Bathing Beach Recreational Water Quality State of the Environment Monitoring Report Summer 2016-2017

Technical Report 2017-2

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Executive summary

This report provides an assessment of microbial water quality at 12 bathing beach sites in the Taranaki region, based on routine summer monitoring of faecal indicator bacteria (enterococci, *E. coli* and faecal coliforms) conducted by the Council between 1 November 2016 and 11 April 2017. The report focusses on enterococci results, as this indicator is considered by health authorities to provide the closest correlation with risks of health effects in New Zealand coastal waters. Results have been assessed for compliance with microbiological water quality guidelines prepared by the Ministry for the Environment (MfE) and the Ministry of Health (MfE, 2003).

Thirteen samples were collected at every monitored beach under dry weather conditions for state of the environment monitoring (SEM) purposes. An extra 11 samples were collected regardless of weather conditions at 8 sites, to satisfy MfE requirements for the number of seasonal samples to be used for grading purposes and to provide more timely results during the holiday periods. The season under review was the first in which the increased frequency has been provided by the Council.

During the 2016-2017 summer season, median faecal indicator bacteria counts for the majority of sites were elevated compared to previous years. The higher counts were likely influenced by unusually heavy rainfall throughout the summer. Out of the 244 samples collected for both SEM and for additional monitoring purposes, 91% were below the Alert level. Of the samples which entered the Alert and Action guideline category (9%), the vast majority (20 out of 23) had been influenced by rainfall and/or freshwater flows.

The guideline MfE Action mode is reached when enterococci counts in two consecutive samples exceed 280 enterococci cfu/100 ml. One site, Waitara West, reached Action mode once during the 2016-2017 season.

Mann-Kendall tests were performed in order to assess long term trends in microbiological water quality. Two sites show a significant decrease in median enterococci counts over the 15-22 years monitored (Fitzroy and Ngamotu beaches), indicating an overall improvement in their microbiological water quality. No site showed a significant increase in enterococci medians over the time period monitored i.e. deterioration in water quality.

Microbiological water quality results were regularly reported on the Taranaki Regional Council website (www.trc.govt.nz) and there was timely liaison with territorial local authorities and the Health Protection Unit of the Taranaki District Health Board throughout the summer bathing season of 2016-2017.

Through the Council's LTP, the Council's target in respect of the microbiological state of coastal bathing sites is that there is *maintenance or increase in the number of sites from 2003 compliant with 2003 Ministry of Health contact recreational guidelines*. In 2003, 10 of 11 coastal bathing sites were compliant with the guidelines (Action levels). In the season under review, 11 of 12 beaches were compliant with the guidelines. The LTP target was therefore met.

Continuation of the bathing beach SEM programme is recommended in the 2017-2018 year.

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1. Introduction

The coastal waters of New Zealand are used for a broad range of recreational activities, including bathing, surfing, diving, sailing, kayaking, and shellfish gathering. Maintaining the quality of this recreational water is therefore an important resource management and environmental health issue.

1.1 State of the environment monitoring (SEM)

Regional councils have responsibilities under the Resource Management Act (1991) to monitor the state of the environment. The purpose of state of the environment monitoring (SEM) is to collect sufficient data to produce information on the general health of the environment. This information can then be used to measure how well management practices, policies and laws are working, and whether environmental outcomes are being achieved. As part of SEM, environmental performance indicators (EPI's) are used to measure human activities and their effects on the environment. Included amongst these EPI's, faecal indicator bacteria (enterococci, *E. coli* and faecal coliforms) can be monitored to assess the contamination of water by human or animal excreta. Levels of these faecal indicators are of particular interest in coastal waters used for recreational activities due to the potential health risks associated.

The Taranaki Regional Council has monitored faecal indicator bacteria at bathing beaches along the Taranaki coast since 1979, with systematic surveys undertaken from 1987. A more comprehensive annual bathing beach monitoring programme has been implemented from the 1995-1996 summer as an on-going component of the SEM programme for the Taranaki region.

The SEM bacteriological bathing water quality programme has three objectives:

- to characterise the bacteriological quality of principal recreation waters in the Taranaki area, and more specifically to determine their suitability for contact recreation;
- to identify changes in contact recreational water quality over time. Therefore the detection of trends is an important component in programme design;
- to assess compliance with recreational water quality guidelines.

*[**Note**: Contact recreation concerns water-based activities involving a high probability of accidental water ingestion. This mainly applies to bathing, but may also include other high-contact water sports e.g. jet-skiing, surfing, kayaking]*

2. Contact recreation water quality standards and guidelines

2.1 Microbiological water quality guidelines for marine recreational areas (2003)

Guidelines for microbiological water quality of marine recreational areas have been prepared by the Ministry for the Environment in conjunction with the Ministry of Health (MfE, 2003). The guidelines use a combination of a qualitative risk grading of the catchment, together with direct measurements of appropriate faecal indicators to assess the suitability of a site for recreation (see 2.2).

In addition, 'Alert' and 'Action' guideline levels are used for surveillance throughout the bathing season. These guideline levels are summarized in Table 1 and are based on keeping illness risk associated with recreational water use to less than approximately 2%. Levels are based on enterococci counts as these bacteria are the preferred indicators for marine waters. Research has shown that enterococci are the indicator most closely correlated with health effects in New Zealand marine waters, in common with general findings overseas (New Zealand Marine Bathing Study). In coastal waters, faecal coliforms and *E. coli* are not as well correlated with health risks, but can be used as indicators, in addition to enterococci, where enterococci levels alone may be misleading.

Table 1 Surveillance, Alert and Action levels for marine waters (2003)

	Mode		
	Surveillance	**Alert**	**Action**
Enterococci (cfu/100ml)	No single sample >140	Single sample >140	Two consecutive single samples >280
Procedure	• Continue routine monitoring	• Increase sample to daily • Undertake sanitary survey • Identify sources of contamination • Consult CAC to assist in identifying possible source	• Increase sample to daily • Undertake sanitary survey • Identify sources of contamination • Consult CAC to assist in identifying possible source • Erect warning signs • Inform the public through the media that a public health problem exists

CAC = Catchment Assessment Checklist

It should be noted that in an 'alert' state, the beach is still considered suitable of swimming, but monitoring becomes more focused.

2.2 Suitability for recreation grading (SFRG) of sites

The 2003 Microbiological Water Quality Guidelines (MfE, 2003) provide for the grading of recreational water bodies based on two components:

- *The Microbiological Assessment Category (MAC):* this is established on the basis of five years' enterococci data for a particular site, providing a quantitative measurement of the actual water quality over time. Sites are assigned MAC categories ranging from A to D, with definitions provided in Table 2. For the Taranaki region, the Taranaki Regional Council provides the Ministry for the

Environment with these data collected as part of the annual bathing beach monitoring programme.

- *The Sanitary Inspection Category (SIC)*: generates a measure of the susceptibility of a water body to faecal contamination. A site is allocated a category of either Very High, High, Moderate, Low or Very Low, and is determined using the SIC flow chart. Information used in the flow chart comes from the Catchment Assessment Checklist (CAC) which provides qualitative risk information on the catchment. Detailed information about SIC, including the SIC flow chart and the CAC can be found in the 2003 Microbiological Water Quality Guidelines (MfE, 2003).

The SIC is combined with the MAC to determine a Suitability for Recreation Grade (SFRG) for each site. The SFRG therefore describes the general condition of a site based on both qualitative risk grading of the catchment and the quantitative measurement of faecal indicators. A grade is established on the basis of the most recent five years' data and recalculation of a grade is typically performed annually.

Table 2 Microbiological Assessment Categories

MAC	MAC definitions for marine waters
A	Sample 95 percentile ≤ 40 enterococci/100ml
B	Sample 95 percentile 41 - 200 enterococci/100ml
C	Sample 95 percentile 201 - 500 enterococci/100ml
D	Sample 95 percentile > 500 enterococci/100ml

SFRGs, as defined by the Ministry for the Environment, are:

- *Very Good*: considered satisfactory for swimming at all times.
- *Good*: satisfactory for swimming most of the time. Exceptions may include following rainfall.
- *Fair*: generally satisfactory for swimming, though there are many potential sources of faecal material. Caution should be taken during periods of high rainfall, and swimming avoided if water is discoloured.
- *Poor*: generally unsuitable for swimming, as indicated by historical results. Swimming should be avoided, particularly by the very young, the very old and those with compromised immunity.
- *Very Poor*: avoid swimming.

All of the 19 coastal sites monitored by the Council had sufficient data available to calculate SFRG grades for the period spanning November 2012 to April 2017 (Appendix II). Of these 19 sites, 15 were graded 'good', 3 were graded 'fair' and 1 was graded 'poor'. None of the beaches graded 'very poor'. As 17 of the 19 beaches were assigned a SIC of 'moderate' it was not possible for any of these beaches to obtain a 'very good' SFRG grading regardless of the enterococci results used to calculate MAC. This was mainly related to either the agricultural nature of the catchment areas or the presence of nearby steams and rivers which heavily influenced the SIC assessment results.

It must be emphasized that the SFRG grade provides a conservative/precautionary guideline intended for assessing the suitability of beaches for contact recreation from a

public health perspective. The grade is of limited use for assessing the state of the environment, as it includes the SIC: a static assessment based on qualitative information. Instead, the remainder of this report will focus on presenting and interpreting actual faecal indicator data collected during routine monitoring. This quantitative information enables the assessment of general trends in coastal water quality, and can be used to measure how well management practices and policies are working, and whether environmental outcomes are being achieved.

It should be noted that the Ministry itself states that the SFRG '*reflects a precautionary approach to managing public health risks and does not represent an accurate picture of water quality in the catchment. …The grades reflect a precautionary approach to managing health risk and are not designed to represent health risks on a particular day. They tend to reflect the poorest water quality measured at a site rather than the average water quality. A site may be graded as poor but still be suitable for swimming much of the time….The indicator does not replace the site-specific information available on council websites*'[1]

Note: Table 3 takes into account data from both standard SEM samples along with extra samples required by MfE (see Section 3).

Table 3 Suitability for recreation grade for the period November 2012 to April 2017

Site	Sanitary Inspection Category	MAC			SFRG Grade	%of all inspection in compliance
		95%ile	No of samples	Category		
Wai-iti	Moderate 13	56.8	26	B	Good	100
Urenui*	Moderate 13	28.6	26	A	Good	100
Onaero	Moderate 13	241.0	104	C	Fair	95
Onaero Settlement	Low 14	98.4	26	B	Good	100
Waitara (East)	Moderate 13	292.0	76	C	Fair	94
Waitara (West)	Moderate 13	180.0	76	B	Good	97
Fitzroy	Moderate 3	41.5	104	B	Good	99
East End	Moderate 3	101.8	65	B	Good	100
Ngamotu	Moderate 3	119.0	104	B	Good	99
Oakura (SC)	Moderate 13	190.0	104	B	Good	96
Oakura (CG)	Moderate 13	41.5	65	B	Good	100
Opunake*	Moderate 3	21.6	104	A	Good	100
Ohawe	Moderate 13	361.0	76	C	Fair	94
Patea (Mana Bay)	Moderate 13	45.5	39	B	Good	97
Patea*	Moderate 13	28.6	26	A	Good	100
Waverley*	Moderate 13	27.4	26	A	Good	100
Wai-inu	Moderate 13	41.6	26	B	Good	100
Back	Low 14	896.0	26	D	Poor	88
Bell Block	Moderate 3	162.4	26	B	Good	96

13 = River - agricultural activities/birds/feral animal
14 = River - focal points of discharge
3 = Urban stormwater

It may be noted that even though 100% of all samples were compliant with the guidelines at 9 sites, these sites could still not be graded as 'very good' due to the way in which the SFRG grade is derived.

[1] *Suitability for swimming: Indicator update July 2013: INFO 690*, Ministry for the Environment

3. Monitoring methodology

3.1 SEM sample collection

The monitoring network is designed to assess coastal water quality in terms of its suitability for contact recreation. As such, the network targets the main bathing times and avoids, as far as possible, the localized influence of diffuse sources (i.e. streams and rivers) on coastal water quality. For these reasons the following criteria have been adopted during sampling:

Sample collection, field measurements, transport and analyses were undertaken according to documented Taranaki Regional Council procedures. It was intended that on average, four samples would be collected from each of the sites in each month when hydrological flow conditions permitted, within two hours of high tide. SEM sampling was performed only under dry weather flow conditions (i.e. not within three days of a fresh). Bathing water samples were taken between the hours of 0900 and 1800 hours (NZDT) to reflect the most likely period for swimming usage. Where necessary, a 2 m sampling pole was used for bacteriological sample collection immediately beneath the water surface and at a minimum of knee depth at the sites (Photo 1). Thirteen samples were collected from each site during the season.

Results for the 2016-2017 bathing season were posted on the Taranaki Regional Council website (www.trc.govt.nz) as soon as checking had been completed. Where single results fell in the Action mode, further sampling was performed when necessary i.e. where historical databases and staff expertise indicated this was warranted.

3.2 Sample analysis

Samples were analyzed for enterococci, *E. coli*, faecal coliforms and conductivity. *E. coli* and faecal coliform numbers were obtained using the mTEC agar method #9213-d, Standard Methods for the Examination of Waters and Wastewaters (APHA, 2005). Enterococci were quantified using the EPA modified method #1600 on mEI agar (EPA, 1986).

At each of the sites the following additional information was recorded: time, water temperature, weather condition, wind condition, surf condition, colour/appearance of water, and number of bathers and other users.

3.3 Programme design

The locations of the twelve sites sampled in the 2016-2017 programme are shown in Figure 1 and Table 4.

Table 4 Location of bathing water bacteriological sampling sites 2016-2017

Beach	Location	GPS	Site code
Onaero	Opposite surf lifesaving club	2628254-6244898	SEA900085
Waitara	East Beach	1706602-5683915	SEA901033
Waitara	West Beach	1705951-5683802	SEA901037
Bell Block	West of Mangati Stream	2609210-6242224	SEA902001
Fitzroy	Opposite surf lifesaving club	2605036-6239351	SEA902025
East End	Opposite surf lifesaving club	2604605-6239000	SEA902035
Ngamotu	Centre of beach	2600022-6237765	SEA902062
Back	To the north of the Herekawe Stream	2598198-6236896	SEA902070
Oakura	Oppostie surf lifesaving club, south of Wairau Stream	2591974-6231726	SEA903030
Oakura	Opposite motorcamp, south of Waimoku Stream	2591700-6231600	SEA903032
Opunake	Centre of beach	2583775-6193800	SEA904090
Ohawe	Adjacent to boat ramp, east of Waingongoro River	2612688-6179169	SEA906010

Primary beach sites are monitored each year (Figure 1). Remaining beach sites are sampled on a three year rotation, with Year 2 beaches sampled during the 2016-2017 monitoring programme (Table 5).

Table 5 Coastal bathing beach sampling programme

Annually sampled	Year 1	Year 2	Year 3
Fitzroy	Patea	Bell Block	Wai-iti
Ngamotu	Patea Bay **	East End	Urenui
Oakura CG	Waverley	Back Beach	Onaero Settlement
Oakura SC	Wai-inu		
Opunake			
Ohawe *			
Onaero (opp. surf club)			
Waitara East			
Waitara West			

**since 1996-97*
*** since 2000-01 summer period*

Photo 1 Bacteriological sampling

3.3.1 Additional monitoring (MfE guidelines)

The revised guidelines (MfE, 2003) require weekly surveillance monitoring during the 5-month recreational period, with a minimum of 20 sampling dates, regardless of weather conditions or state of the tide. Following consultation with the territorial local authorities and the Taranaki District Health Board, TRC added seven sampling dates to the SEM protocol at five of the most popular marine recreational sites (Onaero, Fitzroy, Ngamotu, Oakura and Opunake beaches) in the 2002-2003 period. These seven sampling dates were systematically selected (one per week) in weeks not sampled by the SEM programme. Sampling was undertaken regardless of prior weather conditions or tides but adhering to all other SEM programme protocols. [NB: These data will not be used for trend analysis purposes as they do not comply with the format of the originally established SEM programme].

3.3.2 Weekly monitoring (2016-2017)

In the 2016-2017 period, monitoring frequency was increased to at least weekly between December and February at eight of the most popular coastal recreational sites (Onaero, Waitara West, Waitara East, Fitzroy, Ngamotu, Oakura Surf Club, Opunake and Ohawe), to align fully with the MfE guidelines and the reporting protocols for the LAWA website. Monitoring over the Christmas to New Year period was specifically included to cover a typically popular bathing period. When possible, the SEM protocol of dry weather monitoring (near high water for estuarine sites) was followed. In weeks when weather or tide did not meet the SEM protocol, sampling occurred no later in the week than Thursday to allow posting of results before the weekend. [Note: These additional data have not been used for trend detection purposes as they do not comply with the format of the originally established SEM programme]. This is the first year that the increased intensity of sampling has been implemented.

3.4 Long-term trend analysis

For sites with sufficient data (≥10 years), non-parametric trend analysis was performed using annual median enterococci data. For each site, a LOWESS (Logically Weighted Scatterplot) line (tension 0.4) was fitted to a temporal scatter plot of the enterococci median data. Statistical significance of the trend was tested using a Mann-Kendall test. The sign (+/-) of the Kendall tau value was used to assess whether the trend was positive or negative and the significance of the trend was determined using the p value ($p < 0.05$ = significant).

When multiple correlations are undertaken, there is a chance that some will be found to be significant purely by chance. In order to deal with this potential problem, the Benjamini-Hochberg False Discovery Rate (FDR) method was applied to the results of the Mann-Kendall test. Further justification for this statistical approach can be found in Stark and Fowles (2006).

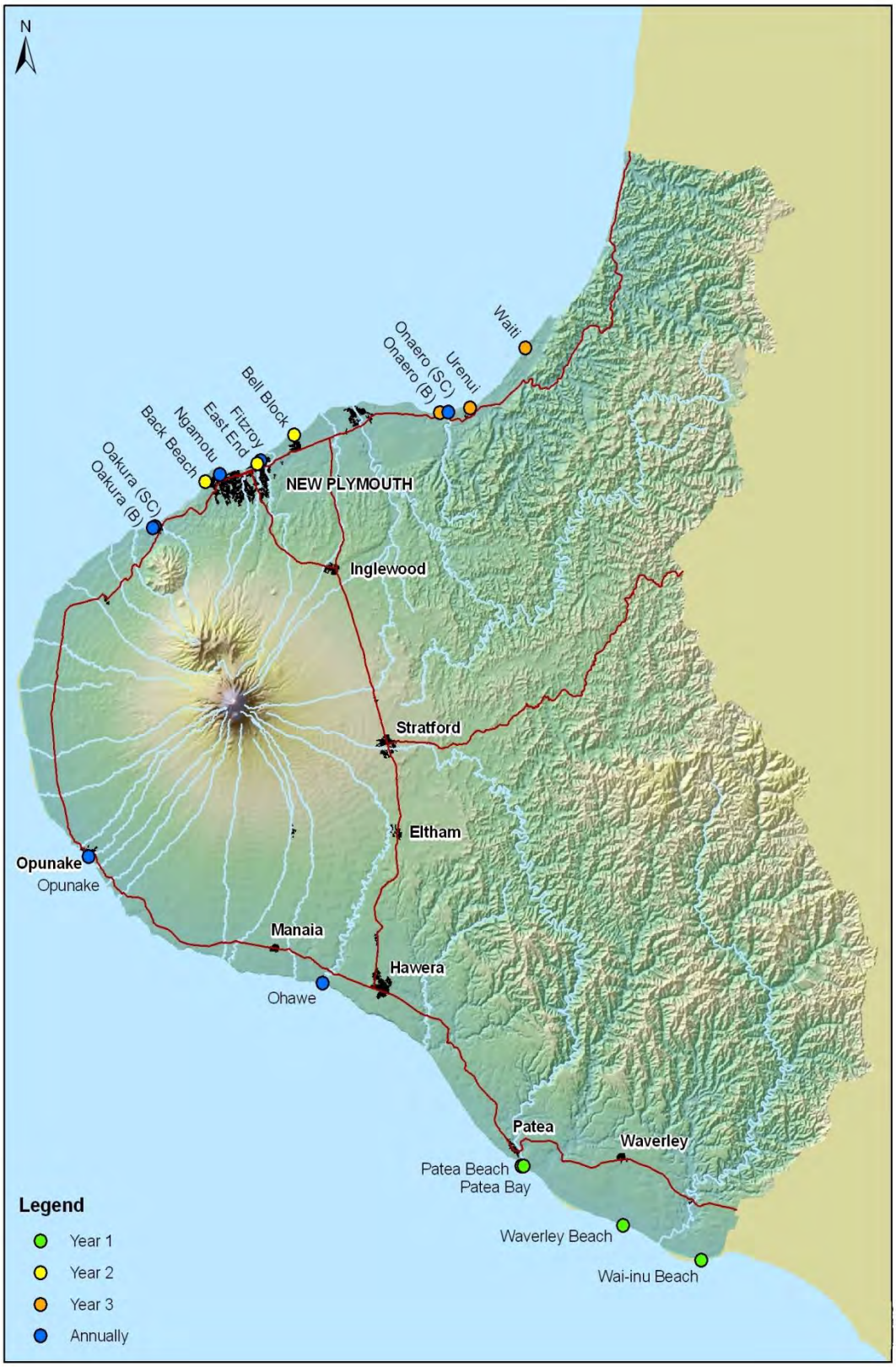


Figure 1 SEM beach bathing bacteriological survey sites

4. Results

From 1 November 2016 to 11 April 2017 a total of 13 samples were collected at each site for the purpose of state of the environment monitoring (SEM). Whenever possible, no SEM sampling was undertaken within three days following significant river freshes. However, occasionally sampling was affected by localized rainfall and elevated river flows. An additional eleven samples were taken at eight of the beaches (Onaero, Waitara West, Waitara East, Fitzroy, Ngamotu, Oakura Surf Club, Opunake and Ohawe) regardless of weather conditions for the purpose of MfE monitoring (as outlined in Sections 3.3.1 and 3.3.2). All results within this report are presented and discussed on a site-by-site basis for the sampling period. The timing of high tide on the dates sampled is provided in Appendix I.

Sampling was confined to weekdays, with no public holidays included. For these reasons, recreational usage of the waters was generally less intensive, often with no apparent usage at the time of sampling. However, all sites are known to be regularly utilized for bathing and other contact recreational activities, particularly at weekends, dependent on suitable weather conditions.

4.1 Onaero Beach

4.1.1 SEM programme

Onaero Beach (Photo 2), located in north Taranaki, is a relatively popular bathing beach, particularly over the Christmas holiday period. The Onaero River drains to the southern end of the beach, making a significant contribution to bacteria counts following rainfall events.

Photo 2 Onaero Beach

The data for this site are presented in Table 6 and Figure 2, with a statistical summary provided in Table 7.

Table 6 Bacteriological results for Onaero Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	10:34	4240	38	8	38	16
30 Nov 2016	09:30	4400	110	10	110	16.2
05 Dec 2016	12:25	4270	6	8	6	19.4
12 Jan 2017	08:05	4280	20	14	20	17.7
30 Jan 2017	09:30	4070	44	24	44	18.3
01 Feb 2017	10:40	3500	100	60	100	18.6
10 Feb 2017	09:35	4450	48	170	54	18.7
16 Feb 2017	11:30	4610	10	10	10	19.7
27 Feb 2017	09:10	4720	6	28	6	19.8
02 Mar 2017	10:45	4670	1	7	1	20.3
17 Mar 2017	10:40	4370	19	28	19	19.8
02 Apr 2017	11:45	4490	32	27	32	19.4
11 Apr 2017	09:00	4410	10	14	10	18.2

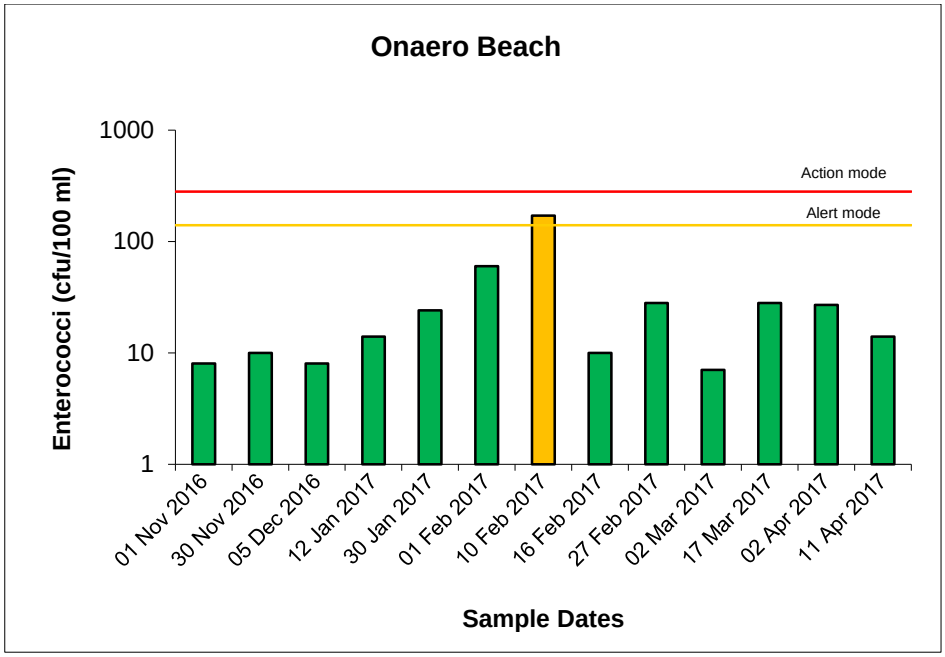


Figure 2 Enterococci counts for the 13 SEM samples taken from Onaero Beach

Table 7 Statistical summary for Onaero Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	3500	4720	4400
E. coli	cfu/100 ml	13	1	110	20
Enterococci	cfu/100 ml	13	7	170	14
Faecal coliforms	cfu/100 ml	13	1	110	20
Temperature	°C	13	16	20.3	18.7

An Alert mode enterococci count (170 cfu/100 ml) was recorded at Onaero Beach on 10 February 2017 associated with lower conductivity (4450 mS/m, Table 6) indicating a small freshwater influence from the Onaero River. All of the other enterococci counts for state of the environment samples were in surveillance mode.

4.1.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Onaero Beach over 18 summers are presented in Table 8 and Figure 3.

Table 8 Summary enterococci data (cfu/100 ml) for summer surveys at Onaero Beach

Summer	96/97	99/00	01/02	02/03	03/04	04/05	05/06	06/07	07/08
Minimum	1	4	5	< 1	<1	<1	<1	2	<1
Maximum	26	40	140	4200	52	1000	46	560	59
Median	13	12	17	9	5	15	4	7	4
Summer	**08/09**	**09/10**	**10/11**	**11/12**	**12/13**	**13/14**	**14/15**	**15/16**	**16/17**
Minimum	2	3	<1	1	<1	1	<1	1	7
Maximum	64	27	96	42	32	25	24	52	170
Median	13	13	11	4	15	5	7	8	14

The median enterococci count obtained for the 2016-2017 summer (14 cfu/100 ml) (Table 9, Figure 3) was towards the higher end of the range previously recorded at this site, likely associated with the wet summer. The maximum enterococci count (170 cfu/100 ml) was within the range previously recorded at this site (Table 8).

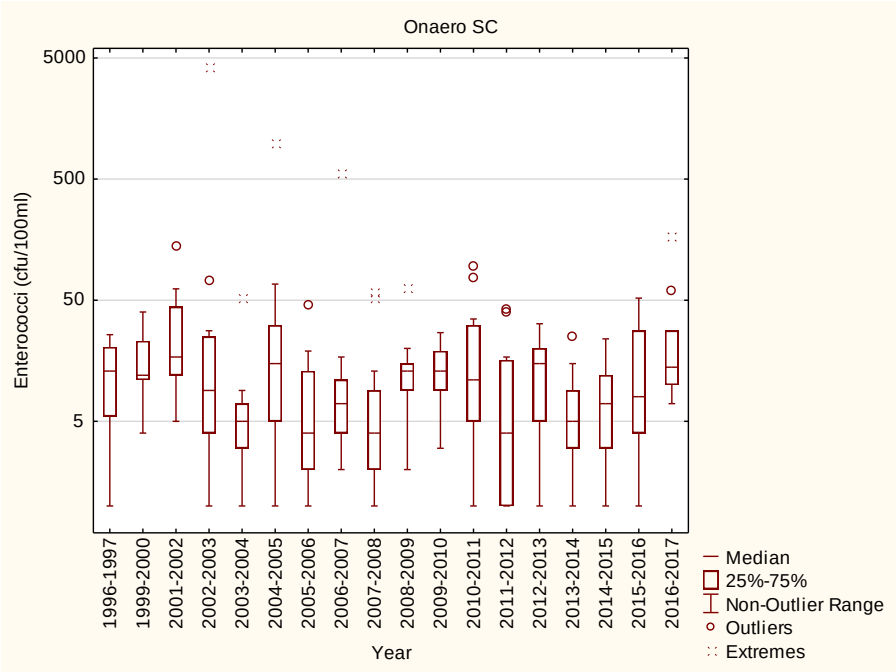


Figure 3 Box and whisker plots of enterococci for all summer SEM surveys at Onearo Beach

4.1.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 12 summer seasons (Figure 4) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

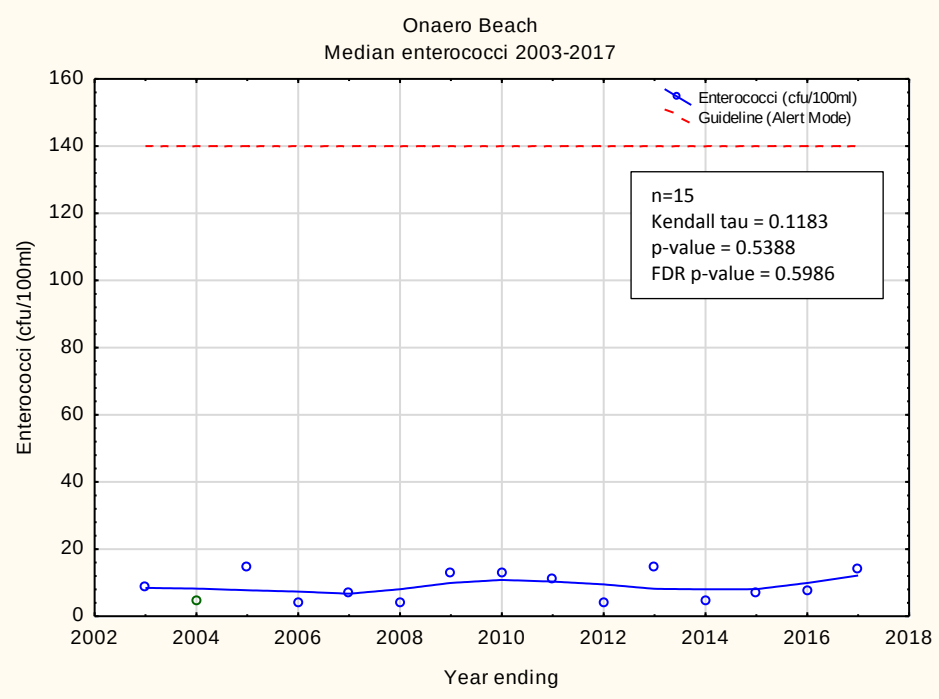


Figure 4 LOWESS trend analysis of median enterococci data at Onaero Beach

Over the 15 seasons monitored, there was a positive trend (i.e. an increase) in median enterococci counts (Kendall tau = 0.118) that was not significant at the 5% level (p = 0.539).

4.1.4 MfE guidelines additional sampling

For the purpose of MfE monitoring, eleven additional samples were collected at regular intervals under varying weather conditions during the survey season. All data, including additional MfE samples, are presented in Table 9 and Figure 5, with a statistical summary provided in Table 10.

Table 9 Bacteriological results for MfE samples at Onaero Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
22 Nov 2016	09:00	1380	260	40	270	17.5
15 Dec 2016	13:00	3840	340	100	340	16.1
21 Dec 2016	08:55	3750	160	27	160	17.3
28 Dec 2016	09:20	4370	80	150	80	17.2
05 Jan 2017	08:45	906	640	200	640	17.3
09 Jan 2017	13:50	2550	400	82	400	19.2
18 Jan 2017	10:45	3770	160	40	160	19
26 Jan 2017	09:10	2080	2100	720	2100	16.8

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
07 Feb 2017	09:00	2520	350	290	360	19
21 Feb 2017	08:30	4040	110	93	110	20.6
07 Mar 2017	11:10	4400	28	12	29	19.3

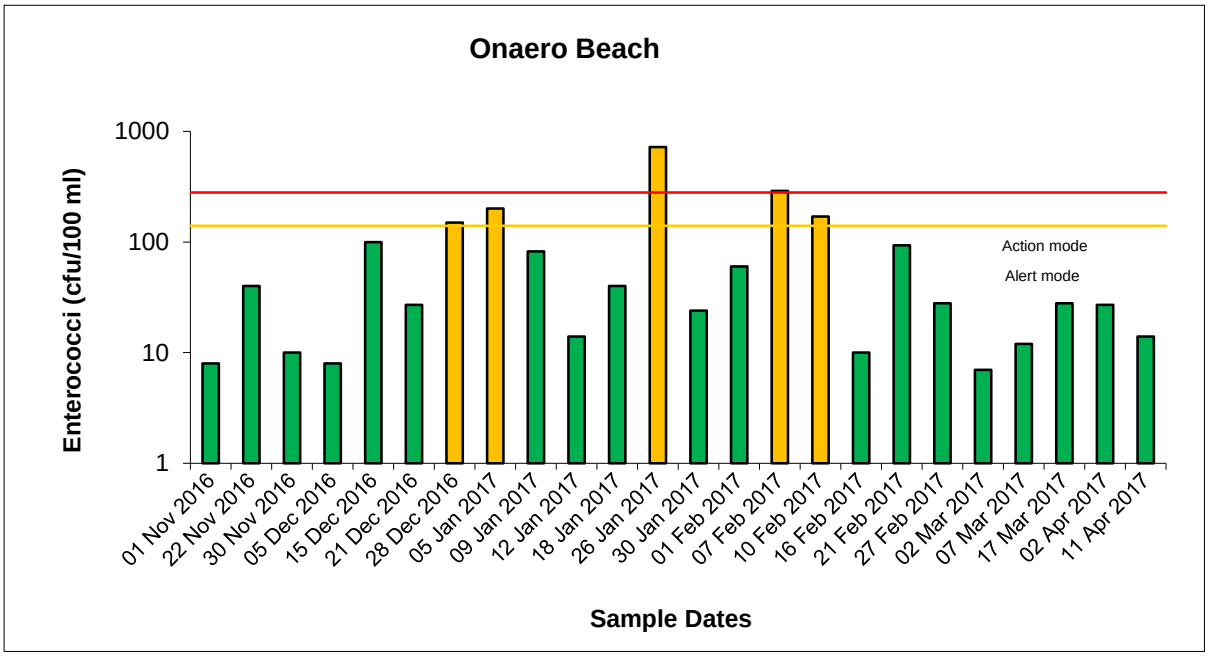


Figure 5 Enterococci numbers for the 24 sample extended survey at Onaero Beach

Table 10 Summary statistics for SEM and MfE samples at Onaero Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	24	906	4720	4255
E. coli	cfu/100 ml	24	1	2100	64
Enterococci	cfu/100 ml	24	7	720	28
Faecal coliforms	cfu/100 ml	24	1	2100	67
Temperature	°C	24	16	20.6	18.7

Elevated enterococci counts obtained on MfE sampling dates were associated with lower conductivity (Table 9, N.B. typical conductivity of seawater is 4750 mS/m). The Onaero River which drains to the southern end of the beach is likely to have made a significant contribution to the higher bacteria counts. In total, five of the twenty four samples collected entered Alert mode (single sample >140 cfu/100ml). Although enterococci counts obtained on two seperate dates exceeded 280 cfu/100 ml (26 January 2017 and 7 February 2017), counts in the follow up samples were below 280 cfu/100 ml and as a result the beach remained in Alert mode.

4.2 Waitara East Beach

4.2.1 SEM programme

Waitara East Beach is located to the east of the Waitara River mouth (Photo 3). Results at this site are influenced by the Waitara River which drains a large agricultural catchment and often contains high levels of bacteria.

Prior to October 2014, municipal wastewater from the Waitara township was discharged through the Waitara Marine Outfall approximately 1.8 km out to sea. Since October 2014, New Plymouth District Council has pumped municipal wastewater from the Waitara township to the New Plymouth Wastewater Treatment Plant and sewage is no longer discharged through the Waitara Marine Outfall during normal operation of the wastewater system.

Photo 3 Waitara East Beach

The data for this site are presented in Table 11 and Figure 6, with a statistical summary provided in Table 12.

Table 11 Bacteriological results for Waitara East Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	10:10	4100	39	9	39	15.9
30 Nov 2016	09:45	2860	1100	150	1100	15.9
05 Dec 2016	12:55	3130	44	4	44	19.1
12 Jan 2017	08:30	3790	33	48	33	18.3
30 Jan 2017	10:10	3500	57	17	64	17.9

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Feb 2017	11:30	3570	24	26	24	18.6
10 Feb 2017	09:10	4500	360	90	360	18.4
16 Feb 2017	12:10	4330	5	5	5	19.1
27 Feb 2017	10:10	4420	360	38	360	19.4
02 Mar 2017	11:40	4100	19	5	19	20.0
17 Mar 2017	12:00	3900	56	5	56	19.9
02 Apr 2017	12:10	4590	3	<1	3	19.5
11 Apr 2017	09:45	4170	92	160	92	18.2

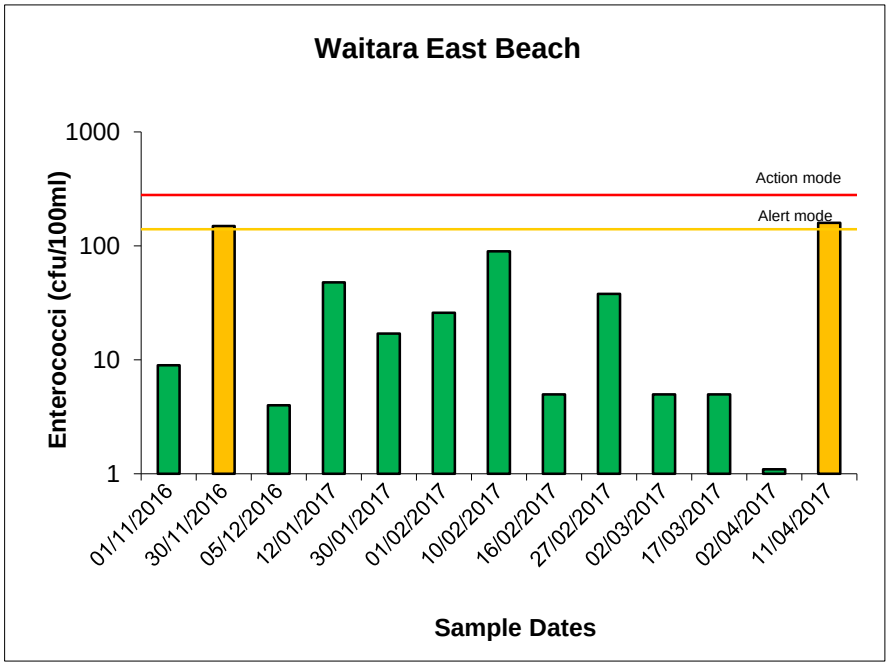


Figure 6 Enterococci counts for the 13 SEM samples taken from Waitara East Beach

Table 12 Statistical summary for Waitara East Beach

Parameter	Unit	Number	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	2860	4590	4100
E. coli	cfu/100 ml	13	3	1100	44
Enterococci	cfu/100 ml	13	4	160	17
Faecal coliforms	cfu/100 ml	13	3	1100	44
Temperature	°C	13	15.9	20	18.6

The two highest enterococci counts (150 and 160 cfu/100 ml) were recorded on 30 November 2016 and 11 April 2017. On both days there was evidence of freshwater influence (2860 and 4170 mS/m, Table 11).

4.2.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Waitara East Beach over 22 summers are presented in Table 13 and Figure 7. Maximum and median enterococci counts obtained during the 2016-2017 summer season were within the range of values previously recorded at this site (Table 16, Figure 7). Maxima at this site are historically high due to the influence of the Waitara River (Table 13).

Table 13 Summary enterococci data (cfu/100 ml) for summer surveys at Waitara East Beach

Summer	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Minimum	1	1	1	3	3	1	4	<1	<1	1	<1
Maximum	950	960	230	250	230	520	290	410	840	310	88
Median	14	11	17	20	40	9	21	13	17	9	9
Summer	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Minimum	1	1	<1	<1	<1	1	<1	<1	<1	<1	<1
Maximum	91	120	2400	210	1000	190	400	220	250	110	160
Median	27	12	41	15	3	6	37	7	1	9	17

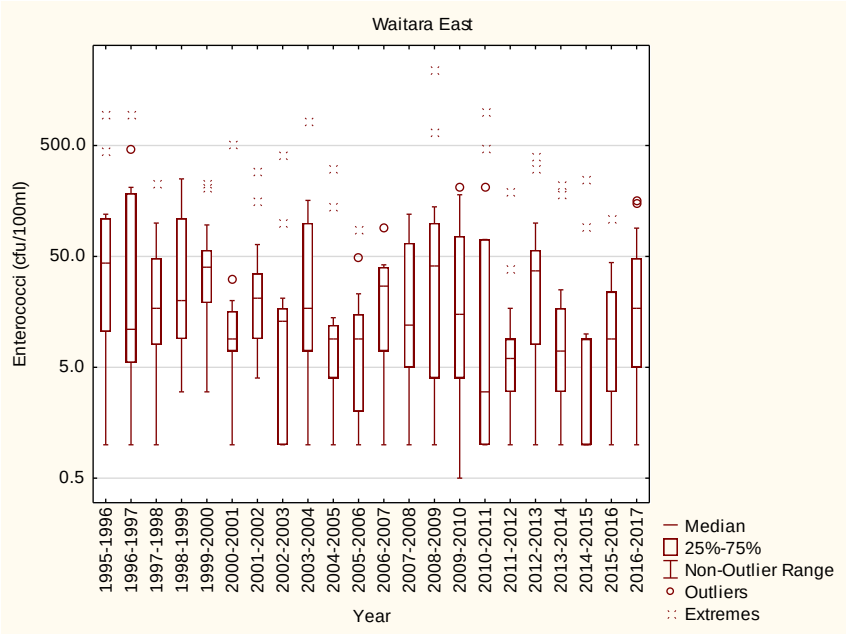


Figure 7 Box and whisker plots of enterococci for all summer surveys at Waitara East Beach

4.2.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 21 summer seasons (Figure 8) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

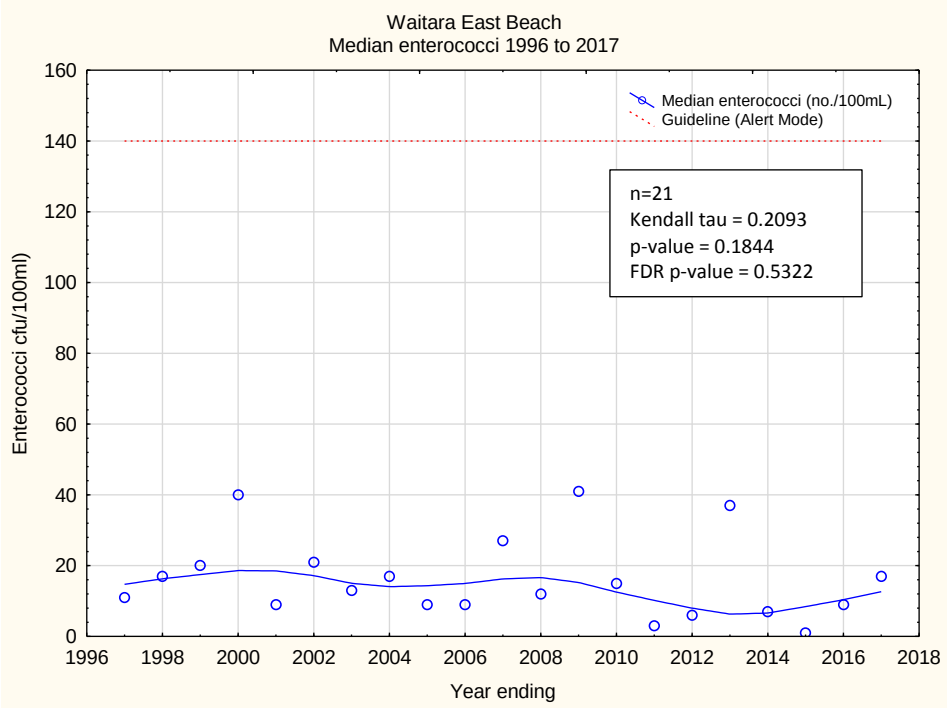


Figure 8 LOWESS trend analysis of median enterococci data at Waitara East Beach

Over the 21 seasons monitored, there was a positive trend (i.e. an increase) in median enterococci counts (Kendall tau = 0.209) that was not significant at the 5% level (p = 0.532).

4.2.4 MfE guidelines additional sampling

For the purpose of MfE monitoring, eleven additional samples were collected at regular intervals under varying weather conditions during the survey season. All data, including additional MfE samples, are presented in Table 14 and Figure 9, with a statistical summary provided in Table 15.

Table 14 Bacteriological results for MfE samples at Waitara East Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
22 Nov 2016	09:35	2270	120	2	120	17.7
15 Dec 2016	10:50	3830	60	21	60	15.5
21 Dec 2016	09:25	1590	200	18	200	18.1

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
28 Dec 2016	09:00	3470	350	72	350	16.5
05 Jan 2017	09:10	1000	1500	1400	1500	17.7
09 Jan 2017	13:30	2940	24	4	26	21.8
18 Jan 2017	10:10	2040	980	100	980	20.2
26 Jan 2017	09:30	2800	2200	650	2200	17.3
07 Feb 2017	09:30	3930	100	14	100	19.5
21 Feb 2017	09:10	4190	130	31	130	20.8
07 Mar 2017	10:40	4390	7	3	7	19

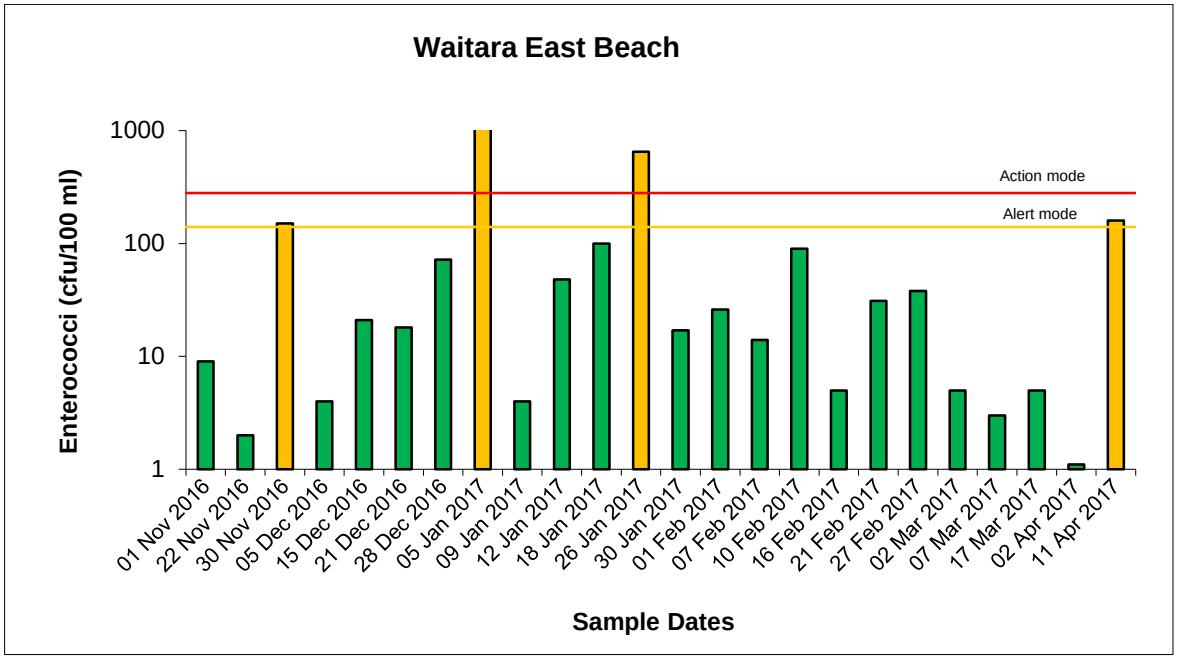


Figure 9 Enterococci numbers for the 24 sample extended survey at Waitara East Beach

Table 15 Summary statistics for SEM and MfE samples at Waitara East Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	24	1000	4590	3810
E. coli	cfu/100 ml	24	3	2200	76
Enterococci	cfu/100 ml	24	<1	1400	20
Faecal coliforms	cfu/100 ml	24	3	2200	78
Temperature	°C	24	15.5	21.8	18.5

Elevated enterococci counts obtained on MfE sampling dates were all associated with lower conductivity (Table 14, N.B. typical conductivity of seawater is 4750 mS/m). In total, four of the twenty four samples collected entered Alert mode (single sample >140 cfu/100ml). Although enterococci counts obtained on two separate dates exceeded 280 cfu/100 ml (5 and 26 January 2017), counts in the follow up samples for the respective dates were below 280 cfu/100 ml and as a result the beach remained in Alert mode and not Action mode (N.B. for Action mode to be reached two consecutive sample of greater than 280 cfu/100 ml are required). The extent to which rainfall, the Waitara River and freshwater run off had affected the samples over the 2016-2017 summer season is reflected in the low median conductivity (3810 mS/m).

4.3 Waitara West Beach

4.3.1 SEM programme

Waitara West Beach is located to the west of the Waitara River mouth (Photo 4). As with Waitara East Beach, the results at this site can be influenced by the Waitara River.

Since October 2014, municipal wastewater from the Waitara Township has been directed to the New Plymouth Wastewater Treatment Plant and is no longer discharged through the Waitara Marine Outfall during normal operation of the wastewater system.

Photo 4 Waitara West Beach

The data for this site are presented in Table 16 and Figure 10, with a statistical summary provided in Table 17.

Table 16 Bacteriological results for Waitara West Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	09:40	3810	24	<1	24	16
30 Nov 2016	10:15	4200	260	40	280	15.8
05 Dec 2016	13:25	3940	10	16	10	20.2
12 Jan 2017	08:55	4130	370	1200	370	18.1
30 Jan 2017	10:40	4330	63	31	63	18
01 Feb 2017	12:00	3680	28	17	28	18.7
10 Feb 2017	08:40	4630	32	34	32	18.5
16 Feb 2017	12:35	4460	11	46	11	19.5
27 Feb 2017	10:40	4670	100	120	110	20.4
02 Mar 2017	12:10	4600	40	24	40	19.8

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
17 Mar 2017	12:15	4160	240	160	250	21.2
02 Apr 2017	12:40	4530	14	40	14	19.4
11 Apr 2017	10:10	4470	48	76	48	18.5

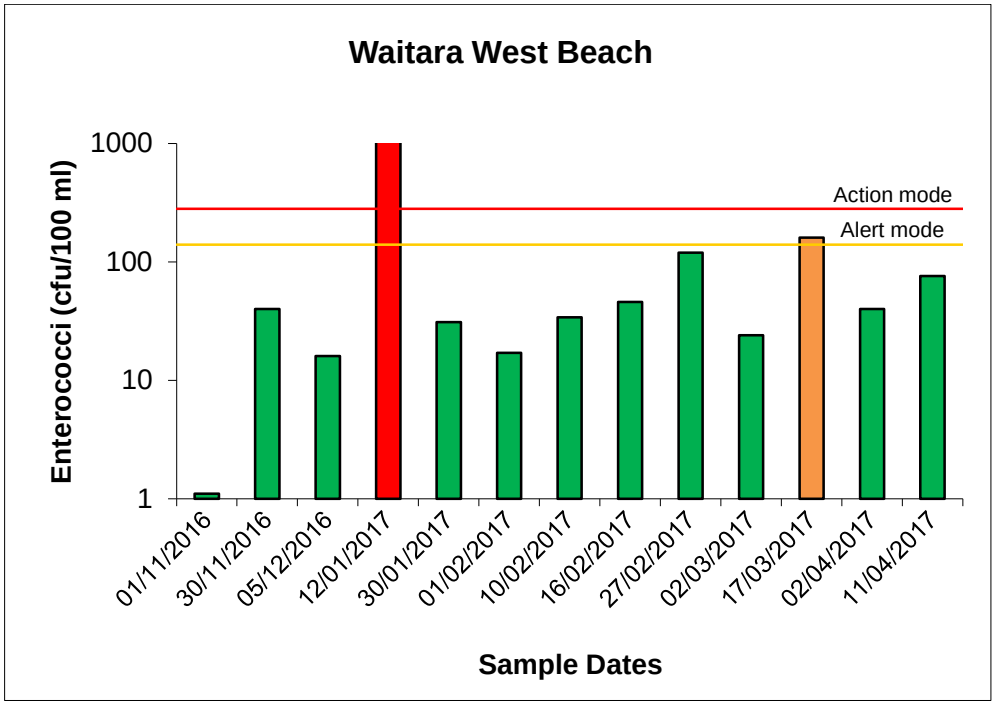


Figure 10 Enterococci counts for the 13 SEM samples taken from Waitara West Beach

Table 17 Statistical summary for Waitara West Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	3680	4670	4330
E. coli	cfu/100 ml	13	10	370	40
Enterococci	cfu/100 ml	13	<1	1200	40
Faecal coliforms	cfu/100 ml	13	10	370	40
Temperature	°C	13	15.8	21.2	18.7

Two elevated enterococci counts were recorded in state of the environment samples during the 2016-2017 monitoring year. The sample taken on 12 January 2017, with an enterococci count of 1200 cfu/100 ml, reached Action level also taking into consideration the high count in the follow up sample collected on 16 January 2017 (2100 cfu/100 ml) i.e. two consecutive samples exceeded 280 cfu/100 ml. The sample collected on 17 March 2017 (160 cfu/100 ml) reached Alert mode. The elevated eneterococci counts were both associated with lower conductivity (4130 mS/m on 12 Janauary and 4160 mS/m on 17 March), indicating freshwater influence, potentially from the Waitara River.

4.3.2 Comparison with previous summer surveys

Summary statistics for enterococci survey data collected at Waitara West Beach over 21 summers are presented in Table 18 and Figure 11. The2016-2017 median enterococci count (40 cfu/100 ml) was towards the higher end of the range previously recorded at this site, likely associated with the wet summer. Enterococci counts at this site are historically high due to the influence of the Waitara River.

Table 18 Summary enterococci data (cfu/100 ml) for summer surveys at Waitara West Beach

Summer	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Minimum	2	1	1	1	3	1	1	1	1	1	1
Maximum	4300	100	340	350	290	240	57	170	800	300	100
Median	21	16	28	5	19	5	11	16	26	7	8
Summer	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Minimum	1	1	2	3	1	<1	3	<1	<1	1	<1
Maximum	240	67	530	42	910	160	90	110	100	590	1200
Median	8	5	120	12	20	13	8	8	4	9	40

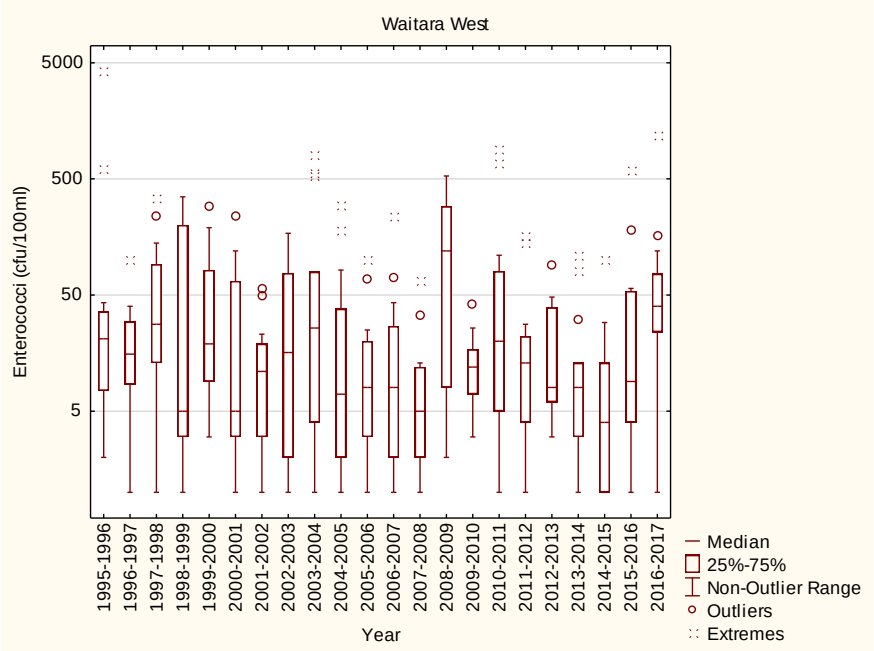


Figure 11 Box and whisker plots of enterococci for all summer SEM surveys at Waitara West Beach

4.3.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 21 summer seasons (Figure 12) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

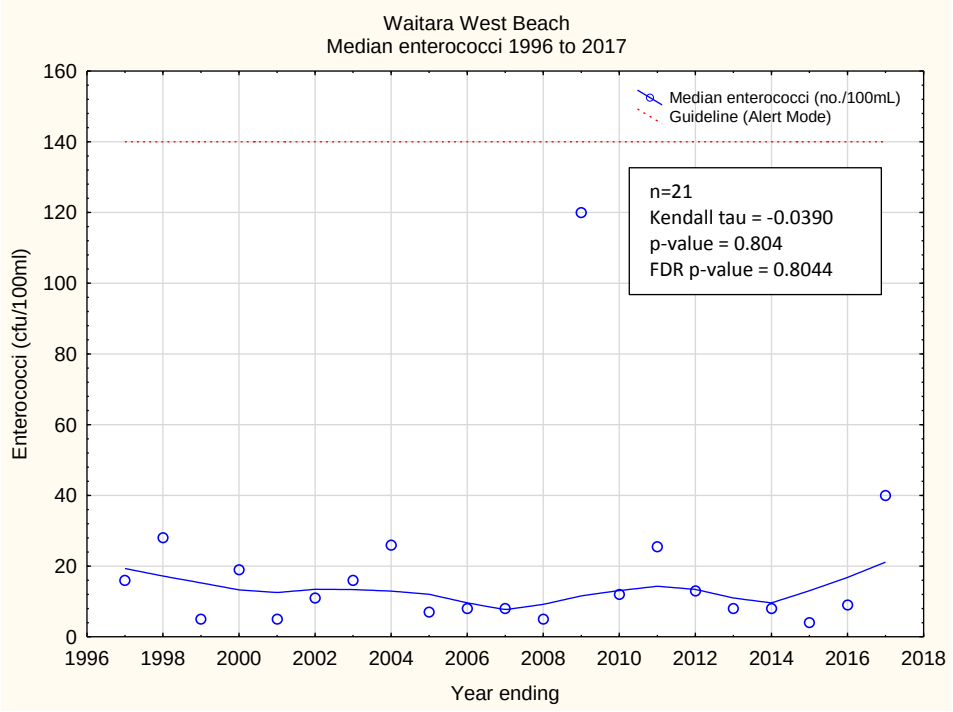


Figure 12 LOWESS trend analysis of median enterococci data at Waitara West Beach

Over the 21 seasons monitored, there was a decreasing trend in median enterococci counts (Kendall tau = -0.039) that was not significant at the 5% level (p = 0.804).

4.3.4 MfE guidelines additional sampling

For the purpose of MfE monitoring, eleven additional samples were collected at regular intervals under varying weather conditions during the survey season. All data, including additional MfE samples, are presented in Table 19 and Figure 13, with a statistical summary provided in Table 20.

Table 19 Bacteriological results for MfE samples at Waitara West Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
22 Nov 2016	09:55	3360	31	<1	31	17.1
15 Dec 2016	11:05	4380	130	110	130	15.7
21 Dec 2016	09:45	3450	54	2	54	18.6
28 Dec 2016	08:40	4320	60	27	60	16.4
05 Jan 2017	09:40	3150	1200	180	1200	18.4
09 Jan 2017	13:10	4440	8	8	8	20.9
18 Jan 2017	09:40	3420	440	46	440	18.2
26 Jan 2017	09:45	4470	200	43	200	17.7

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temperature (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
07 Feb 2017	09:45	2580	540	270	540	19.5
21 Feb 2017	09:35	3780	440	140	460	20.4
07 Mar 2017	10:15	3500	24	13	24	18.5

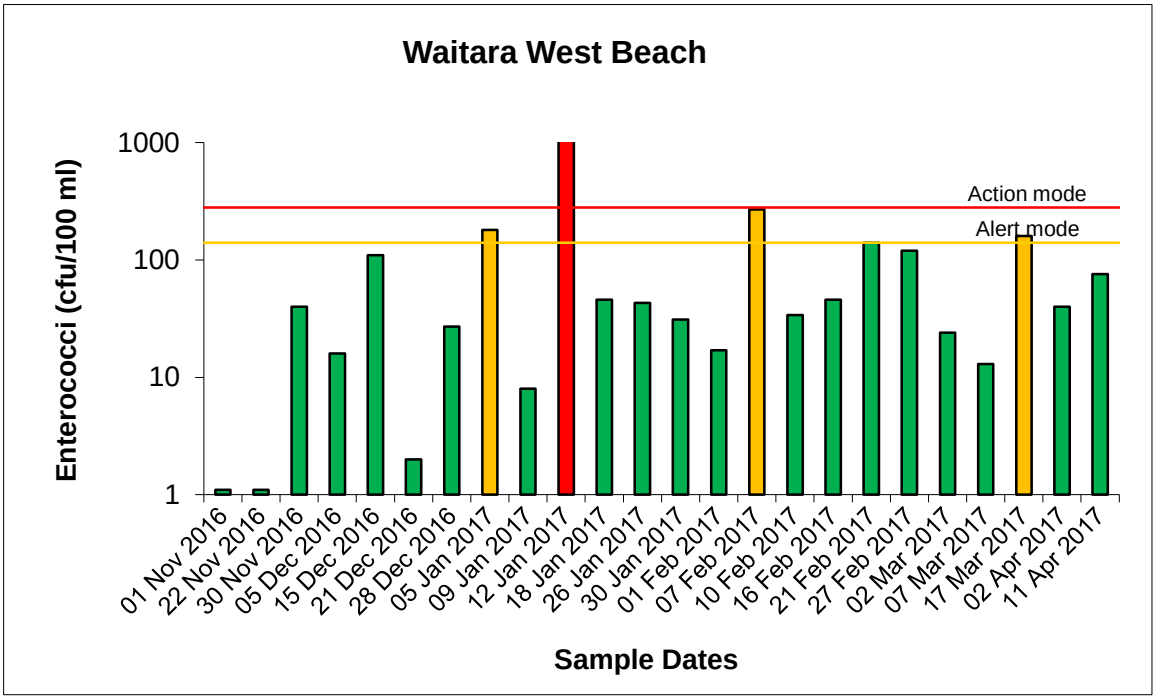


Figure 13 Enterococci numbers for the 24 sample extended survey at Waitara West Beach

Table 20 Summary statistics for SEM and MfE samples at Waitara West Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	24	2580	4670	4180
E. coli	cfu/100 ml	24	8	1200	57
Enterococci	cfu/100 ml	24	0.5	1200	40
Faecal coliforms	cfu/100 ml	24	8	1200	57
Temperature	°C	24	15.7	21.2	18.5

Elevated enterococci counts obtained on MfE sampling dates were associated with lower conductivity (Table 19, N.B. typical conductivity of seawater is 4750 mS/m). In total, three of the twenty four samples collected entered Alert mode (single sample >140 cfu/100 ml) and on one occasion the beach entered Action mode (two consecutive sample of greater than 280 cfu/100 ml). The extent to which rainfall, the Waitara River and freshwater run off had affected the samples over the 2016-2017 summer season is reflected in the low median conductivity (4180mS/m).

Discharge of municipal sewage through the Waitara outfall was terminated in October 2014 for all except contingency events. Review of the monitoring results since then show no pattern of a change in bacteriological levels, implying the outfalls's discharge was not having any discernible ongoing effect upon beach water quality.

4.4 Bell Block Beach

4.4.1 SEM programme

Bell Block Beach (Photo 5) is a moderately popular summer bathing beach located north east of New Plymouth. The Mangati Stream enters the beach in the vicinity of the sample site. This stream drains through a highly modified/industrial catchment, which after rain, may impact significantly on faecal indicator bacteria counts in the receiving waters.

Photo 5 Bell Block Beach

The data for this site are presented in Table 21 and Figure 14, with a statistical summary provided in Table 22.

Table 21 Bacteriological results for Bell Block Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E . coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	09:10	4440	5	1	5	15
30 Nov 2016	11:00	4400	150	57	150	15.6
05 Dec 2016	13:55	4180	14	12	14	19.4
12 Jan 2017	09:25	4320	53	56	56	18.4
30 Jan 2017	11:00	4610	3	5	5	18.2
01 Feb 2017	12:25	4050	77	58	80	18.3
10 Feb 2017	08:15	4570	22	48	22	18.1
16 Feb 2017	13:00	4660	7	15	7	18.9
27 Feb 2017	11:05	4730	1	5	1	20
02 Mar 2017	12:40	4430	42	52	44	20.1
17 Mar 2017	12:45	4560	4	17	4	20
02 Apr 2017	13:25	4590	17	93	17	19.2
11 Apr 2017	10:25	4390	54	82	56	18.5

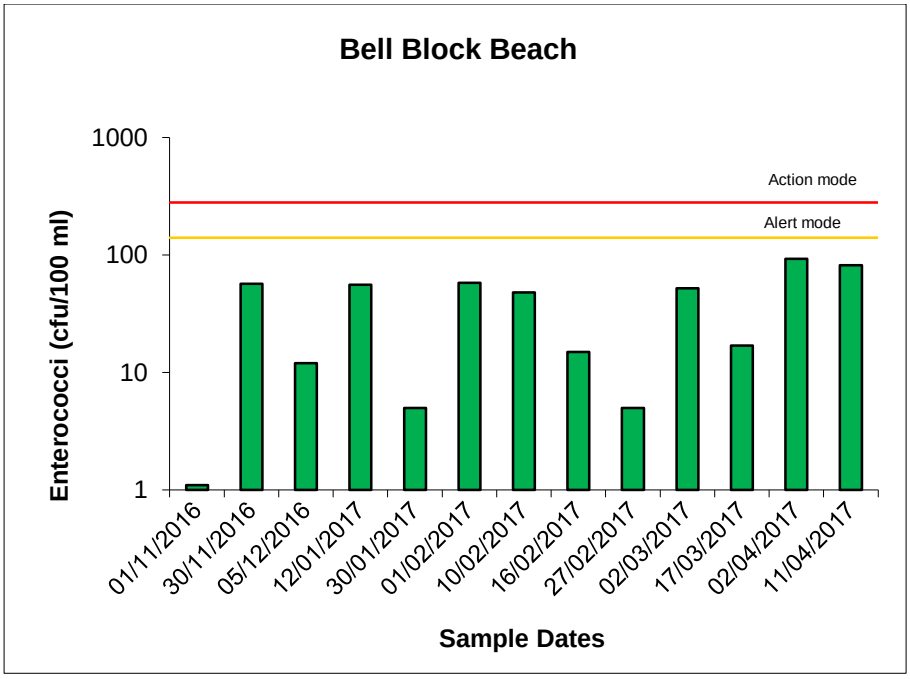


Figure 14 Enterococci counts for the 13 SEM samples taken from Bell Block Beach

Table 22 Statistical results for Bell Block Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4050	4730	4440
E. coli	cfu/100ml	13	1	150	17
Enterococci	cfu/100ml	13	1	93	48
Faecal coliforms	cfu/100ml	13	1	150	17
Temperature	°C	13	15	20.1	18.5

Although the median enterococci count for the site was high (48 cfu/100 ml) all of the thirteen state of the environment samples remained in Surveillance mode.

4.4.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Bell Block Beach are presented in Table 23 and Figure 15.

Table 23 Summary enterococci data (cfu/100 ml) for summer surveys at Bell Block Beach opposite the campground

Summer	1995-96	1998-99	2001-02	2004-05	2007-08
Minimum	3	<1	2	<1	<1
Maximum	480	110	800	600	81
Median	14	4	20	4	42
Summer	**2010-11**	**2013-14**	**2016-17**		
Minimum	1	<1	1		
Maximum	9700	440	93		
Median	5	11	48		

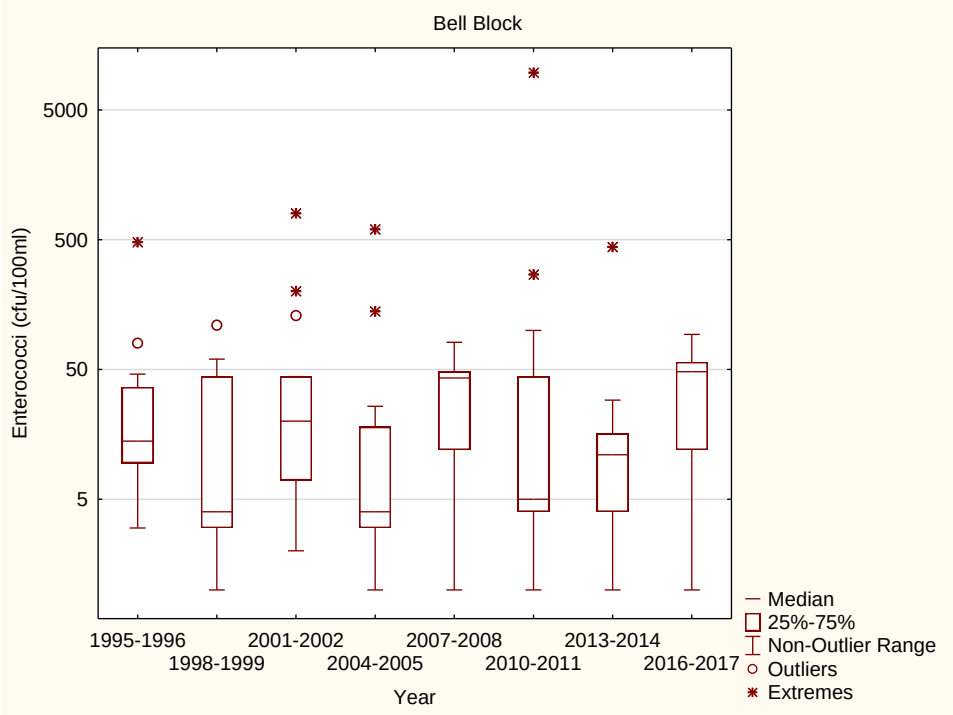


Figure 15 Box and whisker plots of enterococci for all summer SEM surveys at Bell Block Beach

The median enterococci count for the 2016-2017 season was the highest recorded at this site to date. However the maximum count was the lowest recorded at this site to date with all samples collected remaining within Surveillance mode.

4.4.3 Long-term trend analysis

Long-term trend analysis was not undertaken on data from this site as there were an insufficient number of samples (only triennial data available).

4.5 Fitzroy Beach

4.5.1 SEM programme

Fitzroy Beach is situated in New Plymouth and is one of the most popular bathing beaches in Taranaki. It is also a very popular surfing beach due to its central location and high quality waves (Photo 6).

The mouth of the Waiwhakaiho River enters the sea at the eastern end of the beach, approximately 800 m from the sample site, which on rare occasions can contribute significant amounts of freshwater during floods. Draining from a highly modified agricultural and industrial catchment, this can have a significant impact on bacteriological water quality subsequent to heavy rainfall. The river typically has a high level of contamination from birdlife.

Photo 6 Fitzroy Beach

The data for this site are presented in Table 24 and Figure 16, with a statistical summary provided in Table 25.

Table 24 Bacteriological results for Fitzroy Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	09:50	4510	1	11	1	15.2
30 Nov 2016	11:45	4550	11	4	12	15.4
05 Dec 2016	11:30	4440	<1	<1	<1	18.9

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
12 Jan 2017	11:05	4460	12	4	12	18.2
30 Jan 2017	12:50	4420	5	7	5	18.4
01 Feb 2017	13:35	4340	8	3	8	18.4
10 Feb 2017	10:15	4730	89	92	99	17.9
16 Feb 2017	11:35	4740	<1	<1	<1	18.8
27 Feb 2017	11:15	4730	39	4	40	18.8
02 Mar 2017	10:40	4690	1	4	1	18.8
17 Mar 2017	10:55	4620	7	5	7	19.5
02 Apr 2017	13:55	4670	1	5	1	19.7
11 Apr 2017	11:15	4560	27	12	27	19.2

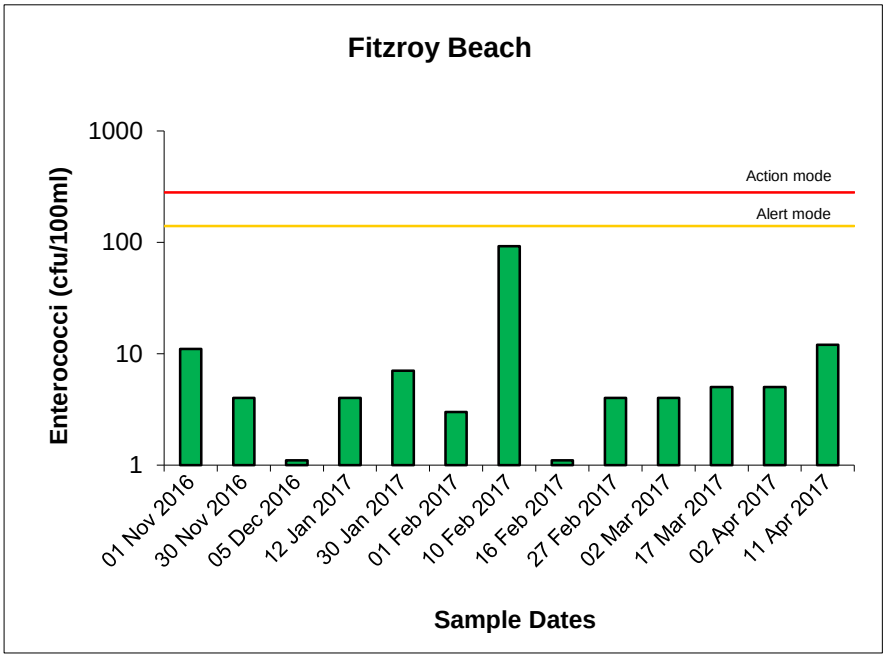


Figure 16 Enterococci counts for the 13 SEM samples taken from Fitzroy Beach

Table 25 Statistical summary for Fitzroy Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4340	4740	4560
E. coli	cfu/100 ml	13	<1	89	7
Enterococci	cfu/100 ml	13	<1	92	4
Faecal coliforms	cfu/100 ml	13	<1	99	7
Temperature	°C	13	15.2	19.7	18.8

Bacteriological water quality at Fitzroy Beach was high throughout the season, with low enterococci median and all counts remaining in Surveillance mode.

4.5.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Fitzroy Beach over 22 summers are presented in Table 26 and Figure 17.

Table 26 Summary enterococci data (cfu/100 ml) for summer surveys at Fitzroy Beach

Summer	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Minimum	3	< 1	< 1	< 1	< 1	< 1	< 1	< 1	<1	<1	<1
Maximum	46	280	40	79	17	98	350	580	98	52	85
Median	10	15	7	7	4	7	9	5	3	4	6
Summer	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Minimum	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1
Maximum	33	44	110	60	43	930	36	45	11	12	92
Median	3	3	10	8	4	3	3	<1	3	3	4

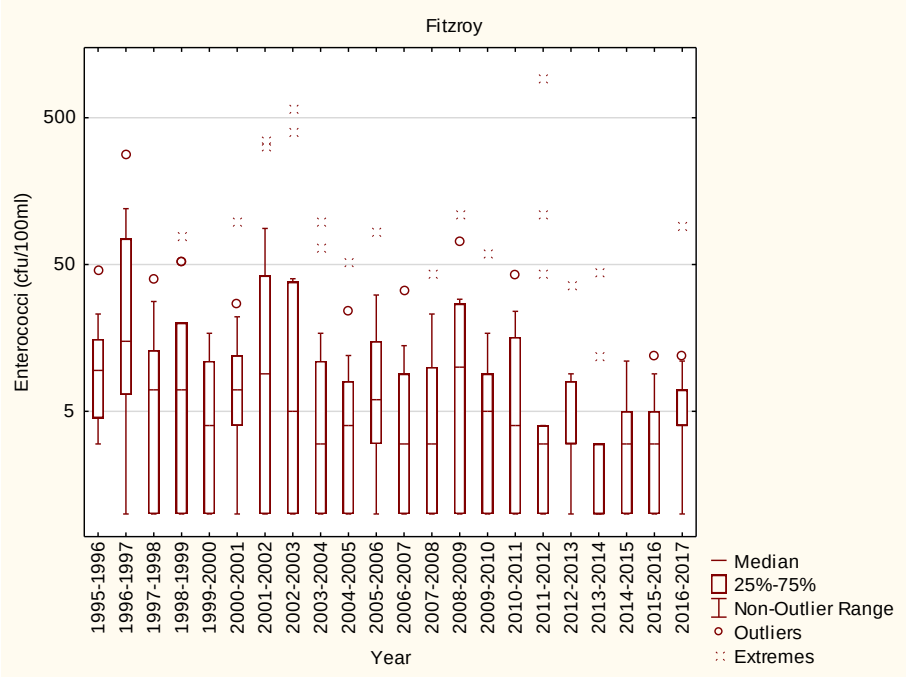


Figure 17 Box and whisker plots of enterococci for all summer SEM surveys at Fitzroy Beach

The low median (4 cfu/100 ml) and maximum (92 cfu/100 ml) enterococci counts recorded in the 2016-2016 monitoring season were typical for this site (Table 26, Figure 17).

4.5.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 22 summer seasons (Figure 18) and

testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

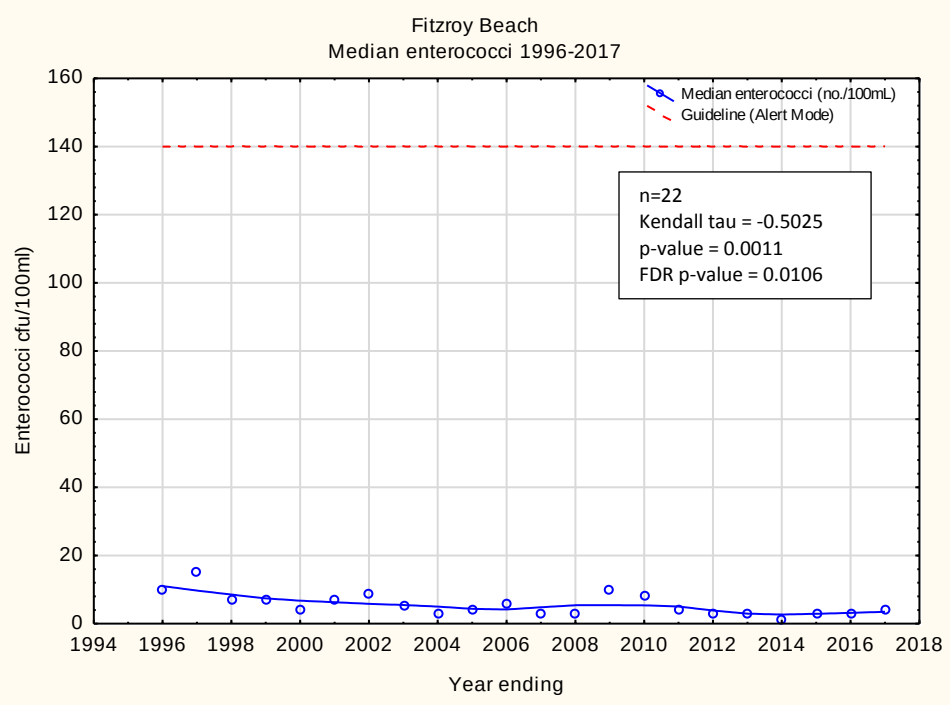


Figure 18 LOWESS trend analysis of median enterococci data at Fitzroy Beach

Over the 22 seasons monitored, there was a decrease in median enterococci counts (Kendall tau = -0.503). This negative trend was significant using the Mann-Kendall test (p = 0.001) and after FDR application (p = 0.011).

4.5.4 MfE guidelines additional sampling

For the purpose of MfE monitoring, eleven additional samples were collected at regular intervals and under varying weather conditions during the survey season. All data, including additional MfE samples, are presented in Table 27 and Figure 19, with a statistical summary provided in Table 28.

Table 27 Bacteriological results for MfE samples at Fitzroy Beach

Date	Time	Conductivity @ 20°C	Bacteria			Temperature
	(NZST)	(mS/m)	*E. coli* (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	(°C)
22 Nov 2016	11:05	4600	4	<1	4	15.7
15 Dec 2016	12:00	4310	600	100	600	15.4
21 Dec 2016	10:30	4660	<1	<1	<1	17.1
28 Dec 2016	08:00	4340	28	5	28	16.0
05 Jan 2017	10:50	4600	9	<1	9	18.1
09 Jan 2017	12:30	4670	1	<1	1	17.6
18 Jan 2017	08:50	4620	13	4	13	17.8
26 Jan 2017	10:35	4320	240	56	240	18.3

Date	Time	Conductivity @ 20°C	Bacteria			Temperature
	(NZST)	(mS/m)	*E. coli* (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	(°C)
07 Feb 2017	11:00	4380	29	23	29	19.1
21 Feb 2017	10:45	4430	6	4	6	21.1
07 Mar 2017	09:05	4720	<1	<1	<1	17.4

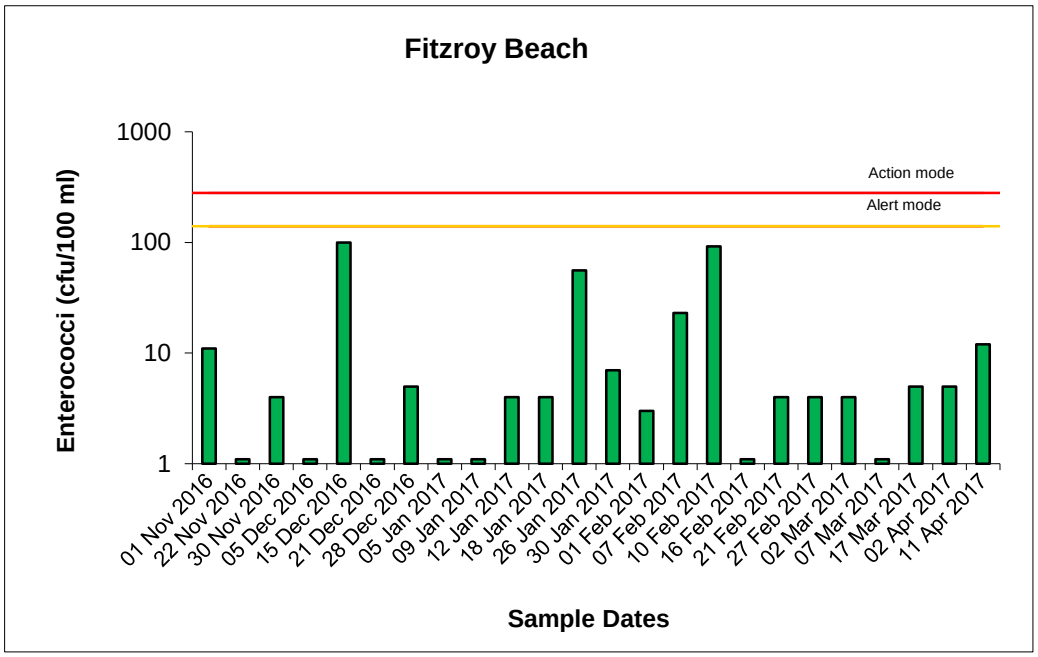


Figure 19 Enterococci counts for the 24 sample extended survey at Fitzroy Beach

Table 28 Summary statistics for SEM and MfE samples at Fitzroy Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	24	4310	4740	4580
E. coli	cfu/100 ml	24	<1	600	8
Enterococci	cfu/100 ml	24	<1	100	4
Faecal coliforms	cfu/100 ml	24	<1	600	8
Temperature	°C	24	15.2	21.1	18.3

Additional sampling resulted in no changes to the overall seasonal median for enterococci (Table 28), with water quality remaining high throughout the season. There was a pronounced fresh water influence in 5 of the additional samples.

4.6 East End Beach

4.6.1 SEM programme

East End Beach is situated approximately 500m south-west of Fitzroy Beach in New Plymouth (Photo 7). This beach is popular with summer bathers and has its own Surf Life-saving Club. The Te Henui Stream enters the sea approximately 200 m to the south-west of the sample site, which can result in high freshwater inputs during significant rainfall events.

Photo 7 East End Beach

The data for this site are presented in Table 29 and Figure 20, with a statistical summary provided in Table 30.

Table 29 Bacteriological results for East End Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/10 0ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	10:00	4510	<1	<1	<1	15.6
30 Nov 2016	11:35	4310	56	30	61	15.3
05 Dec 2016	11:35	4120	3	27	3	18.5
12 Jan 2017	10:50	4270	130	83	130	18.1
30 Jan 2017	12:45	4270	31	25	32	18.1
01 Feb 2017	13:25	4370	13	5	13	18.4
10 Feb 2017	10:05	4750	56	58	56	18.1
16 Feb 2017	11:55	4680	5	8	7	18.5
27 Feb 2017	11:00	4590	36	24	37	18.6

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/10 0ml)	Faecal coliforms (cfu/100 ml)	
02 Mar 2017	11:10	4400	17	12	17	19.3
17 Mar 2017	11:15	4640	1	3	1	19.5
02 Apr 2017	13:40	4660	36	4	36	19.6
11 Apr 2017	11:05	4580	11	5	11	19.1

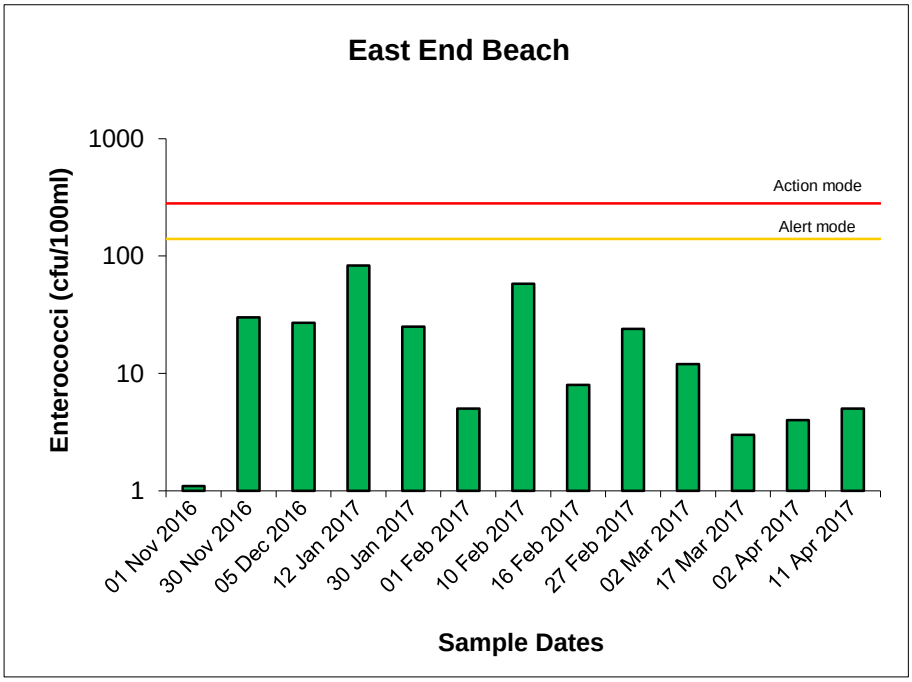


Figure 20 Enterococci counts for the 13 SEM samples taken from East End Beach

Table 30 Statistical results for East End Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4120	4750	4510
E. coli	cfu/100 ml	13	<1	130	17
Enterococci	cfu/100 ml	13	<1	83	12
Faecal coliforms	cfu/100 ml	13	<1	130	17
Temperature	°C	13	15.3	19.6	18.5

In general, water quality was good at this site with all enterococci counts remaining in Surveillance mode (<140 cfu/100 ml).

4.6.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at East End Beach over 7 summer surveys are presented in Table 31 and Figure 21.

Table 31 Summary enterococci data (cfu/100 ml) for summer surveys at East End Beach opposite the campground

Summer	1995-96	1998-99	2001-02	2004-05	2007-08	2010-11	2013-14	2016-17
Minimum	3	1	1	<1	1	<1	<1	<1
Maximum	340	88	200	100	140	57	130	83
Median	18	7	32	4	10	11	3	12

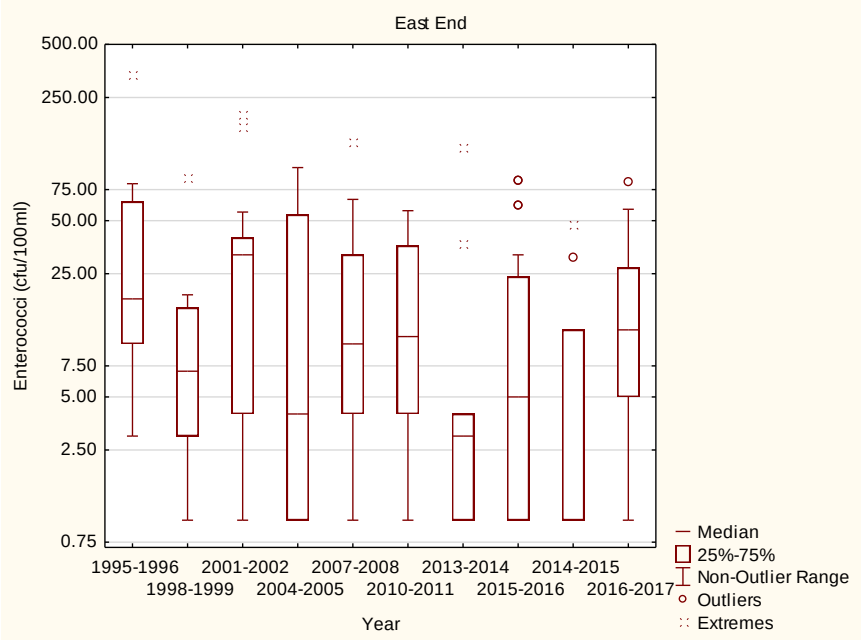


Figure 21 Box and whisker plots of enterococci for all summer SEM surveys at East End Beach

The median enterococci count for the 2016-2017 season was typical for this site (Table 31).

4.6.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 14 summer seasons (Figure 22) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

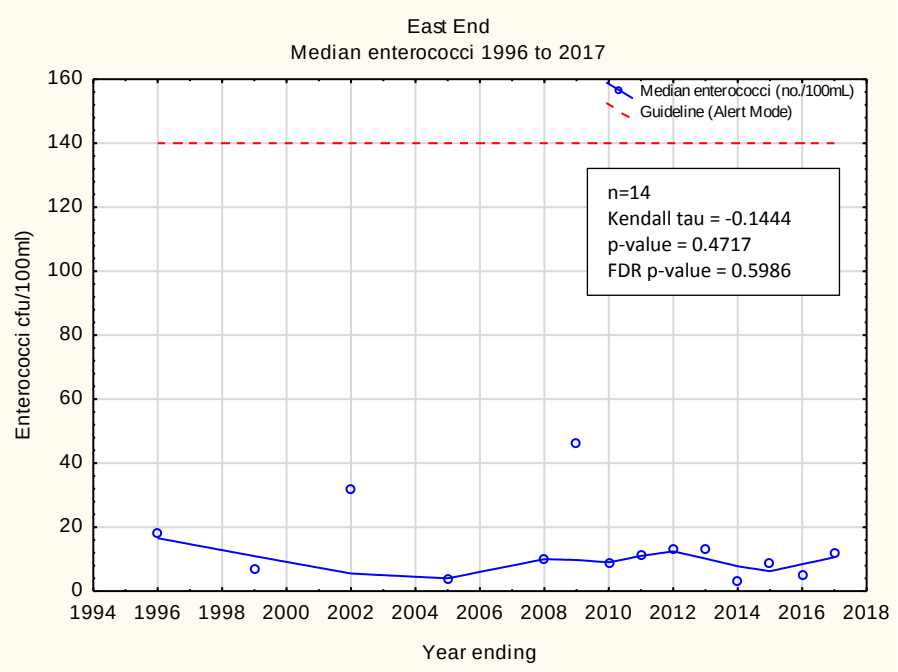


Figure 22 LOWESS trend analysis of median enterococci data at East End Beach

Over the 14 seasons monitored, there was a decreasing trend in median enterococci counts (Kendall tau = -0.144) that was not significant at the 5% level (p = 0.472).

4.7 Ngamotu Beach

4.7.1 SEM programme

Ngamotu Beach (Photo 8) is situated within Port Taranaki, in close proximity to boat traffic and Port activities. It receives urban stormwater and a piped stream. Due to its sheltered location, situated between two breakwaters, this beach is very popular with young children and school groups and is often used for sports events.

Photo 8 Ngamotu Beach

Data for this site are presented in Table 32 and Figure 23, with a statistical summary provided in Table 33.

Table 32 Bacteriological results for Ngamotu Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	10:45	4490	<1	1	<1	16.6
30 Nov 2016	10:45	4580	17	3	17	15.2
05 Dec 2016	12:30	4420	<1	<1	<1	18.7
12 Jan 2017	09:45	4720	190	27	190	17.9
30 Jan 2017	11:55	4660	300	21	300	18.2
01 Feb 2017	12:35	4590	25	16	25	18.3
10 Feb 2017	09:15	4700	380	170	400	18.0
16 Feb 2017	12:50	4710	11	5	11	19.0
27 Feb 2017	10:00	4730	23	9	23	19.2
02 Mar 2017	11:45	4740	<1	1	<1	19.4

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
17 Mar 2017	11:45	4460	29	28	29	21.1
02 Apr 2017	12:45	4580	11	40	13	19.6
11 Apr 2017	10:25	4510	80	27	83	18.8

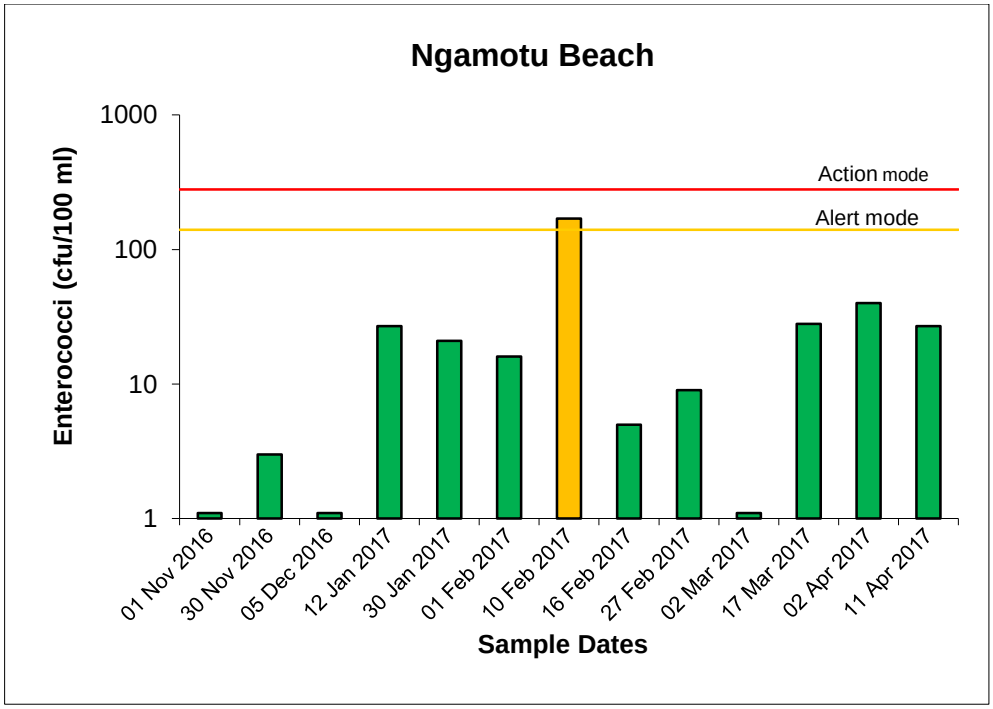


Figure 23 Enterococci counts for the 13 SEM samples taken from Ngamotu Beach

Table 33 Statistical summary for Ngamotu Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4420	4740	4590
E. coli	cfu/100 ml	13	<1	380	23
Enterococci	cfu/100 ml	13	<1	170	16
Faecal coliforms	cfu/100 ml	13	<1	400	23
Temperature	°C	13	15.2	21.1	18.7

One state of the environment sample entered Alert mode (10 February 2017, 170 enterococci cfu/100 ml). The sample was taken during dry weather, reflected by the high conductivity of the sample (4700 mS/m). The reason behind the elevated count remains unexplained. It is noted that black-backed gulls, red-billed gulls and white-fronted terns can flock at this beach (Photo 8).

4.7.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Ngamotu Beach over 22 summers are presented in Table 34 and Figure 24.

Table 34 Summary enterococci data (cfu/100 ml) for summer surveys at Ngamotu Beach

Summer	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Minimum	< 1	1	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1	1
Maximum	160	600	310	72	85	240	630	140	60	230	90
Median	16	13	5	20	11	10	44	27	5	14	13
Summer	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Minimum	1	1	1	<1	<1	1	<1	<1	<1	<1	<1
Maximum	48	350	55	23	180	1000	29	51	110	110	170
Median	12	4	9	4	8	8	4	4	7	7	16

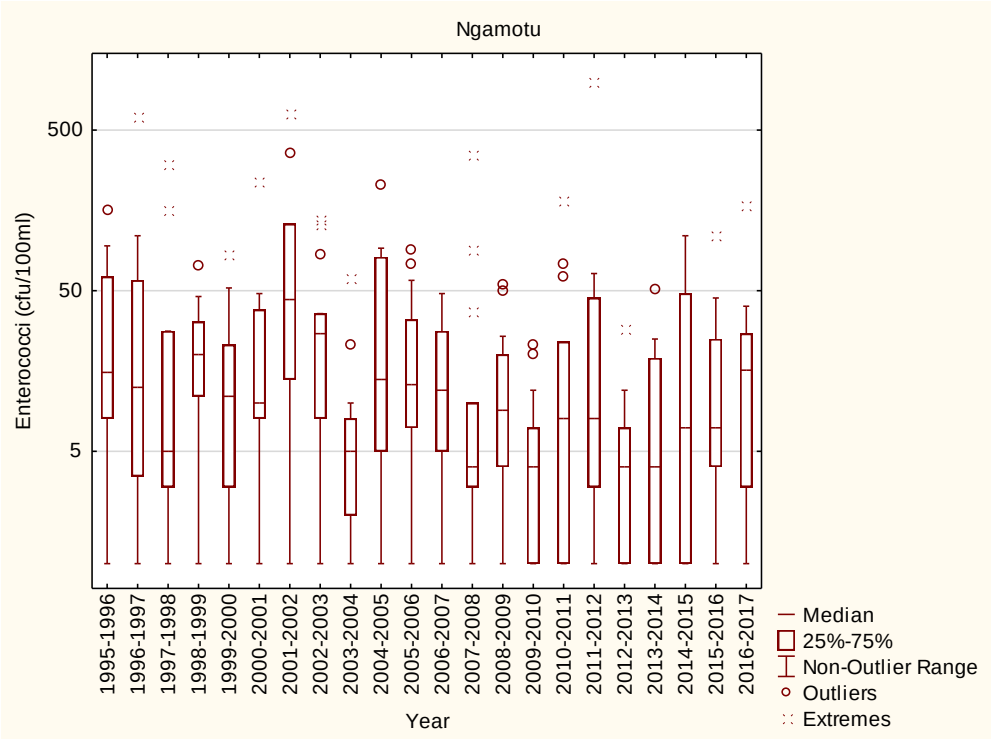


Figure 24 Box & whisker plots of enterococci for all summer SEM surveys at Ngamotu Beach

The median enterococci count (16 cfu/100ml) obtained for the 2016-2017 summer season was the highest recorded at this site for fourteen years.

4.7.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 22 summer seasons (Figure 25) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

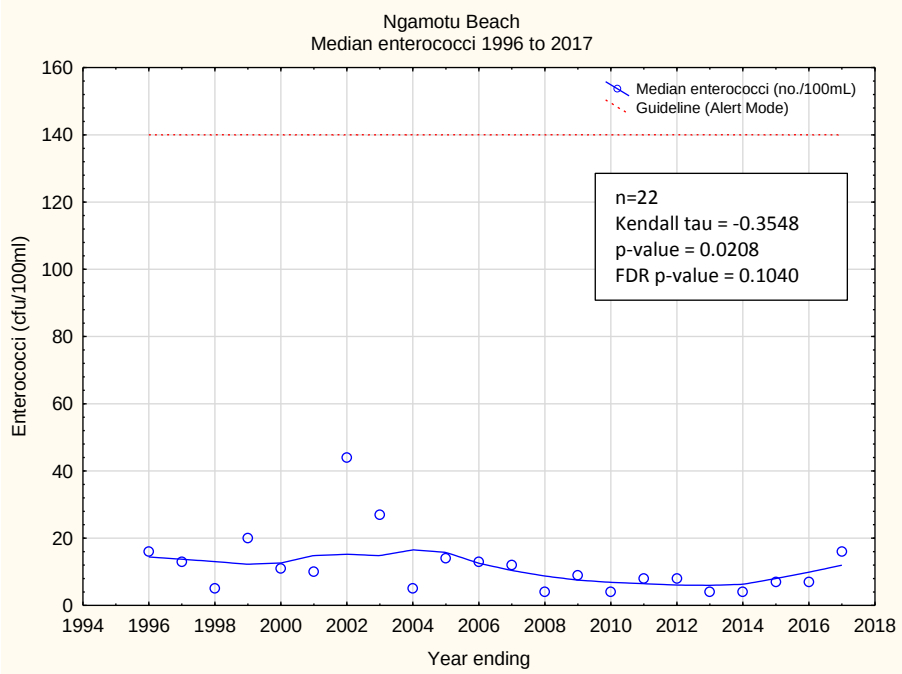


Figure 25 LOWESS trend analysis of median enterococci data at Ngamotu Beach

Over the 22 seasons monitored, there was a decrease in median enterococci counts (Kendall tau = -0.355). This negative trend was significant using the Mann-Kendall test (p = 0.021) but not significant after FDR application (p = 0.104).

4.7.4 MfE guidelines additional sampling

For the purpose of MfE monitoring, eleven additional samples were collected at regular intervals and under varying weather conditions during the survey season. All data, including additional MfE samples, are presented in Table 35 and Figure 26, with a statistical summary provided in Table 36.

Table 35 Bacteriological results for MfE samples at Ngamotu Beach

Date	Time	Conductivity @ 20°C	Bacteria			Temperature
	(NZST)	(mS/m)	*E. coli* (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	(°C)
22 Nov 2016	11:20	4580	<1	<1	<1	17.7
15 Dec 2016	10:20	4620	19	27	19	15.6
21 Dec 2016	11:10	4610	1	1	1	19
28 Dec 2016	07:20	4370	11	<1	11	14.9
05 Jan 2017	11:30	4650	1	5	3	18.9
09 Jan 2017	11:50	4780	<1	4	<1	18.9
18 Jan 2017	08:00	4720	12	8	12	17.1
26 Jan 2017	11:20	4690	<1	1	<1	18
07 Feb 2017	11:30	4480	10	10	10	19.5
21 Feb 2017	11:10	4310	46	170	48	22.2
07 Mar 2017	08:35	4650	88	160	88	17.4

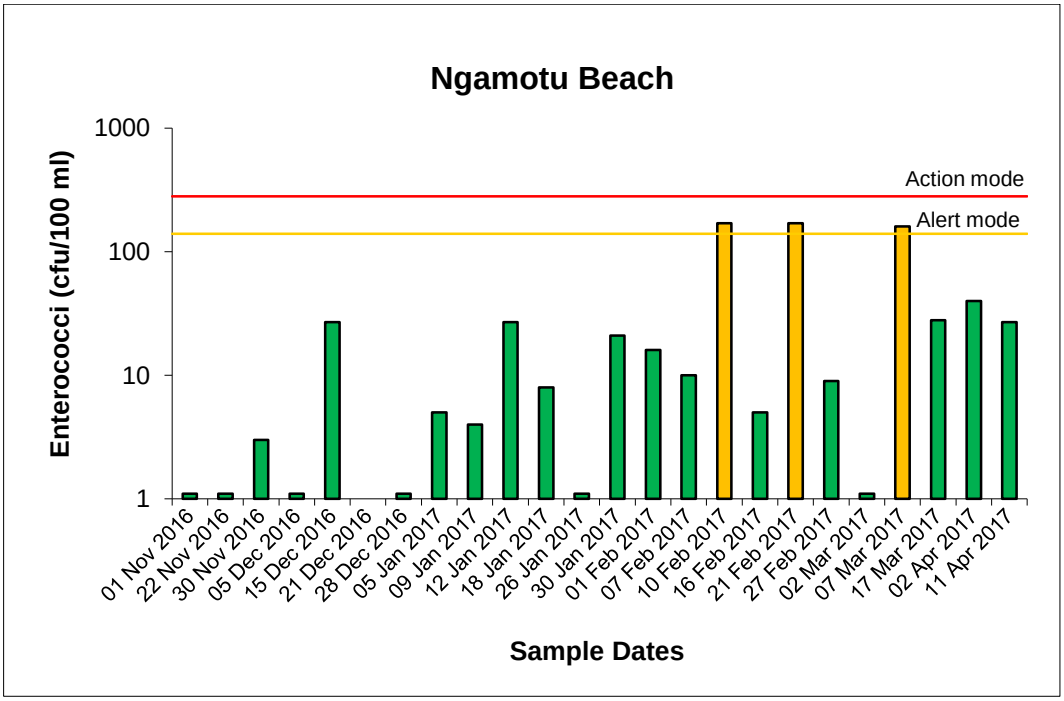


Figure 26 Enterococci counts for the 24 sample extended survey at Ngamotu Beach

Table 36 Summary statistics for SEM and additional samples at Ngamotu Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	24	4310	4780	4615
E. coli	cfu/100 ml	24	<1	380	16

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Enterococci	cfu/100 ml	24	<1	170	13
Faecal coliforms	cfu/100 ml	24	<1	400	16
Temperature	°C	24	14.9	22.2	18.9

Additional sampling resulted in two further Alert mode results. The high conductivity of these samples didn't indicate strong freshwater influence (Table 35). There was a slight decrease in seasonal median for all faecal indicator bacteria (Table 36), when the additional samples are taken into account alongside the SEM programme samples.

4.8 Back Beach

4.8.1 SEM programme

Back Beach (Photo 9) is situated to the west of New Plymouth. It is a very well used beach for swimming over the summer months and popular with surfers year-round. The Herekawe Stream enters the beach approximately 50 m from the sampling site.

Photo 9 Back Beach

The data for this site are presented in Table 37 and Figure 27, with a statistical summary provided in Table 38.

Table 37 Bacteriological results for Back Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	11:05	4270	8	5	8	15.2
30 Nov 2016	10:30	4370	42	25	44	15.4
05 Dec 2016	12:45	4200	16	7	16	17.8
12 Jan 2017	09:25	4680	140	230	160	17.2
30 Jan 2017	11:40	4500	51	53	51	17.7
01 Feb 2017	12:20	4530	73	95	74	18.1
10 Feb 2017	08:55	4600	47	43	47	18.1
16 Feb 2017	13:05	4680	13	32	13	18
27 Feb 2017	09:45	4690	600	670	750	18.8

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Mar 2017	07:07	4540	56	100	56	18.5
02 Mar 2017	12:00	4480	88	110	88	19
17 Mar 2017	11:55	4680	1	5	1	19.5
02 Apr 2017	12:35	4560	8	31	9	19.1
11 Apr 2017	10:15	4510	72	190	72	18.2

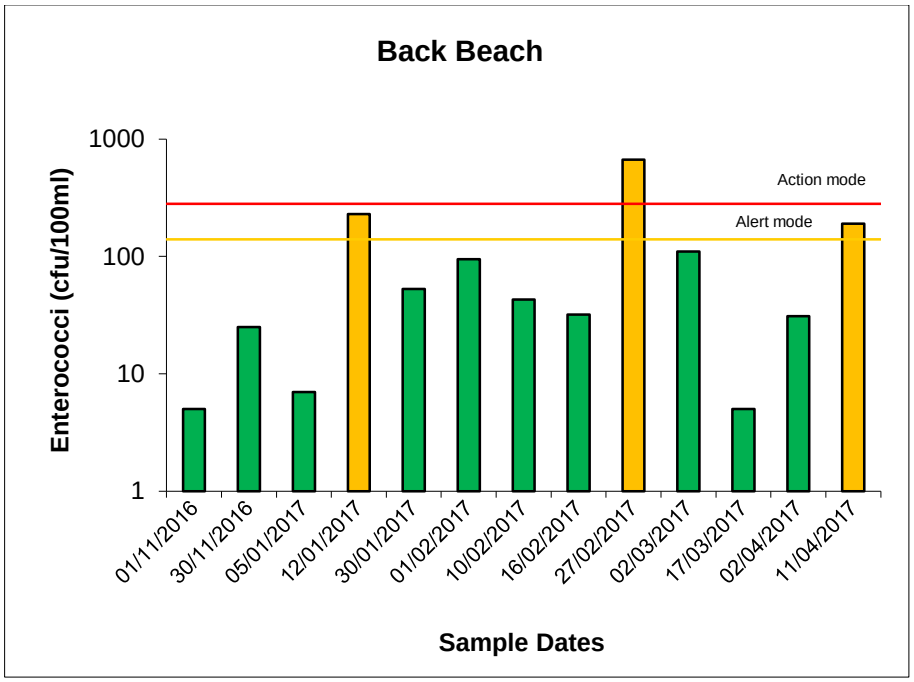


Figure 27 Enterococci counts for the 13 SEM samples taken from Back Beach

Table 38 Statistical results for Back Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4200	4690	4530
E. coli	cfu/100 ml	13	1	600	47
Enterococci	cfu/100 ml	13	5	670	43
Faecal coliforms	cfu/100 ml	13	1	750	47
Temperature	°C	13	15.2	19.5	18.1

The median enterococci count at this site was relatively high (43 cfu/100 ml). A number of high individual counts were recorded on different dates throughout the 2016-2017 summer season, with three exceeding 140 enterococci cfu/100 ml. This site can be susceptible to high faecal indicator bacteria counts at high tide due to the sea channeling into a restricted area with potential influence from the Herekawe Stream and faecal contamination from a range of wild and domesticated animals, together with bird life.

4.8.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Back Beach over 8 summer surveys are presented in Table 39 and Figure 28.

Table 39 Summary enterococci data (cfu/100 ml) for summer surveys at Back Beach

Summer	1995-96	1998-99	2001-02	2004-05	2007-08	2010-11	2013-14	2016-17
Minimum	<1	<1	3	2	5	8	1	5
Maximum	500	160	140	480	110	170	1800	670
Median	12	11	15	24	15	32	27	43

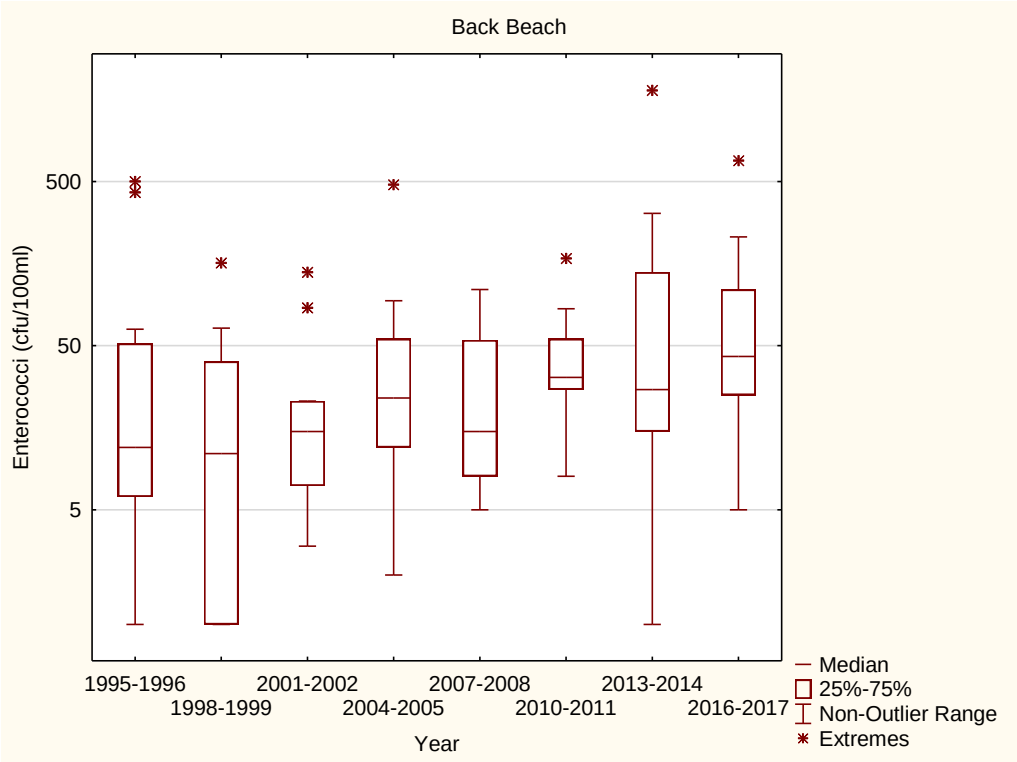


Figure 28 Box and whisker plots of enterococci for all summer SEM surveys at Back Beach

The median enterococci count for the 2016-2017 season (43 cfu/100 ml) was the highest recorded at this site to date. The maximum enterococci count (670 cfu/100 ml) was at the higher end of the historical range for this site (Figure 28).

4.8.3 Long-term trend analysis

Long-term trend analysis was not undertaken on data from this site as there were an insufficient number of samples (only triennial data available).

4.9 Oakura Beach SC (opposite surf lifesaving club)

4.9.1 SEM programme

Oakura Beach (Photo 10) is popular with beach bathers during summer, and frequented by surfers all year-round. Two small lowland streams (Waimoku and Wairau) enter the beach on either side of the site, and as a consequence concentrations of faecal indicator bacteria can increase significantly during periods of high rainfall.

Photo 10 Oakura Beach

The data from this site are presented in Table 40 and Figure 29, with a statistical summary provided in Table 41.

Table 40 Bacteriological results for Oakura Beach SC

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	11:40	3740	63	32	67	15.3
30 Nov 2016	09:45	4430	28	5	28	15.9
05 Dec 2016	13:30	4390	4	1	4	19.5
12 Jan 2017	08:50	4530	40	25	40	17
30 Jan 2017	10:55	4560	20	39	21	18.4
01 Feb 2017	11:45	4520	25	25	25	17.9
10 Feb 2017	08:25	4370	130	91	130	17.5

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
16 Feb 2017	13:40	3800	99	160	100	17.9
27 Feb 2017	09:10	4740	<1	1	<1	18.5
02 Mar 2017	12:45	4720	<1	<1	<1	18.7
17 Mar 2017	12:30	4550	<1	<1	<1	20.4
02 Apr 2017	12:05	4660	3	9	3	19.4
11 Apr 2017	09:40	4550	3	3	3	18.5

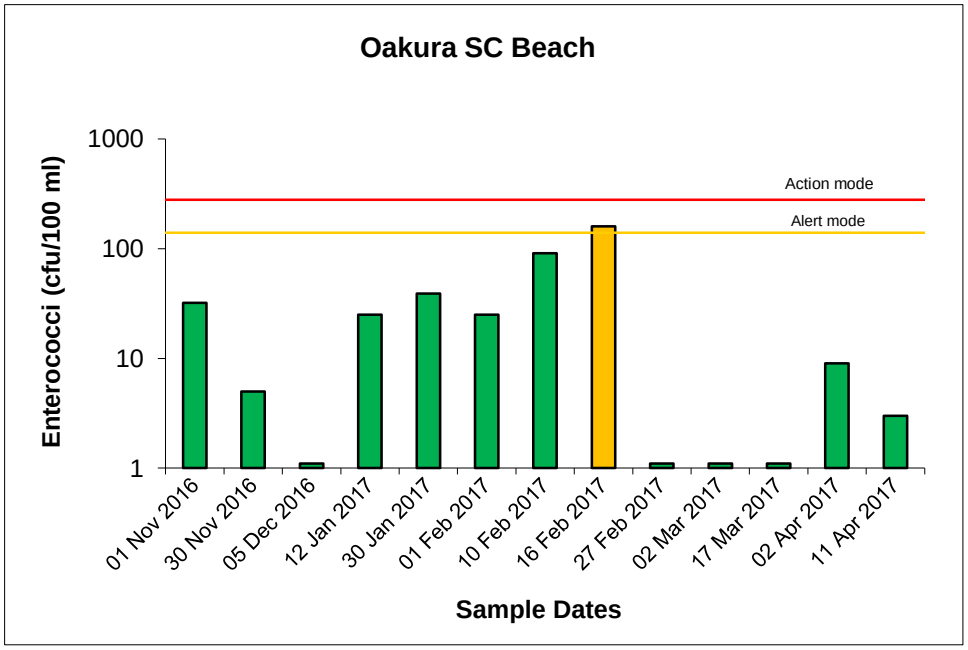


Figure 29 Enterococci counts for the 13 SEM samples taken from Oakura Beach SC

Table 41 Statistical summary for Oakura Beach SC

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	3740	4740	4530
E. coli	cfu/100 ml	13	<1	130	20
Enterococci	cfu/100 ml	13	<1	160	9
Faecal coliforms	cfu/100 ml	13	<1	130	21
Temperature	°C	13	15.3	20.4	18.4

The location of the Waimoku and Wairau stream mouths can influence water quality at this site. Microbial source tracking has shown that resident wildfowl are the principal contributors to elevated faecal indicator bacteria counts within these streams, particularly in the case of the Waimoku Stream (TRC 2011-01).

The Waimoku Stream (site WMK000298) was sampled on 13 occasions during the 2016-2017 summer season and faecal indicator bacteria counts were found to be

consistently high (770-5700 *E. coli* cfu/100 ml, 460-2500 enterococci cfu/100 ml).

Over the 2016-2017 summer season the Waimoku Stream gradually cut east across Oakura Beach towards the surf lifesaving club due to the build up of sand at the stream mouth (Photo 11). It appears that the stream had most influence on coastal water quality at the monitoring site during January and February when higher faecal indicator bacteria counts were recorded.

The Waimoku Stream was straightened (digging a channel through sand bank) by New Plymouth District Council but not until after all beach bathing monitoring had been completed for the 2016-2017 summer season. The purpose of straightening the stream was to reduce erosion to the east of the stream mouth.

Photo 11 Changing position of the Waimoku Stream mouth in relation to Oakura Beach: 1 November 2016 (top), 30 November 2016 (second down), 12 January 2017 (third down), 27 February 2017 (fourth down), 21 March 2017 (bottom)

4.9.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Oakura Beach opposite the surf lifesaving club over 22 summers are presented in Table 42 and Figure 30.

Table 42 Summary enterococci data (cfu/100 ml) for summer surveys at Oakura SC

Summer	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Minimum	< 3	< 3	< 1	5	< 1	1	4	1	< 1	2	1
Maximum	800	56	60	56	880	16	120	180	94	250	300
Median	31	8	21	16	7	5	25	8	8	25	12
Summer	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Minimum	<1	4	5	5	2	1	7	4	4	<1	<1
Maximum	230	160	250	800	100	130	460	650	180	54	160
Median	11	32	20	45	17	36	17	29	57	3	9

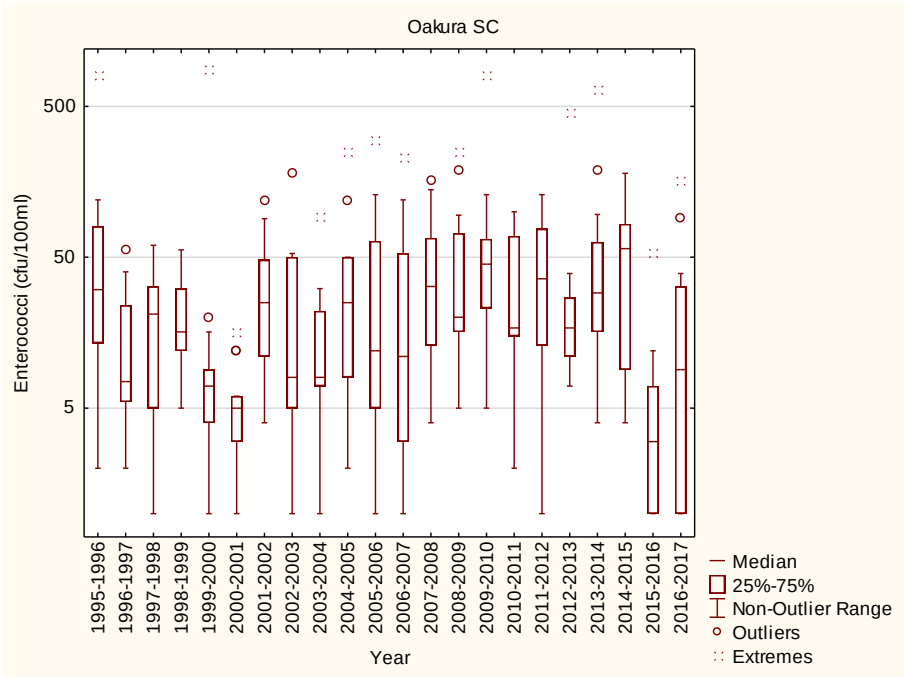


Figure 30 Box & whisker plots of enterococci for all summer SEM surveys at Oakura SC

The median enterococci count (9 cfu/100 ml) obtained for the 2016-2017 summer season was at the lower end of the range for this site (Table 42, Figure 30). Interannual variation in median enterococci counts at this site can be largely attributed to the changing location of the small stream mouths relative to the sampling site. It is recommended that photographs continue to be taken so that changes in position of the stream mouth can be tracked over a summer season and between summer seasons.

4.9.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 22 summer seasons (Figure 31) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

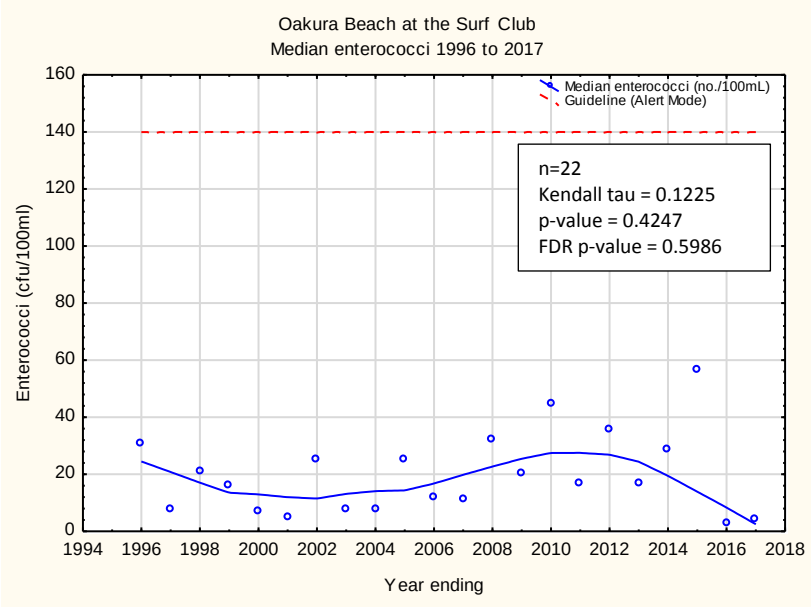


Figure 31 LOWESS trend analysis of median enterococci data at Oakura Beach SC

Over the 22 seasons monitored, there was a positive trend (i.e. an increase) in median enterococci counts (Kendall tau = 0.123) that was not significant at the 5% level (p = 0.599).

4.9.4 MfE guidelines additional sampling

For the purpose of MfE monitoring, eleven additional samples were collected at irregular intervals and under varying weather conditions during the survey season. All data, including additional MfE samples, are presented in Table 43 and Figure 32, with a statistical summary provided in Table 44.

Table 43 Bacteriological results for MfE samples at Oakura Beach SC

Date	Time	Conductivity @ 20°C	Bacteria			Temperature
	(NZST)	(mS/m)	*E. coli* (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	(°C)
22 Nov 2016	12:05	4390	76	8	80	16.5
15 Dec 2016	09:55	4480	140	40	140	14.9
21 Dec 2016	11:45	4580	1	1	1	18.3
28 Dec 2016	07:00	4200	120	33	120	15.1
05 Jan 2017	11:55	4330	56	50	58	19.7
09 Jan 2017	10:30	4520	16	6	17	16.2
18 Jan 2017	07:45	4580	36	14	36	17.6
26 Jan 2017	11:40	3940	77	82	81	18
07 Feb 2017	11:55	4050	360	440	370	18.4
21 Feb 2017	11:35	3840	100	190	100	20.5

Date	Time	Conductivity @ 20°C	Bacteria			Temperature
	(NZST)	(mS/m)	*E. coli* (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	(°C)
07 Mar 2017	08:00	4690	1	8	1	17.5

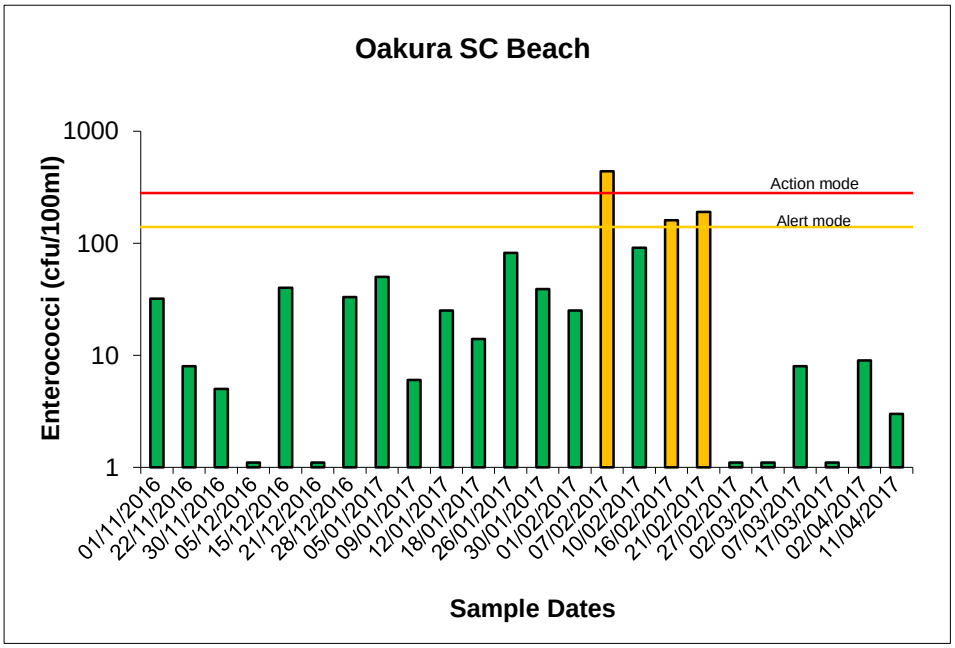


Figure 32 Enterococci numbers for the 24 sample extended survey at Oakura Beach SC

Table 44 Summary statistics for SEM and MfE samples at Oakura Beach SC

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	24	3740	4740	4500
E. coli	cfu/100 ml	24	<1	360	32
Enterococci	cfu/100 ml	24	<1	440	20
Faecal coliforms	cfu/100 ml	24	<1	370	32
Temperature	°C	24	14.9	20.5	18.0

Additional sampling increased the seasonal medians for all faecal indicator bacteria and reduced the median conductivity indicating increased freshwater influence (Tables 48 and 52). All three Alert mode samples (>140 cfu/100 ml) were associated with low conductivity (Table 43) indicating increasing effect from the Waimoku and Wairau streams.

4.10 Oakura Beach CG (opposite camp ground)

4.10.1 SEM programme

This site, situated at the west end of Oakura Beach in front of the campground, is a popular site with bathers and surfers (Photo 12).

Photo 12 Oakura Beach in front of the campground

The data for this site are presented in Table 45 and Figure 33, with a statistical summary provided in Table 46.

Table 45 Bacteriological results for Oakura Beach CG

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	12:00	4520	<1	<1	<1	15.5
30 Nov 2016	09:25	4510	7	3	7	15.3
05 Dec 2016	13:35	4550	3	5	3	19.1
12 Jan 2017	08:30	4640	5	8	5	16.9
30 Jan 2017	10:45	4690	<1	<1	<1	18.3
01 Feb 2017	11:30	4610	4	5	4	17.9
10 Feb 2017	08:20	4650	51	49	51	17.5
16 Feb 2017	13:55	4680	<1	1	<1	18.4
27 Feb 2017	08:35	4740	<1	4	<1	18.5
02 Mar 2017	13:15	4410	16	29	16	19
17 Mar 2017	12:45	4560	<1	4	<1	20.8
02 Apr 2017	11:45	4700	1	1	1	19.1
11 Apr 2017	09:20	4460	31	36	31	18.3

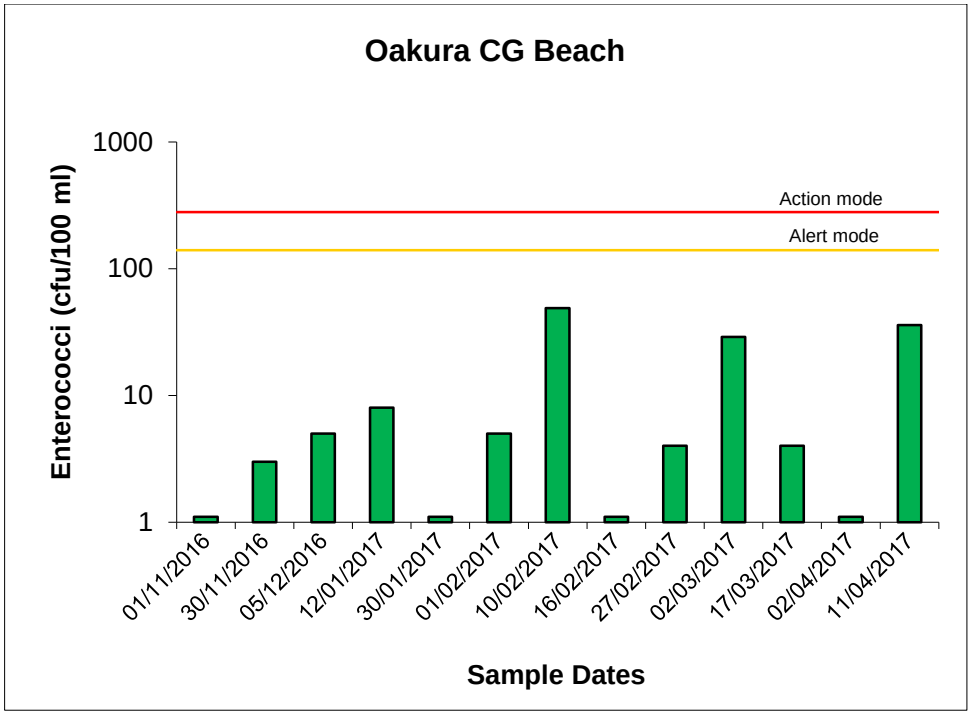


Figure 33 Enterococci counts for the 13 SEM samples taken from Oakura Beach CG

Table 46 Statistical results for Oakura Beach CG

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4410	4740	4610
E. coli	cfu/100 ml	13	<1	51	3
Enterococci	cfu/100 ml	13	<1	49	4
Faecal coliforms	cfu/100 ml	13	<1	51	3
Temperature	°C	13	15.3	20.8	18.3

Water quality was extremely good at this site with low medians for all faecal indicator bacteria (≤4 cfu/100ml), despite a frequent although minor freshwater influence. All samples remained in Surveillance mode throughout the monitoring period.

4.10.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Oakura Beach opposite the campground over 22 summer surveys are presented in Table 47 and Figure 34.

Table 47 Summary enterococci data (cfu/100 ml) for summer surveys at Oakura Beach opposite the campground

Summer	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Minimum	2	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	<1
Maximum	280	150	24	16	48	240	31	17	24	90	8
Median	9	5	2	4	3	3	7	3	3	6	1
Summer	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Minimum	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Maximum	260	18	30	25	33	79	260	37	160	21	49
Median	3	7	6	1	<1	4	3	3	4	1	4

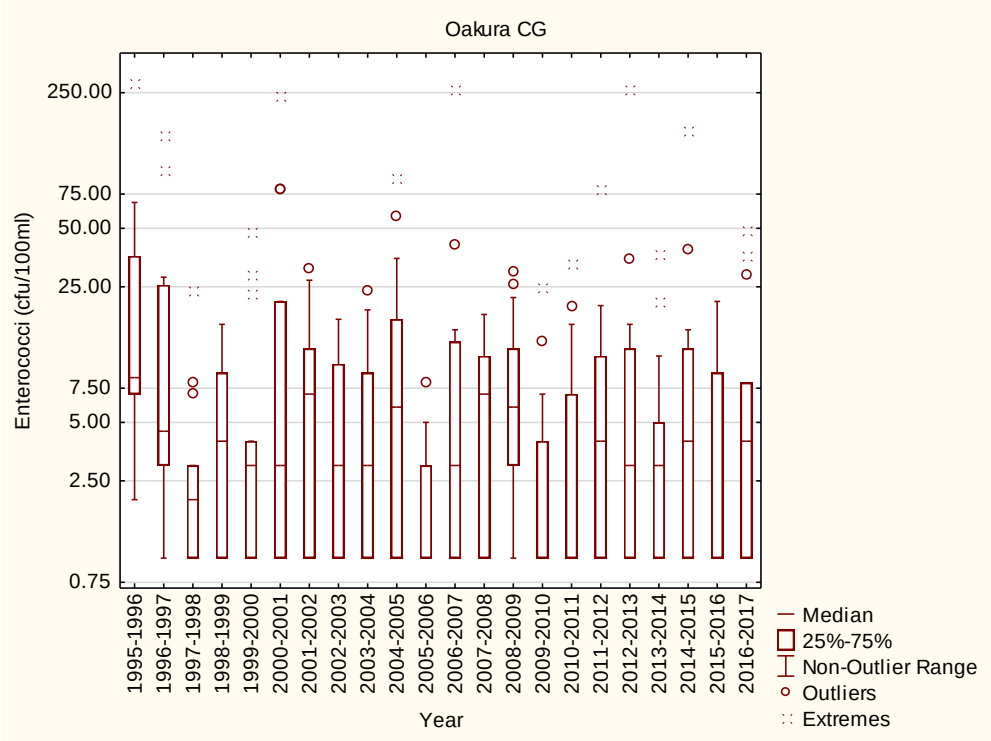


Figure 34 Box and whisker plots of enterococci for all summer SEM surveys at Oakura Beach opposite the campground

The median enterococci count for the 2016-2017 season was within the low range previously recorded at this site. Over the past 22 summers water quality has remained consistently high at this site (Table 47).

4.10.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 22 summer seasons (Figure 35) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

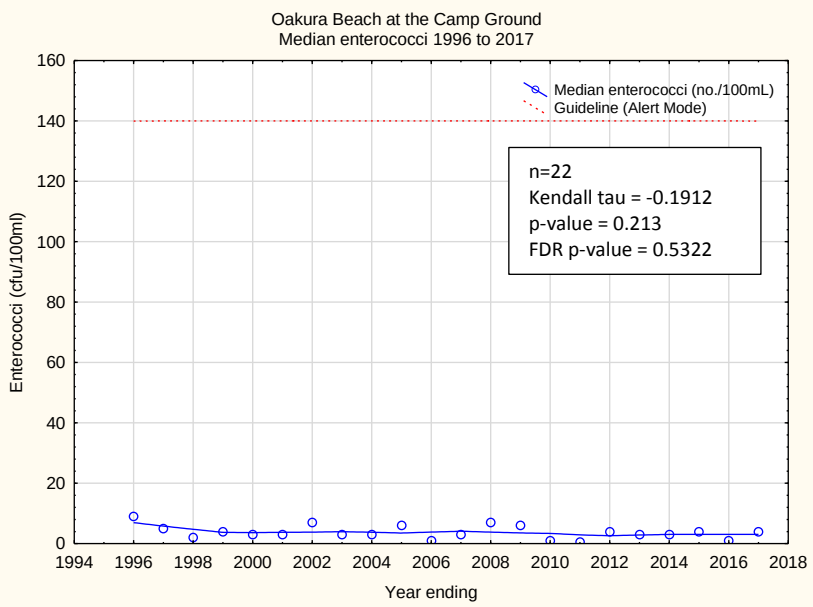


Figure 35 LOWESS trend analysis of median enterococci data at Oakura Beach Camp Ground

Over the 22 seasons monitored, there was a decreasing trend in median enterococci counts (Kendall tau = -0.191) that was not significant at the 5% level (p = 0.213).

4.11 Opunake Beach

4.11.1 SEM programme

Opunake Beach (Photo 13) is a very popular swimming beach in south Taranaki. There are no large rivers in the vicinity. However, the outlet of a freshwater stream from the Opunake Power Station enters at the southern end of the beach.

Photo 13 Opunake Beach

The data for this site are presented in Table 48 and Figure 36, with a statistical summary provided in Table 49.

Table 48 Bacteriological results for Opunake Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	11:20	4530	<1	<1	<1	15.9
30 Nov 2016	11:00	4550	12	21	24	16.3
05 Dec 2016	14:10	4580	1	3	1	19.0
12 Jan 2017	08:20	4580	3	5	3	18.5
30 Jan 2017	11:55	4700	3	1	3	18.1
01 Feb 2017	13:35	4700	1	4	1	18.4
10 Feb 2017	10:45	4710	4	1	9	16.6
16 Feb 2017	13:45	4710	280	79	360	19.1
27 Feb 2017	10:50	4710	1	1	1	19.4

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
02 Mar 2017	13:10	4730	1	3	1	20.0
17 Mar 2017	12:45	4620	3	1	3	19.1
02 Apr 2017	14:15	4680	3	5	3	19.6
11 Apr 2017	11:45	4680	4	4	4	18.8

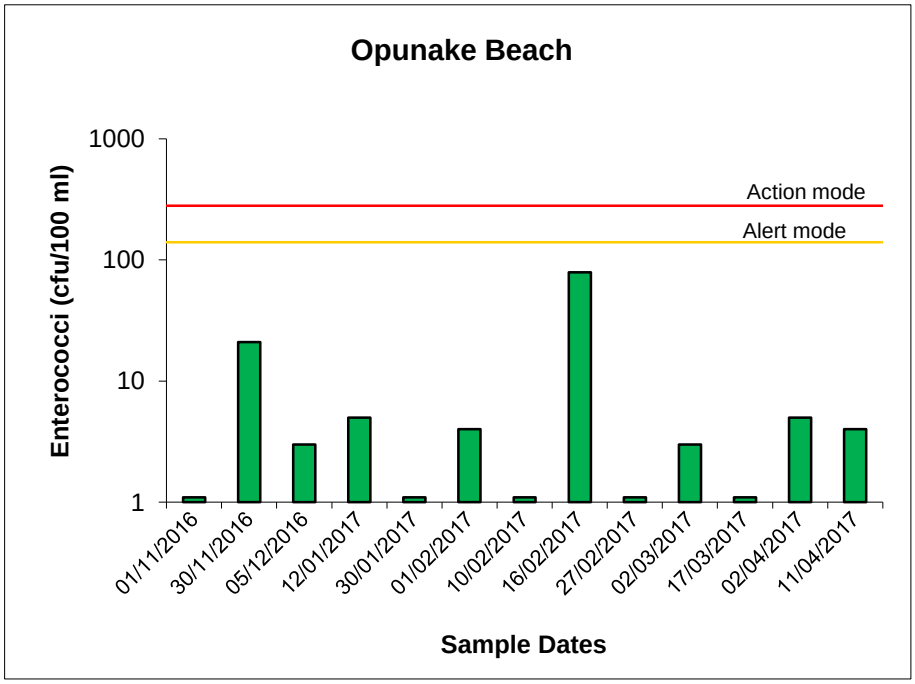


Figure 36 Enterococci counts for the 13 SEM samples at Opunake Beach

Table 49 Statistical summary for Opunake Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	4530	4730	4680
E. coli	cfu/100 ml	13	<1	280	3
Enterococci	cfu/100 ml	13	<1	79	3
Faecal coliforms	cfu/100 ml	13	<1	360	3
Temperature	°C	13	15.9	20	18.8

Median concentrations were low for all faecal indicator bacteria (3 cfu/100 ml) indicating excellent water quality at this site. All samples remained in Surveillance mode throughout the monitoring period.

4.11.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Opunake Beach over 22 summers are presented in Table 50 and Figure 37.

Table 50 Summary enterococci data (cfu/100 ml) for summer surveys at Opunake Beach

Summer	1995-96	1996-97	1999-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Minimum	<1	<1	1	<1	<1	<1	<1	<1	<1	<1	<1
Maximum	74	60	73	7	41	69	140	20	9	10	19
Median	9	< 1	5	< 1	1	2	4	1	1	1	2
Summer	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-15**	**2015-16**	**2016-17**
Minimum	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Maximum	8	11	25	4	100	17	7	49	28	130	79
Median	1	<1	2	<1	<1	3	<1	1	4	1	3

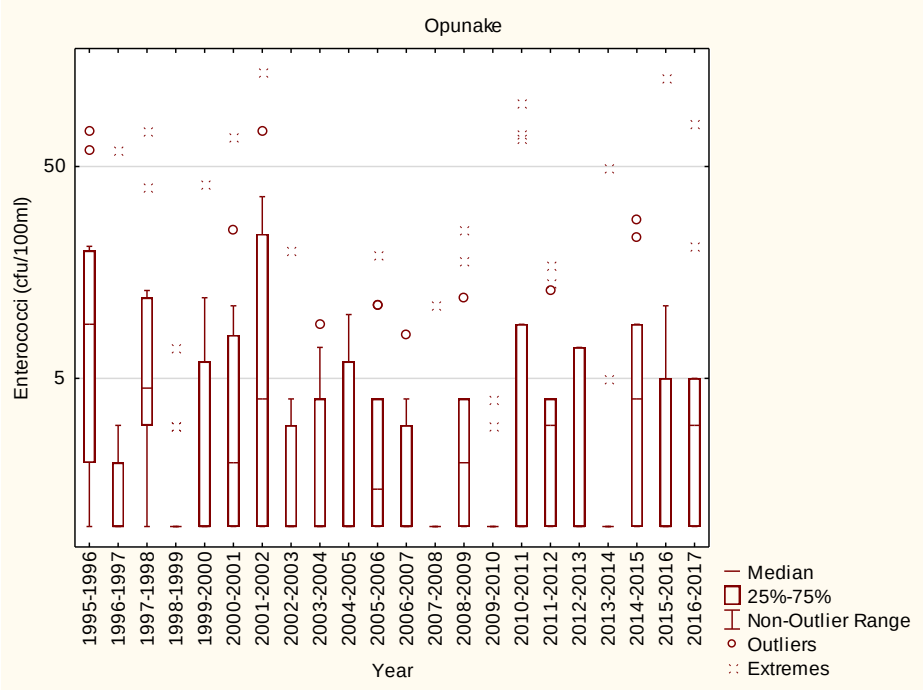


Figure 37 Box and whisker plots of enterococci for all summer SEM surveys at Opunake Beach

The low enterococci data obtained for Opunake Beach during the 2016-2017 summer continues the trend of excellent water quality at this site (Table 50, Figure 37).

4.11.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 22 summer seasons (Figure 38) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

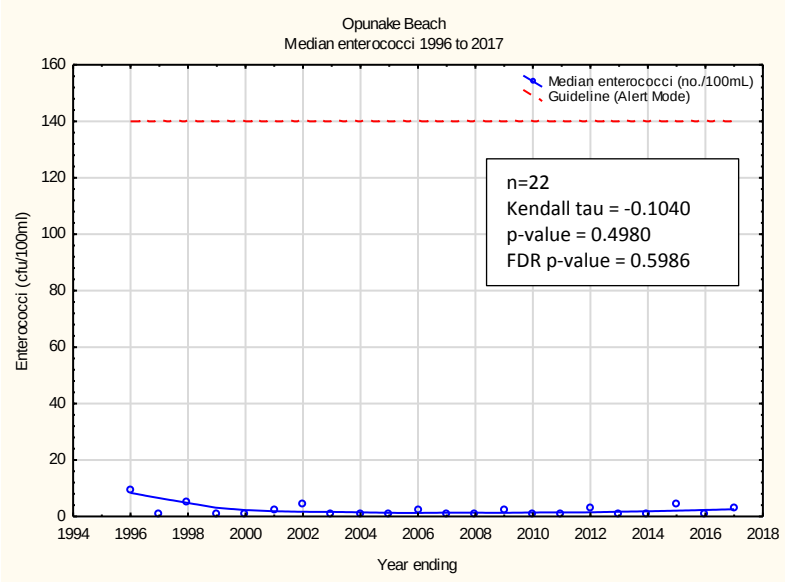


Figure 38 LOWESS trend analysis of median enterococci data at Opunake Beach

Over the 22 seasons monitored, there was a decreasing trend in median enterococci counts (Kendall tau = -0.104) that was not significant at the 5% level (p = 0.498).

4.11.4 MfE guidelines additional sampling

For the purpose of MfE monitoring eleven additional samples were collected at regular intervals and under varying weather conditions during the survey season. All data, including additional MfE samples are presented in Table 51 and Figure 39, with a statistical summary in Table 52.

Table 51 Bacteriological results for MfE samples at Opunake Beach

Date	Time	Conductivity @ 20°C	Bacteria			Temperature
	(NZST)	(mS/m)	*E. coli* (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	(°C)
22 Nov 2016	11:01	4450	<1	<1	<1	16.9
15 Dec 2016	09:10	4550	8	8	8	17.3
21 Dec 2016	11:30	4650	<1	<1	<1	17.6
28 Dec 2016	10:26	4340	73	7	73	18.5
05 Jan 2017	09:50	4610	1	7	1	17.0
09 Jan 2017	08:30	4720	17	3	17	17.4
18 Jan 2017	09:45	4620	4	5	4	18.2
26 Jan 2017	10:57	4640	17	1	17	15.6
07 Feb 2017	10:30	4590	3	8	3	19.2
21 Feb 2017	12:20	4670	1	1	1	20.5
07 Mar 2017	11:30	4680	<1	1	<1	20.1

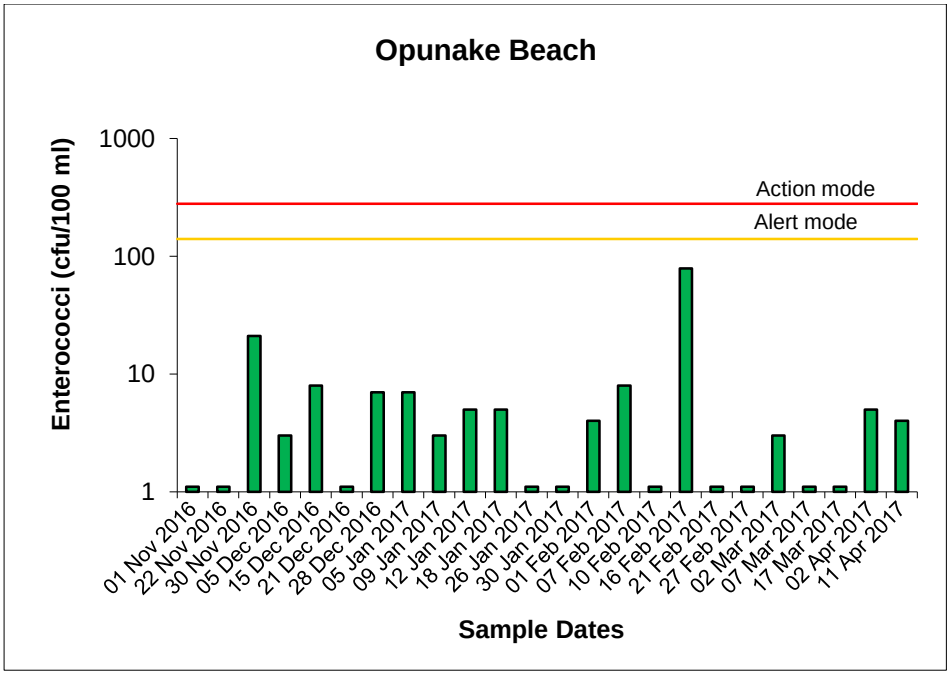


Figure 39 Enterococci numbers for the 24 sample extended survey at Opunake Beach

Table 52 Summary statistics for SEM and MfE samples at Opunake Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	24	4340	4730	4645
E. coli	cfu/100 ml	24	<1	280	3
Enterococci	cfu/100 ml	24	<1	79	3
Faecal coliforms	cfu/100 ml	24	<1	360	3
Temperature	°C	24	15.6	20.5	18.5

The additional MfE samples made no difference to the medians for all faecal indicator bacteria, reflecting consistently high water quality at this site.

4.12 Ohawe Beach

4.12.1 SEM programme

Ohawe Beach (Photo 14) is located close to the large Waingongoro River in South Taranaki. The river catchment drains highly modified agricultural land.

Photo 14 Ohawe Beach

Data from this site are presented in Table 53 and Figure 40, with a statistical summary provided in Table 54.

Table 53 Bacteriological results for Ohawe Beach

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
01 Nov 2016	09:50	4340	7	<1	7	16.1
30 Nov 2016	09:20	3580	460	26	480	15.9
05 Dec 2016	12:35	4330	28	<4	28	18.1
12 Jan 2017	09:50	3860	170	160	170	18.5
30 Jan 2017	10:24	4160	16	12	24	18.3
01 Feb 2017	11:50	4380	12	26	12	19.1
10 Feb 2017	08:55	4660	4	4	4	18.1
16 Feb 2017	12:25	4030	18	18	18	19.1
27 Feb 2017	09:20	4680	5	7	8	19.5
02 Mar 2017	11:30	4560	130	26	130	20.2
17 Mar 2017	11:25	4060	20	26	20	18.6

Date	Time (NZST)	Conductivity @ 20°C (mS/m)	Bacteria			Temp (°C)
			E. coli (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	
02 Apr 2017	12:55	3890	22	20	22	18.6
11 Apr 2017	10:10	4580	12	28	16	17.6

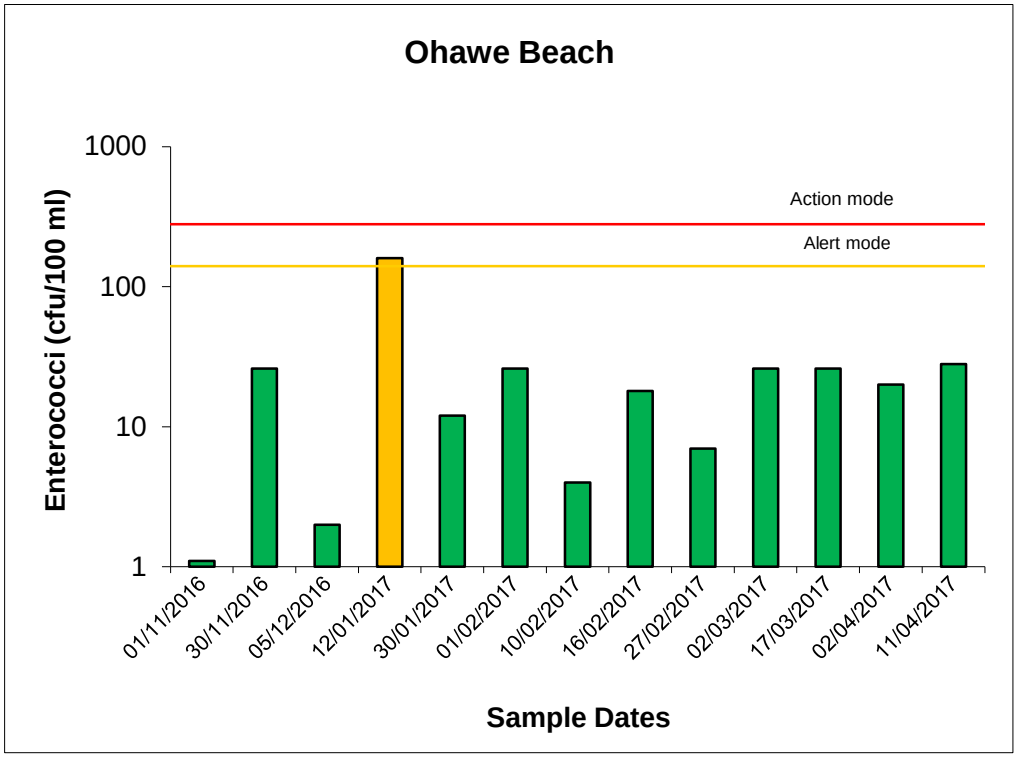


Figure 40 Enterococci counts for the 13 SEM samples at Ohawe Beach

Table 54 Statistical summary for Ohawe Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	13	3580	4680	4330
E. coli	cfu/100 ml	13	4	460	18
Enterococci	cfu/100 ml	13	<1	160	20
Faecal coliforms	cfu/100 ml	13	4	480	20
Temperature	°C	13	15.9	20.2	18.5

The site can be significantly influenced by the Waingongoro River (see low conductivities recorded throughout the season, Table 53). Microbial source tracking from samples taken at the river mouth and just upstream of the Ohawe settlement indicated that the main source of faecal contamination in the river is from ruminants and wildfowl (TRC 2013-01). The one 'Alert' level sample showed obvious evidence of freshwater influence (12 January 2017, 160 cfu/100 ml, 3860 mS/m).

4.12.2 Comparison with previous summer surveys

Summary statistics for enterococci data collected at Ohawe Beach over 18 summers are presented in Table 55 and Figure 41.

Table 55 Summary enterococci data (cfu/100 ml) for summer surveys at Ohawe Beach

Summer	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07
Minimum	15	7	<1	1	3	3	5	3	<1	1	<1
Maximum	72	650	280	68	450	1600	180	11000	330	1600	80
Median	21	40	17	23	48	48	16	29	23	13	7
Summer	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**2012-13**	**2013-14**	**2014-2015**	**2015-16**	**2016-17**	
Minimum	<1	2	3	<1	2	<1	<1	4	3	1	
Maximum	1800	280	350	83	160	630	400	270	620	160	
Median	5	20	16	7	34	37	5	24	40	20	

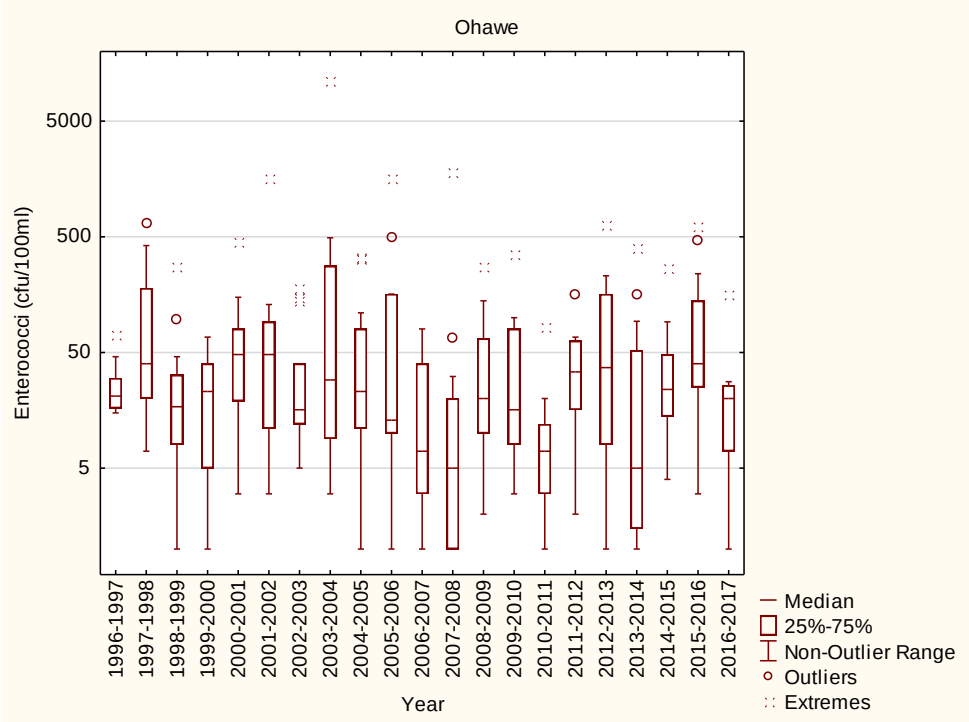


Figure 41 Box and whisker plots of enterococci for all summer surveys at Ohawe Beach

The median and maximum enterococci counts obtained for the 2016-2017 summer season were within the range previously recorded at this site. Maxima and medians at this site are historically variable due to the influence of the Waingongoro River (Table 55).

4.12.3 Long-term trend analysis

Trend analysis was performed by applying a LOWESS fit (tension 0.4) to a time scatterplot of the median enterococci data for 21 summer seasons (Figure 42) and testing the significance of any trend using the Mann-Kendall test at the 5% level, followed by Benjamini-Hochberg False Discovery Rate (FDR) analysis.

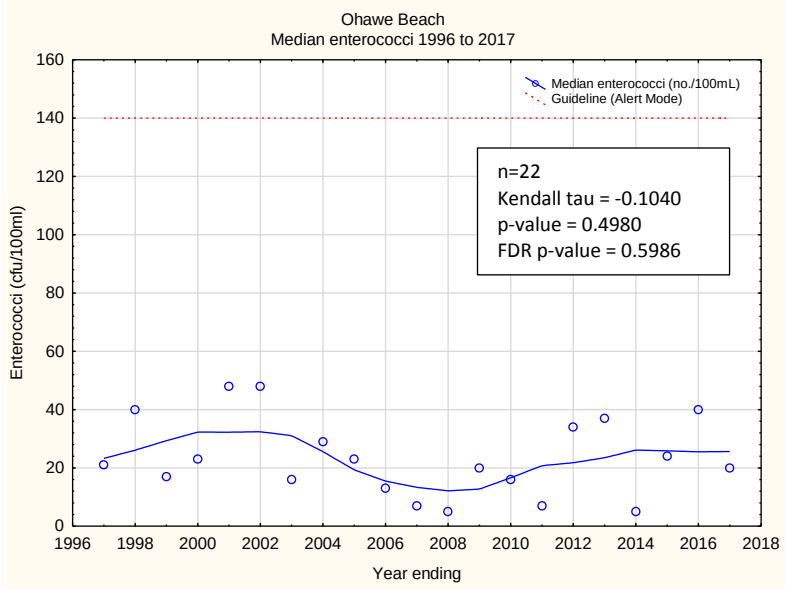


Figure 42 LOWESS trend analysis of median enterococci data at Ohawe Beach

Over the 22 seasons monitored, there was a decreasing trend in median enterococci counts (Kendall tau = -0.104) that was not significant at the 5% level (p = 0.498).

4.12.4 MfE guidelines additional sampling

For the purpose of MfE monitoring, eleven additional samples were collected at regular intervals and under varying weather conditions during the survey season. All data, including additional MfE samples, are presented in Table 56 and Figure 43, with a statistical summary provided in Table 57.

Table 56 Bacteriological results for MfE samples at Fitzroy Beach

Date	Time	Conductivity @ 20°C	Bacteria			Temperature
	(NZST)	(mS/m)	*E. coli* (cfu/100 ml)	Enterococci (cfu/100 ml)	Faecal coliforms (cfu/100 ml)	(°C)
22 Nov 2016	09:25	2150	68	12	68	16.8
15 Dec 2016	08:00	2630	51	34	51	17
21 Dec 2016	09:33	2740	40	8	40	17.5
28 Dec 2016	08:58	3460	54	57	54	16.4
05 Jan 2017	08:33	3700	48	10	54	17
09 Jan 2017	09:50	3540	20	17	23	17.8
18 Jan 2017	08:00	3590	64	28	72	18.8
26 Jan 2017	09:15	3630	77	40	77	16.6
07 Feb 2017	09:00	4310	8	4	8	19.8
21 Feb 2017	11:05	3080	34	18	34	21
07 Mar 2017	10:00	4100	45	7	45	18.9

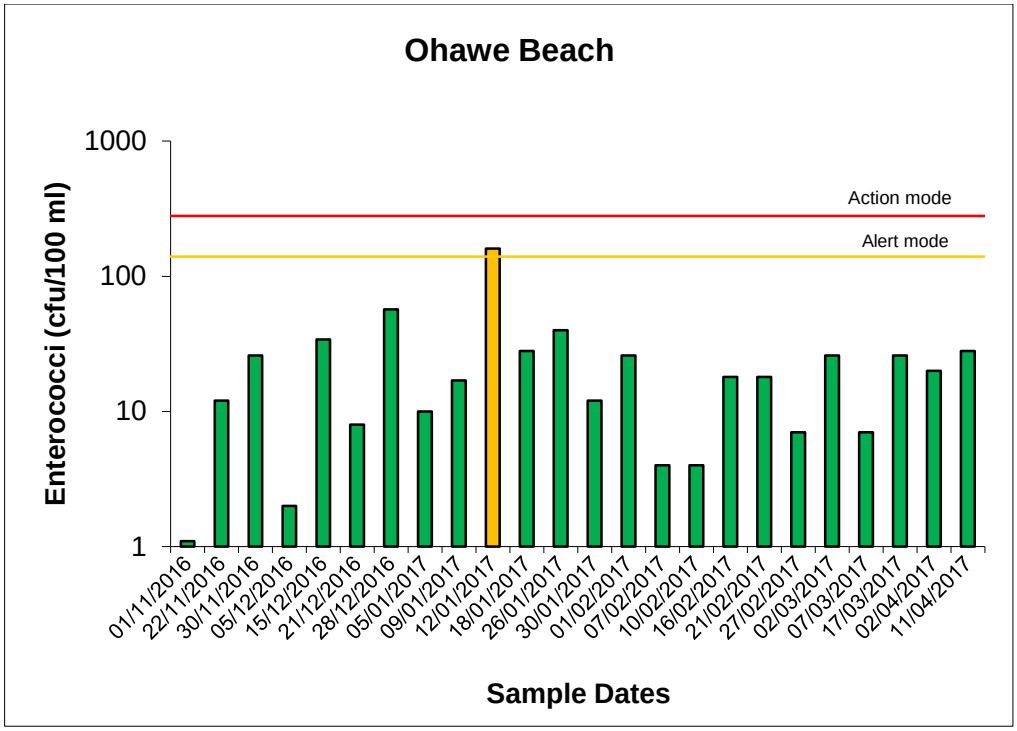


Figure 43 Enterococci counts for the 24 sample extended survey at Fitzroy Beach

Table 57 Summary statistics for SEM and MfE samples at Fitzroy Beach

Parameter	Unit	Number of samples	Minimum	Maximum	Median
Conductivity @ 20°C	mS/m	24	2150	4680	3960
E. coli	cfu/100 ml	24	4	460	31
Enterococci	cfu/100 ml	24	<1	160	18
Faecal coliforms	cfu/100 ml	24	4	480	31
Temperature	°C	24	15.9	21	18.2

Additional sampling resulted in a decrease in enterococci median but an increase in *E. coli* and faecal coliform medians (Tables 54 and 57), when combined with the SEM programme samples. All additional samples collected remained in Surveillance mode.

5. General summary

5.1 Regional overview

During the 2016-2017 summer season, median faecal indicator bacteria counts for the majority of sites were elevated compared to long-term medians. The higher counts were likely influenced by unusually heavy rainfall throughout the summer (Figure 44). However, it should be noted that over the long term, most sites are showing indicative reductions in median measures of indicator bacteria (Kendall tau results, Table 58). Despite the wet conditions, out of the 244 samples collected at 12 beach sites, 92% were below guideline Alert levels (140 enterococci cfu/100 ml). One site, Waitara West, reached Action mode (two consecutive samples >280 enterococci cfu/100 ml) for one set of results during the 2016-2017 season. Of the samples which entered the Alert and Action guideline categories (9% i.e. 23 samples), the majority (20 out of 23) had been influenced by rainfall or freshwater. Sites that had sufficient data to calculate a Suitability for Recreation Grade during the 2016-2017 year obtained a grade of either 'good' (8/12), 'fair' (3/12) or 'poor' (1/12). These grades reflect qualitative risk grading of the catchment in addition to quantitative enterococci results (see Section 2.2).

Table 58 Summary enterococci results for the TRC beach bathing monitoring programme 2016-2017

Beach sites[1]	Enterococci median (cfu/100 ml)		Number of samples reaching Alert mode (>140 cfu/100 ml) & *Action mode (2x >280 cfu/100 ml)*		Trend analysis[4]			Suitability for recreation grade (SFRG)[6]
	SEM[2]	SEM+MfE[3]	SEM[2]	SEM+MfE[3]	Kendall tau[5]	Mann-Kendall p value	False Discovery Rate p value	
Opunake	3	3	0	0	-0.104	0.498	0.599	Good
Fitzroy	4	4	0	0	-0.503	0.001	0.011	Good
Oakura CG	4	-	0	-	-0.191	0.213	0.532	Good
Oakura SC	9	20	1	3	0.123	0.425	0.599	Good
East End	12	-	0	-	-0.144	0.472	0.599	Good
Onaero	14	28	1	5	0.118	0.539	0.599	Fair
Ngamotu	16	13	1	3	-0.355	0.021	0.104	Good
Waitara East	17	20	2	4	0.209	0.184	0.532	Fair
Ohawe	20	18	1	1	-0.104	0.498	0.599	Fair
Waitara West	40	40	1, *1*	3, *1*	-0.039	0.804	0.804	Good
Back Beach	43	-	3	-	-	-	-	Poor
Bell Block	48	-	0	-	-	-	-	Good

[1]Sites ordered in ascending order of SEM median enterococci
[2]SEM results based on 13 samples
[3]SEM+MfE results based on 20 samples (MfE data obtained at selected sites only)
[4]Trend analysis performed on SEM data only (Section 3.4)
[5]A negative/positive Kendall tau indicates a decreasing/increasing temporal trend in median enterococci respectively
[6]The Suitability for Recreational Grade is calculated using the Microbial Assessment Category (based on five years enterococci data) and the Sanitary Inspection Category (a qualitative risk assessment based on the catchment) as explained in Section 2.2
- = insufficient data

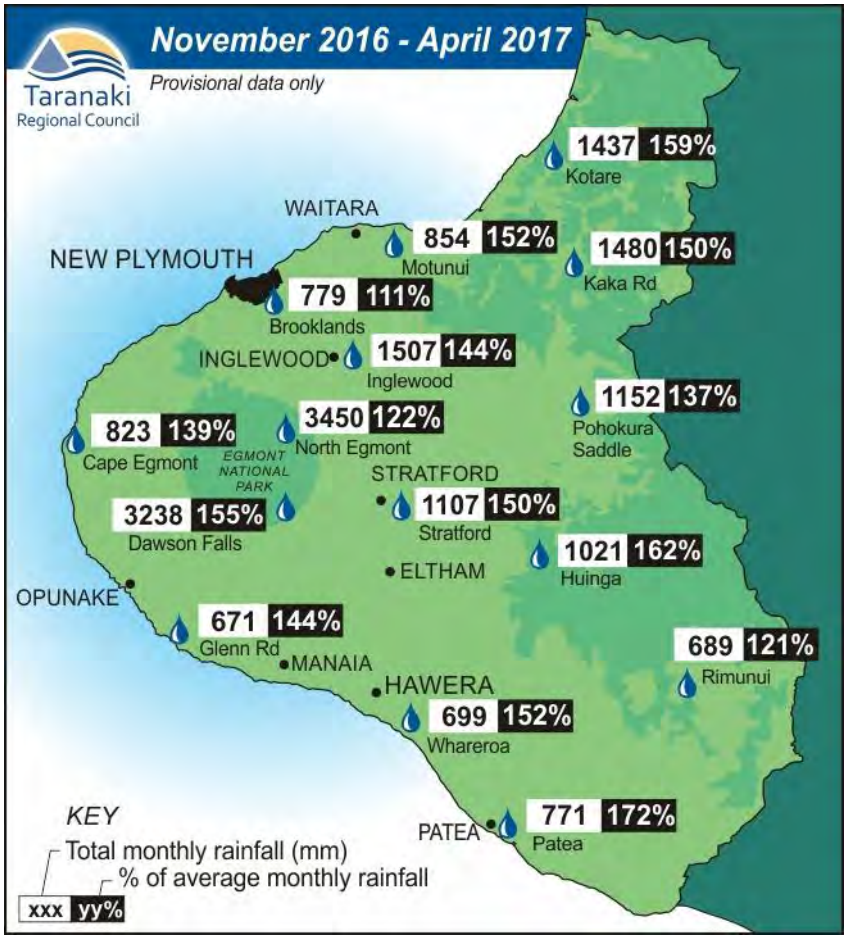


Figure 44 Average rainfall data for Taranaki November 2016 to April 2017

During the 2016-2017 season Opunake had the region's lowest median enterococci count of 3 cfu/100 ml (Table 58). Water quality at this site has remained consistently high since the Council beach monitoring programme began in 1995-1996 (Figure 46).

Bell Block and Back Beach recorded the highest enterococci medians of the 2016-2017 season (48 and 43 cfu/100ml respectively). The median enterococci counts obtained for the 2016-2017 summer season were the highest to date at these sites, likely influenced by the high rainfall over the summer season (Figure 44). Bacteriological water quality at these two sites has been historically variable due to the influence of streams near to the sampling location.

Long term trend analysis (15-22 years data) showed a significant (at the 5% level) decrease in enterococci medians at 2 of the 10 sites monitored (Fitzroy and Ngamotu). All other sites showed no significant change (Table 58, Kendall tau and Mann-Kendall p values). The site at Fitzroy Beach showed the greatest improvement in microbiological water quality since 1995 (Table 58, Kendall tau -0.503, Mann-Kendall p value 0.001). Improvements in water quality might have arisen due to work undertaken by the New Plymouth District Council as part of the Stormwater Upgrade Project at Fitzroy. As a result of this project there is now less flow of stormwater to the stormwater infiltration galleries located in the Fitzroy beach car park.

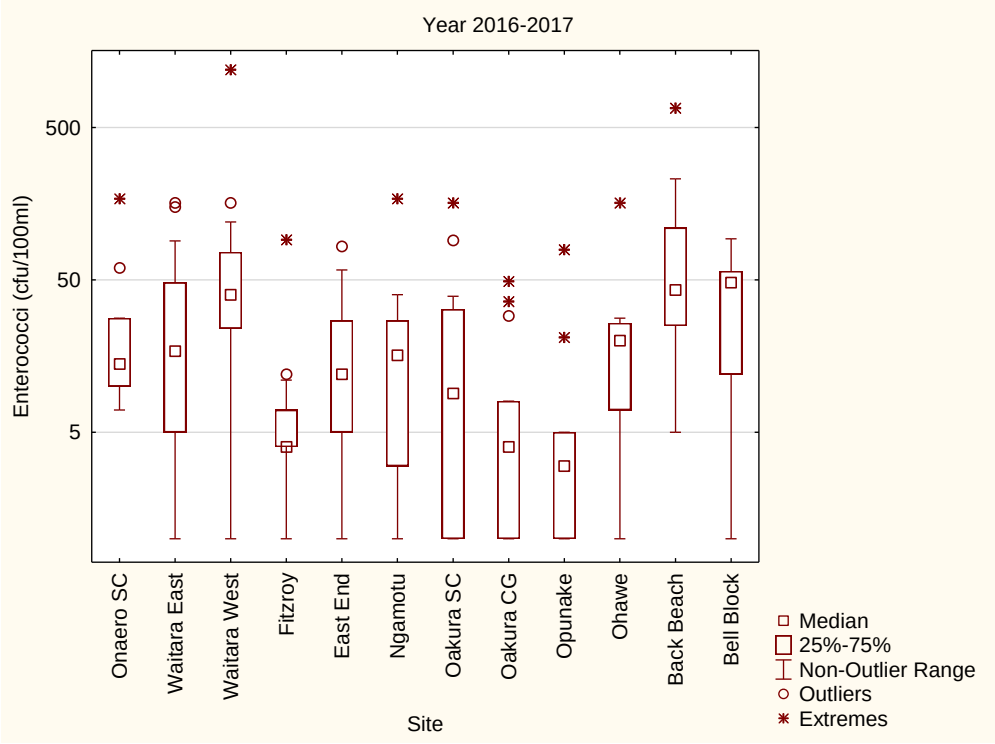


Figure 45 Box and whisker plots of enterococci at all sites during the 2016-2017 season (SEM data only)

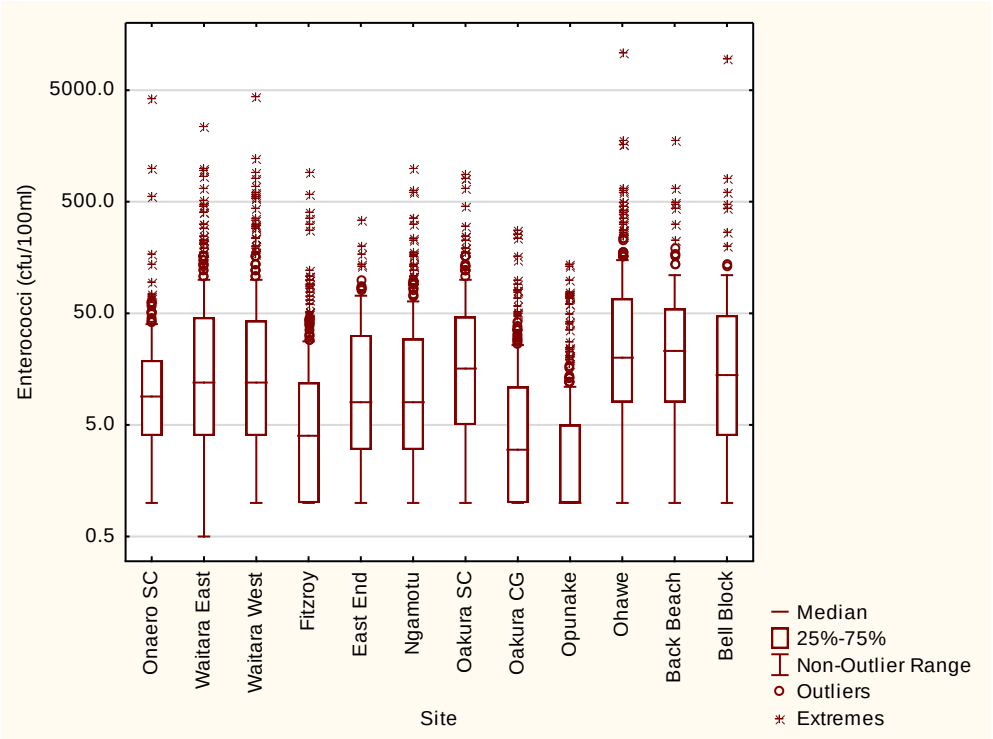


Figure 46 Box and whisker plots of long term enterococci data from 1995/implementation of monitoring to 2017 (SEM data only)

5.3 Conclusion

During the 2016-2017 summer season, median faecal indicator bacteria counts for the majority of sites were elevated compared to previous years, likely influenced by high rainfall (Figure 44). Despite the wet conditions, 91% of samples remained below guideline Alert levels (<141 enterococci cfu/100 ml). Of the samples which individually entered the Alert (22 samples) and Action (1 sample) guideline categories (9%), the vast majority (20 out of 23) had been influenced by rainfall or freshwater.

Many of the beach sites monitored in Taranaki are located close to stream or river mouths which can act as a source of contamination during heavy rainfall. The majority of these rivers and streams drain catchments with intensive agricultural land use, including dairying. Microbial source tracking has revealed that in addition to ruminants, birds (wildfowl and gulls) can also act as a key source of contamination in Taranaki freshwater environments (TRC 2017). In order to minimize potential health risks, the Council recommends reducing coastal recreational activities in the vicinity of stream mouths for two-three days following heavy rainfall.

Photo 15 Black-backed gulls at the mouth of the Waiwhakaiho River

6. Recommendations

As a result of the 2016-2017 summer marine contact recreation bacteriological survey it is recommended:

1. THAT the 2017-2018 summer survey be performed at 13 sites continuing with the existing sampling protocol (annual, plus Year 3 sites).
2. THAT the 2017-2018 summer survey also includes an additional eleven samples collected at eight sites (Onaero, Waitara West, Waitara East, Fitzroy, Ngamotu, Oakura Surf Club, Opunake and Ohawe) in accordance with MfE, 2003 guidelines and to provide up to date information on beach conditions throughout the holiday periods.
3. THAT follow-up sampling be performed as deemed necessary by Council staff. This should include follow-up samples within 24 hours of any samples exceeding 280 cfu/100 ml in order to assess if Action level has been reached.
4. THAT photographs of the position of the Waimoku Stream and Waingongoro River mouths are taken over the 2017-2018 season to aid the interpretation of faecal indicator bacteria results at the Oakura Beach and Ohawe Beach sites respectively.
5. THAT reporting of results be performed as appropriate during the season, and in an Annual Report upon completion of the season's programme.

Glossary of common terms and abbreviations

The following abbreviations and terms are used within this report:

Action mode	Two consecutive single samples greater than 280 enterococci cfu/100ml
Alert mode	Single sample greater than 140 enterococci cfu/100ml
Bacteriological faecal indicators	Micro-organisms selected as indicators of faecal contamination
Bathers	Those who enter the water, and either partially or fully immerse themselves
Bathing season	Generally the bathing season extends between 1 November and 31 March
Beach	The shore or any access point to the sea
cfu	Colony forming units. A measure of the concentration of bacteria usually expressed as per 100 ml sample
Condy	Conductivity, an indication of the level of dissolved salts in a sample, usually measured at 20°C and expressed in mS/m
Contact recreation	Recreation activities that bring people physically in contact with water, involving a risk of involuntary ingestion or inhalation of water
E.coli	*Escherichia coli*, member of the Enterobacteriaceae, an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 millilitre sample
Enterococci	Members of the Streptococcus group of bacteria characterised as faecal in origin. Enterococci provide an indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 ml of sample
Faecal coliform	An indicator of the possible presence of faecal material and pathological micro-organisms. Usually expressed as colony forming units per 100 ml sample
False Discovery Rate (FDR)	The expected proportion of true hypothesis rejected out of the total number of rejections
Follow-up sample	Second sample taken to confirm an initial high result; usually within 24-72 hours depending on accessibility/sample turnaround time, etc.
Median	Central value when values are arranged in order of magnitude
Microbiological Assessment	A measurement of water quality over time as provided by historical (five years) microbiological results – A, B, C or D Category (MAC)
RMA	Resource Management Act 1991 and subsequent amendments
Sanitary Inspection Category (SIC)	A measure of the susceptibility of a water body to faecal contamination – Very High, High, Moderate, Low or Very Low
Suitability for Recreation Grade (SFRG)	A combination of Sanitary Inspection Category (SIC) and Microbiological Assessment Category (MAC), describes the general condition of a site at any given time, based on both risk and indicator bacteria counts
Temp	Temperature, measured in °C (degrees Celsius)
Water quality	The bacteriological condition of a water body as it relates to human health, measured using indicator bacteria

For further information on analytical methods, contact the Council's laboratory

Bibliography and References

APHA (2005). Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association, and the Water Environment Federation.

Benjamini, Y and Hochberg, Y, 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society B (57):289-300.*

EPA, 1986. Ambient water quality criteria for bacteria. (United Environmental Protection Agency Report 440/5-84-002.

Department of Health, 1992. Provisional microbiological water quality guidelines for recreational and shellfish gathering waters in New Zealand. Public Health Services, Department of Health, Wellington.

Ministry for the Environment, 1998. Bacteriological Water Quality Guidelines for Marine and Fresh Water: Guidelines for the management of recreational and marine shellfish gathering waters (draft). Ministry for the Environment and Ministry of Health, Wellington. December 1998.

Ministry for the Environment, 1999. Supporting manual to the 1998 Bacteriological Water Quality Guidelines for Marine and Fresh Water (draft). Ministry for the Environment and Ministry of Health, Wellington. July 1999.

Ministry for the Environment , 2003. Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment and Ministry of Health, Wellington.

Stark, JD and Fowles, CR 2006: An approach to the evaluation of the temporal trends in Taranaki State of the Environment Macroinvertebrate Data. Cawthron Institute Report No 1135. 88pp

Taranaki Regional Council, 1995-1998: State of the Environment Monitoring Report Bathing Beach Water Quality. Technical Report 98-09

Taranaki Regional Council, 1998-1999 and 1999-2000: State of the Environment Monitoring Report Bathing Beach Water Quality. Technical Report 2000-03

Taranaki Regional Council, 2001 Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2000-2001. Technical Report 2001-07

Taranaki Regional Council, 2002 Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2001-2002. Technical Report 2002-01

Taranaki Regional Council, 2002. State of Environment Monitoring Report Bathing Beach Water quality 2000-01 and 2001-02. Technical Report 2002-45

Taranaki Regional Council, 2003. Bathing Beach Water Quality State of Environment Monitoring Report 2002-2003. Technical Report 2007-20.

Taranaki Regional Council, 2004. Bathing Beach Water Quality State of Environment Monitoring Report 2003-2004. Technical Report 2007-13.

Taranaki Regional Council, 2005. Bathing Beach Water Quality State of Environment Monitoring Report 2004-2005. Technical Report 2007-17.

Taranaki Regional Council, 2006. Bathing Beach Water Quality State of Environment Monitoring Report 2005-2006. Technical Report 2007-18.

Taranaki Regional Council, 2007. Bathing Beach Water Quality State of Environment Monitoring Report 2006-2007. Technical Report 2007-19.

Taranaki Regional Council, 2008. Bathing Beach Water Quality State of Environment Monitoring Report 2007-2008. Technical Report 2008-01.

Taranaki Regional Council, 2009. Bathing Beach Water Quality State of Environment Monitoring Report 2008-2009. Technical Report 2009-11.

Taranaki Regional Council, 2010. Bathing Beach Water Quality State of Environment Monitoring Report 2009-2010. Technical Report 2010-08.

Taranaki Regional Council, 2010 Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report. Summer 2009-2010. Technical Report 2010-11.

Taranaki Regional Council, 2011: Bathing beach water quality. State of the Evironment monitoring report. Summer 2010-2011. Technical Report 2011-15.

Taranaki Regional Council, 2011: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2010-2011 . Technical Report 2011-01.

Taranaki Regional Council, 2012: Bathing beach water quality. State of the Evironment monitoring report. Summer 2011-2012. Technical Report 2012-19.

Taranaki Regional Council, 2012: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2011-2012 . Technical Report 2012-01.

Taranaki Regional Council, 2013: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2012-2013 . Technical Report 2013-01.

Taranaki Regional Council 2013: New Plymouth District Council New Plymouth Wastewater Treatment Plant marine outfall and sludge lagoon annual report 2012-2013. TRC Technical Report 2013-25.

Taranaki Regional Council, 2013: Bathing beach water quality. State of the Evironment monitoring report. Summer 2012-2013. Technical Report 2013-17.

Taranaki Regional Council, 2014: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2013-2014 . Technical Report 2014-01.

Taranaki Regional Council, 2015: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2014-2015 . Technical Report 2015-01.

Taranaki Regional Council, 2015: Bathing beach water quality. State of the Evironment monitoring report. Summer 2014-2015. Technical Report 2015-11.

Taranaki Regional Council, 2016: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2015-2016 . Technical Report 2016-01.

Taranaki Regional Council, 2016: Bathing beach water quality. State of the Evironment monitoring report. Summer 2015-2016. Technical Report 2015-2.

Taranaki Regional Council, 2017: Freshwater contact recreational water quality at selected Taranaki sites. State of the Environment Report Summer 2016-2017 . Technical Report 2017-01.

Appendix I

High tide times

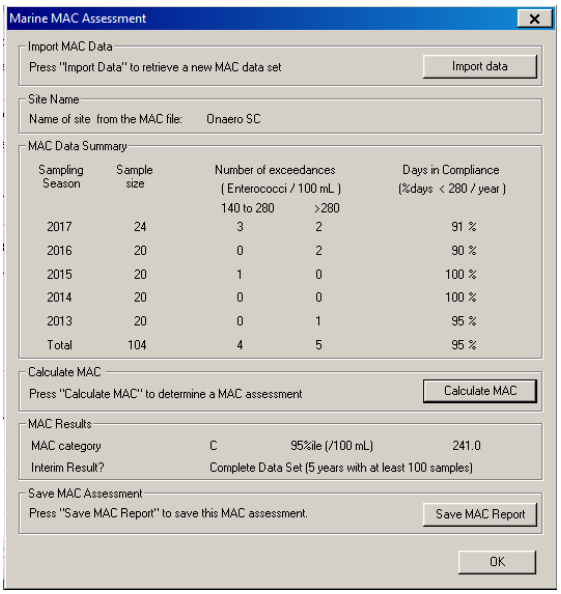
High tide times (NZST) at New Plymouth for 2016-2017 sampling dates

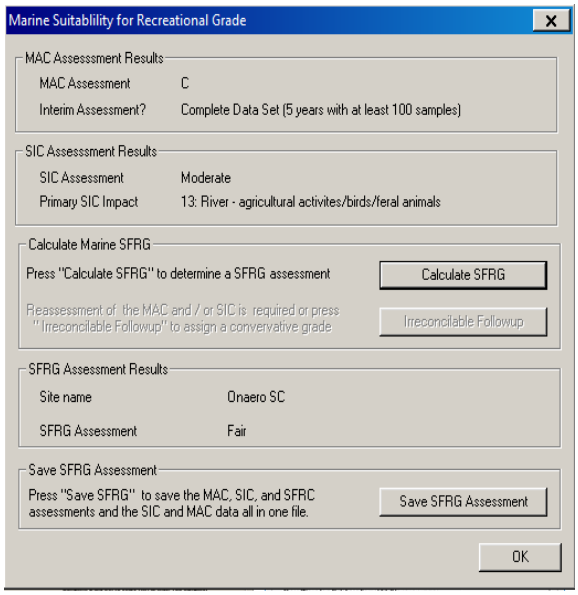
Date	Time of HT
01 Nov 2016	11:29
30 Nov 2016	11:08
05 Dec 2016	14:15
12 Jan 2017	10:29
30 Jan 2017	12:16
01 Feb 2017	13:36
10 Feb 2017	16:29
16 Feb 2017	14:14
27 Feb 2017	11:15
02 Mar 2017	13:16
17 Mar 2017	13:38
02 Apr 2017	13:42
11 Apr 2017	16:06

Appendix II

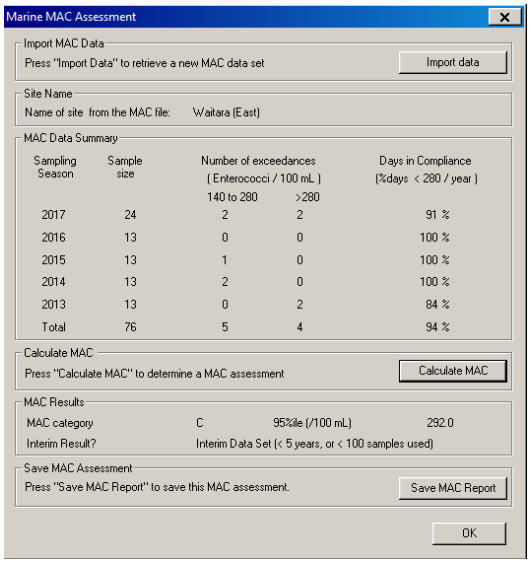
MAC assessments 2012-2017

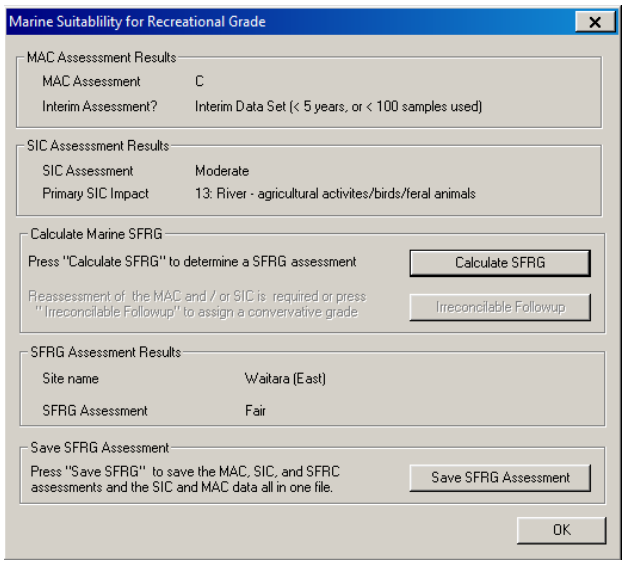
Onaero Beach



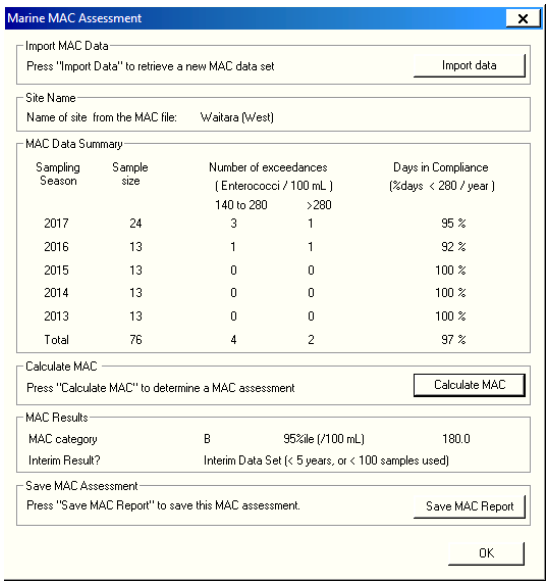


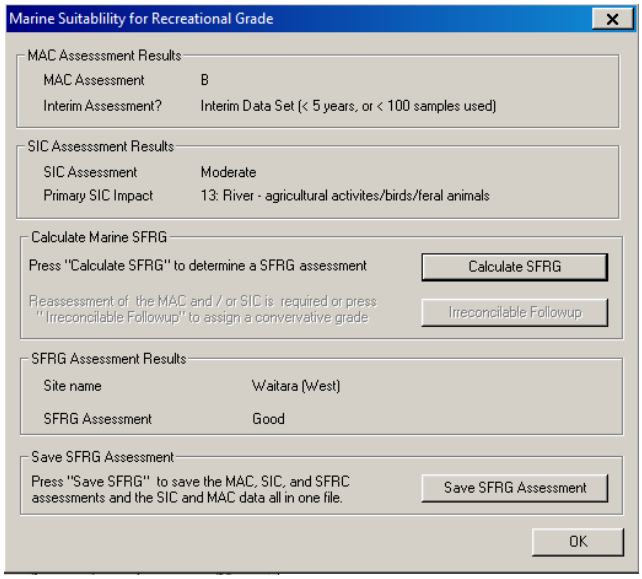
Waitara East



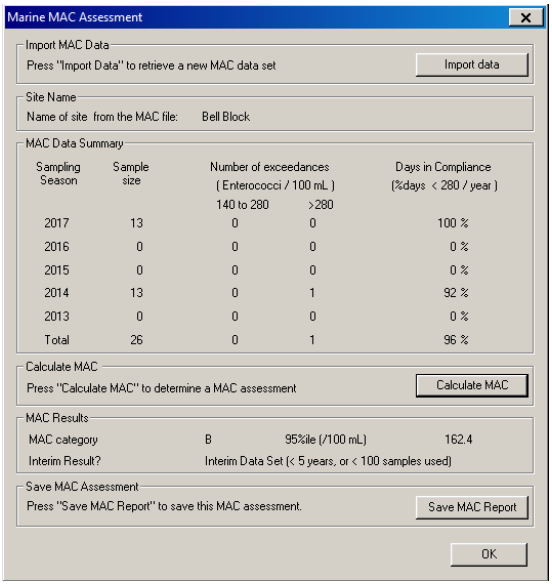


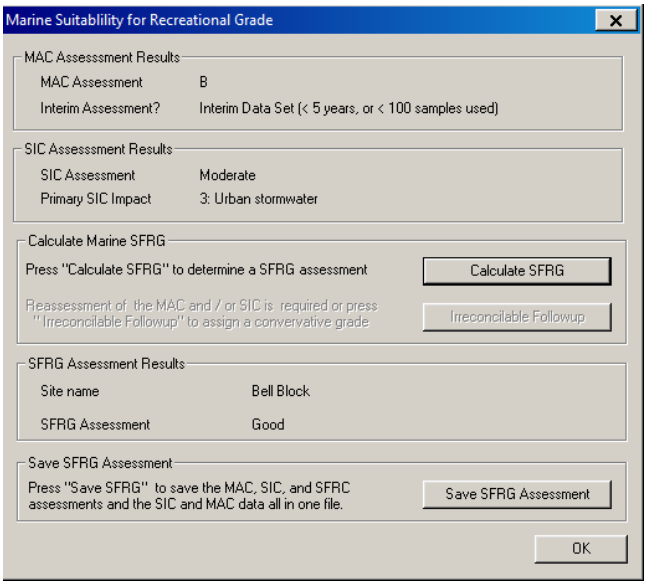
Waitara West



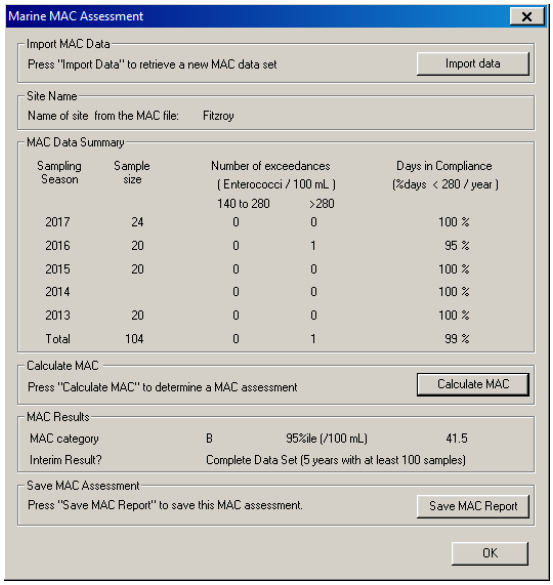


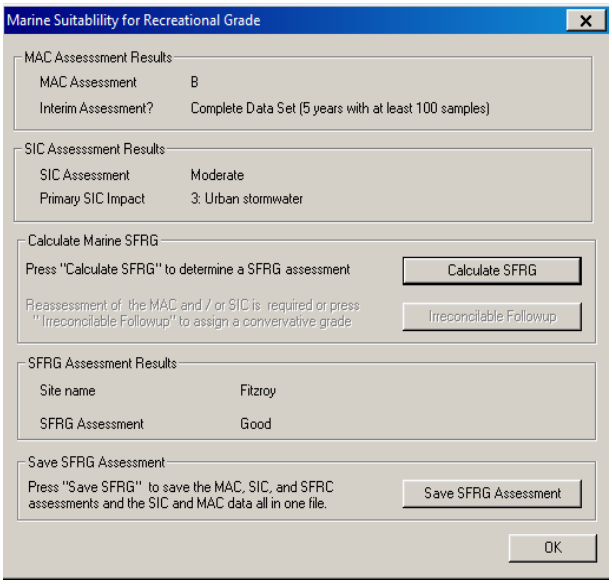
Bell Block





Fitzroy





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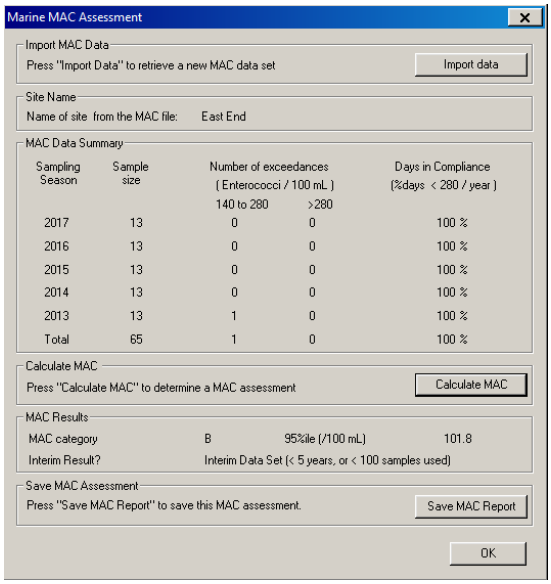
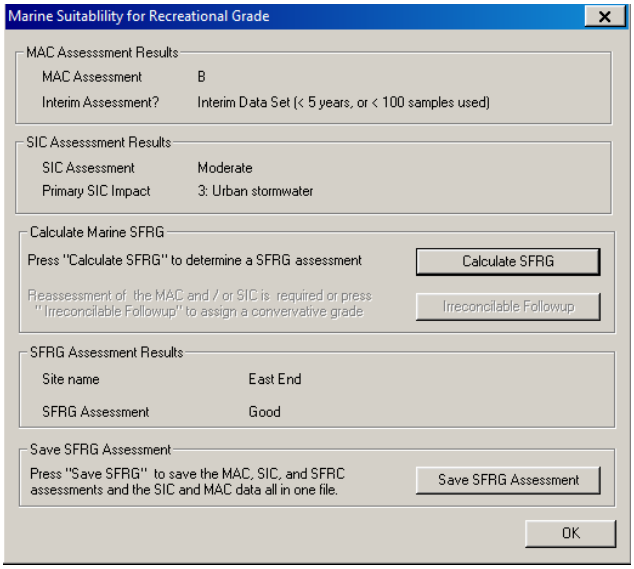
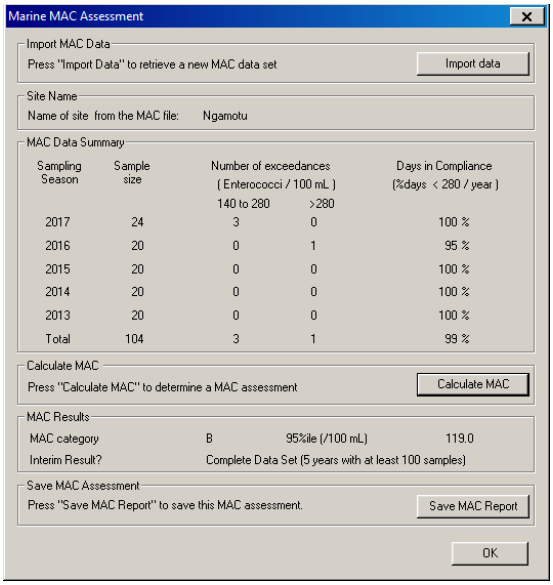
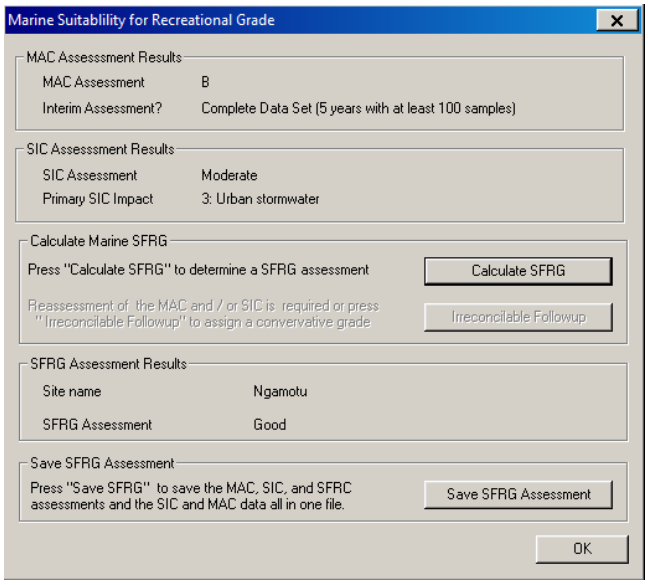


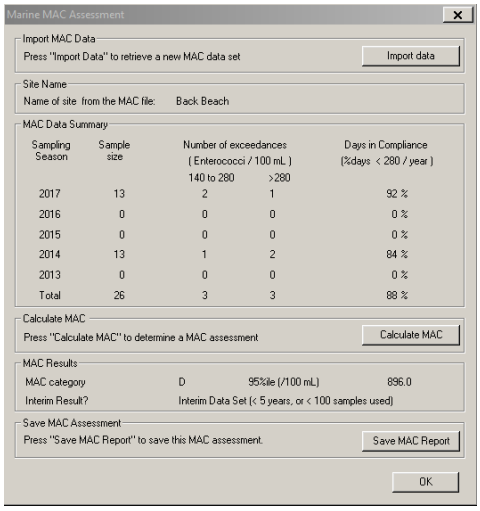


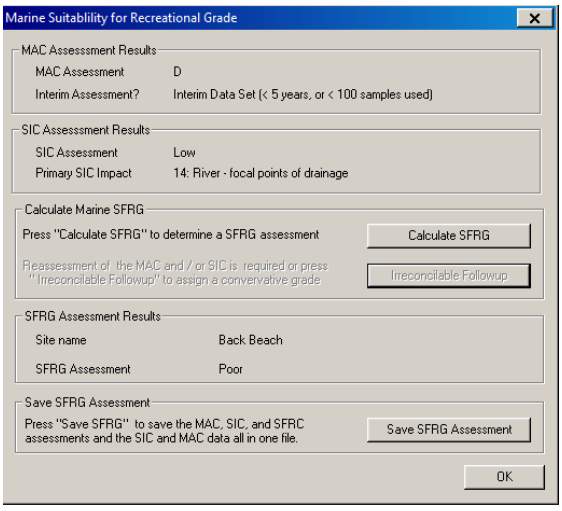
Ngamotu



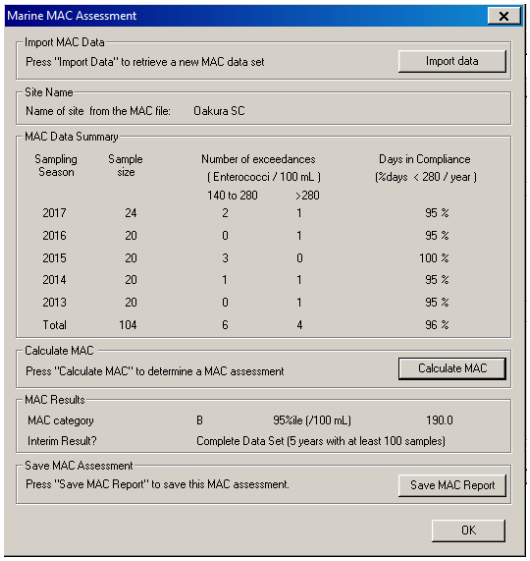


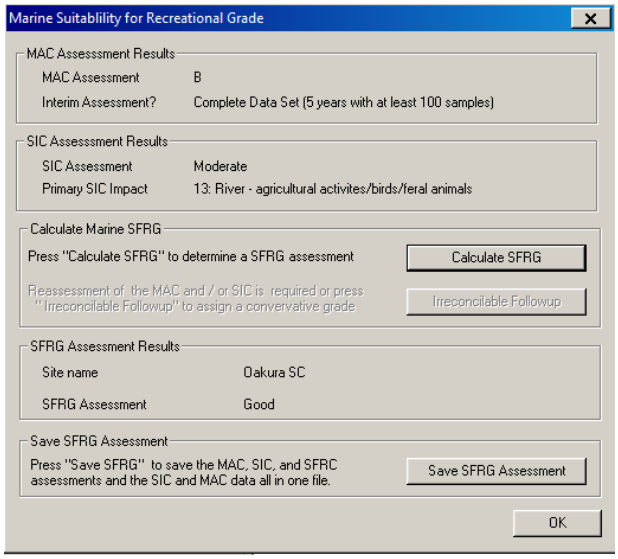
Back





Oakura SC





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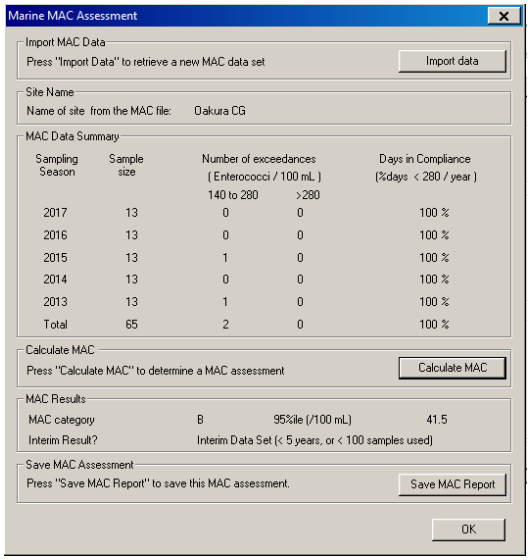
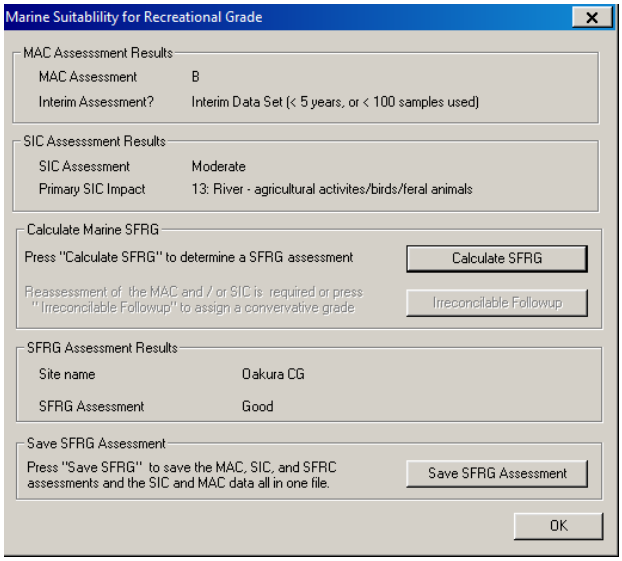
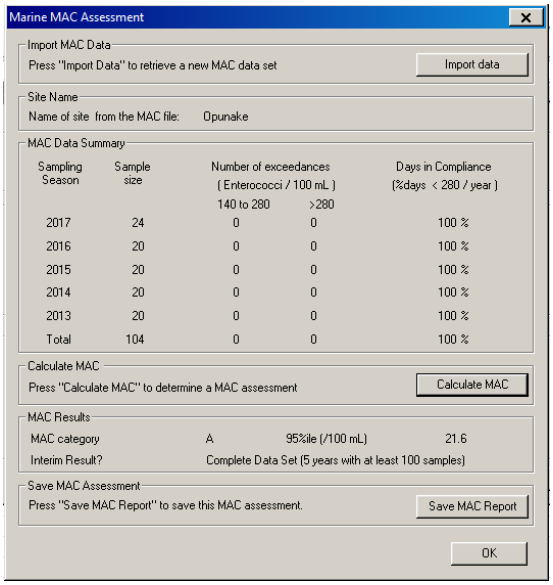
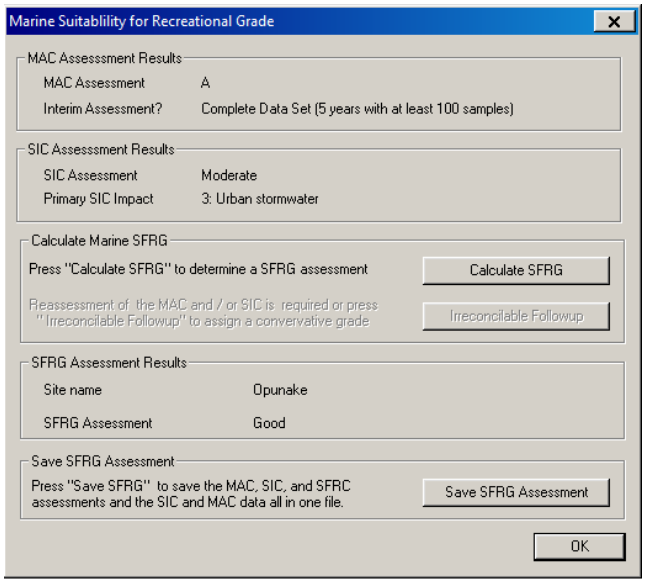




Opunake





Ohawe