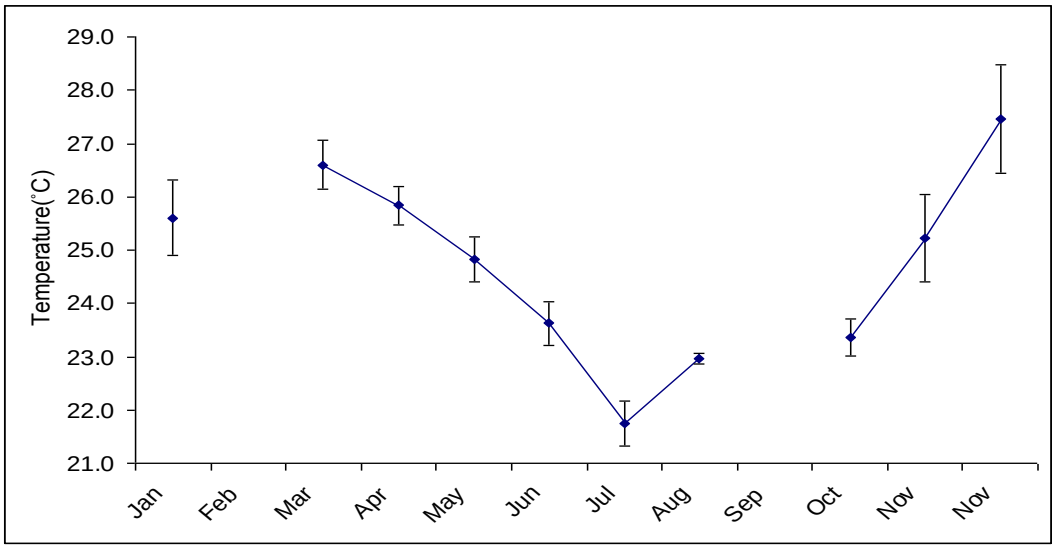

Figure 3. Average Annual temperature (ºC) for all sites with standard errors in Rarotonga streams from January to November 2006.

The pH of the streams ranged from 6.7 at Avana in November to 8.7 at North Airport Drain in October (Appendix 4) which is well within the values expected for streams (Department of Health, Clean Water Branch Hawaii 1994). Salinity in the streams ranged from 0‰ to 0.45‰ with the Rutaki Stream consistently having the lowest mean salinity (0.09‰) and Paringaru Stream the highest at 0.26‰ (Appendix 4). Dissolved oxygen concentrations in the streams ranged from 5.1 mg/l (65.2%) in Betela in November to 8.8 mg/L (102.2%) in Avana in October (Appendix 4).

3.2 Nutrients

Lagoon

DRP concentrations ranged from 0.5 to 13 µg/L (Fig 4). DRP concentrations in January were low at all sites except for Sheraton, in contrast, July and August had higher concentrations at all sites. All samples analysed were above the recommended guideline except in January and at the Ecotours site in February.

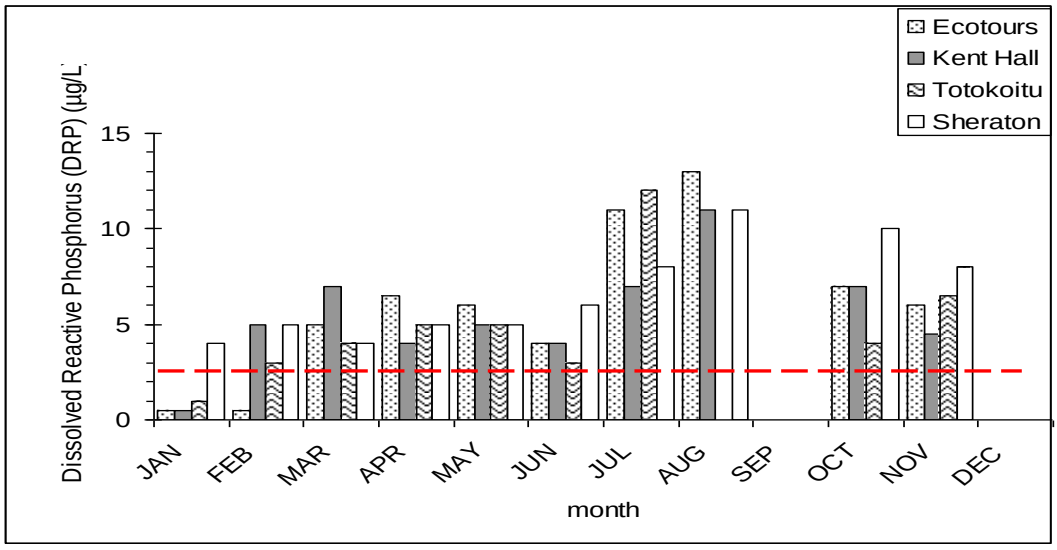

Figure 4. Dissolved Reactive Phosphorus (DRP) concentrations for Rarotonga lagoon 2006 and the dotted line indicates the guideline for the protection of coral reef health at 2.6 µg/L (Bell 1992).

Ammonia (NH_4-N) concentrations ranged from 0.5 to 40 µg/L (Fig 5). Low ammonia concentrations occurred in January and February for all sites except at Sheraton in February. High concentrations occurred at Ecotours in the months of April, May and August. Kent Hall and Sheraton had highest concentrations in July and August.

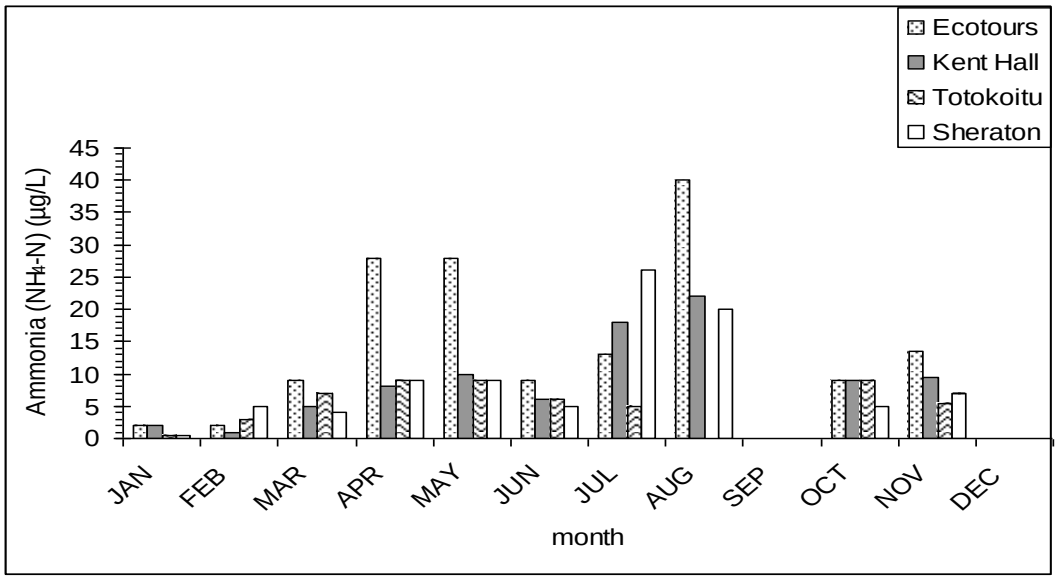

Figure 5. Ammonia (NH_4-N) concentrations for Rarotonga lagoon 2006.

Concentrations for nitrate (NO_3-N) ranged from 0.5 to 50 µg/L (Fig 6). Low nitrate concentrations occurred at all sites in January. Kent Hall recorded the highest nitrate concentrations in February to July and in November. Nitrate concentrations at Totokoitu were low for most of the sampling occasions ranging from 0.5 to 7 µg/L.

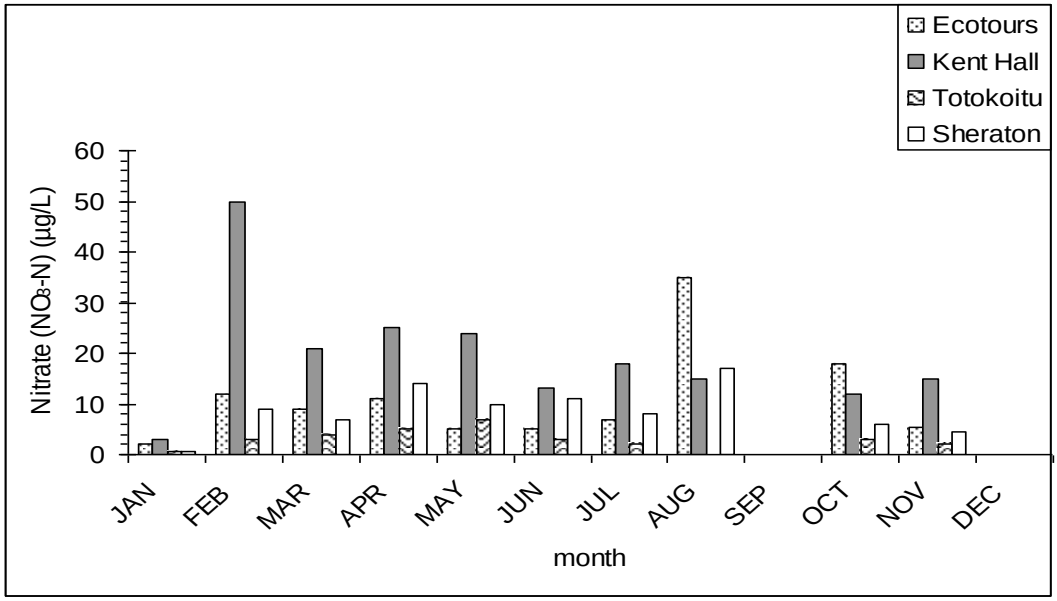

Figure 6. Nitrate (NO_3-N) concentrations for Rarotonga lagoon 2006.

The guideline concentration for DIN (NO_3-N + NH_4-N) for the protection of coral reef health is 14 µg/L (Bell 1992). Kent Hall exceeded the guideline on nine out of ten sampling occasions, Ecotours exceeded it on seven occasions and Sheraton exceeded it on four occasions (Fig 7).

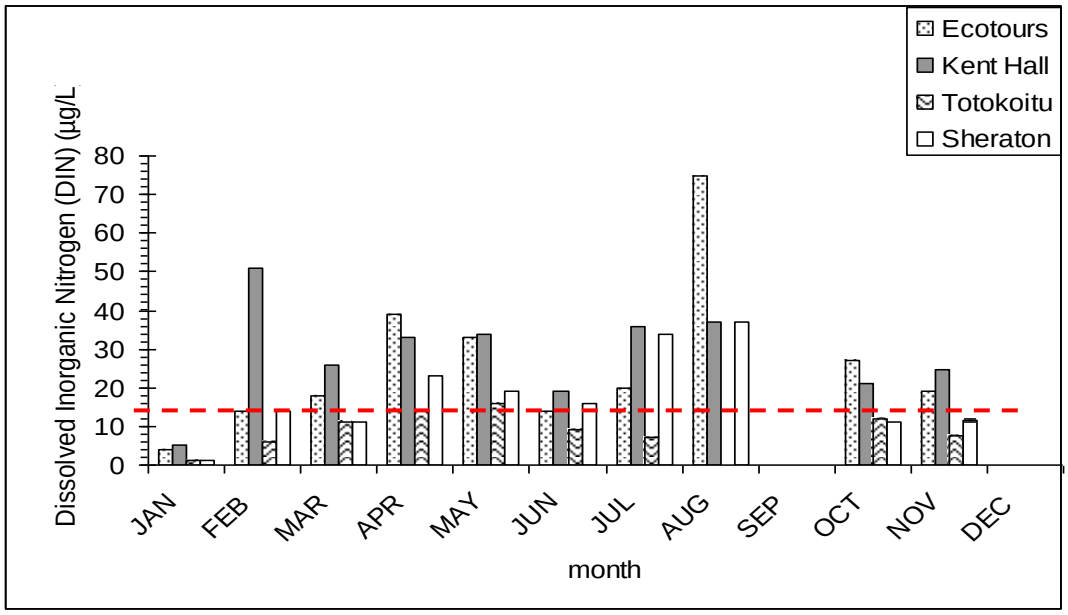

Figure 7. DIN concentrations for Rarotonga lagoon 2006 and the dotted line indicates the guideline for the protection of coral reef health at 14 µg/L (Bell 1992).

The DRP concentration at the sites where sampling began in October 2006 ranged from 2 to 26 µg/L (Fig 8). On the 7th of November 2006, all sites except the Social Centre were above the guideline recommended by Bell (1992) at 2.6 µg/L for the protection of coral reef health. East Airport Drain and Avana Mudflat recorded higher DRP concentrations on the 3rd of October and the 28th of November respectively (see Fig 8), than that at the former sites (see Fig 4).

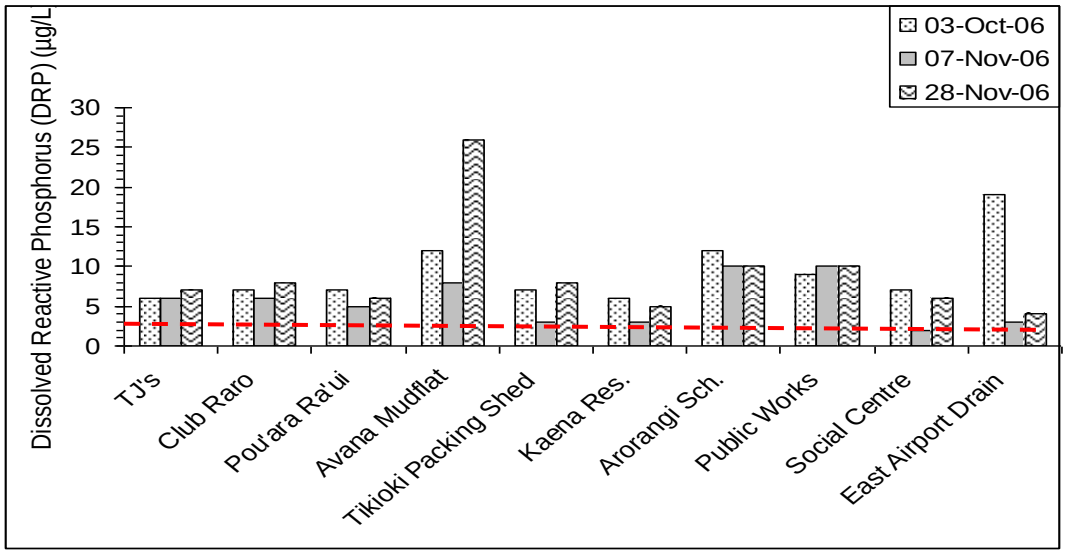

Figure 8. Dissolved Reactive Phosphorus (DRP) concentrations for the sites where sampling began in October 2006. The dotted line indicates the guideline for the protection of coral reef health at 2.6 µg/L (Bell 1992).

Concentration for ammonia at the new lagoon sites ranged from 1 to 18 µg/L (Fig 9). The ammonia concentration recorded at all new sites were within the range recorded at Ecotours, Kent Hall, Totokoitu and Sheraton (Fig 5).

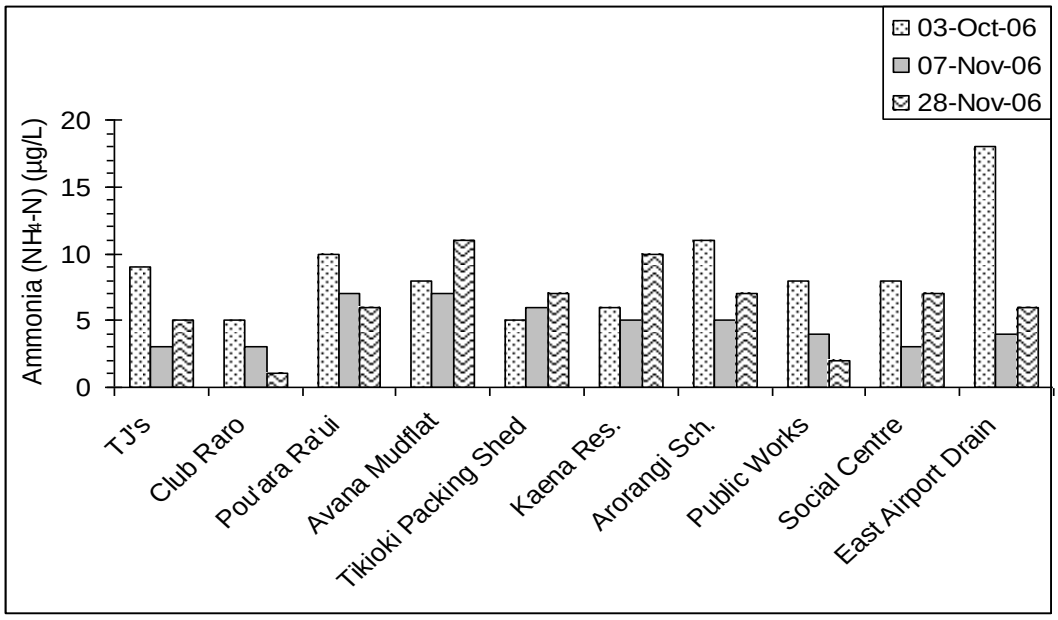

Figure 9. Ammonia (NH_4-N) concentrations for sites where sampling began in October 2006.

Nitrate concentration ranged from 0.5 to 133 µg/L. Avana Mudflat had the highest nitrate concentration, recorded on the 28th of November. The remaining sites had nitrate concentration up to 32 µg/L (Fig 10).

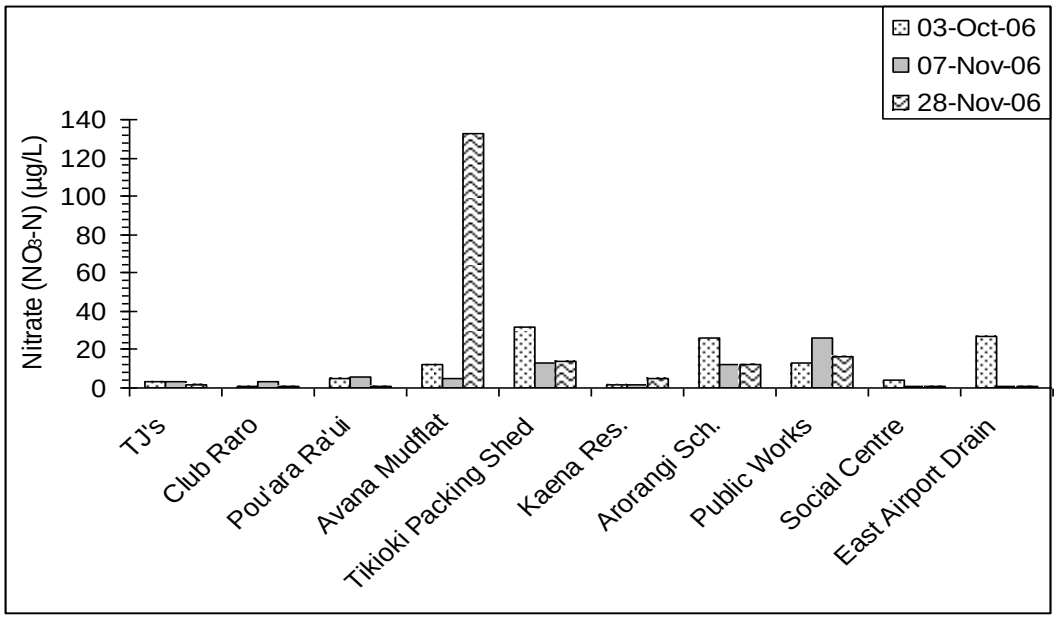

Figure 10. Nitrate (NO_3-N) concentrations for the lagoon sites where sampling began in October 2006.

Concentration for DIN ranged from 2 to 144 µg/L. Avana Mudflat recorded high DIN concentration on the 28th of November. There were seven out of ten new sites in November that had DIN concentrations below the recommended guideline of 14 µg/L (Bell 1992).

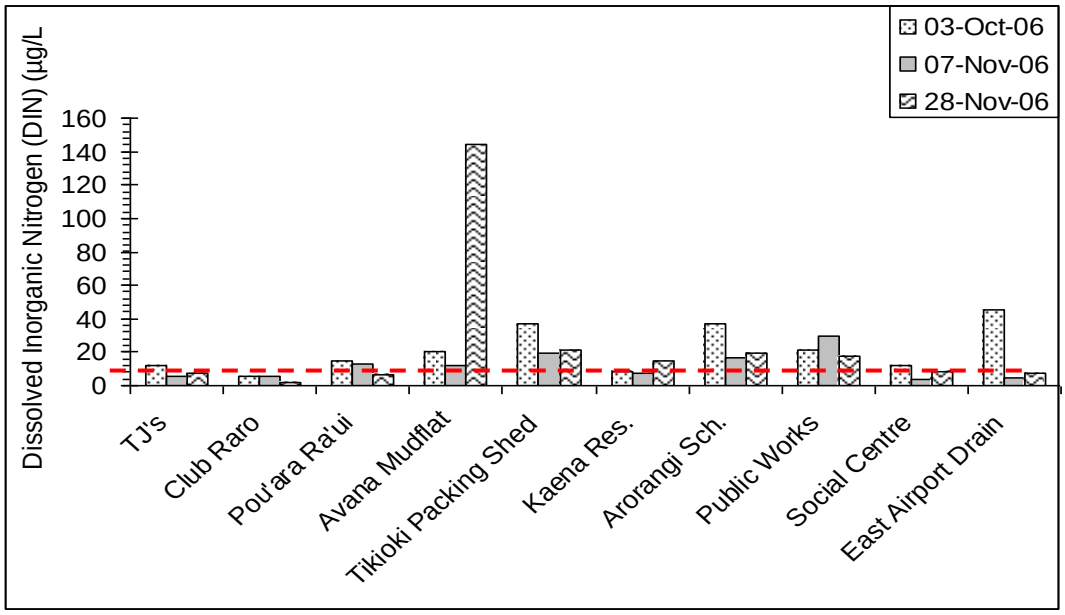

Figure 11. Dissolved Inorganic Nitrogen (DIN) concentrations for the new lagoon sites where sampling began in October 2006. The dotted line indicates the guideline for the protection of coral reef health at 14 µg/L (Bell 1992).

Streams

Concentrations for DRP ranged from 4 to 110 µg/L (Fig 12). Totokoitu and Rutaki streams had consistently high DRP concentrations. In March and June, Akapuao was the only stream that had DRP concentration at or below the guideline for lowland rivers in tropical areas of 4 µg/L (ANZECC 2000).

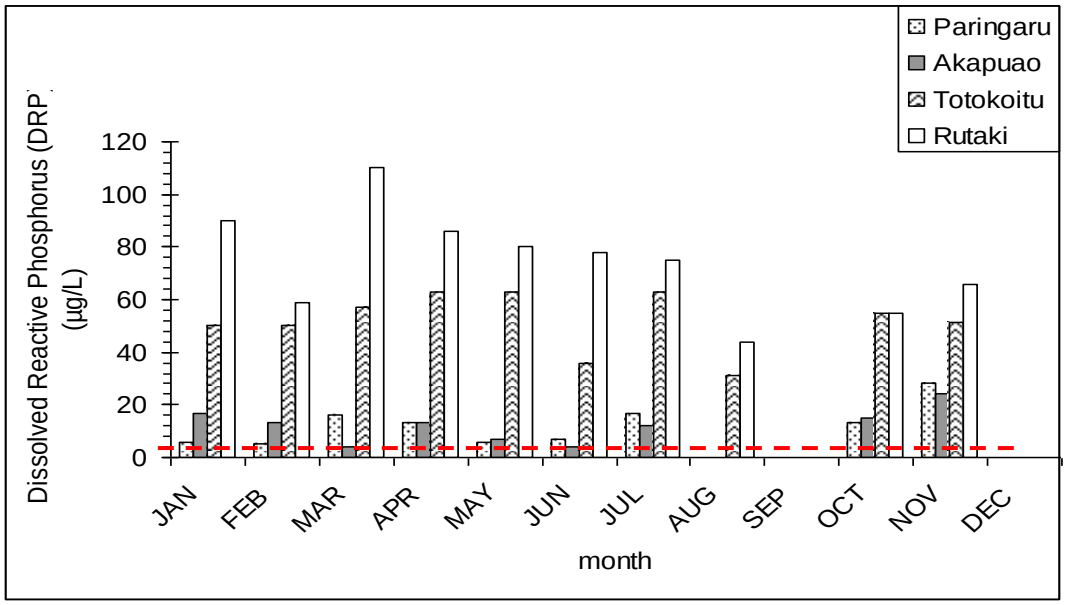

Figure 12. Dissolved Reactive Phosphorus (DRP) concentrations for Rarotonga streams 2006 and the dotted line indicates the guideline for lowland rivers in tropical areas at 4 µg/L (ANZECC 2000).

Ammonia (NH_4-N) concentrations ranged from 0.5 to 671 µg/L (Fig 13). Akapuao stream had high ammonia concentrations ranging from 106 to 671 µg/L except in February and October. Rutaki and Totokoitu streams had lower ammonia concentrations than the ANZECC guideline on four and five occasions, respectively.

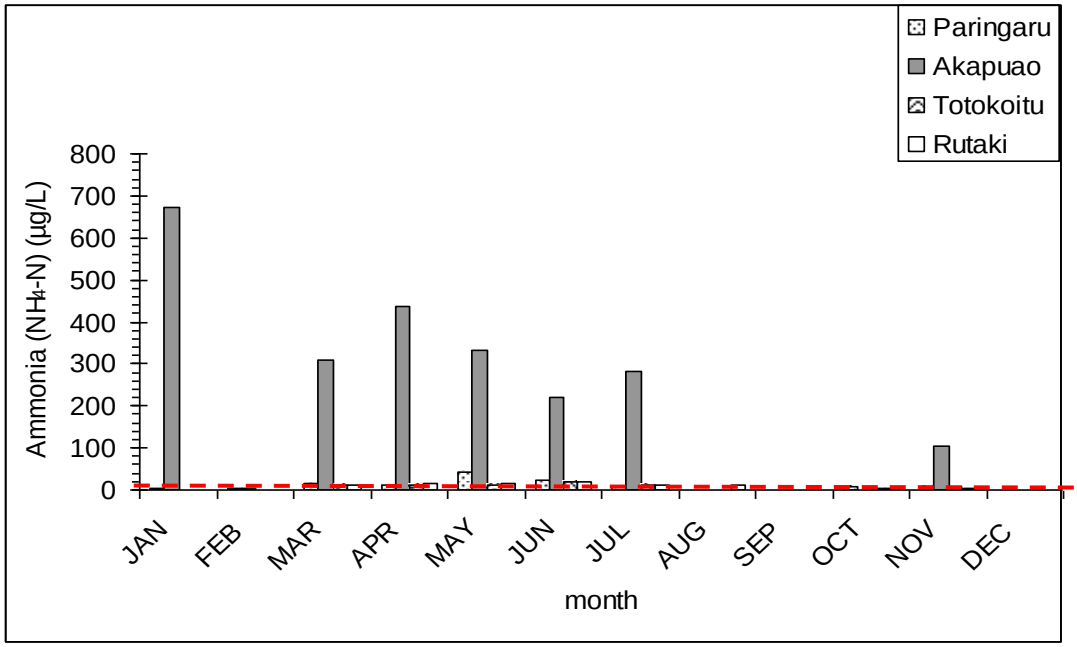

Figure 13. Ammonia (NH_4-N) concentrations for Rarotonga streams 2006 and the dotted line indicates the guideline for lowland rivers in tropical areas at 10 µg/L (ANZECC 2000).

Nitrate (NO_3-N) concentrations ranged from 0.5 to 1200 µg/L. Paringaru stream had the highest nitrate concentrations except in January and November. Akapuao stream had high nitrate concentrations in November at 603 µg/L and low in May at 3 µg/L. Totokoitu and Rutaki streams had consistently low nitrate concentrations.

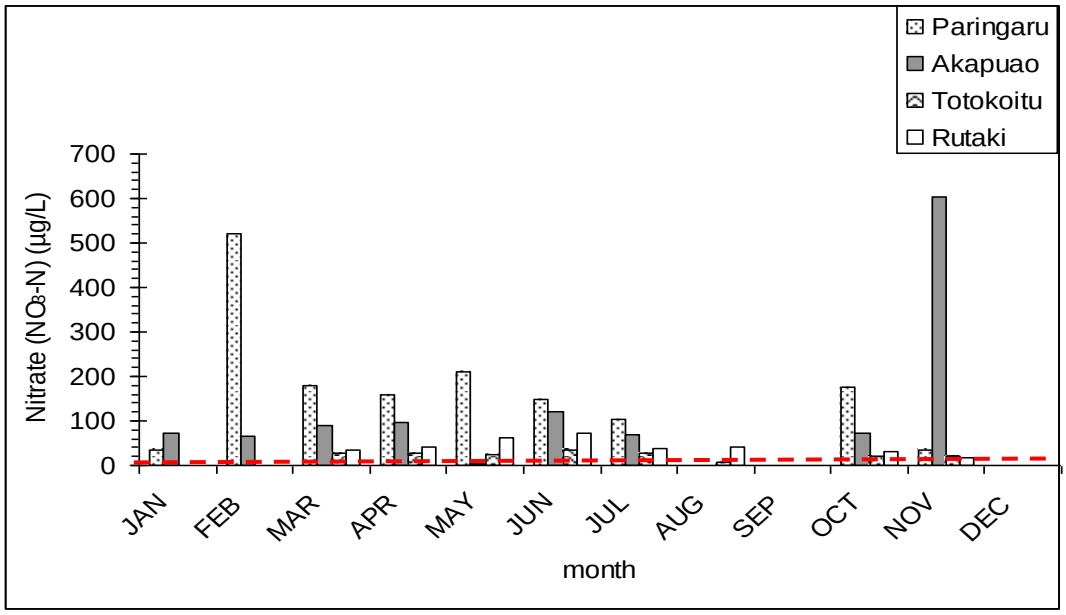

Figure 14. Nitrate ($N0_3$-N) concentrations for Rarotonga streams 2006 and the dotted line indicates the guideline for lowland rivers in tropical areas at 10 µg/L (ANZECC 2000).

DRP concentration ranged from 11 to 78 µg/L. All new sites were above the guideline of 4 µg/L for lowland rivers in tropical areas (ANZECC 2000). North Airport Drain had the lowest DRP concentration (Fig15).

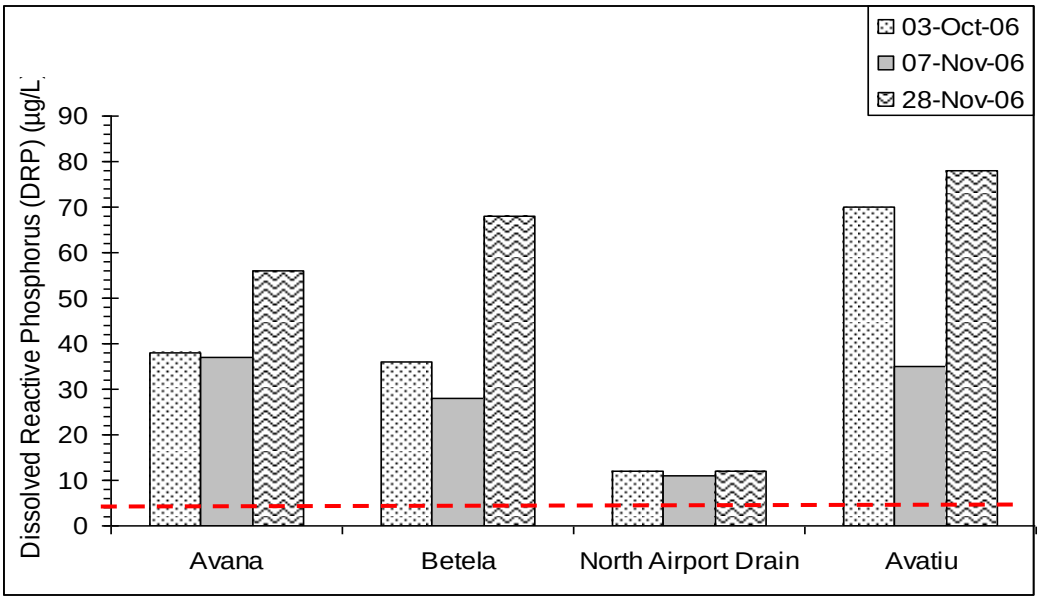

Figure 15. Dissolved Reactive Phosphorus (DRP) concentrations for the new stream sites where sampling began October 2006. The dotted line indicates the guideline for lowland rivers in tropical areas at 4 µg/L (ANZECC 2000).

Concentration for ammonia ranged from 0.5 to 5 µg/L. All sites recorded ammonia concentrations that were below the 10 µg/L guideline (ANZECC 2000).

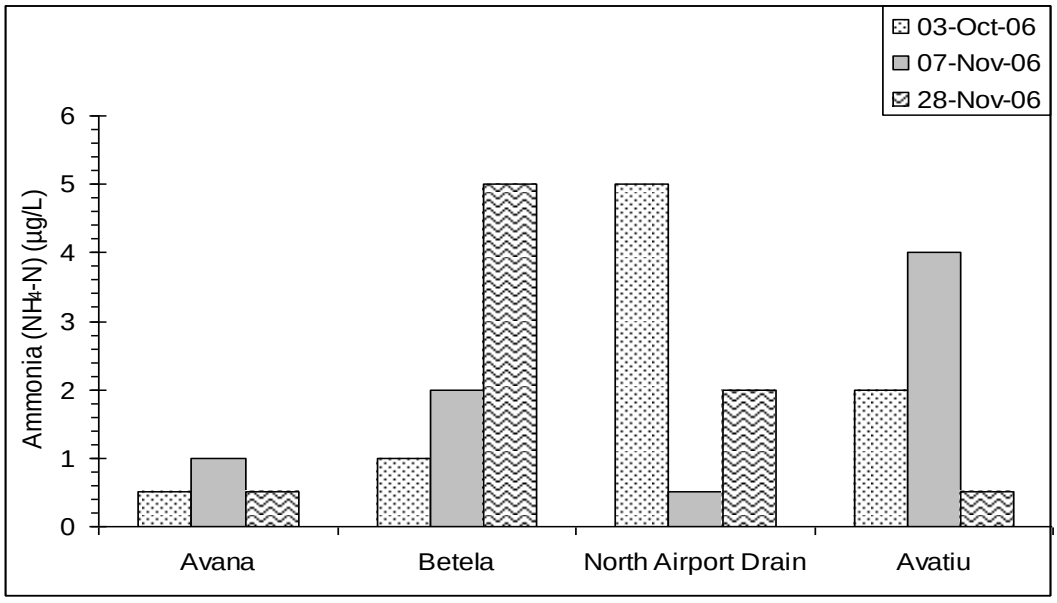

Figure 16. Ammonia (NH_4-N) concentrations for the stream sites where sampling began in October 2006. The guideline for ammonia concentration in lowland rivers in tropical areas is at 10 µg/L (ANZECC 2000).

Nitrate concentration ranged from 0.5 to 177 µg/L. On 7 November 06, all new sites recorded nitrate concentrations that were less than the 10 µg/L guideline (ANZECC 2000).

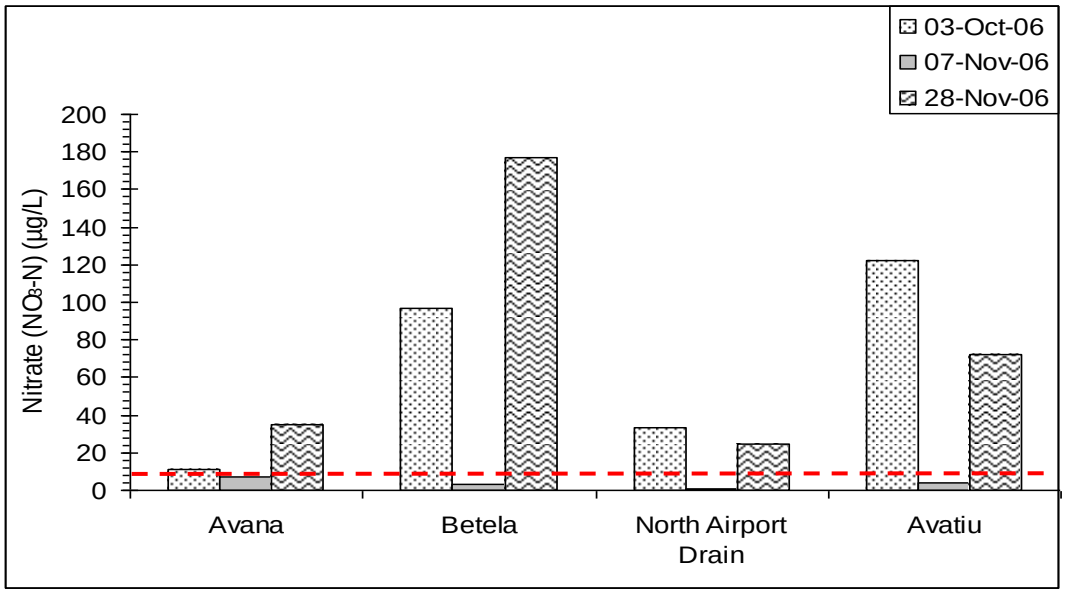

Figure 17. Nitrate ($N0_3$-N) concentrations for the new stream sites where sampling started in October 2006. The dotted line indicates the guideline for lowland rivers in tropical areas at 10 µg/L (ANZECC 2000).

The nutrient concentrations at the new stream sites ranged from 11 to 78 µg/L for DRP concentration, from 0.5 to 5 µg/L for ammonia concentration and from 0.5 to 177 µg/L for nitrate concentration.

3.3 Chlorophyll *a* and Total Suspended Solids

Lagoon

The chlorophyll *a* concentrations in the lagoon ranged from 0.05 – 5.1 µg/L with the highest concentrations measured from January to May. Samples from the Ecotours site consistently recorded high chlorophyll *a* concentrations as did the Kent Hall site (Fig 18). The Sheraton and Totokoitu sites consistently had lower chlorophyll *a* concentrations (Fig 18). The sites added, starting from October ranged from 0.1-0.6 µg/L (Appendix 3).

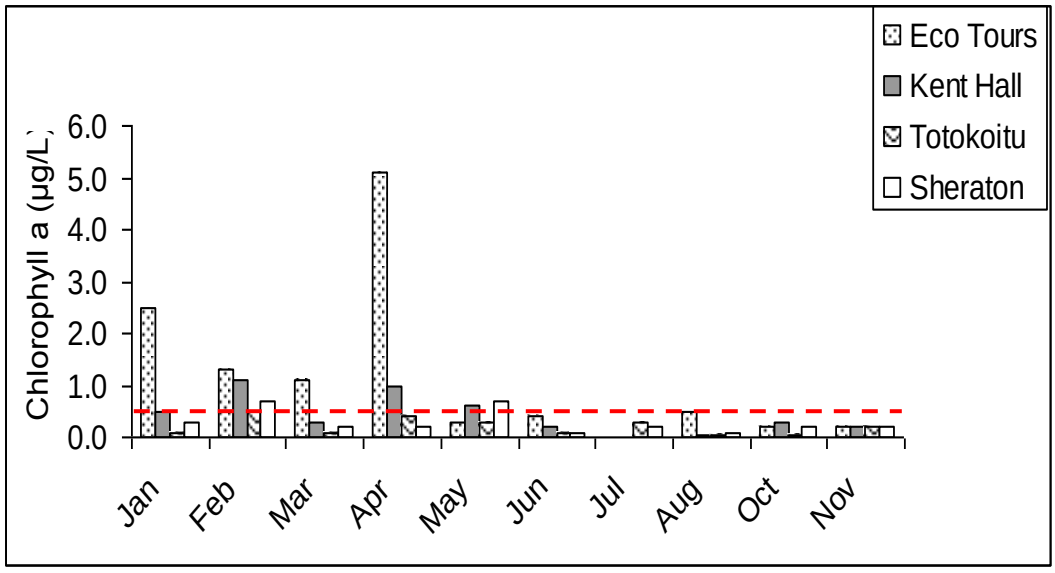

Figure 18. Chlorophyll *a* concentrations for the Rarotonga lagoon 2006. The horizontal line shows the 0.5 µg/L concentration recommended for the protection of coral reef health (Bell 1992).

The total suspended solids concentrations were variable ranging from 0.15 – 8.68 mg/L with the Ecotours site consistently recording the highest concentrations. The sites added starting from October ranged from 0.41-29.76 mg/L with high concentrations being recorded at sites 1, 2, 3, 4 in October (Appendix 3).

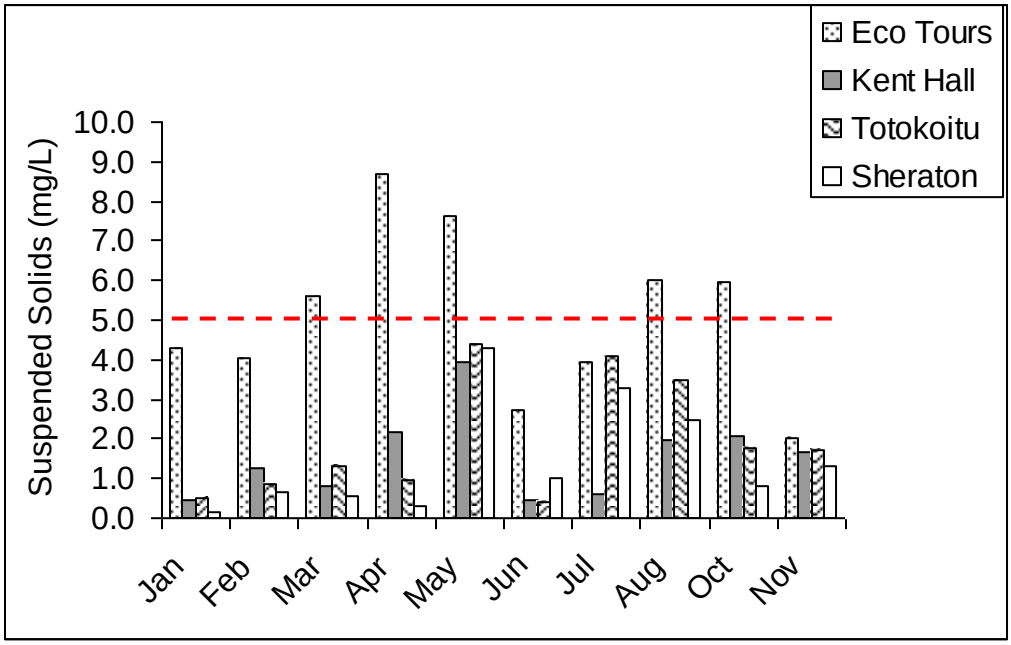

Figure 19. Total Suspended Solids for the Rarotonga lagoon 2006. The horizontal line represents the 5.0mg/L concentration recommended for the protection of coral reef health (Bell 1992).

Streams

The total suspended solids concentrations for the streams were variable, ranging from 0.39 – 28.13 mg/L. Akapuao had the highest total suspended solids concentrations on 8 out of the 10 sampling occasions. The highest total suspended solids concentrations for all the sites except Rutaki were recorded on the 5th of May. The sites sampled after October had low concentrations that ranged from 0.49-2.65 mg/L.

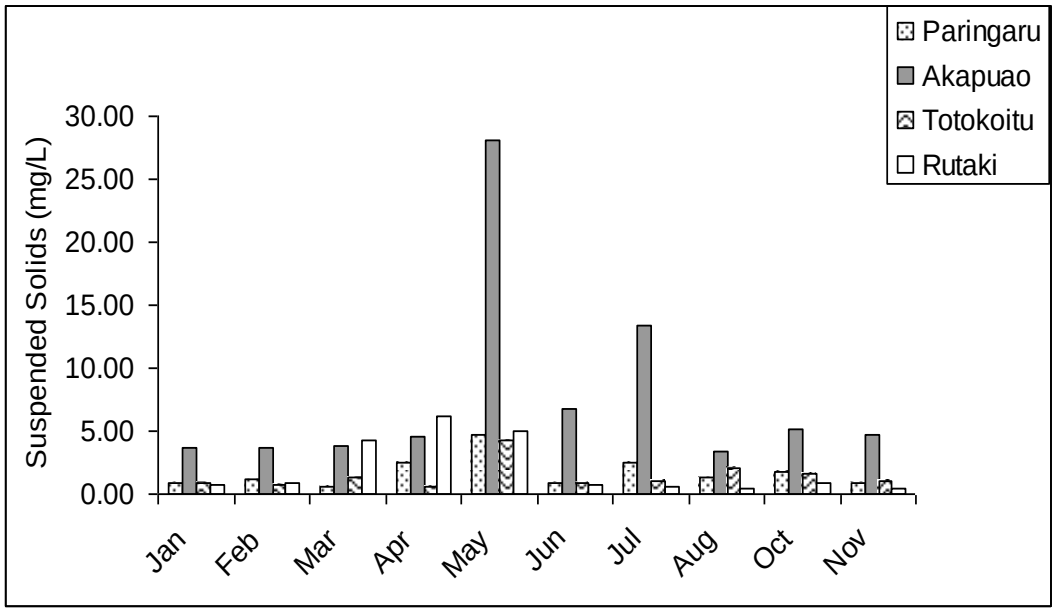

Figure 20: Total suspended solids for Rarotonga streams 2006.

3.4 Bacteria

Lagoon

From January to December, most of the 14 lagoon sites were in "A and B" category however on some sampling dates there were sites that were out of those categories. In the month of January and September the East Airport Drain site was in category "C and D" (Table 4) based on WHO standards, which recommends the water is not safe for swimming (Table 1). In December there was an increase in the numbers of Enterococci recorded at the Pou`ara Raui and Avana Mudflat sites which were in category "C" based on WHO standards. Rainfall is often considered to be a contributing factor to the elevated Enterococci numbers in the water however Enterococci and rainfall in the 3 days prior to sampling showed no relationship ($r^2 = 0.29$) (data not shown).

Table 4. Summary of 2006 Enterococci numbers per 100ml. There are 4 color codes used in the table which represents WHO standards (Table 1). Green represents category "A", Yellow category "B", Orange category "C" and Red category "D".

SAMPLING DATE	TJ's	Club Raro	Pou'ara Ra'ui	Avana Mudflat	Ecotours	Tikioki Packing Shed	Kent Hall	Totokoitu Station	Sheraton	Kaena Res.	Arorangi School.	Public Works	Social Centre	East Airport Drain
10/01/2006	5		5	5	5	5	5	5	5	5	5	5	5	480
7/02/2006	110		5	5	99	5	5	5	5	5	5	20	5	44
7/03/2006	5		26	5	5	5	5	5	5	5	5	5	5	5
4/04/2006	5		20	5	5	5	5	5	5	5	5	5	5	5
2/05/2006	5		5	5	5	5	5	5	5	5	5	5	5	5
4/07/2006	1		4	86	149	19	2	78	20	4	11	3	2	7
1/08/2006	44		25	43	12	190	46	20	18	5	30	20	4	23
5/09/2006	8		1	1	23	1	16	13	14	1	28	2	1	1440
3/10/2006	1	0	4	13	4	2	1	10	15	1	28	4	3	78
7/11/2006	4	1	0	4	2	0	1	5	2	4	2	1	2	7
28/11/2006	6	0	310	380	24	3	2	106	16	0	51	1	3	28

Streams

Enterococci numbers were in "C and D" category – not recommended for swimming (WHO) in the 11 months of sampling at all sites (Table1). But, in the months of October and November at North Airport Drain Site, Enterococci numbers were in "A" and "B" category which is recommended for swimming. The North Airport Drain was the only site at which low numbers of Enterococci were found in the streams throughout the sampling period.

Table 5. Summary of 2006 Enterococci numbers per 100ml. There are 4 color codes used in the table which represents WHO standards (Table 1). Green represents category "A", Yellow category "B", Orange category "C" and Red category "D".

SAMPLING DATE	Avana	Paringaru	Akapuao	Totokoitu	Rutaki	Betela	North Airport Drain	Avatiu
10/01/2006		710	20000	780	1300			
7/02/2006		206	400	680	520			
7/03/2006		1200	4300	4600	2500			
4/04/2006		300	960	1200	3200			
2/05/2006		720	900	2800	1040			
4/07/2006		17500	10100	1300	1235			
1/08/2006		680	6300	1040	1760			
5/09/2006		295	1205	1465	545			
3/10/2006	410	435	2750	1360	1280	590	29	390
7/11/2006	805	1150	7500	880	3350	805	48	450
28/11/2006	1280	1930	6500	1930	4400	1890	590	4850

4. Discussion

4.1 Lagoon

Anderson *et al* (2004) reported that water and air temperatures follow similar trends with the warmest temperatures from December through to June and cooler from July to late November. For 2006 the trend is similar with the warmest temperatures from January to June and cooler from July and starting to warm in November. In 2005 the coolest months were May/June to September and the warmer months were October to April. The temperatures for lagoon sites in 2006 showed a seasonal trend with mean temperatures being high from November to June and lower from July to October. Temperature ranged between 21.1ºC and 30.15ºC in 2006. Anderson *et al* (2004) reported 23ºC and 32ºC in 2004 and in 2005 ranged from 20.7ºC to 29.9ºC in 2005 (MMR database). The water temperatures recorded in 2006 were similar to those in 2005 but lower than those recorded in 2004.

Two sites from the south/southwest side Sheraton and Ecotours DO concentrations were below the Clean Water Branch Hawaii (1994) recommendations. Hall *et al* (2006) also reported DO concentrations were lower than expected in the lagoon in the Titikaveka area. Anderson *et al* (2004) reported that sites located on the more sheltered south/southwest of the island (between Avana Mudflats and Sheraton) had the lowest DO and sites with narrow and shallow inner reef and on the western side of the island where often prevailing ocean swell had the highest DO. Anderson *et al* (2004) also reported that ocean passages, lagoon depth and width have an influence on DO levels at sites around Rarotonga lagoon.

All lagoon sites had an increase in the mean DRP and ammonia concentrations, except at Totokoitu, and a decrease in the mean nitrate concentration, except at Sheraton, in comparison to the same sites the year before. These were consistent findings with Hall *et al* (2006) with Ecotours and Kent Hall having high mean

ammonia and nitrate concentration respectively. At all the sites sampled the mean DRP concentrations (Appendix 3) were above the 2.6 µg/L recommended by Bell (1992). For the DIN concentration, all sites except for Totokoitu, were above the 14 µg/L recommended by Bell (1992). This indicates that adverse impacts on the coral reefs could be occurring. The Redfield ratio was 10, 12, 4 and 5 for Ecotours, Kent Hall, Totokoitu and Sheraton, which indicates that the growth of phytoplankton and macro algae in the lagoon are very likely to be limited by the concentration of nitrogen in the water. This means that additional nitrogen entering the lagoon from land based sources may increase phytoplankton and macro algal growth in the lagoon.

The chlorophyll *a* concentrations at the Ecotours and the Kent Hall were above the 0.5 µg/L recommended to protect coral reef health (Bell 1992) on 4 out of the 10 sampling occasions for Ecotours and 3 out of 10 for Kent Hall. The mean chlorophyll *a* concentration of 1.3 µg/L at Ecotours was above the guidelines and the mean chlorophyll *a* concentration at Kent Hall of 0.5 µg/L was borderline for the protection of coral reef health. These results were consistent with Hall *et al* (2006) who recorded mean chlorophyll *a* concentrations at the Ecotours and Kent Hall sites which were over the guidelines recommended for the protection of coral reefs in 2004 and 2005. The Totokoitu site which Hall *et al* (2006) recorded as borderline in 2005 was below the guideline in 2006 with a mean of 0.2 µg/L.

The Ecotours site also consistently recorded high total suspended solids concentrations with concentrations above the 5.0 mg/L recommended for the protection of coral reef health (Bell 1992) on 5 out of the 10 sampling occasions.
The Ecotours site had a mean concentration of 5.09 mg/L and was the only site above the guidelines recommended for the protection of coral reefs. Kent Hall had the highest mean concentration of 4.3 mg/L in 2005, (Hall *et al* 2006) which was double the mean concentration at the same site in 2006. The Totokoitu and Sheraton sites were consistently below the guidelines for the protection of coral

reefs in 2005 and 2006. On 3/10/2006 all sites that were located north east of the island (TJ's, Club Raro, Pou'ara Ra'ui and Avana Mudflats) had suspended solids that were well above the concentration recommended for the protection of coral reefs.

The Enterococci numbers recorded in Rarotonga lagoon indicate that almost on all occasions the water was safe for contact recreation based on WHO standards. The East Airport site was the only site that had concentration of Enterococci that were in the category "C" and "D" which the WHO does not recommend for swimming. The Enterococci numbers recorded in 2004 in the Rarotonga lagoon ranged from 0 – 4000 per 100 ml (Anderson *et al*, 2004). In 2005, the numbers recorded increased to a range of 0 – 20,000 per 100 ml. In comparison the numbers that were recorded in 2006 were lower and ranged from 0 – 1220 per 100 ml. This indicates that the bacterial water quality in Rarotonga lagoon was better in 2006 than in the previous 2 years.

Overall the Ecotours was the site with the lowest water quality lagoon site, and was over the concentration recommended for the protection of coral reefs for DRP, DIN, chlorophyll *a* and total suspended solids. The Kent Hall and the Sheraton sites were over the DRP and DIN guideline concentrations for coral reef health. Both were below the guidelines for total suspended solids. Totokoitu had the best water quality with only concentration above the guidelines for coral reef health. All of the sites were safe for swimming except for the East Airport Drain which was over the WHO standards for contact recreation on two sampling occasions. This report gives an overview of lagoon water quality for four sites throughout the year and for the other sites for a 3 month period. To gain a greater understanding of lagoon water quality monitoring needs to be continued at all sites on a monthly basis.

4.2 Streams

The temperatures for stream sites showed a seasonal trend with mean temperatures being high from November to May and lower from June to October. The range and mean stream temperature in 2005 were lower than those recorded in 2006. The streams DO concentrations were higher in 2006 than in 2005. Three streams (Akapuao, North Airport Drain, and Paringaru) consistently showed higher temperatures, salinities and lower DO concentrations than the other streams. Hall *et al* (2006) reported that the water quality in four streams (Akapuao, Totokoitu, Paringaru and Rutaki) were highly variable which was associated in some cases with rainfall and potentially some activity in the stream catchments. Streams (Akapuao, North Airport Drain, and Paringaru) with slow to stagnant flow rate potentially have lower DO, concentrations compared to faster flowing streams for the same period.

The Totokoitu and Rutaki streams having high mean DRP concentrations and low DIN concentrations, which is consistent with data collected in 2006 (Hall *et al*. 2006). The ammonia concentration in the Akapuao stream was an order of magnitude lower than that recorded by Hall *et al* (2006). Nitrate concentrations at all sites have decreased considerably except for Rutaki, which had similar results to Hall *et al* (2006). The mean concentrations for all sites were all above the ANZECC guideline for ammonia and DRP (Appendix 2). Totokoitu and Rutaki streams were well below the ANZECC guideline for nitrate. The DIN concentration in Paringaru and Akapuao streams were higher and likely to be reflecting activities in the catchments. The lowest nutrient concentration was recorded in Totokoitu and Rutaki streams, which have moderate level of horticulture and agriculture activities.

The Akapuao Stream consistently had elevated total suspended solids concentrations and had the highest mean concentration of 7.72 mg/L Totokoitu had the lowest mean suspended solids concentration of 1.45 mg/L. This is

considerably lower than in 2005 when the stream had a mean concentration of 6.7 mg/L. The Paringaru and Rutaki Streams were consistently low in both 2005 and 2006. On a single occasion, the Akapuao Stream was above 25mg/L which the concentration is recommended for the protection of flora and fauna in British and European streams (ANZEC 2000). In 2005 this guideline was exceeded 3 times (Hall *et al* 2006).

Rarotonga streams are mostly found in "C" and "D" category which is not recommended for recreational contact. The high number of Enterococci recorded in these streams may have come from human activities upstream. During heavy rain, all human and animal waste gets swept into the streams and into the lagoon. Therefore, there is the potential that the numbers of Enterococci in the lagoon increase due to this run off.

5. Acknowledgments

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7. Appendices

7.1 Appendix 1. Means and range for nutrient, chlorophyll *a* and total suspended solids data for Rarotonga lagoon sites. (All results are reported in Appendix 3).

Sites		DRP	NH_4-N	NO_3-N	CHl a	TSS
		(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)
Ecotours	mean	6	16	11	1.3	5.09
	range	0.5-13	2-40	2-35	0.2-5.1	2.00-8.68
Kent Hall	mean	5	9	19	0.5	1.54
	range	0.5-11	1-22	3-50	0.1-1.1	0.44-3.95
Totokoitu	mean	5	6	3	0.2	1.95
	range	1-12	0.5-9	0.5-7	0.1-0.5	0.38-4.37
Sheraton	mean	7	9	8	0.3	1.49
	range	4-11	0.5-26	0.5-17	0.1-0.7	0.15-4.29

7.2 Appendix 2. Means and ranges for nutrient and total suspended solids data for Rarotonga stream sites. (All results are reported in Appendix 4).

Sites		DRP	NH_4-N	NO_3-N	TSS
		(µg/L)	(µg/L)	(µg/L)	(mg/L)
Paringaru	mean	14	13	160	1.73
	range	5-42	2-41	6-521	0.56-4.73
Akapuao	mean	13	246	180	7.71852
	range	4-32	0.5-671	3-1200	3.40-28.13
Totokoitu	mean	52	7	19	1.45125
	range	31-63	0.5-19	0.5-36	0.65-4.30
Rutaki	mean	73	8	33	2.02522
	range	40-110	0.5-20	0.5-72	0.39-6.11

7.3 Appendix 3: Water quality data lagoon sites.

Site Number	Location	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH_4-N (µg/L)	NO_3-N (µg/L)	Chl *a* (µg/L)	TSS (mg/L)	Entrococci (cells/100mL)
1	TJ's	10-Jan-06	28	36.6									5
1	TJ's	7-Feb-06	28.3	36.3									110
1	TJ's	7-Mar-06	28.9	36.4									5
1	TJ's	4-Apr-06	28.2	34.5									5
1	TJ's	2-May-06	27.2	35.7									5
1	TJ's	6-Jun-06	25.7	35.3									
1	TJ's	4-Jul-06	25.1	37									1
1	TJ's	1-Aug-06	25.1	37.2									44
1	TJ's	5-Sep-	23.2										8

		06											
1	TJ's	3-Oct-06	24.6	35.8	94.9	6.4	7.9	6	9	3	0.05	25.28	1
1	TJ's	7-Nov-06	23.6	33.2			7.9	6	3	3	0.20	2.67	4
1	TJ's	28-Nov-06	27.4	35.7			8.1	7	5	2			6
2	Club Raro	3-Oct-06	25.5	35.5	97.8	6.6	7.6	7	5	1	0.05	28.26	0
2	Club Raro	7-Nov-06	24.4	34			8	6	3	3	0.20	2.00	1
2	Club Raro	28-Nov-06	27.6	35.8			8.1	8	1	1			0
3	Pou'ara Ra'ui	10-Jan-06	28.2	36.6									5
3	Pou'ara Ra'ui	7-Feb-06	8.5	36.8									5
3	Pou'ara Ra'ui	7-Mar-06	29.9	36.3									26
3	Pou'ara Ra'ui	4-Apr-06	27.6	34.3									20

3	Pou'ara Ra'ui	2-May-06	27.2	36.5									5
3	Pou'ara Ra'ui	6-Jun-06	25.9	35									
3	Pou'ara Ra'ui	4-Jul-06	23.6	36.2									4
3	Pou'ara Ra'ui	1-Aug-06	24.6	36.9									25
3	Pou'ara Ra'ui	5-Sep-06	23.6										1
3	Pou'ara Ra'ui	3-Oct-06	24.8	35.8	105.7	7.2	8.1	7	10	5	0.60	29.76	4
3	Pou'ara Ra'ui	7-Nov-06	24.2	34.3			8.1	5	7	6	0.30	1.33	0
3	Pou'ara Ra'ui	28-Nov-06	27.7	35.6			8.2	6	6	0.5			310
4	Avana Mudflat	10-Jan-06	27.9	35									5
4	Avana Mudflat	7-Feb-06	27.6	35.9									5
4	Avana Mudflat	7-Mar-	29.4	34.2									5

		06											
4	Avana Mudflat	4-Apr-06	27.5	31.6									5
4	Avana Mudflat	2-May-06	27.5	34.7									5
4	Avana Mudflat	6-Jun-06	26.4	33.6									
4	Avana Mudflat	4-Jul-06	23.3	28.7									86
4	Avana Mudflat	1-Aug-06	24.6	35.8									43
4	Avana Mudflat	5-Sep-06	21.1										1
4	Avana Mudflat	3-Oct-06	24.8	35.9	75.8	5.1	8.1	12	8	12	0.10	25.42	13
4	Avana Mudflat	7-Nov-06	24.8	32.8			8	8	7	5	0.50	0.41	4
4	Avana Mudflat	28-Nov-06	29.3	33.4			8.2	26	11	133			380
5	Ecotours	10-Jan-06	28.3	34.5				0.5	2	2	2.50	4.31	5

5	Ecotours	7-Feb-06	27.6	34.5				0.5	2	12	1.30	4.06	99
5	Ecotours	7-Mar-06	28.8	34.5				5	9	9	1.10	5.60	5
5	Ecotours	4-Apr-06	27.9	33.8				5 8	26 30	11 11	5.10	8.68	5
5	Ecotours	2-May-06	4:48	34.9				6	28	5	0.30	7.65	5
5	Ecotours	6-Jun-06	25.9	34.3				4	9	5	0.40	2.72	
5	Ecotours	4-Jul-06	23.1	36.4				11	13	7		3.92	149
5	Ecotours	1-Aug-06	24.2	37.4				13	40	35	0.50	6.01	12
5	Ecotours	5-Sep-06	22.9										23
5	Ecotours	3-Oct-06	24.2	34.3	72	5	8.1	7	9	18	0.20	5.97	4
5	Ecotours	7-Nov-06	24.5	33.7			7.9	4	6	5	0.20	2.00	2
5	Ecotours	28-Nov-	30.2	32.9			8.2	8	21	6			24

		06											
6	Tikioki Packing Shed	10-Jan-06	28.3	34.4									5
6	Tikioki Packing Shed	7-Feb-06	27.7	36									5
6	Tikioki Packing Shed	7-Mar-06	28.5	34.7									5
6	Tikioki Packing Shed	4-Apr-06	28.2	35.3									5
6	Tikioki Packing Shed	2-May-06	27.5	35.2									5
6	Tikioki Packing Shed	6-Jun-06	25.9	32.8									
6	Tikioki Packing Shed	4-Jul-06	24.1	35.1									19
6	Tikioki Packing Shed	1-Aug-06	24.2	37.2									190
6	Tikioki Packing Shed	5-Sep-06	23.3										1

6	Tikioki Packing Shed	3-Oct-06	24	34.5	77.5	5.4	8.1				0.20	3.93	2
6	Tikioki Packing Shed	7-Nov-06	25.1	32.7			8				0.50	3.33	0
6	Tikioki Packing Shed	28-Nov-06	29.7	34.6			8.1						3
7	Kent Hall	10-Jan-06	28.2	35.1				0.5	2	3	0.50	0.44	5
7	Kent Hall	7-Feb-06	27.7	35.8				5	1	50	1.10	1.24	5
7	Kent Hall	7-Mar-06	28.3	35.5				7	5	21	0.30	0.79	5
7	Kent Hall	4-Apr-06	28.4	33.4				4	8	25	1.00	2.18	5
7	Kent Hall	2-May-06	27.8	35.6				5	10	24	0.60	3.95	5
7	Kent Hall	6-Jun-06	25.5	34.7				4	6	13	0.20	0.46	
7	Kent Hall	4-Jul-06	24.3	35.9				7	18	18		0.62	2

7	Kent Hall	1-Aug-06	24.2	37				11	22	15	0.05	1.96	46
7	Kent Hall	5-Sep-06	23										16
7	Kent Hall	3-Oct-06	23.8	34.1	77.2	5.4	8	7	9	12	0.30	2.09	1
7	Kent Hall	7-Nov-06	24.6	32.8			8	4	9	14	0.20	1.67	1
7	Kent Hall	28-Nov-06	28.7	35.2			8	5	10	16			2
8	Totokoitu Station	10-Jan-06	28.1	35.8				1	0.5	0.5	0.10	0.52	5
8	Totokoitu Station	7-Feb-06	28.5	36.1				3	3	3	0.50	0.86	5
8	Totokoitu Station	7-Mar-06	28.5	35.2				4	7	4	0.10	1.31	5
8	Totokoitu Station	4-Apr-06	27.8	32.3				5	9	5	0.40	0.96	5
8	Totokoitu Station	2-May-06	27.5	35.3				5	9	7	0.30	4.37	5
8	Totokoitu Station	6-Jun-	26.5	34.8				3	6	3	0.10	0.38	

		06											
8	Totokoitu Station	4-Jul-06	24.3	35.2				12	5	2	0.30	4.09	78
8	Totokoitu Station	1-Aug-06	24.1	36.6							0.05	3.49	20
8	Totokoitu Station	5-Sep-06	23.7										13
8	Totokoitu Station	3-Oct-06	23.6	35.2			8	4	9	3	0.05	1.78	10
8	Totokoitu Station	7-Nov-06	24.3	33.2			7.9	4	6	3	0.20	1.73	5
8	Totokoitu Station	28-Nov-06	30.1	31.3			8.1	9	5	1			106
9	Sheraton	10-Jan-06	27.7	35.1				4	0.5	0.5	0.30	0.15	5
9	Sheraton	7-Feb-06	28.2	35				5	5	9	0.70	0.65	5
9	Sheraton	7-Mar-06	28.1	34.9				4	4	7	0.20	0.58	5
9	Sheraton	4-Apr-06	28.2	33.4				5	9	14	0.20	0.30	5

9	Sheraton	2-May-06	27.5	35.6				5	9	10	0.70	4.29	5
9	Sheraton	6-Jun-06	26.3	34				6	5	11	0.10	1.02	
9	Sheraton	4-Jul-06	25.1	35.8				8	26	8	0.20	3.30	20
9	Sheraton	1-Aug-06	24.6	35.9				11	20	17	0.10	2.45	18
9	Sheraton	5-Sep-06	24.3										14
9	Sheraton	3-Oct-06	23.8	32.6	74.1	5.2	8.1	10	5	6	0.20	0.83	15
9	Sheraton	7-Nov-06	24.1	33.9			8	8	7	4	0.20	1.33	2
9	Sheraton	28-Nov-06	29.2	34.7			8.1	8	7	5			16
10	Kaena Restaurant	10-Jan-06	27.7	35.7									5
10	Kaena Restaurant	7-Feb-06	27.9	36.2									5

10	Kaena Restaurant	7-Mar-06	29.9										5
10	Kaena Restaurant	4-Apr-06	28.2	35.6									5
10	Kaena Restaurant	2-May-06	27.7	36.3									5
10	Kaena Restaurant	6-Jun-06	26.3	33.7									
10	Kaena Restaurant	4-Jul-06	24.7	36.5									4
10	Kaena Restaurant	1-Aug-06	24.8	38.8									5
10	Kaena Restaurant	5-Sep-06	24.8										1
10	Kaena Restaurant	3-Oct-06	24.3	35.8	77.9	5.3	8.1	6	6	2	0.20	2.08	1
10	Kaena Restaurant	7-Nov-06	24.1	34.3			8	3	5	2	0.10	2.00	4

10	Kaena Restaurant	28-Nov-06	29.2	35.6			8.1	5	10	5			0
11	Arorangi School	10-Jan-06	28.9	35.2									5
11	Arorangi School	7-Feb-06	28.1	35.8									5
11	Arorangi School	7-Mar-06	29	33.8									5
11	Arorangi School	4-Apr-06	28.5	32.3									5
11	Arorangi School	2-May-06	27.4	34.7									5
11	Arorangi School	6-Jun-06	26.4	32.6									
11	Arorangi School	4-Jul-06	24.6	36.2									11
11	Arorangi School	1-Aug-06	24.6	37									30
11	Arorangi School	5-Sep-06	24.6										28
11	Arorangi School	3-Oct-	24.8	31.1	93.3	6.5	8.1	12	11	26	0.40	2.11	28

		06											
11	Arorangi School	7-Nov-06	24.3	32.8			8	10	5	12	0.30	3.50	2
11	Arorangi School	28-Nov-06	29.4	34.9			8.2	10	7	12			51
12	Public Works	10-Jan-06	28.9	33.1									5
12	Public Works	7-Feb-06	27.9	34.3									20
12	Public Works	7-Mar-06	29.1	31.6									5
12	Public Works	4-Apr-06	28.3	30.4									5
12	Public Works	2-May-06	27.7	32.8									5
12	Public Works	6-Jun-06	26.7	34.2									
12	Public Works	4-Jul-06	24.7	35.3									3
12	Public Works	1-Aug-06	24.8	34.8									20

12	Public Works	5-Sep-06	24.7										2
12	Public Works	3-Oct-06	24.5	33.8	81.4	5.6	8.1	9	8	13	0.05	2.27	4
12	Public Works	7-Nov-06	24	32.6			8	10	4	26	0.10	2.67	1
12	Public Works	28-Nov-06	29.2	34.3			8.1	10	2	16			1
13	Social Centre	10-Jan-06	29	36.7									5
13	Social Centre	7-Feb-06	28.7	37.2									5
13	Social Centre	7-Mar-06	29.9	36.4									5
13	Social Centre	4-Apr-06	28.2	34.8									5
13	Social Centre	2-May-06	29.1	36.6									5
13	Social Centre	6-Jun-06	27	35									
13	Social Centre	4-Jul-	24.7	36.9									2

		06											
13	Social Centre	1-Aug-06	25	39.1									4
13	Social Centre	5-Sep-06	24.8										1
13	Social Centre	3-Oct-06	24.6	35.8	74.7	5.1	8.1	7	8	4	0.30	4.57	3
13	Social Centre	7-Nov-06	24.4	34.3			8	2	3	1	0.05	2.17	2
13	Social Centre	28-Nov-06	28.6	35.8			8	6	7	1			3
14	East Airport Drain	10-Jan-06	29.4	30.9									480
14	East Airport Drain	7-Feb-06	28.3	34.1									44
14	East Airport Drain	7-Mar-06	29.7	34.1									5
14	East Airport Drain	4-Apr-06	29.1	30.3									5

14	East Airport Drain	2-May-06	28.3	35									5
14	East Airport Drain	6-Jun-06	29.1	30.3									
14	East Airport Drain	4-Jul-06	25.5	36									7
14	East Airport Drain	1-Aug-06	25.2	33.3									23
14	East Airport Drain	5-Sep-06	25.5										1440
14	East Airport Drain	3-Oct-06	24.9		92.8	6.7	8.2	19	18	27	0.60	9.37	78
14	East Airport Drain	7-Nov-06	24.6	34.3			8.1	3	4	1	0.20	4.83	7
14	East Airport Drain	28-Nov-06	28.8	35.5			8.1	4	6	1			28

7.4 Appendix 4: Water quality data stream sites.

Location	Site Number	Date	Temperature (ºC)	Salinity (‰)	DO Saturation (%)	DO (mg/L)	pH	DRP (µg/L)	NH4-N (µg/L)	NO3-N (µg/L)	TSS (mg/L)	Entrococci (cells/100mL)
Avana	1	3-Oct-06	22.6	0.1	102.2	8.8	7.2	38	0.5	11	0.49	410
Avana	1	7-Nov-06	23.4	0.1				37	1	7	2.65	805
Avana	1	28-Nov-06	26.6	0.1	99.4	8	6.7	56	0.5	35		1280
Paringaru	2	10-Jan-06	26.9	0.23				6	2	33	0.88	710
Paringaru	2	7-Feb-06						5	2	521	1.15	206
Paringaru	2	7-Mar-06	27.3	0.24				16	17	181	0.56	1200
Paringaru	2	4-Apr-06	26.1	0.2				13	13	159	2.51	300
Paringaru	2	2-May-06	25.6	0.5				6	41	212	4.73	720
Paringaru	2	6-Jun-06	24.7	0.3				7	24	149	0.90	

Paringaru	2	4-Jul-06	22.9	0.2				17	9	102	2.46	17500
Paringaru	2	1-Aug-06	23.2	0.2							1.39	680
Paringaru	2	5-Sep-06										295
Paringaru	2	3-Oct-06	24	0.2	72.5	6.1	7.3	13	8	175	1.77	435
Paringaru	2	7-Nov-06	24.3	0.3				14	9	6	0.94	1150
Paringaru	2	28-Nov-06	34	0.2			6.8	42	5	64		1930
Akapuao	3	10-Jan-06	26.7	0.18				17	671	72	3.63	20000
Akapuao	3	7-Feb-06						13	4	65	3.73	400
Akapuao	3	7-Mar-06	27.5	0.12				4	308	89	3.80	4300
Akapuao	3	4-Apr-06	26	0.2				13	435	96	4.50	960
Akapuao	3	2-May-06	25.5	0.2				7	334	3	28.13	900

Akapuao	3	6-Jun-06	23.7	0.2				4	219	120	6.70	
Akapuao	3	4-Jul-06	21.9					12	282	70	13.45	10100
Akapuao	3	1-Aug-06	22.7	0.2							3.40	6300
Akapuao	3	5-Sep-06										1205
Akapuao	3	3-Oct-06	23.7	0.2	65.9	5.6	7	15	0.5	74	5.18	2750
Akapuao	3	7-Nov-06	24.6	0.3				32	72	6	4.67	7500
Akapuao	3	28-Nov-06	27.4	0.1	95.7	7.6	6.8	17	139	1200		6500
Totokoitu	4	10-Jan-06	24.1	0.08				50	0.5	0.5	0.94	780
Totokoitu	4	7-Feb-06						50	1	0.5	0.80	680
Totokoitu	4	7-Mar-06	25.7	0.17				57	11	27	1.29	4600
Totokoitu	4	4-Apr-06	24.8	0.1				63	12	29	0.65	1200

Totokoitu	4	2-May-06	23.9	0.1				63	12	24	4.30	2800
Totokoitu	4	6-Jun-06	22.7	0.1				36	19	36	0.93	
Totokoitu	4	4-Jul-06	21.1	0.1				63	10	29	0.96	1300
Totokoitu	4	1-Aug-06	23	0.1				31	0.5	7	2.05	1040
Totokoitu	4	5-Sep-06										1465
Totokoitu	4	3-Oct-06	22.4	0.1	92.9	8.1	7.1	55	4	19	1.60	1360
Totokoitu	4	7-Nov-06	23.4	0.1				44	3	19	1.00	880
Totokoitu	4	28-Nov-06	27	0.1	96.2	7.7	7.1	59	8	19		1930
Rutaki	5	10-Jan-06	24.7	0.1				90	0.5	0.5	0.76	1300
Rutaki	5	7-Feb-06						59	0.5	0.5	0.92	520
Rutaki	5	7-Mar-06	25.9	0				110	10	36	4.29	2500

Rutaki	5	4-Apr-06	26.5	0				86	16	41	6.11	3200
Rutaki	5	2-May-06	24.3	0.1				80	16	61	4.96	1040
Rutaki	5	6-Jun-06	23.4	0.1				78	20	72	0.76	
Rutaki	5	4-Jul-06	21.1	0.1				75	10	38	0.63	1235
Rutaki	5	1-Aug-06	23	0.1				44	10	43	0.39	1760
Rutaki	5	5-Sep-06										545
Rutaki	5	3-Oct-06	22.4	0.1	92.7	8.1	7.3	55	3	32	0.94	1280
Rutaki	5	7-Nov-06	24.3	0.1				40	2	22	0.50	3350
Rutaki	5	28-Nov-06	25.2	0.1	93.2	7.7	6.9	91	0.5	12		4400
Betela	6	3-Oct-06	23.2	0.1	95.5	8.2	6.9	36	1	97	2.48	590
Betela	6	7-Nov-06	24.8	0.1				28	2	3	2.00	805

Betela	6	28-Nov-06	28.3	0.2	65.2	5.1	6.7	68	5	177		1890
North Airport Drain	7	3-Oct-06	25.3	0.2			8.7	12	5	33	2.35	29
North Airport Drain	7	7-Nov-06	30.5	0.3				11	0.5	0.5	0.67	48
North Airport Drain	7	28-Nov-06	26.8	0.1	81.8	6.5	8	12	2	25		590
Avatiu	8	3-Oct-06	23.4	0.1	98.5	8.4	7.5	70	2	122	2.65	390
Avatiu	8	7-Nov-06	26.5	0.2				35	4	4	1.33	450
Avatiu	8	28-Nov-06	24.6	0.1	98.9	8.2	7.1	78	0.5	72		4850

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