Faecal contamination of shellfish on the Horowhenua coast

Manaaki
Taha Moana

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FAECAL CONTAMINATION OF SHELLFISH ON THE HOROWHENUA COAST

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Prepared for Taiao Raukawa and Manaaki Taha Moana

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MIHIMIHI[1]

Tuia i runga, tuia i raro, tuia i waho, tuia i roto, tuia te here tangata, ka rongo te pō, ka rongo te ao.

Ka tuku te ia o whakaaro kia rere makuru roimata atu ki te kāhui ngū kua hoki atu ki te waro huanga roa o te wairua, rātou kei tua o te ārai, takoto, okioki, e moe.

Tātou ngā waihotanga o te reka ki a tātou, ā, e mihi kau atu ana mātou ki a kōutou i kotahi ai te whakaaro i raro i te korowai whakamarumaru o tēnei taonga, Manaaki Taha Moana (MTM).

Tihei Mauri Ora, ki a tātou katoa.

Ki ngā taniwhā hikurauroa i putaputa mai ai i ngā rua kōniwhaniwha, ngā whare maire, ngā whare wānanga me ngā whare whakahuruhuru manu ā pūtea nei o te motu, tēnā koutou.

Ki ngā manu tioriori e karangaranga ana te taha wairua ki te taha tangata i runga i ngā marae mahamaha o Rongomaraeroa, whātoro atu ana ki ngā unaunahi nunui e pīataata mai rā i te nuku o te ika, te mata o te whē,

Tēnā hoki koutou, oti rā, tēnā tātou katoa.

WHAKATAUKI

Rarangi maunga, tū i te ao, tū i te pō. Rārangi tāngata, ka ngaro!

The ranges of mountains stand steadfast through time. However, lines of humankind fall as time goes by.

[1] Composed by Tipene Hoskins

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1. INTRODUCTION

This research was undertaken as part of the Manaaki Taha Moana (MTM) programme (see Box 1).

Bivalve shellfish such as toheroa, tuatua, and pipi are important kaimoana species for Māori. The depletion (quantity) and degradation (in quality) of kaimoana resources is of immense concern to iwi. Degradation can be caused by toxins (*e.g.* heavy metals) and / or biological (*e.g*. faecal bacteria) contamination, either of which can make kaimoana unfit for human consumption.

Faecal contamination of kaimoana is of concern to Māori both as a health issue — because of the presence of pathogens — and because contact of faecal material with food sources is offensive. Sources of faecal contamination in the coastal marine environment include human sewerage / wastewater infrastructure, farmed animals, and wild animals such as possums and birds. Faecal contamination of coastal waters is higher after rainfall, when effluent deposited on the land during dry periods, is washed into rivers and the sea.

Box 1. Manaaki Taha Moana

Manaaki Taha Moana (MTM) is a six-year programme, which runs from 1 October 2009 to 30 September 2015. Research is being conducted primarily in two areas:

1. Tauranga Moana region
2. Horowhenua coastline between Hōkio Stream, south of Foxton Beach, and Waitohu Stream, just north of Ōtaki Beach.

This programme of research activities has built upon previous research with Ngāti Raukawa ki te Tonga in the lower North Island through the programme, Ecosystem Services Benefits in Terrestrial Ecosystems for Iwi and Hapū (MAUX0502).

Professor Murray Patterson (School of People, Environment and Planning, Massey University) is the Science Leader for the MTM programme.

A number of different organisations are contracted to deliver the research. Caine Taiapa of the Manaaki Te Awanui Trust is Research Leader Māori for the Tauranga Moana case study and Dr Huhana Smith is Research Leader Māori in the Horowhenua coastal case study through Te Reo a Taiao Raukawa, the Ngāti Raukawa Environmental Resource Unit (Taiao Raukawa). Freshwater and marine expertise comes from Cawthron Institute (Nelson), information technology expertise from WakaDigital Ltd (Tauranga), and project management and ecological economics expertise comes from the School of People, Environment and Planning, Massey University (Palmerston North).

Taiao Raukawa (on behalf of hapū of Ngāti Raukawa ki te Tonga and affiliates) is linked with other iwi and groups, particularly Muaūpoko hapū and whanau who have tangata whenua status in the northern Waiwiri to Hōkio case study area. The research team tries to engage extensively with all iwi and hapū, kaitiaki (environmental guardians) and other end-user groups, who have been set up in each case study region.

Manaaki Taha Moana is a collaborative, action and kaupapa Māori research project that uses and bolsters mātauranga Māori or Māori knowledge systems within whenua (lands), awa (waterways), repo (wetlands) and moana (sea and harbours).

The Horowhenua MTM research activity centres on an area of interrelated hapū (collective of multiple whanau groups), within a south-west coastal rohe (region). This area once had extensive coastal forest, with streams, rivers, estuaries, a series of lakes, lagoons and dune wetlands that teemed with freshwater food and fibre resources and kaimoana (tidal and marine resources). The coastal, cultural landscape is bounded by the Tasman Sea and extends from the Hōkio Stream in the north to the dynamic Waitohu Stream, wetland and estuary at Ōtaki Beach in the south. The case study includes awa and awa iti (rivers and streams), repo (wetlands), roto (dune lakes) and moana (seas and estuaries) within the coastal region (Smith *et.al* 2014).

Bivalve shellfish such as toheroa, tuatua and pipi feed by filtering particles of organic material from the water. When faecal material from contaminated water is taken up by filter feeders, it becomes concentrated in the digestive system and tissues of the shellfish. While faecal contaminants are not necessarily harmful to the shellfish themselves, many of the associated pathogenic organisms (bacteria, viruses and parasites) are potentially harmful to humans who consume them.

Faecal coliform bacteria, including *Escherichia coli* (*E. coli*), live in the intestinal track of humans and many other animals. Termed faecal indicator bacteria (FIB), the relative abundance of faecal coliforms or *E. coli* found in water is a commonly-used indicator of faecal contamination. The New Zealand Ministry of Health has identified levels of FIB contamination at which shellfish are deemed to be marginally acceptable and unacceptable for human consumption (MfE/MoH 2003).

Ministry of Health guidelines define levels at which bacteria are detectable but acceptable in terms of health risk. The inability to provide manuhiri[2] with healthy locally-sourced food is an erosion of mana[3]. But even if health risks are minimal, contamination of mahinga kai[4] with faecal material is, in itself, offensive to Māori. It may be that any detectable level of faecal indicator bacteria is therefore considered unacceptable.

[2] Guests
[3] Status
[4] A place where food is gathered

The Horowhenua coast historically held abundant populations of toheroa (Redfearn 1974; Moore & Royal 2012). These are now rare or absent along most of this coast. The dominant shellfish on the intertidal beach between Hōkio in the north and Ōtaki in the south are tuatua / pipi[5]. While not as highly valued as toheroa, tuatua / pipi are nonetheless a taonga[6] species and are widely and regularly collected for food along the Horowhenua coast (Moore & Royal 2013).

Revered in recent memory by kaumātua as an abundant food resource, the Waiwiri coastal foreshore adjacent to the mouth of the Waiwiri Stream, once provided local hapū and kaitiaki with a plentiful supply of shellfish, including toheroa. Anecdotal evidence suggests that the stream has suffered severe ecological degradation in the past 35 years, particularly the last decade. There is concern about the cumulative effects of loss of riparian vegetation, sedimentation, and increased nutrient and faecal loading in the Lake Waiwiri (Papaitonga) catchment to sea (Allen *et.al* 2012, Smith *et.al.* 2014).

In a previous study (Allen *et al.* 2012), *E. coli* concentrations from shellfish harvested near the Waiwiri river mouth, approximately 3 km south of Hōkio, were more than three times (and up to ten times) over the limit recommended for human consumption (230 MPN/100g NZ MoH 1995). These shellfish had been collected after moderate to heavy rainfall, and there remained some uncertainty about contamination levels under conditions of lower rainfall. Moreover, it was not clear how well the results at Waiwiri reflected contamination at other sites along the coast. Accordingly, tuatua / pipi were sampled for FIB on three occasions: following a long summer dry period, after moderate rainfall, and after light rainfall. This study was a component of a larger study along the Hōkio to Ōtaki coast, which included analysis of land cover and a shellfish survey (Newcombe *et al.* in prep.).

2. METHODS

The 13 sites selected for the shellfish survey (Newcombe *et al.* in prep.) were also used as sampling sites for the faecal indicator bacteria (FIB) *Escherichia coli*. The locations of these sites are shown in Figure 1.

[5] The shellfish referred to collectively as 'tuatua / pipi' are two very similar species: *Paphies subtriangulata* and *P. donacina*. Throughout New Zealand these species are most commonly referred to as tuatua, *P. donacina* can also be called Southern tuatua. Apparently no distinction is generally made between the two species by shellfish harvesters. In the study area there were a range of views on the names for *P. subtriangulata* and *P. donacina.* Some people used the term 'pipi', others used 'tuatua', and some felt that the smaller shellfish of these species are termed 'pipi' while the larger ones are 'tuatua'. Because of the different usage locally, and throughout New Zealand, choosing a single name would cause confusion. Referring to both scientific names is unwieldy; therefore it seems to be the best approach in this document to refer to *Paphies subtriangulata* and *P. donacina* as 'tuatua / pipi'.
The estuarine species *P. australis* is commonly referred to as 'pipi' in many parts of New Zealand. In the Kuku area, the estuarine species (probably *P. australis*) is referred to as 'kokata' (pers. comm. H. Smith).

[6] Treasure, anything prized — applied to anything considered to be of value.

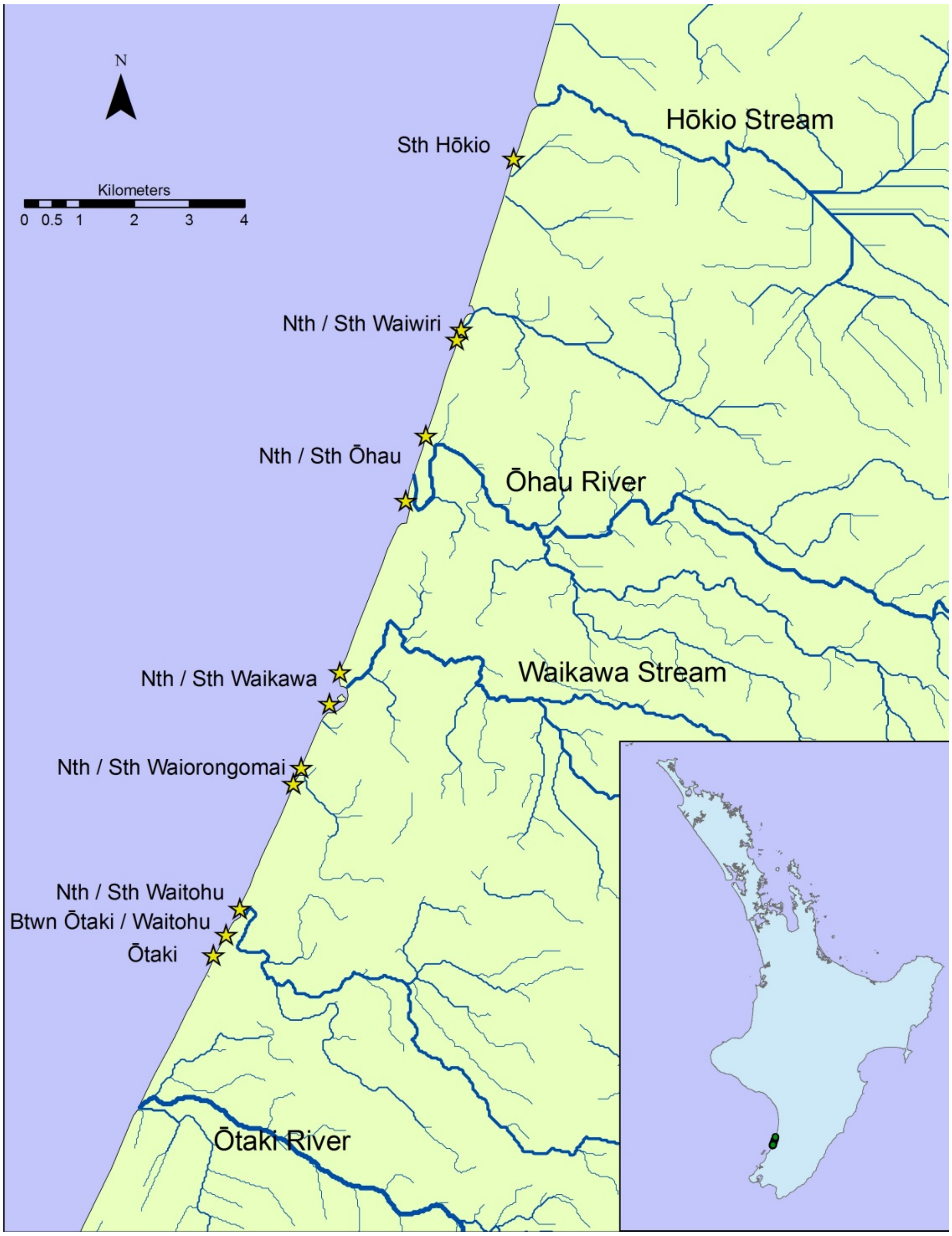

Figure 1. Location of sites at which tuatua / pipi were collected for analysis of the concentration of faecal indicator bacteria *Escherichia coli*.

The first sampling event (5 and 6 April, 2014) followed a dry period, the second (6 and 7 May 2014) followed a moderate rain event, and the third (22 May, 2014) followed a light rainfall (Table 1). Only five sites were sampled on the first two sampling occasions, but unexpectedly high faecal contamination was found, this motivated the decision to test all thirteen study sites on the final sampling date.

Table 1. Rainfall in the five days prior to each of three shellfish sampling events at three different recording stations[7].

Data source	Sampling 1 (5 and 6 April, 2014)	Sampling 2 (6 and 7 May 2014)	Sampling 3 (22 May, 2014)
Metservice[8] at Levin	5 April 0 4 April 0 3 April 0 2 April 0 1 April 0 31 March 0	6 May 1 mm 5 May 11 mm 4 May 1.6 mm 3 May 0 2 May 0 1 May 2.4 mm	21 May 1.6 mm 20 May 0 19 May 0 18 May 0 17 May 0
Waitarere Forest Climate Station[9]	5 April 0 4 April 0 3 April 0.2 mm 2 April 0 1 April 1 mm 31 March 0	6 May 0.8 5 May 8.4 mm 4 May 2 mm 3 May 1 mm 2 May 0.2 mm 1 May 0	21 May 0.8 20 May 0 19 May 0 18 May 0 17 May 0
Greater Wellington Regional Council at Ōtaki Depot[10]	31 March 0 1 April 0 2 April 0 3 April 0 4 April 0 5 April 0	6 May 1 mm 5 May 12.5 mm 4 May 0 3 May 1 mm 2 May 0 1 May 0	21 May 2.0 mm 20 May 0 19 May 0 18 May 0 17 May 0

Approximately twenty tuatua / pipi were collected per site on each sampling occasion. The shellfish were collected from the low intertidal or shallow subtidal zone and placed on ice for transport back to the Cawthron Institute, where they were processed according to the MPI Method Version 9, February 2013[11].

[7] Rainfall at sites in the Manawatu catchment was almost always within the ranges listed here, and in particular all these sites had nil rainfall recorded in the days leading up to the first sampling event, except for a single reading of 1 mm on March 31 at Manawatu at Moutoa. Other sites examined were Mangaone at Milson Line, Mangaone at Valley Road, Ngahere Park Climate Station, Makino at Halcombe Road, Makino at Cheltenham, Pohangina at Alphabet Hut, Kumeti at Rua Roa, and Mangatainoka at Hillwood Hukanui. http://www.horizons.govt.nz/managing-environment/resource-management/water/river-heights-and-rainfall/Choose-river-rainfall-chart/

[8] Levin rainfall daily totals. www.metservice.com

[9] Rainfall at Waitarere Forest Climate Station. www.horizons.govt.nz

[10] This site is located at Greater Wellington's Ōtaki depot on the south side of Ōtaki township. http://graphs.gw.govt.nz/OtakiŌtaki-Depot

[11] Enumeration of *E. coli* in bivalve molluscan shellfish. MPI Method Version 9, Feb 2013. MPN (most probable number) multiple tube technique.

3. RESULTS AND DISCUSSION

3.1. Shellfish contamination

Shellfish on the Horowhenua coast from Hōkio to Ōtaki had concentrations of *Escherichia coli* bacteria indicative of widespread faecal contamination. There was a high level of contamination at many sites, even under conditions of only minor local rainfall, and contamination was apparent even after a dry period. Ministry of Health guidelines state that shellfish with more than 230 to 330 faecal coliform bacteria per 100 grams of flesh are ‘marginally’ fit for human consumption, and that levels higher than 330/100 g are ‘unacceptable’ (MoH 1995).

Following five days with only very minor rainfall (and none recorded near the coast), concentrations of *E. coli* in tuatua / pipi collected from south of Waiwiri Stream were estimated at 330/100mg, and thus at the very top of the MoH’s marginal range for human consumption (Table 2). Concentrations found in shellfish from the mouth of the Hōkio Stream measured 230/100 g, just below the range deemed marginally fit for human consumption (Table 2). Concentrations were lowest north of Waiwiri, and on either side of the mouth of the Waiorongomai Stream, being well within the MoH’s acceptable range (Table 2).

Of the 13 sites that were sampled following minor rainfall, *E. coli* concentrations in the shellfish were ‘unacceptable’ at seven sites, ‘marginally acceptable’ at three sites and ‘acceptable’ at three sites (Table 2).

When five sites were tested following moderate rainfall, shellfish contained *E. coli* concentrations that were, in all cases, unacceptable for human consumption (> 330/100 g), ranging as high as 5,400/100 g (Table 2).

Table 2. *E. coli* bacteria concentrations found in tuatua / pipi collected from beaches on the Horowhenua coast. Figures are most probable number (MPN)/100 g from the MPI method 2013. Shaded cells indicate values above those recommended by the New Zealand Ministry of Health as marginally acceptable (orange) or unacceptable (red) for human consumption (faecal coliform counts, (MoH1995)[12]). Green indicates that no *E. coli* were detectable with the methods used in this study. Italicised values indicate the maximum value of a given category (acceptable / marginally acceptable). Blank cells indicate that no shellfish were collected on that date.

Location (Figure 1)	No recent rainfall (early April)	After minor rainfall (late May)	After moderate rainfall (early May)
South of Hōkio	*230*	700	5400
North of Waiwiri	140	1100	490
South of Waiwiri	*330*	310	1300
North of Ōhau		1400	
South of Ōhau		1300	
North of Waikawa		*330*	
South of Waikawa		790	
North of Waiorongomai	<20	50	790
South of Waiorongomai	130	130	490
North of Waitohu		170	
South of Waitohu		490	
Between Ōtaki surf club and Waitohu		490	
Ōtaki surf club		*330*	

It was expected that some degree of contamination would be found during this current study because faecal contamination in shellfish had been recorded at Waiwiri previously (Allen *et al.* 2012). In the 2012 study, however, the extent to which contamination was associated with rainfall intensity was unclear. In our study Waiwiri was not the most severely contaminated site, and the highest concentrations recorded were more than twice that recorded at Waiwiri in 2012 (Allen *et al.* 2012). Moreover, almost all of the 13 sites had unacceptably high levels of FIB. Also in our study, moderate levels of contamination were recorded, even after dry conditions — when contamination levels were expected to be low because runoff from the land was minimal. The highest FIB concentrations (5,400 *E. coli* per 100 g of shellfish flesh) were measured south of Hōkio after moderate rainfall, but extremely high levels (> 1,000) were also recorded at Waiwiri and Ōhau after rainfall.

[12] m = Represents an acceptable level and values above it are marginally acceptable or unacceptable in the terms of the sampling plan.
M = A microbiological criterion which separates marginally acceptable quality from defective quality. Values above M are unacceptable in the terms of the sampling plan and detection of one or more samples exceeding this level would be cause for rejection of the lot.
Faecal coliform (/100 g) m = 2.3×10^2 M = 3.3×10^2

Over the total of 26 samples tested, only one had no detectable *E. coli* (north of Waiorongomai on the first sampling occasion) and seven had concentrations that were admissible with respect to the MoH guidelines. However, no sites were found to have shellfish that contained acceptable concentrations of FIB on all sampling occasions. Thus our results suggest that, even after periods of no local rainfall, shellfish cannot be reliably considered to be uncontaminated at any of the 13 sites we tested.

3.2. Sources of faecal contamination

Water quality often becomes degraded when streams run through intensively used urban and rural land, where contamination is carried out into coastal waters. Levels of *E. coli* in some of the streams and rivers that flow into the coastal study area are available on the website of Land and Water Aotearoa (LAWA, www.lawa.org.nz).

E. coli levels in freshwater (reported on LAWA) from lowland un-forested sites in Waikawa and Waitohu streams ranged from 331 to 750/100 ml. These levels were below the median level for similar sites nationwide (rural or urban). In the Ōhau River, lower numbers of *E. coli* (70/100 ml) were recorded at a single lowland site for which data was available. Water quality at this site was in the higher 50% of all rural sites with respect to *E. coli* contamination (Table 3). As would be expected, forested sites had lower *E. coli* levels than rural and urban sites. While not in the immediate study area, plumes from the Manawatu River may impact coastal water quality as far south as Ōtaki[13]. Water quality in the lower Manawatu River is among the lower half or quarter of similar sites nationwide.

[13] Satellite images from NASA's Aqua Terra Satellite (via cawthroneye: www.cawthron.org.nz/apps/cawthroneye/) indicate that on some occasions the Manawatu River plume extends as far as Kapiti Island, although the relative input of the Manawatu, Rangitikei, and more minor rivers and streams cannot be identified by simply viewing these images.

Table 3. *E. coli* concentrations measured in water samples from rivers and streams in and near the study area. Data from www.lawa.org.nz, downloaded 06/06/2014. Comparison data shows how the median levels of *E. coli* compares to other sites with similar land use (category for comparison shown in brackets).

Catchment / Site	*E. coli* (/100 ml)	Land use	Comparison	Trend
Ōhau				
Haines property	70	Lowland rural	best 50% (all rural)	none
Gladstone reserve	41	Lowland forest	worst 50% (all forest)	none
Waikawa				
Huritini	331	Lowland rural	worst 25% (all rural)	none
Manakau at S.H.1 Bridge	750	Lowland rural	worst 25% (all rural)	none
North Manukau Rd	17	Lowland forest	best 50% (all forest)	none
Waitohu				
Norfolk Cres	400	Lowland rural	worst 25% (all rural)	degradation
Mangapouri Stream at Bennetts Rd	710	Lowland urban	worst 50% (all urban)	none
Forest Park	5	Upland forest	best 25% (all forest)	none
Manawatu				
Whirokino	330	Lowland rural	worst 50% (all rural)	none
u/s PPCS Shannon	305	Lowland rural	worst 25%[14] (all rural)	none
Mangaore at u/s Shannon STP	73	Lowland forest	worst 50% (all forest)	none

Estimates of pastoral farming extent can be made using satellite imagery to map land cover (Allen *et al.* 2012), however this does not provide information on the nature of farming activity (*e.g.* dairy *vs* beef and sheep), or the intensity of activity at the time of shellfish sampling. For the sampling sites in this study, the proportion of the sub-catchment that was in high producing exotic grassland (typically grazed for wool, lamb, beef, dairy, and deer production) in 2008 / 2009 ranged from 28% to 61% (Table 2).

A study in the Horizons Regional Council (Horizons) region found that *E. coli* concentrations in freshwater were measurably higher where there was more sheep and beef farming, while forestry (native, and total) showed the inverse relationship to *E. coli* levels (Ballantine & Davies-Colley 2009). We did not see a similar relationship between average faecal contamination in shellfish (Table 2) and proportion of the catchment in high producing exotic grassland (Table 4) (linear regression, $R^2 = 0.04$). This is likely because of the small sub-catchment size we were studying and the mixing and long-shore transport of land-derived contaminants once they reached the sea. Contaminated water is likely to have come from further afield as well as the immediate catchments above the sites where shellfish were sourced.

[14] The comparative data for Whirokino and u/s PPCS Shannon are inconsistent as they appear on LAWA.

Table 4. Current land cover for seven shellfish study areas (as % for the area). Shellfish sampling sites were grouped into the appropriate sub-catchments such that 'Hōkio' = 1 site, 'Waiwiri' = 2 sites, 'Ōhau' = 2 sites, 'Waikawa' = 2 sites, 'Waiorongomai' = 2 sites, and 'Ōtaki / Waitohu' = 4 sites (Newcombe *et al.* 2014)

	Total (ha)	Exotic forest (%)	High producing exotic grassland (%)	Low producing exotic grassland (%)	Sand dune (%)	Urban (%)	Native (%)	Other (%)
Hōkio	240	27	28	24	8	4	10	1
Ōhau	586	18	56	4	14	0	2	6
Waiwiri	254	43	47	4	6	0	1	0
Waikawa	358	10	44	26	10	7	1	3
Waiorongomai	521	11	60	20	2	0	3	5
Ōtaki / Waitohu	1071	4	61	1	2	18	2	13

In a previous study[15], the animal origins of faecal contamination were identified in the Waiwiri Stream, and in shellfish near the mouth of the Waiwiri Stream, using genetic techniques (Allen *et al.* 2012). The overwhelmingly dominant source of contamination was cows. Despite the presence of a human sewage treatment facility in that catchment, no indication of human faecal material was found in the shellfish samples taken from the beach (three sites were sampled on two occasions). However, sampling was only carried out following moderate to heavy rainfall, and results may have been different if testing was carried out under a variety of climatic histories.

To understand the dominant sources of faecal contamination in shellfish, it may be appropriate to model freshwater inputs and particle transport along the coast. Analysis of coastal oceanography and microbial source tracking could be used to identify the key sources of faecal contamination so that riparian planting and other land management measures can be targeted to most effectively reduce contamination of coastal waters.

3.3. Bacterial contamination of streams and coastal waters

Horizons Regional Council (Horizons) monitors faecal indicator bacteria (FIB) levels in water samples from the coast at Hōkio and Waikawa beaches, and the Greater Wellington Regional Council monitors at Ōtaki Beach during summer months. However this is for safety with respect to recreational contact with the water, not for the consumption of shellfish.

The Horizons FIB swimming risk information showed 'very good' water quality at Hōkio and Waikawa beaches from data collected since 2005, with > 95% compliance with MoH guidelines (Roygard *et al.* 2013).

[15] Part of the same larger project: Maanaki Taha Moana, www.mtm.ac.nz

Faecal indicator bacteria data from GWRC suggests that Ōtaki is less contaminated than most beaches on the Kāpiti Coast. The FIB[16] counts in water samples at Ōtaki Beach had a median value of 5/100 ml over 19 sampling dates in the year ending June 2013. This was the fourth lowest out of 14 sites on the Kāpiti Coast sampled under the GWRC marine recreation site monitoring programme. The maximum level recorded at Ōtaki was 170/100 ml, while levels over 1,000 were recorded at multiple sites further south (Morar & Perrie 2013). Water samples from Ōtaki Beach did not exceed Ministry for the Environment / Ministry of Health (MfE / MoH 2003) bacteriological 'trigger' values for recreational water quality in the 2012 / 2013 summer sampling period (Morar & Greenfield 2013).

The GWRC recognises that after heavy or prolonged rainfall, contamination from urban and agricultural runoff is common. Accordingly they advise against contact with the water for two days after such rainfall[17]. The Horizon's website states that "[i]f the water looks clean and clear and it is a sunny day, it should be safe to swim". However it was noted by one of the authors of this report (H.S.) that faecal contamination in shellfish as documented in this study did not seem to be correlated with her observations of water clarity at the beach.

Faecal coliforms (another measure of FIB, which includes *E. coli*) were also measured weekly throughout summer in water samples from Ōtaki and six other marine shellfish gathering sites in the GWRC area (Morar & Greenfield 2013). In 2012 / 13 levels of faecal coliforms exceeded MfE / MoH guideline criteria[18] (MfE / MoH 2003) for water quality at shellfish gathering sites on a quarter of sampling dates. The other Kāpiti sites were Peka Peka Beach, which exceeded 43 MPN/100 mL on 15% of sample dates, and Raumati Beach, which exceeded 43 MPN/100 mL on 45% of sample dates (Morar & Greenfield 2013).

Despite beaches in the study area being relatively uncontaminated compared to other beaches in the region, and often testing below MfE / MoH guideline levels for recreational contact and shellfish gathering, our results showed high and widespread contamination of shellfish. This suggests that it is important to test levels of bacteria in shellfish directly rather than rely solely on water sampling to indicate shellfish contamination levels.

[16] Enterococci, a different group of faecal indicator bacteria from *E. coli* and faecal coliforms
[17] http://graphs.gw.govt.nz/recreational-water-quality/
[18] The median faecal coliform content of samples taken over a shellfish gathering season shall not exceed 14 MPN/100 mL; and not more than 10% of samples collected over a shellfish gathering season should exceed 43 MPN/100 mL.

3.4. Management of contamination sources

The occurrence of relatively high levels of contamination, even under conditions of low rainfall, may be due to livestock having access to streams, or runoff from tracks and roads entering waterways.

De-vegetation of riparian[19] margins has had numerous negative effects on aquatic ecosystems, including those that cause or exacerbate bacterial contamination (MfE 2001). Best management practices to limit contamination include removing stock access to waterways and the planting of riparian margins (MfE 2001; Quinn 2009).

3.5. Council and industry initiatives to reduce contamination

Greater Wellington Regional Council's regional plan is undergoing a review. The draft plan includes proposed rules that require stock exclusion from streams and rivers in most lowland areas. A series of collaborative planning processes are planned for five large areas (termed 'super-catchments') in the region. The Kāpiti area, which includes part of the coast assessed in this study, will be the last of these to be addressed, planned for 2018–2020.

Horizon's has projects for riparian enhancement in selected 'focus catchments'. This includes extending fencing and planting of Lake Horowhenua, tributaries and outflow (Hōkio Stream), and ongoing plantings or follow up work on plantings in the Waiwiri Steam, Ohau Loop, and Waikawa Stream (Roygard *et al.* 2013).

Lake Horowhenua, Waiwiri, and Waikawa catchments are also target zones for the contaminant management rules of the Horizon's One Plan. This involves specific control of existing intensive farming land use activities. Requirements include stock exclusion from wetlands or lakes that are rare, threatened, or at-risk habitats, and from rivers that are permanently flowing or more than 1 m wide.

Similar measures are outlined as part of the Sustainable Dairying: Water Accord[20] (to which Dairy NZ, Fonterra, and a number of other industry organisations are partners, and which is supported by regional councils). Expectations include that:

- Dairy farms will exclude dairy cattle from significant waterways and significant wetlands.
- Riparian planting will occur where it would provide a water quality benefit.
- The crossing of waterways by dairy cows will not result in degradation of those waterways.

[19] Riverbank
[20] www.dairynz.co.nz

However, waterways less than 1 m wide and shallower than 30 cm are not included in commitments to stock exclusion or riparian planting.

4. CONCLUSIONS AND RECOMMENDATIONS

Faecal contamination of tuatua / pipi on beaches from Hōkio to Ōtaki was worse than expected, and high even after dry periods or very light local rainfall. This represents both a human health risk and a degradation of mana to tangata whenua.

Analysis of shellfish flesh seems to indicate higher risk from contaminated shellfish than suggested by monitoring of coastal water quality.

Improved stock exclusion and riparian management of freshwater are key to avoiding contamination of coastal kaimoana with faecal material.

Microbial source tracking could be used to identify the type of faecal material contaminating shellfish along the coast. Modelling of near shore hydrodynamics would assist in the understanding of the relative importance and spatial influence of different rivers and streams to contamination of the coastal environment.

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As aptly summed up by two local leaders:

Moko Morris of Ōtaki was “thrilled to have my children involved in this local hapū initiative, whose vision is to secure better outcomes for all who enjoy the moana[21]. We learnt and laughed alongside all those contributing to the future health of Tangaroa[22]. It was an honour to be engaged in active kaitiakitanga and to strengthen whanaungatanga[23] amongst us.”

[21] sea
[22] entity of the sea
[23] interrelationships

Keremihana Heke, customary kaitiaki for Ngāti Tukorehe and Deputy Principal for Whakatupuranga Rua Mano Kura Kaupapa, Ōtaki, was a key participant in the shellfish survey with his whanau. "Having our tamariki[24] involved and exposing them to the stories of their pakeke[25] about the numbers of shellfish gathered in past years, was invaluable. I was reminded of how important it is for my own mokopuna[26] that we continue to work with our environment for the betterment of the resource for future generations. Nā Rangi tāua, nā Tuānuku tāua — We are all descendants of the Sky and the Earth."

Samples were processed at Cawthron by Ron Fyfe and his team at Cawthron Analytical Services.

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[24] Children
[25] Adult relatives
[26] Grandchildren

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