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Memo

TO	Pim de Monchy, Stephen Park (Bay of Plenty Regional Council)
COPY	Stephanie Brown, Simon Banks (Opus International Consultants)
FROM	Keith Hamill
DATE	16 July 2014
FILE	wk-1024
SUBJECT	**Microbiological health risk of bathing and shellfish gathering in the Maketū estuary**

Background

The 'Kaituna River Re-diversion and Ongatoro/Maketū Estuary Enhancement Project' is seeking consent to re-divert water from the Kaituna River back into Ongatoro/ Maketū Estuary. The existing flap gates at Ford's cut currently allow about 3.4 m^3/s [1] of water into the estuary, with 87% from the Kaituna River. After the proposed re-diversion about 12.8 m^3/s of water will enter the estuary via Ford's cut, with 76% from the Kaituna River and the remainder from the sea (DHI 2014, Hamill 2014).

This memo describes the potential effects of the proposed re-diversion on microbiological water quality in the Ongatoro/Maketū estuary. In assessing potential effects I have relied on the results of dilution modelling by DHI (2014). This accounted for expected microbial inputs from the Kaituna River, Waitipuia Stream and drains. The potential inputs of faecal indicator bacteria (i.e. faecal coliform bacteria and *Enterococci* bacteria) were based on monthly monitoring results in the Kaituna River downstream of Waiari for the period January 2007 to January 2014.

Microbial guideline values

Shellfish gathering guidelines

The recreational shellfish-gathering bacteriological guideline values set in MfE and MoH (2003) are:

> *The median faecal coliform content of samples taken over a shellfish-gathering season shall not exceed a Most Probable Number (MPN) of 14/100 mL, and not more than 10% of samples should exceed an MPN of 43/100 mL (using a five-tube decimal dilution test).*
>
> *These guidelines should be applied in conjunction with a sanitary survey. There may be situations where bacteriological levels suggest that waters are safe, but a sanitary survey may indicate that there is an unacceptable level of risk.*

These recreational shellfish-gathering water quality guidelines only cover microbiological contamination. They do not cover marine biotoxins, which at times can pose a risk in shellfish gathered at Maketū.

It should be noted that these guidelines are solely a management tool, they do not relate to a specific risk of infection and they do not guarantee that shellfish grown in water of this quality will be safe. They

[1] 24 hour average for a mean tide, at mean river flow.

are however useful for assessing changes in conditions, the potential impact of rain events, and for making decision on when harvesting should be curtailed. Faecal coliforms and other 'faecal indicator bacteria, do not necessarily cause disease themselves but indicate the risk of disease-causing organisms.

Ministry of Health sets criteria for faecal bacteria in shellfish flesh (MoH 1995). These criteria allow faecal coliform concentration up to 230 MPN/100mL with up to two samples from the same batch allowed to exceed this level. However, if a single sample result exceeds 330 MPN/100 g then the entire batch is deemed to be non-compliant with the standard. For the purpose of comparing monitoring results with this standard I have compared 230 MPN/100mL with median results and 330 MPN/100mL with maximum results from a site.

Bathing water guidelines

The recreational bathing water guidelines for marine waters is based on a 'traffic light' system with different action proposed for 'surveillance', 'alert' and 'action levels'. These are described in Box 1. In order to be graded as 'good' or better a marine site must have a 95 percentile value of <200 enterococci/100mL and a Sanitary Inspection Category of 'moderate'

Box 1: Surveillance, alert and action levels for marine waters (MfE and MoH 2003)

Surveillance/Green Mode: No single sample greater than 140 enterococci/100 mL.

- Continue routine (e.g. weekly) monitoring.

Alert/Amber Mode: Single sample greater than 140 enterococci/100 mL.

- Increase sampling to daily (initial samples will be used to confirm if a problem exists).
- Consult the CAC to assist in identifying possible sources.
- Undertake a sanitary survey, and identify sources of contamination.

Action/Red Mode: Two consecutive single samples (resample within 24 hours of receiving the first sample results, or as soon as is practicable) greater than 280 enterococci/100 mL.

- Increase sampling to daily (initial samples will be used to confirm if a problem exists).
- Consult the CAC to assist in identifying possible sources.
- Undertake a sanitary survey, and identify sources of contamination.
- Erect warning signs.
- Inform public through the media that a public health problem exists.

Current microbial water quality in Maketū estuary

Microbial bathing quality is monitoring weekly over summer (Nov to March) in the entrance channel of the Maketū estuary (near the rock). The results for the period from 2007 to 2014 are a median of 2 enterococci/100mL and a 95 percentile of 83 enterococci/100mL. The Amber mode was exceeded less than three percent of the time. The Action mode was exceeded by a single sample less than one percent of the time and was never exceeded by two consecutive samples, i.e. the lower estuary consistently met the bathing water guidelines. Bimonthly water quality sampling by BOPRC at the boat ramp shows similar results, i.e. the median and 95 percentile enterococci values were respectively 6 enterococci/100mL and 74 enterococci/100mL (2007 to 2013[2]).

Compliance monitoring for the current re-diversion consent includes sampling of bacteria in shellfish and shellfish waters every summer (see Park 2011). The lower estuary site (site 9) had a median faecal coliform result of 4.5 MPN/100mL and a 90 percentile of 40 MPN/100mL – i.e. it complied with the shellfish gathering guidelines (period 2001-2011, high and low tide). Faecal coliform concentrations were considerably higher during low tide compared to high tide (i.e. a median of 1 MPN/100mL compared to 26 MPN/100mL respectively). Bimonthly water quality sampling by BOPRC at the boat ramp shows similar results, i.e. the median and 90 percentile faecal coliform values were respectively 8.5 and 74 MPN/100mL (period 2001 to 2013)[3].

Shellfish flesh samples were also within the guideline values. The median faecal coliform concentration in shellfish flesh was 80 FC/100g and 135 FC/100g for pipi and cockle respectively, but the single sample maximum value of 330 FC/100g was exceeded on 23% and 26% of the time for pipi and cockle respectively (period 2001-2013). In other words, bacteria in the shellfish flesh samples were within guideline values most of the time (median values) but occasionally exceed acceptable limits.

Faecal coliform concentrations in the Maketū estuary are considerably higher during rain events. For example, bimonthly sampling at the boat ramp since 1996 has found that the faecal coliform concentration is 2.7 times more likely to exceed 14 MPN/100mL during a rain event than during dry weather, and 3.2 times more likely to exceed 43 MPN/100mL during a rain event than during dry weather[4]. These differences were statistically significant (i.e. binomial analysis p-values of 0.001 and 0.01 respectively).

Modelled microbial water quality in Maketū estuary: before and after the re-diversion

DHI (2014) modelled the microbial water quality in the Maketū estuary based on mixing of external inputs (i.e. Kaituna River, Waitipuia Stream, drains and sea water), and using conservative assumptions for bacteria die-off. The modelled dilutions were used to calculate the proportion of time that shellfish gathering guideline values would be exceeded in the mid-lower estuary, and the proportion of time that the bathing water guideline values would be exceeded in the lower estuary near the boat ramp.

In order to calculate key statistics for bacteria, a different approach was applied to the same datasets as used in the DHI (2014) analysis. The distribution of enterococci and faecal coliform bacteria from the Kaituna River was divided by the distribution of predicted dilutions from the DHI model for each site (shellfish and bathing), before and after re-diversion[5]. The analysis accounted for the full distribution of data (rather than a summary statistic) using Monte Carlo sampling methods in the statistical programme @RISK. The output was a full distribution of predicted bacteria concentrations at each site in the estuary.

Similar estimates were made of the percent of time that guideline limits will be exceeded by both the DHI (2014) method and the Monte Carlo sampling method. For this report I have quoted the Monte Carlo sampling method.

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[2] Sampled on a mid to high tide, usually outgoing.

[3] These statistics excludes targeted rain event sampling.

[4] For period 1996-2013, 14 MPN/100mL was exceeded on respectively 35 and 13 occasions for samples with and without rain; 43 MPN/100mL was exceeded on respectively 16 and 5 occasions for samples with and without rain. A rain event was defined as >0.3mm as a three day average.

[5] $C_{est} = ((C_{rv} - C_{sea})/D) + C_{sea}$; where C est, C rv and C sea = concentration in the estuary, river and sea respectively, D = dilution as modelled by DHI (2014). This simplifies to C_{rv}/D when C sea is 0.

The model over-estimated faecal coliform concentration in shellfish water compared to measured results (e.g. a modelled 90 percentile value of 49 MPN/100mL compared to measured value of 40 MPN/100mL), and under-estimated faecal coliform and enterococci concentrations in bathing waters near the boat ramp (e.g. a modelled 95 percentile of 37 Enterococci /100mL compared to a measured concentration of 74 ENT/100mL). This is likely to be due to conservative assumptions in the model over-estimating effects at the shellfish site and localised contamination affecting actual monitoring results near the boat ramp. This localised contamination could be from stormwater runoff, but could also be related to sea gulls that are common in this part of the estuary.

The model results indicate that the proposed re-diversion will generally increase the concentration of bacteria in the water of Maketū estuary. This will have negligible impact on the suitability of the lower estuary for bathing. The lower estuary will still have a 'good' or better bathing water grading, and it will still be rare for enterococci concentrations to increase beyond the 'surveillance' mode, and only about 1% of samples will trigger resampling under the 'action' mode. The shellfish gathering guidelines will continue to be met most of the time (i.e. the median will be < 14 MPN/100mL), but the 90 percentile guideline will be exceeded more frequently, increasing from about 12% exceedance to about 19% exceedance after the re-diversion, i.e. this is respectively 2% and 9% more often than the allowable 10% exceedance.

An interesting feature of the dilution in the lower Maketū estuary is that the proposed re-diversion will increase the proportion of time that there will be lower dilution of faecal bacteria from the Kaituna River, but it will also increase the proportion of time that there will be very high dilutions (e.g. >40 times dilution) (see Figure 1). This dynamic is because although there will be an increase in FC bacteria loading to the estuary, the concentration of FC bacteria entering via Ford's cut will decrease (see Table 5), and there will be times in the tidal cycle when the water entering via Ford's cut will be dominated by seawater. Overall, the increase in the frequency of times with low dilution drives the increase in the concentration of microbial bacteria in the estuary derived from external sources.

Table 1: Predicted bacteria concentrations in the Maketū estuary before and after re-diversion based on modelled dilutions and Monte Carlo sampling of Kaituna River bacteria concentrations. Shaded cells correspond to guideline values.

	Bathing exisiting	Bathing proposed	Shellfish exisiting	Shellfish proposed
dilution average	22.2	63.9	29.2	60.6
dilution median	19.8	7.1	12.2	5
FC average	12.2	24.4	21	35.1
FC median	4	6.2	5.4	8.8
FC 90%ile	26.7	57.5	49	84
FC 95%ile	45.5	100.6	86.3	146
% >14 MPN/100mL			30%	41%
% >43 MPN/100mL			11.70%	19.20%
ENT average	10.3	20.3		
ENT median	1.71	2.4		
ENT 90%ile	19	38.37		
ENT 95%ile	37.2	78.3		
% >280 ENT/100mL	0.30%	1.10%		

FC = faecal coliform bacteria, ENT = enterococci bacteria

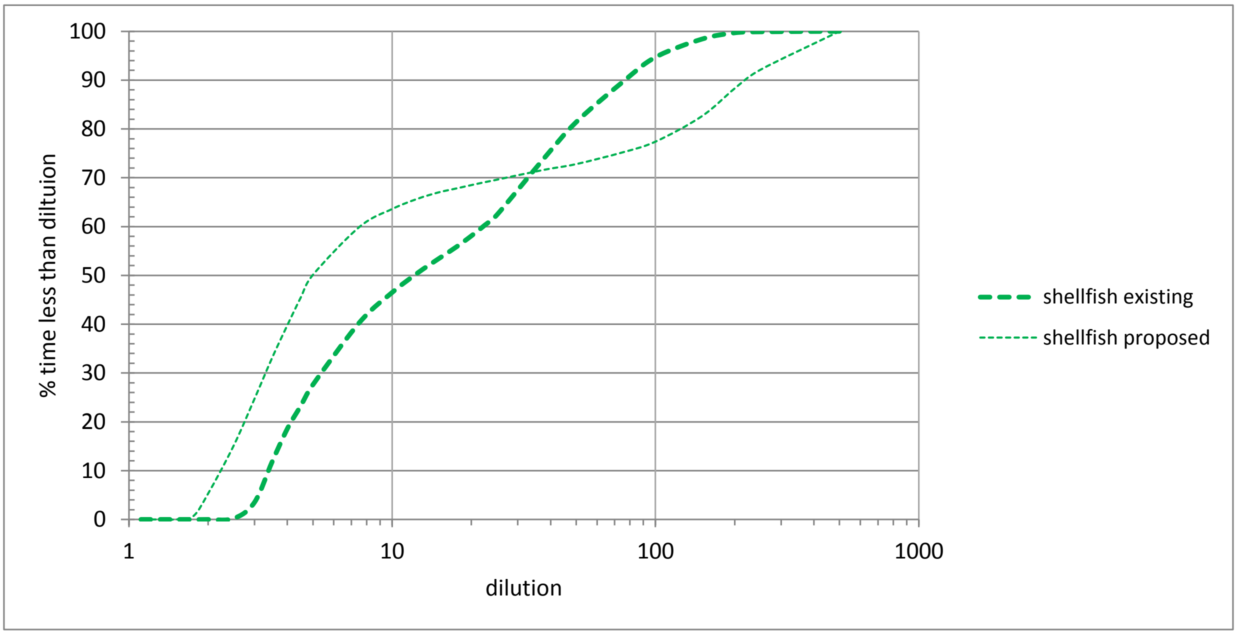


Figure 1: Change in cumulative dilution at the shellfish gathering site as modelled before and after the re-diversion.

Microbial water quality trends in the Kaituna River and Maketū estuary

The microbial water quality of the Kaituna River has considerably improved over the last two decades. The improvement is particularly apparent in the concentration of faecal coliform bacteria which has reduced from a median of 900 MPN/100mL before 2000 to 83 MPN/100mL since 2007. The reduction in faecal coliforms was statistically significant but the reduction in enterococci bacteria was not (based on a student t-test) (Table 2).

The reduction in the concentration of faecal coliform bacteria in the Kaituna River has continued since 2005. The reduction in faecal bacteria was most apparent at the Te Matai site (ca. 12.5 km upstream) but was also strong (9.5% per year) at the site downstream of the Waiari confluence (ca. 8.5 km upstream) (Table 3, Figure 2). In contrast to improving microbial water quality in the Kaituna River, there was no trend in microbial water quality in the estuary (at the boat ramp) since 2005 (Table 3 and Figure 3).

The poor correspondence in long term microbial water quality trends between the Kaituna River and the estuary suggests that factors other than the current Kaituna River input are important in driving microbial water quality in the estuary. The importance of other factors is also indicated by the initial improvement in microbial water quality in the estuary when the Kaituna River was partially re-diverted in 1996[6]. An equivalence test found 'strong evidence' of lower enterococci concentrations in the estuary in five years after 2006 compared to the five years before and no significant change in faecal coliform concentrations. This occurred despite high faecal coliform concentrations in the Kaituna River at the time (Figure 3).

While the input of the Kaituna River does have an important influence on microbial water quality in the Kaituna River, it is not the only influence. Bacteria also enter the estuary from the Waitipuia Stream, drains, stormwater runoff and directly from birds. It is possible that the conservative assumptions used in the modelling have over-estimated the relative impacts of the Kaituna River on microbial water quality in the estuary.

Table 2: Improvement in microbial water quality in the Kaituna River at Te Matai.

Statistic	**Faecal coliform**		**Enterococci**	
	1990-2000	2007-2014	1990-2000	2007-2014
n	43	86	44	86
median	900	83	77.5	30
average	1970	153	113	79
90 percentile	4840	225	236	125

Table 3: Trends in microbial water quality in Kaituna River and Maketū estuary since July 2005. Shaded cells indicate a statistically significant trend.

			RAW		**Rain adjusted**		**% variance explained by**
Site	**Variable**	**median**	***p*-value**	**PAC**	***p*-value**	**PAC**	**rainfall**
Kaituna River at Te Matai	Faecal coliform	64	<0.0001	-25%	<0.0001	-26%	89%
Kaituna River at Te Matai	Enterocicci	27	0.27	-2.80%	0.15	-3.70%	90%
Kaituna River d/s Waiari	Faecal coliform	90	0.014	-8.20%	0.04	-8.30%	88%
Kaituna River d/s Waiari	Enterocicci	32.5	0.15	-3.10%	0.14	-3.70%	68%
Maketu estuary at boat ramp	Faecal coliform	10.5	0.9	0.00%	1.00	0%	11%
Maketu estuary at boat ramp	Enterocicci	5.5	0.5	1.50%	0.90	0%	10%

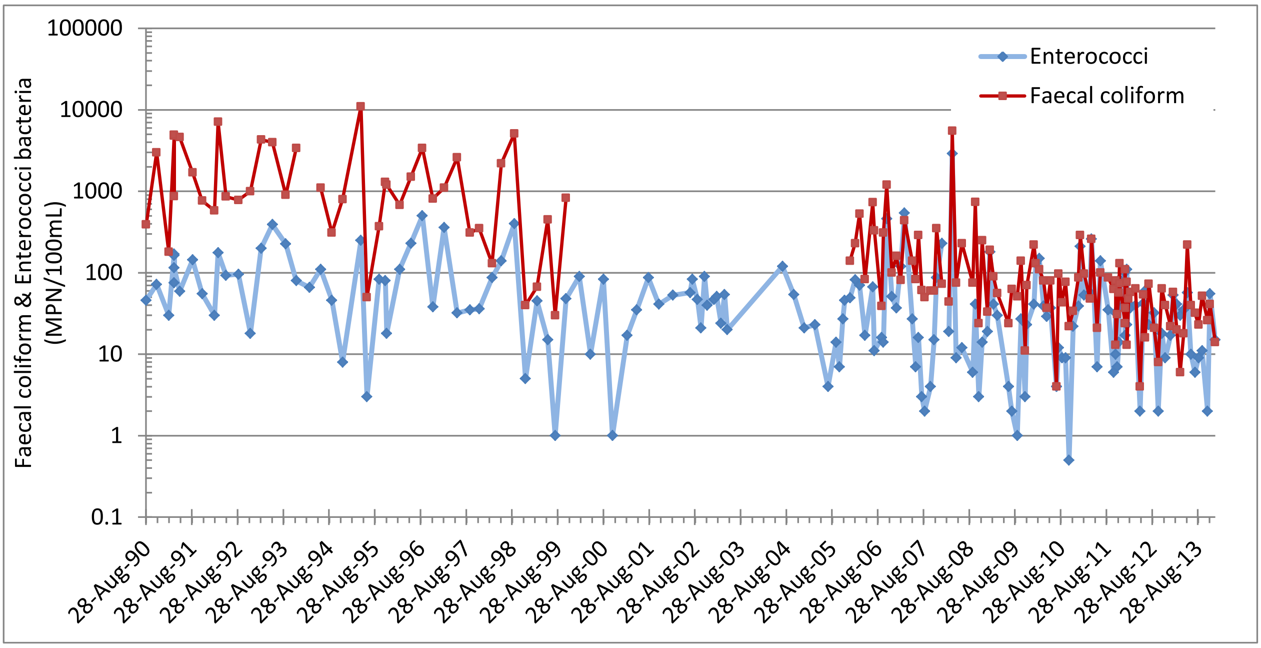
Seasonal Kendall analysis using four seasons and multiple values per season. Co-variate adjustment used a GAM adjustment of the daily rainfall.

The analysis excluded data from target rain event sampling that occurred in recent years.

Period in river: July 2005 to Jan 2014. Period in estuary: July 2005 to April 2013.

PAC = Percent annual change

6 The current consent applied for a stage re-diversion of 100,000 m^3 per tidal cycle. The control structure was damaged in February 1996 and the gates fully opened. In February 1997 the flow through the gates was restricted to 20,000 m^3 per tidal cycle, after which flow was gradually increased.



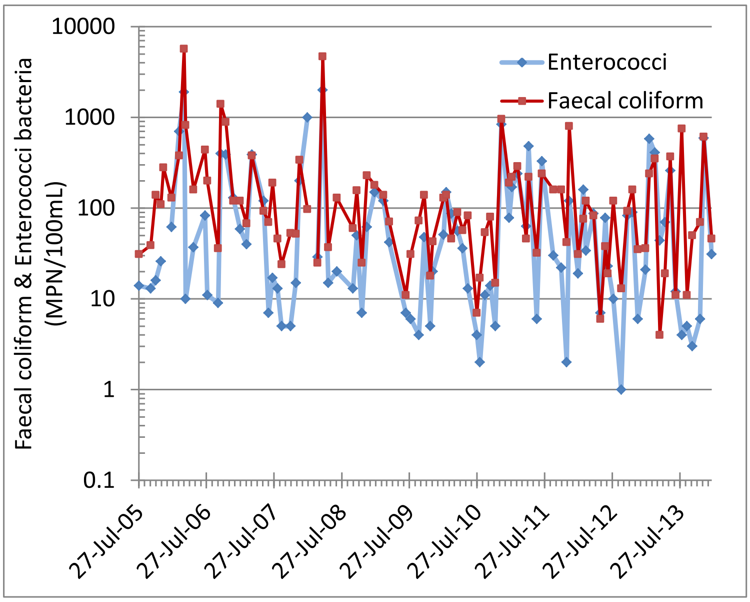


Figure 2: Faecal indicator bacteria concentration in the Kaituna River at Te Matai (top) and downstream of Waiari (bottom graph). The graph does not include data from targeted rain event monitoring that occurs since 2011.

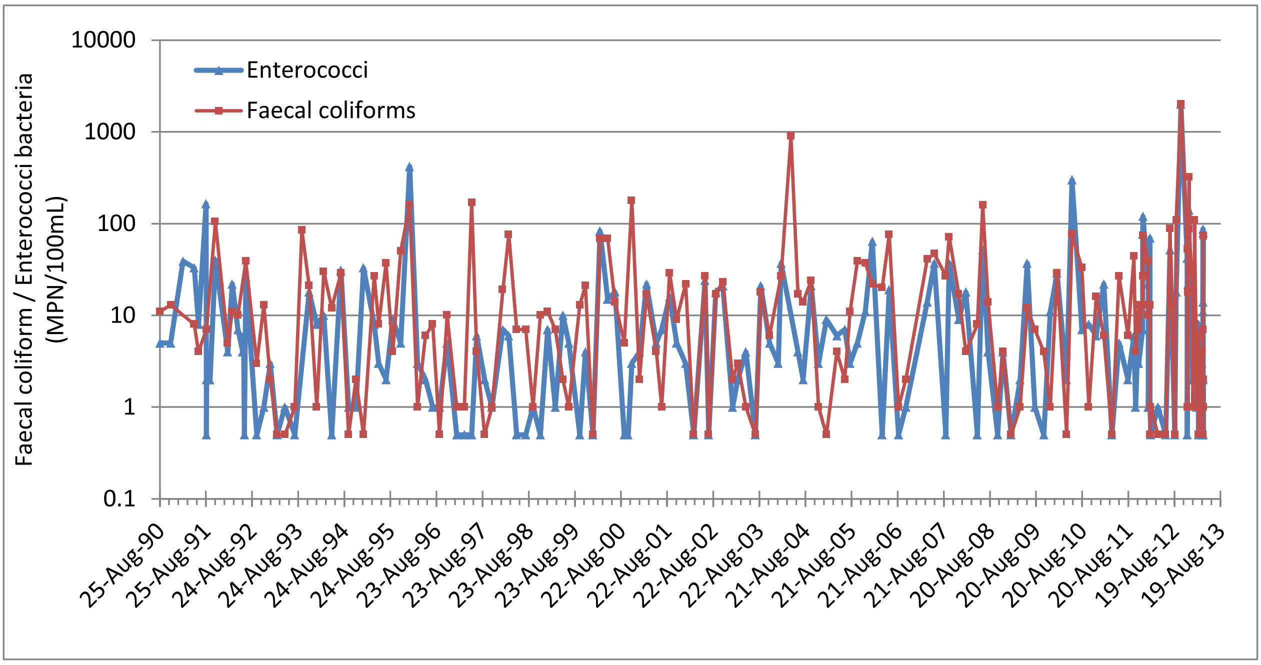


Figure 3: Faecal indicator bacteria concentration in the Maketū estuary at the boat ramp. The graph does not include data from targeted rain event monitoring that occurs since 2011.

Potential faecal load from birds

Wildfowl can carry pathogens that are potentially harmful to humans[7] and have found to be a significant source of faecal coliform bacteria to some lagoons and beaches. Faecal bacteria counts can be highly variable between bird species, feeding habits and the time of year (Wright et al. 2009, Gilpin et al. 2007, Fleming and Fraser 2001, Derolez et al. 2009). Don and Donovan (2001) assess the potential impact of birds on the bacterial input to Rotorua lakes and found that there was a potentially high faecal loading from birds. Their calculations assumed an average quantity of guano produced per day was 3.2% of body weight, and adjusting for the percentage of time birds were expected to spend on the water.

Gilpin et al. (2007) found that Black Swans were a significant potential source of faecal contamination to water and shellfish. They calculated they had a mean daily output of 11 x10^6 faecal coliforms (about 418 g wt/day, and 30,000 FC/g wt). Gulls have relative high concentrations of faecal bacteria in their faeces compared to other geese, i.e. 3.68 x10^8/g wt compared to 1.53 x 10^4/g wt, however geese had about 15 times more faeces (by weight) than gulls. The difference in bacteria concentration was attributed to differences in diet (Alderisio and DeLuca 1999). Wright et al. (2009) found that ducks and gulls had a similar concentration of enterococci bacteria in guano but the concentration in heron were an order of magnitude higher.

Bird FC load Method

In order to make a first order assessment of the contribution of birds to faecal contamination in the Maketū estuary, I used literature values of guano weight and faecal concentration where these were available. For bird species where information was not available I assumed that daily guano production (as wet weight) was 7% of body weight (median of available data). For species with no available information on guano bacteria concentrations, I assumed a concentration of 3.1 x 10^6 FC/ g wet weight i.e. the summer average for geese measured by Alderisio and DeLuca (1999). Faecal bacteria data is

[7] Including *Campylobacter* sp., *Clostridium* sp., *Salmonella* sp., *Aeromonas* sp., *Giardia* and *Cryptosporidium* sp.

highly skewed so where possible I applied the median bacteria concentrations rather than the average concentrations.

The number of birds on Maketū estuary was based on June 2013 bird counts for the whole estuary from the NZ Ornithological Society. Birds associated with the sand dunes (e.g. dotterel) were not included in the calculations. There is little information on the total proportion of time that birds spend on the estuary, so for the purpose of this assessment I have assumed that red billed gull and black backed gull spend 5% of the time in the estuary and all other bird species spend on average 25% of their time on the estuary.

Bird FC load: results and discussion

Wildfowl have the potential to be a significant source of faecal coliform bacteria within Maketū estuary in addition to bacteria entering via the river. My calculations show that birds could contribute about 6.4×10^{10} to the estuary on a daily basis, which corresponds to respectively 33% and 10% of the current and proposed median faecal coliform load to the estuary via Fords cut (Table 4 and Table 5). When compared to the average faecal coliform load via Fords cut, it corresponds to 13% and 4% of the current and proposed load respectively.

The presence of seagulls had a large influence in the results because of the high concentration of faecal bacteria in gull guano. There will be a high degree of variability around these estimates because there is a high degree of variability in faecal coliforms in bird guano (Gilpin et al. 2007, Alderisio and DeLuca 1999). Furthermore, there is little information on faecal coliform bacteria concentrations for many marine birds, and the information that is available is often expressed as average values rather than median values or provision of a full dataset.

My calculations assume a uniform mixing of bird guano over the whole estuary. In reality the distribution of birds is patchy and the influence of birds on microbial water quality will be much greater in areas close to where they congregate. There is a colony of 500 red-billed bull and 28 black back gull nesting on the end of the spit which has the potential to cause localised contamination[8]. Rain events may also increase the influence of birds on microbial water quality by washing faecal material from beaches and paddocks into the estuary. The influence of other animals will also become apparent during rain events, for example Wright et al. (2009) found that dogs were the largest contributing animal source of enterococci bacteria to a bathing beach in Florida. One faecal event from a dog was equivalent to 6,940 bird faecal events.

A better estimate of the influence of birds on microbial water quality in the estuary could be determined by developing a model based on the Monte Carlo approach. However the accuracy of this method would be largely influenced by having more complete data on faecal bacteria excreted by birds.

[8] Bird numbers from Maketū Ongatoro Wetland Society Inc (2014)

Table 4: Number of birds in Maketū estuary and estimate of daily faecal coliform load. Bird count from NZOS, June 2013.

Species	No. birds around estuary	Estimate of time on water	mean bird wt (kg)	Guano wet weight (g /day)	FC per g wt	FC/bird/day	FC/day	References
Canada goose	400	0.25	4.5	250	128,000	3.200E+07	3.200E+09	1
Pied Stilt	200	0.25	0.19	13.3	3,100,000	4.123E+07	2.062E+09	
Mallard	196	0.25	1.2	130	128,000	1.664E+07	8.154E+08	3
Pied Oystercatcher	167	0.25	0.55	38.5	3,100,000	1.194E+08	4.983E+09	
Red-billed Gull	117	0.05	0.28	19.6	166,000,000	3.254E+09	1.903E+10	1
Variable Oystercatcher	112	0.25	0.72	50.4	3,100,000	1.562E+08	4.375E+09	
black swan	97	0.25	5.5	418	30,000	1.254E+07	3.041E+08	2
White-faced Heron	95	0.25	0.55	38.5	3,100,000	1.194E+08	2.835E+09	
Royal Spoonbill	60	0.25	1.8	126	3,100,000	3.906E+08	5.859E+09	
Black-backed Gull	39	0.05	0.95	50	166,000,000	8.300E+09	1.619E+10	2, 3
Pied Shag	32	0.25	1.6	112	3,100,000	3.472E+08	2.778E+09	
Paradise Shelduck	23	0.25	1.55	108.5	128,000	1.389E+07	7.986E+07	
Black Shag	5	0.25	2.2	154	3,100,000	4.774E+08	5.968E+08	
Little Shag	5	0.25	0.8	56	3,100,000	1.736E+08	2.170E+08	
gannet	2	0.25	1.6	112	3,100,000	3.472E+08	1.736E+08	
white heron	1	0.25	0.9	63	3,100,000	1.953E+08	4.883E+07	
Total FC load per day							**6.354E+10**	

Note:

Reference: 1 = seasonal median from Alderiso and DeLuca (1999), 2= Gilpin et al. (2007), 3= Fleming and Fraser (2001).

Bird survey was undertaken in June 2013 at high tide.

Shaded cells indicate data with a literature value.

Table 5: Estimated load and concentration of faecal bacteria entering the Maketū Estuary via Ford's cut compared to the faecal bacteria load from birds.

	current	proposed
Volume/day (m^3)	307,400	1,149,000
Freshwater fraction	0.87	0.76
Median FC in Kaituna River (MPN/100mL)	74	74
FC external load via Ford's cut (FC/day)	1.908E+11	6.228E+11
Median FC at Ford's cut (FC/100mL)	64.4	56.2
FC load via birds (FC/day)	6.35E+10	6.35E+10
Bird FC load as % of external load	33.3%	10.2%

FC = faecal coliform bacteria

Summary of potential effects of the re-diversion

The microbial water quality in the lower estuary near the boat ramp consistently meets bathing water guidelines. It is rare for enterococci concentrations to increase beyond the 'surveillance' mode, and less than 1% of samples trigger resampling under the 'action' mode. The proposed re-diversion is expected to increase the concentration of bacteria in the lower estuary, but this will have negligible impact on the health risk for bathing. It will still be rare for enterococci concentrations to increase beyond either the 'surveillance' mode, and only about 1% of samples will trigger resampling under the 'action' mode.

The microbial water quality in the lower estuary currently meets shellfish gathering guidelines most of the time (i.e. the median is less than 14 MPN/100mL), but high levels are borderline compared to what is allowed under the guidelines, i.e. a 90 percentile of 40 MPN/100mL and the single sample maximum for shellfish flesh is exceeded about 23% to 26% of the time. The higher levels of bacteria are mostly associated with rain events, i.e. bacteria levels are over three times more likely to exceed the upper shellfish guideline value (of 43 MPN/100mL) during a rain event than during dry weather.

It is recommended that shellfish are not gathered within two to five days following rainfall. Shellfish depurate 90 to 95% of bacteria and viruses within two days. The rate of depuration[9] varies with temperature, salinity and tidal cycle, thus during a large rain event the rate of depuration may be slower and a longer withholding period would be justified (e.g. up to five days) (Ball et al. 2008). Depuration can also be achieved by holding the live shellfish in tanks of clean seawater for one to three days prior to consumption.

The model indicates that after the re-diversion the shellfish gathering guidelines will continue to be met most of the time (i.e. the median will be < 14 MPN/100mL), but the 90 percentile guideline will be exceeded more frequently, increasing from about 12% exceedance to about 19% exceedance after the re-diversion, i.e. this is respectively 2% and 9% more often than the allowable 10% exceedance under the shellfish gathering guidelines. The majority of exceedance is still likely to be associated with rain events. In practical terms, this will not change the current advice to shellfish gathering, i.e. people should avoid gathering shellfish from the estuary within two to five days of rain. The re-diversion will also not change the health risk of shellfish gathering due to biotoxins (e.g. PSP).

The modelled calculations of microbial contamination at the shellfish water site appear to be conservative and probably over-estimate the water quality change that will occur as a result of the re-diversion. Although the Kaituna River input does have a significant impact of water quality in the estuary, the original re-diversion in 1996 resulted in improved microbial water quality rather than a decline. This highlights that there are range of factors influencing water quality in the estuary.

The bacteria enter the estuary from a number of sources including rural and urban drains and streams, waterfowl, septic tanks, run-off from grazed land. The main load of bacteria to the estuary is via the Kaituna River, Waitipuia Stream, and drains - the impact of these has been modelled. However, other sources such as wildfowl, septic tanks and direct stormwater runoff have not been included in the model and may have a significant localised impact in parts of the estuary. The impact of these will not change as a result of the proposed re-diversion.

The concentration of faecal indicator bacteria in the Kaituna River has significantly declined since 2005. This improving trend may continue as discharges are managed in the wider catchment. Completing the reticulation of sewage to all houses in Maketū will also reduce the risk of faecal contamination in the estuary. If these changes happen, then the shellfish gathering risk will also decrease over the long term.

References

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[9] Depuration is the purification of shellfish due to the defecation of sediment and any undigested food material in the gut.

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